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 95-2540(1997)
Thai Industrial Standard
for
Steel Wires for Prestressed Concrete

1. Scope

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

1.2 This standard covers cold-drawn wire : plain wire, indented wire, ribbed wire, and crimped wire, stress relieved having nominal diameter 4,5, 6, 7, 8, 9, 10 and 12.2 mm and non-stress relieved or mill coil wire having nominal diameter 2.5, 3, 4, 5, 6, 7 and 8 mm, normal relaxation and low relaxation.

2. Definitions

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

2.1 Steel wires for prestressed concrete : hereinafter referred to as “wire” : A solid product obtained from high carbon steel wire rod by cold working.

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

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

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

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

2.6 Cold-drawn wire : A solid product obtained from a rod by cold working through dies or rollers.

2.7 Plain wire : Wire with a surface as obtained in the drawing die. The wire has a constant nominal cross-section and does not show periodical irregularities along the length in either the surface or axis.

2.8 Indented wire: Wire whose has indentations at regular intervals along the length.

2.9 Crimped wire: Wire which has a regular deformation of the wire axis in either a single plane or in helical form produced by a subsequent mechanical process.

2.10 Non-stress relived or mill coil wire: Wire in the condition after cold drawing. It may be covered by a residue of drawing lubricant.

2.11 Stress relieved wire: Cold-drawn wire that has been subjected to one of the following treatments in a continuous linear manner:

(1) the wire passes through a sequence of flexures followed by a short-term heat treatment;

(2) the wire is given a short-term heat treatment under plastic deformation (under conditions of longitudinal strain).

2.12 Proof force: Force at which extension is equal to a specified percentage of the original gauge length.

3. Kind, type and class

3.1 Wires are classified into 2 kinds i.e.
- 3.1.1 Non-stress relieved wire or mill coil wire;
- 3.1.2 Stress relieved wire.

3.2 Wires are divided into 4 types i.e.
- 3.2.1 Plain wire;
- 3.2.2 Indented wire;
- 3.2.3 Ribbed wire;
- 3.2.4 Crimped wire.

3.3 Stress relieved wire are separated into 2 classes i.e.
- 3.3.1 Normal relaxation;
- 3.3.2 Low relaxation.

4. Sizes

4.1 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.
Testing on mass per metre shall be in accordance with clause 10.1.

4.2 The nominal diameter, nominal cross-sectional area, mass per metre and tolerance on mass per metre of stress relieved wires are as given in Table 2.
Testing on mass per metre shall be in accordance with clause 10.1.

4.3 Internal diameter of coil shall be demonstrated according to annex B.

Table 1 Nominal diameter, nominal cross-sectional area, mass per metre and characteristic values for non-stress relieved wires.
(clauses 4.1, 6.4.1, 10.4.3 and 10.5.3)

Nominal diameter	Nominal tensile srength[1)]	Nominal cross-sectional area	Mass per length		Characterstics value[2)], min		
			Nominal	Permissible deviation	maximum force[4)]	0.1% proof force	Bend radius
mm	N/mm²	mm²	(g)	(g)	kN	kN	mm
2.5	1960	4.91	38.5	± 1.25	9.62	7.7	7.5
2.5	1860	4.91	38.5	± 1.25	9.13	7.3	7.5
3	1860	7.07	55.5	± 1.5	13.1	10.5	7.5
3	1770	7.07	55.5	± 1.5	12.5	10.0	7.5
4	1770	12.6	98.9	± 2.0	22.3	17.8	10
4	1670	12.6	98.9	± 2.0	21.0	16.8	10
5	1770	19.6	154	± 3.1	34.7	27.8	15
5	1670	19.6	154	± 3.1	32.7	26.2	15
6	1770	28.3	222	± 3.7	50.1	40.1	15
6	1670	28.3	222	± 3.7	47.3	37.8	15
7	1670	38.5	302	± 4.3	64.3	51.4	20
7	1570	38.5	302	± 4.3	60.4	48.3	20
8	1570	50.3	395	± 5.9	79.0	63.2	20
8	1470	50.3	395	± 5.9	73.9	59.1	20

Note 1) The nominal tensile strength is for designation purposes only and is calculated from the nominal cross-sectional area and the characteristic maximum force and rounded off to the nearest 10 N/mm².

