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Steel wire ropes — Pre-fabricated parallel wire strands for suspension bridge main cable — Specifications

Câbles en acier — Câbles à fils parallèles préfabriqués pour câble porteur de pont suspendu — Spécifications

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Foreword

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This document was prepared by Technical Committee ISO/TC 105, *Steel wire ropes*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Steel wire ropes — Pre-fabricated parallel wire strands for suspension bridge main cable — Specifications

1 Scope

This document specifies the production methods, specifications, requirements, test methods, inspection rules, marks, packing, transportation and storage for pre-fabricated parallel wire strand (PPWS), which are made of hot-dip galvanized or zinc-aluminium coated high tensile steel wires described in ISO 19203.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 4986, *Steel casting — Magnetic particle inspection*

ISO 4992-2, *Steel castings — Ultrasonic examination — Part 2: Steel castings for highly stressed components*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 10474:2013, *Steel and steel products — Inspection documents*

ISO 17558:2006, *Steel wire ropes — Socketing procedures — Molten metal and resin socketing*

ISO 19203, *Steel wire rod and wire products — Hot-dip galvanized and zinc-aluminium coated steel wires for bridge cables — Specifications*

EN 1774, *Zinc and zinc alloys — Alloys for foundry purposes — Ingot and liquid*

3 Terms and definitions

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

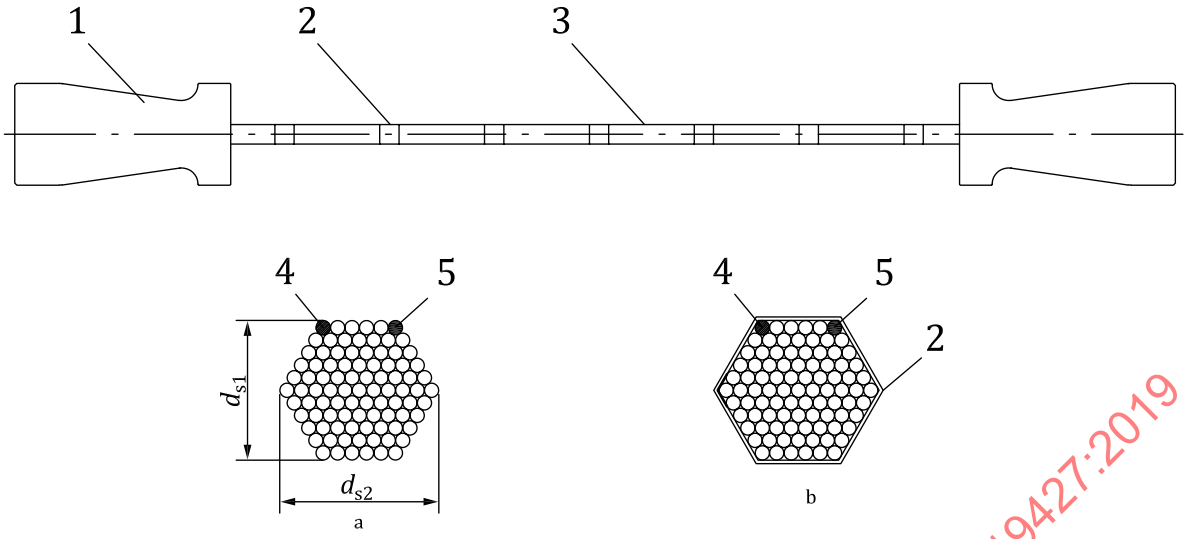
ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
pre-fabricated parallel wire strand
PPWS
strand factory pre-fabricated by assembling a group of wires laid parallel in a hexagonal (regular or irregular) shape, bound together at intervals by binding tape, and fitted with *sockets* (3.3) at each end

Note 1 to entry: The section and the structure of PPWS is shown in Figure 1.