2) In view of the small tolerance on mass per length, characteristic forces have been specified rather than stresses.
3) The mass per length is calculated by adopting conventionally the value 7.85 kg/dm² as the density of steel.
4) In order to prove the suitability of the material, which is only used in certain appliances (e.g. for railway sleepers, piles or tanks) there is a requirement for a force at 1% total elongation to be at least 80% of the characteristic maximum force.

Table 2 Nominal diameter, nominal cross-sectional area, mass per metre and characteristic values for stress relieved wires. (clauses 4.2, 6.5.1, 10.4.3 and 10.5.3)

Nominal diameter	Nominal tensile srength[1)]	Nominal cross-sectional area	Mass per length		Characteristics value[2)], min			
			Nominal[3)]	Permissible deviation	Maximum force[4)] kN	Proof force		Bend radius
						0.1% proof force[4)5)6)] kN	0.2% proof force[4)6)] kN	
mm	N/mm²	mm²	(g)	(%)		kN	kN	mm
4	1770	12.6	98.9	± 2.0	22.3	18.5	19.0	10
4	1670	12.6	98.9	± 2.0	21.0	17.5	17.9	10
5	1770	19.6	154	± 3.1	34.7	28.8	29.5	15
5	1670	19.6	154	± 3.1	32.7	27.2	27.8	15
6	1770	28.3	222	± 3.7	50.1	41.6	42.6	15
6	1670	28.3	222	± 3.7	47.3	39.3	40.2	15
7	1670	38.5	302	± 4.3	64.3	53.4	54.7	20
7	1570	38.5	302	± 4.3	60.4	50.1	51.3	20
8	1670	50.3	395	± 5.9	84.0	69.7	71.4	20
8	1570	50.3	395	± 5.9	79.0	65.6	67.1	20
9	1470	63.6	499	± 7.2	93.5	74.8	76.1	25
10	1570	78.5	617	± 8.6	123	98.6	101	25
10	1470	78.5	617	± 8.6	115	92.3	94.3	25
12.2	1570	117	918	± 0.5	184	147	151	30
12.2	1470	117	918	± 0.5	172	138	141	30

Note
1) The nominal tensile strength is for designation purposes only and is calculated from the nominal cross-sectional area and the characteristic maximum force and rounded off to the nearest 10 N/mm².
2) In view of the small tolerance on mass per length, characteristic forces have been specified rather than stresses.
3) The mass per length is calculated by adopting conventionally the value 7.85 kg/dm² as the density of steel.
4) For wires of diameter larger than 8 mm, the characteristic 0.1% and 0.2 % proof forces are approximately 80%, respectively 82%, of the characteristic maximum force. For wires 8 mm and smaller, the corresponding figures are approximately 83%, respectively 85%.
5) The modulus of elasticity may be taken to be 205 ± 10 kN/mm².
6) 0.1% proof force is mandatory and 0.2% proof force is for information only (see ISO 6934-1), except when other wise agreed.

5. Chemical composition

Chemical composition should be related to the kind and size of product and tensile strength. If requested by the purchaser the cast analysis shall be given. The content of both sulfur and phosphorus shall not exceeding 0.04%.

6. Requirements

6.1 General requirements
Each coil of steel wires shall be uniformly wire and be free from joints or weld.
Compliance is checked by visual inspection.

6.2 Curvature
Steel wire shall be straight. When tested in accordance with clause 10.2, the curve shall be not greater than 30 mm.

6.3 The diameter of the indentation shall be in accordance with clause A.1. And pitch of crimping shall be in accordance with clause A.2.

6.4 Mechanical properties for non-stress relieved wire

6.4.1 Maximum force and proof force shall be in accordance with Table 1.
Testing shall be in accordance with clause 10.3 or other equivalent test method.

6.4.2 Elongation and ductility

6.4.2.1 When tested as directed in clause 10.3, the percentage total elongation at maximum force, shall be not less than 1.5%. All wires shall show a ductile fracture with a construction visible to the naked eye.

6.4.2.2 All wires shall withstand a reverse bend test as directed in clause 10.4, the maximum number of bends is four for plain wires and three for indented and ribbed wires.

6.4.3 Relaxation
When tested as directed in clause 10.5, the relaxation at an initial force of 70% of the characteristic maximum force shall be not more than 10%. If required, the same test shall be performed at an initial force of 60% of the characteristic maximum force. The maximum relaxation is then 8%.
Note: In case the relaxation at 1000 h is completed, testing for follow-up is not required.

6.4.4 Fatique
If agreed between purchaser and manufacturer, fatique behaviour shall be demonstrated according to the clause 10.6, without damage.

6.5 Mechanical properties for stress relieved wire

6.5.1 Maximum force and proof force shall be in accordance with Table 2.
Testing shall be in accordance with clause 10.3 or other equivalent test method.

6.5.2 Elongation and ductility

6.5.2.1 When tested as directed in clause 10.3, the percentage total elongation at maximum force, shall be not less than 3.5%. All wires shall show a ductile fracture with a construction visible to the naked eye.

6.5.2.2 All wires shall withstand a reverse bend test as directed in clause 10.4, the maximum number of bends is four for plain wires and three for indented and ribbed wires.

6.5.3 Relaxation

When tested as directed in clause 10.5, the relaxation at an initial force of 70% of the characteristic maximum force shall be in accordance with Table 3. If required, the same test shall be performed at an initial force of 60% and 80% of the characteristic maximum force. The maximum relaxation is then Table 3.

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

Table 3 Relaxation
(clause 6.5.3)

Initial force of the characteristic maximum force (%)	Type	
	Normal relaxation, max %	Low relaxation, max %
60	4.5	1.0
70	8.0	2.5
80	12.0	4.5

6.5.4 Fatique

If agreed between purchaser and manufacturer, fatique behaviour shall be demonstrated according to the clause 10.6, without damage.

7. Marking and labelling

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 strand 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 WIRE";
- followed by the letter "M" for non-stress relieved wires or
- followed by the letter "S" for stress relieved wires.

(2) Letter referring to wire surface
- P = plain
- I = indented
- C = crimped
- R = ribbed

(3) Nominal diameter;
(4) Nominal tensile strength;
(5) Relaxation class:
- relax 1 for normal relaxation;
- relax 2 for low relaxation

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

Example PC wire-SI-7-5170-Relax 1 : Stress-relieved indented wire of nominal diameter 7 mm and nominal strength 1570 N/mm² with class 1 relaxation.

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 langauge 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 steel wire of the same kind, 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 4.

Table 4 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 4, 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 6.4.1, 6.4.2 and 6.4.3 or clauses 6.5.1, 6.5.2 and 6.5.3, that lot of wire strand shall be deemed to comply with the requirements. Should any test piece fail to fulfil the requirements of clauses 6.4.1, 6.4.2 and 6.4.3 or clauses 6.5.1, 6.5.2 and 6.5.3, 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 6.4.1, 6.4.2 and 6.4.3 or clauses 6.5.1, 6.5.2 and 6.5.3, 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 6.4.1, 6.4.2 and 6.4.3 or clauses 6.5.1, 6.5.2 and 6.5.3, 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.

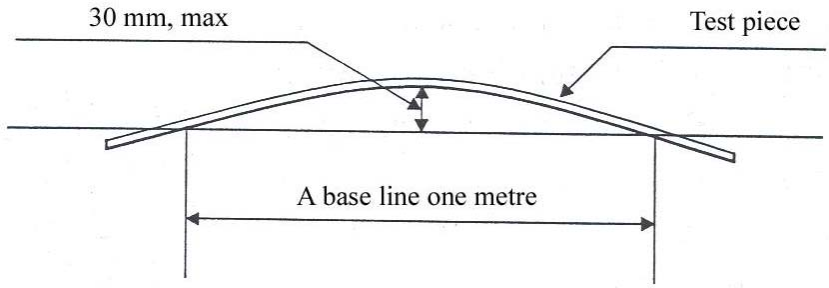


Figure 1 Measurement of curvature
(clause 10.2)

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

Test piece shall be marked the gauge length and end of the grips as shown in Figure 2.

10.3.2.1 The gauge length of the extensometer (G) shall be equal to 200 mm

10.3.2.2 The distance between the grips (P) should be greater than each end of the gauge length not less than 25 mm.

10.3.3 Calculation of cross-sectional area

10.3.3.1 Cross-sectional area of plain-wire shall be calculated from the desired diameter of wire of the gauge length.

10.3.3.2 For indented, ribbed and crimped wire shall be calculated from diameter of wire.

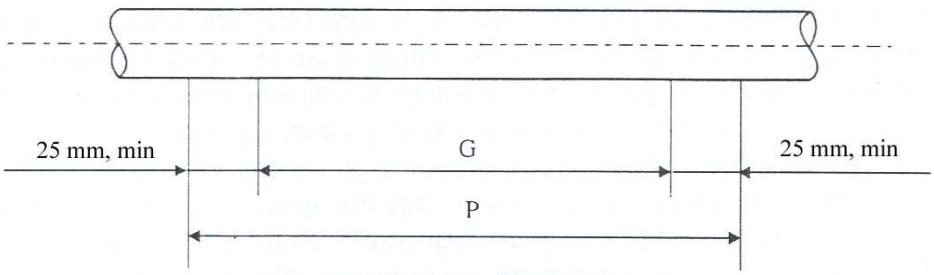


Figure 2 Test piece
(clause 10.3.2)