Key

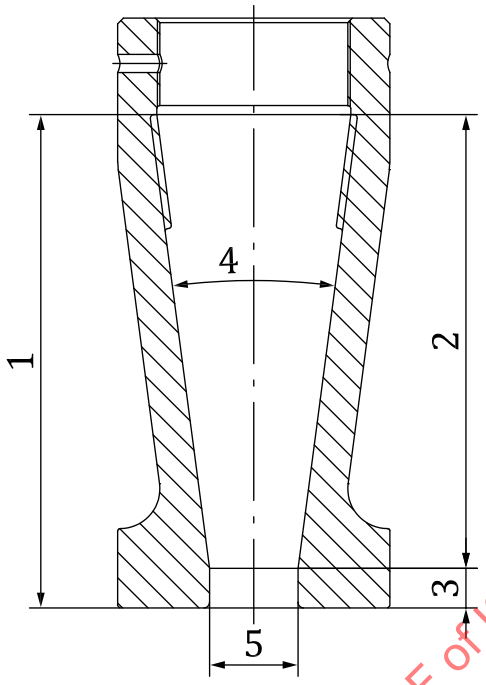
1	socket	d_{s1}	hexagon diagonal distance (across corners), in mm
2	binding tape	d_{s2}	hexagon width distance (across flats), in mm
3	PPWS	a	Cross-section of strand (without binding tape).
4	gauge wire	b	Cross-section of strand (with binding tape).
5	coloured wire (red)		

Figure 1 — Diagram of structure of PPWS

3.2
binding tape
plastic tape reinforced by plastic fibres

Note 1 to entry: The tapes are bound at intervals to keep the shape of strand tight and can permit the wires to open or spread sufficiently to adjust the stresses in the strand during reeling and unreeling.

3.3
socket
PPWS (3.1) termination incorporating a *socket basket* (3.5), see Figure 2



Key

1 overall basket length [tapered portion plus parallel portion(s), if applicable, plus radius at rope entry]
2 tapered portion of socket basket
3 parallel portion of socket basket and any radius at strand entry
4 angle of tapered basket
5 diameter at strand entry

Figure 2 — Typical socket basket

Note 1 to entry: Length adjusting system shall be provided at connection between PPWS socket and anchorage structure.

3.4
socketing medium
molten metal alloy or resin

3.5
socket basket
tapered portion of a *socket* (3.3) within which the evenly splayed out wires are secured

3.6
PPWS grade
R_m
level of requirement of nominal tensile strength grade which is designated by a number

EXAMPLE 1 770, 1 960.

Note 1 to entry: *PPWS* (3.1) strength grade correspond to the strength grades of the wires in the PPWS. It is expressed in MPa.

3.7
nominal wire diameter
d
nominal diameter of the perpendicular cross-section of the steel wire after coating

Note 1 to entry: It is expressed in millimetres.

3.8
nominal metallic cross-sectional area
A
design value obtained from the sum of the metallic cross-sectional areas of the wires in the *PPWS* (3.1) based on their nominal diameters:

$$A = \frac{\pi}{4} d^2 \times n$$

where n is the number of steel wires composing PPWS

Note 1 to entry: It is expressed in mm^2.

3.9
nominal breaking force
F_n
value of minimum breaking force based on the nominal wire sizes, wire tensile strength grades for the *PPWS* (3.1) class or construction as given in the manufacturer's design, which is obtained as follows:

$$F_n = R_m \times A \,/1\,000$$

Note 1 to entry: It is expressed in kN.

3.10
measured breaking force
F_m
breaking force obtained using a prescribed method

Note 1 to entry: It is expressed in kN.

3.11
nominal PPWS length mass
m
mass of unit length of *PPWS* (3.1) obtained from the product of the *nominal metallic cross-sectional area* (3.8) and density of steel wires after coating and calculated as follows:

$$m = A \times \gamma_w$$

where γ_w is the density of coated steel wire

Note 1 to entry: It is expressed in kg/m.

Note 2 to entry: γ_w is expressed in kg/m^3 (see ISO 19203:2018, Annex C).

3.12
unstressed length
length which corresponds to the actual length without load supplied using a prescribed method

3.13
free length
L_0
cable length excluding *socket* (3.3) lengths, which is the length between the front faces of sockets

Note 1 to entry: It is expressed in m.

3.14
gauge wire
wire used to control the length of the *PPWS* (3.1) during manufacturing, which is measured and marked under specific marking load while temperature is uniform

3.15
coloured wire
wire used to check twist condition of *PPWS* (3.1) during construction, which is painted with distinct colour on its total length

3.16
unit of product
set of 20 pieces of *PPWSs* (3.1) subsequently produced

4 Designation of product

The PPWS shall be ordered in accordance with this document and be designated as follows:

a) ISO 19427;

b) PPWS;

c) nominal diameter of steel wire, in millimetres;

d) number of steel wires composing PPWS;

e) PPWS grade;

f) coating type:

EXAMPLE 1 A PPWS made up of 91 pieces of zinc coated steel wires with diameter of 5 mm and grade of 1770, is designated:

ISO 19427-PPWS-5,00-91-1770-Zn

where Zn is hot-dip zinc coated.

EXAMPLE 2 A PPWS made up of 127 pieces of zinc-aluminium alloy coated steel wires with diameter of 7 mm and grade of 1860, is designated:

ISO 19427-PPWS-7,00-127-1860-ZnAl

where ZnAl is zinc-aluminium alloy coated.

5 Requirements

5.1 Traceability

The traceability shall be done from the beginning to the end of manufacturing. The manufacturer shall use suitable means to ensure the conformity of products and identify the status of products with respect to monitoring and measurement requirements throughout production and delivery.

The manufacturer shall control the unique identification of the products, and shall retain the documented information necessary to enable traceability.

5.2 Lengths and fabrication tolerances

5.2.1 The gauge wire shall be in the outside of the PPWS. The total length of the PPWS and all measuring points for the sockets, saddles and the key point such as main span middle point and side span middle point shall be marked on the gauge wire under specific marking load while temperature is uniform. The length of gauge wire shall take into account elongation, sag correction and temperature correction based on unstressed length of the cable.

The tension load shall be varied according to the wire diameter. For 5 mm diameter wires, the load shall be more than 50 kg. For 7 mm diameter wires, the load shall be more than 100 kg.

5.2.2 The gauge wire tolerance of the total length shall be within (L_0 / 15 000) for lengths more than 30 m. The tolerance shall be within 2 mm for total lengths less than or equal to 30 m. The length tolerance between the marks of the gauge wire shall be within (L_0 / 15 000) or 2 mm, whichever is greater.

5.2.3 The coloured wire shall be in the outside of the PPWS to check the twist condition of the PPWS during the erection process. The coloured wire shall also be made by covering the steel wire with colour paint, such as red, along the total length.

5.2.4 The mark of the total length of the PPWS and all measuring points for the sockets, saddles and the key points such as the main span middle point and side span middle point shall be transferred and marked according to the mark of the gauge wire.

5.2.5 Tolerance for the total length of the PPWS is composed of allowances associated with manufacturing of gauge wire and socketing. The allowance for gauge wire is ±(1/15 000 L_0) or 2 mm, whichever is greater. The allowance for socketing is ±5 mm.

NOTE In case of using Zn alloy as a filler material, the alloy shrinks at ambient temperature. As a result, this shrink causes initial cone draw when PPWS are loaded. The manufacturer needs to minimize this initial cone draw in an appropriate way, such as pre-compression from a back face of a socket cone.

5.3 Material and manufacture

5.3.1 The wires of PPWS shall conform to ISO 19203. Welds are not allowed in the wires in PPWS.

5.3.2 When placing the order, the purchaser may nominate the material of sockets. Socket material shall be agreed between the purchaser and manufacturer. The chemical composition and mechanical properties, such as tensile and Charpy properties, shall be agreed between the purchaser and manufacturer.