10.3.4 Procedure

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

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

10.3.4.3 Loading rate not exceeding 30 MPa 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.

10.3.4.4 Determination of proof strength

(1) An extensometer shall be hold at 2 gauge marks on test pieces.

(2) The scale of extensometer shall be adjusted at zero point, then the load shall be increased as consistent as defined in clause 10.3.4.3. 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 (see Figure 3), 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 maybe.

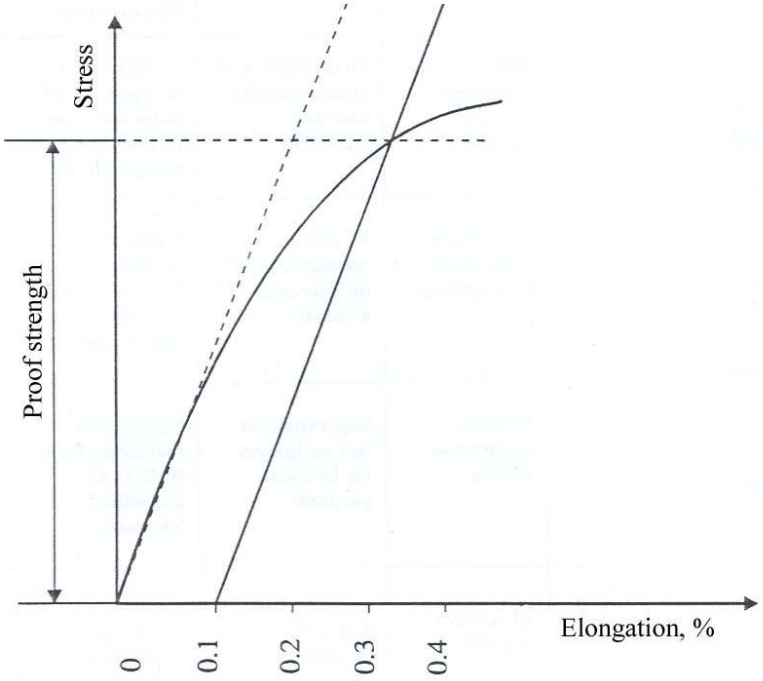


Figure 3 Proof strength, non-proportional extension
(clause 10.3.4.4(3))

10.3.4.5 Elongation
Determination of elongation shall be made after complete fracture occurs.

10.4 Reverse bend test

10.4.1 Testing machine shall be in accordance with Figure 4.

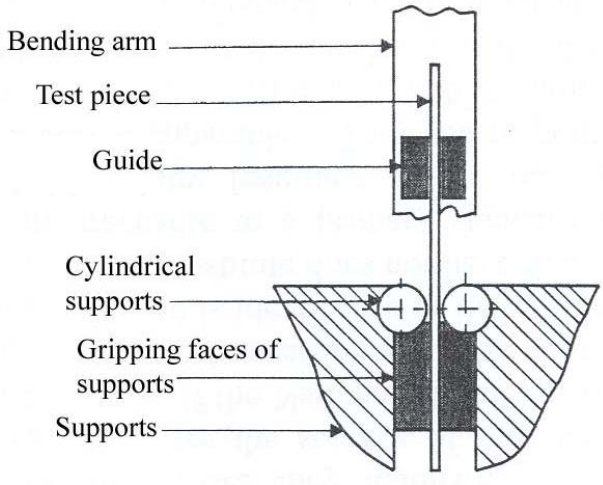
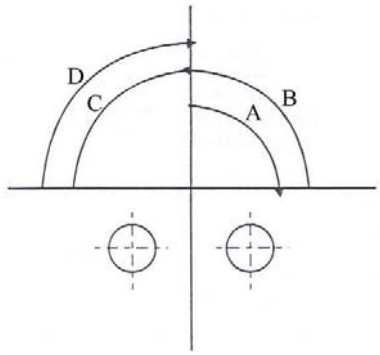


Figure 4 Testing machine
(clause 10.4.1)

10.4.2 Preparation of test pieces
Test piece shall be passed the testing as directed in clause 10.2.

10.4.3 Procedure
The test consists of repeated bending of a test piece through 90° in opposite directions in one plane. The test piece is gripped at one end as shown in Figure 4, and each bend is made over a cylindrical surface of specified radius as given in Table 1 or 2. One reverse bend consists of bending the test piece through an angle of 90° and then returning it to its original position as shown in Figure 5. The rate of bending not exceeding one bend per second.