5.3.3 The socket castings shall be subject to visual, magnetic particle and ultrasonic inspection. The other non-destructive examinations (such as liquid penetration, radiographic etc.) shall be done in conditions agreed at the time of enquiry and order. The severity levels for every method, areas of the socket to be tested, percentage and/or frequency of testing shall be agreed between the manufacturer and purchaser. The acceptance criteria (severity level) shall be agreed between the manufacturer and purchaser.

5.3.4 For each socket, wherever transitions cause stress concentrations, transitions shall generally be rounded and machined. Edges on the sockets shall be rounded to make them suitable for zinc coating or painting. Specification for corrosion protection of socket shall be specified by the purchaser.

5.3.5 The socketing medium is as follows:

— Zinc-copper alloy: ZnCu2, which contains (98 ± 0,2) % Zn, (2,0 ± 0,2) % Cu.

— Zinc-aluminum-copper alloy: ZnAl6Cu1 in accordance with EN 1774, which contains (5,8 ± 0,2) % Al, (1,4 ± 0,2) % Cu and the rest, of Zn.

— The resin compound material may be used in the socketing medium of PPWS. The physical property of resin shall meet the requirements of ISO 17558:2006, Annex C.

— The manufacturer may use other socketing medium if the purchaser agrees.

5.3.6 Bundles of steel wires shall be wrapped by binding tape to form the shape in hexagon as in Annex A. The binding tape interval distance is 1,5 m to 2,5 m. Typical sectional dimensions are given in Annex B.

5.3.7 The binding tape shall have sufficient strength to confine the wires of the PPWS during reeling but it shall permit the wires to open or spread sufficiently to adjust for the stresses in the PPWS during reeling.

5.3.8 During socketing, the following requirements shall be met:

— The individual steel wires of each PPWS shall be splayed out and cleaned.

— Inserting the PPWS bundle end into the socket. Concentricity of the PPWS and the socket shall be optimized by positioning and alignment of PPWS axis and socket axis.

— The wires shall be evenly distributed within the cone.

— The wires shall be securely clamped together so that the wires do not slip during socketing.

5.3.9 After socketing, the following requirements shall be met:

— The socket basket is filled to the top with the socketing medium.

— The back of the molten metal cone shall be pressed into the socket with a load of not less than 50 % of the nominal breaking force or 1,1 times the service load of the PPWS applied by a suitable diameter jacking head, the pressure being maintained for 5 min.

— Initial cone draw in the resin socket assembly shall be removed by proof loading or alternative means.

— The axis of the PPWS and the front surface of the socket shall be at a right angle in any direction. The angle deviation shall be no more than 0,5°.

5.3.10 The PPWS shall be coiled or reeled on a drum or frame. The coiling or reeling diameter shall meet the following requirements:

— The coil or reel diameter shall be larger than 1,8 m for PPWS of 5 mm diameter wires.

— The coil or reel diameter shall be larger than 2,1 m for PPWS of 7 mm diameter wires.

NOTE The PPWS is composed of wires: an inner diameter of a coiled or reeled PPWS can be changed by considering the diameter of wire.

5.4 Mechanical property

5.4.1 Tensile property

The measured breaking force of the PPWS shall be equal to or greater than the nominal breaking force of the PPWS. The typical nominal breaking force are given in Annex C.

5.4.2 Modulus of elasticity

The modulus of elasticity shall be (200 ± 10) GPa.

5.4.3 Fatigue property

If requested, the fatigue property of the PPWS shall meet the following requirements.

— The load cycle is 2×10^6, the upper load is $0{,}45 \times F_n$, the stress range shall be 150 MPa according to the PPWS strength.

— Break is allowed in a maximum of 5 % of the total number of wires.

— After the fatigue test, the PPWS shall be taken to tensile failure and the failure load shall be not less than 95 % of F_n or as agreed between manufacturer and purchaser.

NOTE The PPWS is generally used for the main cables of suspension bridges. The ratio of live loads which work to the main cable is small because most loads are dead loads consisting of the weight of the cable wires themselves and the deck. Therefore, the fatigue test is not required for the materials of the main cable. The fatigue test is a special requirement.

6 Test methods

6.1 Material test

The socket shall be tested as below:

— Chemical testing shall be done to verify steel composition per the specified casting standard agreed between the manufacturer and purchaser.

— Material tests of socket shall be tested in accordance with the requirements and the following testing methods: ISO 6892-1 for tensile testing and ISO 148-1 for Charpy-V-impact testing.

— The ultrasonic tests and magnetic particle tests shall be done according to ISO 4992-2 and ISO 4986.

— The socket appearance shall be inspected by visual means.

— The other non-destructive examination shall be done according to the agreement between the manufacturer and purchaser.

6.2 Tensile test of PPWS

6.2.1 A sample from each PPWS unit of product shall be fixed to the sockets and subjected to the tensile test.

6.2.2 Tensile test shall be loaded until 5 % wire breakage (including wire pulled out from the socketing medium) at least or socket broken/socketing medium broken occurs. The load at which the wires, socket or socket medium break is F_m. The test force shall be applied steadily during the test. After 80 % of F_n has been achieved, the force shall be applied at a rate of not more than 0,5 % of F_n per second.

6.2.3 If required tensile load has not been reached when a single wire breaks, allow test to continue until the required load is met or multiple breaks occur, confirming maximum load possible has been reached. The broken wire number should be less than 5 % of wires of PPWS. The maximum load should not be less than nominal breaking force of PPWS.

6.2.4 If the breaking of more than 5 % of wires of PPWS occurs at a force less than the nominal breaking force, the PPWS is rejected.

The tensile test shall be performed on three samples taken from the same unit of production from the same steel wire coils. The remaining PPWSs are accepted only when all the measured breaking force of three tests achieve no less than the nominal breaking force.

6.3 Modulus of elasticity

The modulus of elasticity shall be determined from the slope of the linear portion of the force-extension diagram in the range between 0,2 F_n and 0,6 F_n, divided by the nominal cross-sectional area of the test piece. The interval for determining the modulus of elasticity shall be 0,05 F_n.

The slope may be calculated either by a linear regression of the measured data stored in a data storage facility or by a best-fit visual technique over the above-defined portion of the registered curve.

The gauge length of the extensometer used in the test shall be at least 2 m.

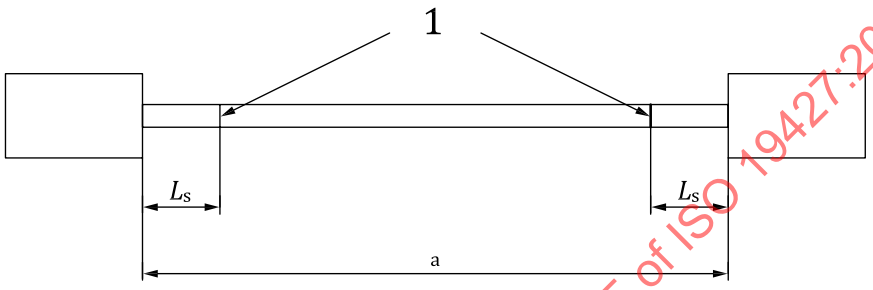
6.4 The test of socketing process

The following items shall be checked:

— The socket basket is filled to the top with the socketing medium.

— The axis of the PPWS and the front surface of the socket shall be checked by angle ruler.

— Measure the distance between socket and socket mark (L_S in Figure 3) by ruler after socket cone pressing.



Key

1 socket mark

L_S length tolerance of socketing

a Total length of PPWS L_0 (1 ± 1 15 000).

Figure 3 — Measure length

6.5 Fatigue test

6.5.1 Testing shall be carried out on the completed PPWS, including original sockets and socket medium. The free length of test specimen shall be minimum 3,0 m.