A, B: First bend
C, D: Second bend

Figure 5 Counting method
(clause 10.4.3)

10.5 Relaxation

10.5.1 Tests carried out controlled conditions shall be made at a temperature of 20±2°C.

10.5.2 The distance between the ends of the grips shall exceeding 100 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).

10.5.3 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.

10.5.4 Values for relaxation is calculated from the formula:

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

10.6 Fatique

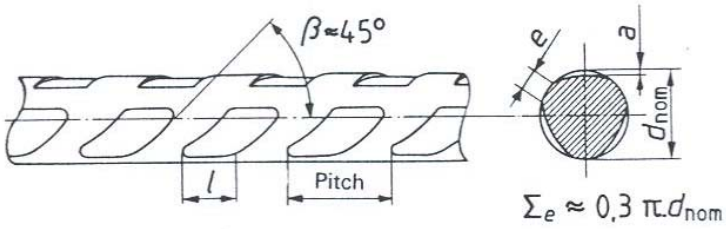
The strands shall withstand, without fatique, 2×10^6 cycles of a stress fluctuating down from a maximum stress of 70% of the nominal tensile strength.

The stress range shall be 200 N/mm² for plain wire and 180 N/mm² for indented and ribbed wire. In the absence of data use 100 N/mm² provisionally as the stress range for crimped wire.

Annex A.
Example of Indentation and crimps

A.1 A list of recommended indentation dimensions is given in Table A.1 or Table A.2.

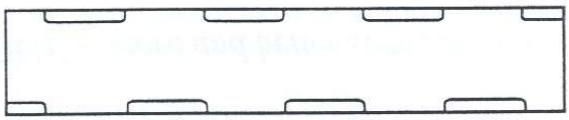
Table A.1 : Indentations (Italic)
(clause A.1)



Units in millimetre

Nominal wire diameter	Nominal Indentation dimensions		
	Depth a	Length l min	Pitch min
≤ 5 > 5	0.12 + 0.05 0.15 + 0.05	3.5 5.0	5.5 8.0

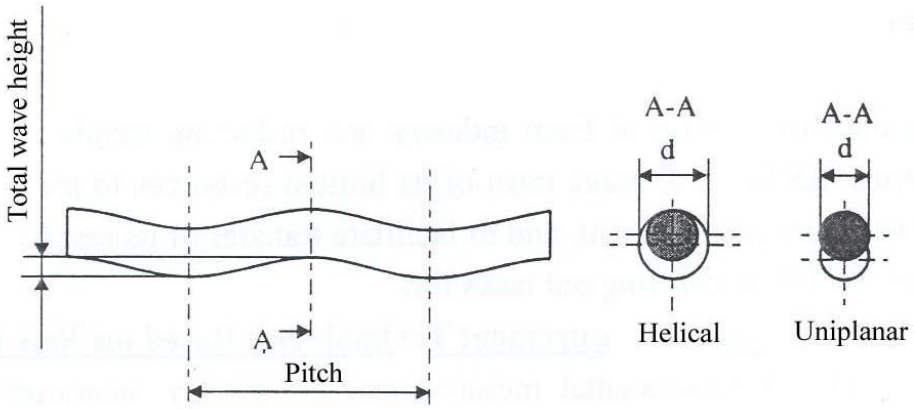
Table A.2 : Straight Indentation (Italic)
(clause A.1)



Nominal wire diameter	Depth mm	
	min	max
4 5 7 9	0.05 0.05 0.10 0.15	0.20 0.20 0.25 0.25

A.2 A list of recommended crimps is given in Table A.3.

Table A.3 Crimps dimensions
(clause A.2)



Type of crimp	Pitch	Total wave height (excluding the wire diameter, d)	
		Helical	Uniplanar
Short pitch	50d to 10d	5%d to 10%d	10%d to 20%d
Long pitch	8d to 12d	6%d to 12%d	12%d to 25%d