6.5.2 The specimen is mounted in the testing machine. The test specimen shall then be loaded to a maximum force of 0,45 F_n. Subsequently, the specimen is subjected to a fatigue test with two million load cycles, and an axial stress range 150 MPa. After the fatigue test, the PPWS shall be tensioned to 95 % of F_n or as agreed between manufacturer and purchaser.

7 Inspection

7.1 Inspection and inspection documents

Inspection shall be carried out by manufacturer in accordance with Clause 6 before delivery. The inspection documents shall be based on inspection certificate 3.1 or 3.2 of ISO 10474:2013. A type of the inspection certificate shall be agreed between the manufacturer and purchaser.

7.2 Acceptance unit, number of samples and test pieces

The finished PPWS products shall be sampled and tested in accordance with Table 1.

Table 1 — Frequency of sampling and testing of PPWS

Property		Frequency of sampling and testing
Socket	Dimension	100 %
	Appearance	100 %
	Mechanical test	1 per heat treatment charge and casting
	Chemical test	1 per casting charge
	Magnet particle inspection	Agreed between manufacturer and purchaser
	Ultrasonic test	Agreed between manufacturer and purchaser
	Coating	10 %
Length	Gauge wire length	each gauge wire
	Socketing length	each socket
Tensile property		1 per 20 pieces
Modulus of elasticity		1 per 20 pieces
Fatigue test		Agreed between manufacturer and purchaser
Socketing medium quantity		Every socket
Perpendicularity of socket and PPWS		Every socket

7.3 Evaluation of test results for mechanical, chemical, and coating properties

The material shall be deemed to conform to the requirements of this document if all the results of the tests comply. If these conditions are not met, then the following procedures shall apply:

a) When results for the properties specified by a minimum and or maximum value do not conform to the requirements, 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.

b) If the two additional results conform to the requirements of this document, then the unit of product shall be deemed to conform to this document.

c) 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 manufacturer shall immediately take measures to determine the reason and rectify the fault.

7.4 Sorting and reprocessing

The manufacturer has the right to carry out sorting or reprocessing of non-conforming products, either before or after retests, and to submit these products as a new test unit in accordance with 7.2. Manufacturer shall report non-conforming products to the purchaser before sorting or reprocessing. If the inspection results conform to this document and is agreed by the purchaser, these products can be delivered as qualified products. If requested, the manufacturer shall inform the purchaser which method of sorting or reprocessing is used. The manufacturer shall state such manner of the sorting and reprocessing in the method statement and get the approval from the purchaser.

8 Identification and marking

8.1 Each PPWS shall be legibly and permanently marked with the PPWS serial number. The marking detail shall be in accordance with agreement between the purchaser and manufacturer.

8.2 Each socket shall be permanently marked with marks or symbols that provide identification with the manufacturer's certificate of test.

8.3 The identification marking shall not affect the performance of the socket and PPWS.

8.4 Each PPWS shall be delivered with metal or plastic labels attached on which is shown the relationship between the internal production number of the PPWSs and the identification number of the sockets, enabling to trace all the information of the cable wire to be used and of the test results, and are stamped.

9 Storage and handling

9.1 The PPWS shall be delivered and stored in a wrapped condition, so that both PPWS and socket are protected against mechanical wear and tear, precipitation and similar.

9.2 During storage, the PPWS shall be protected against rain and long-term exposure to hot-humid environments. Storage condition and inspection interval shall be agreed between manufacturer and purchaser.

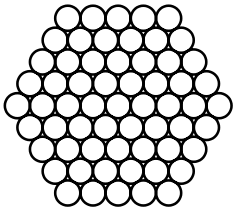
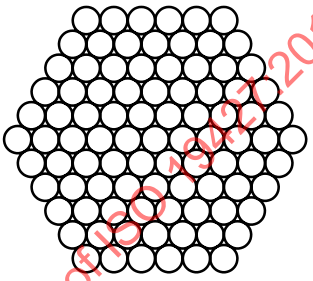
9.3 Each PPWS shall be handled with utmost care during storage and handling.

10 Transportation

Transportation of the PPWS in connection with reloading shall take place in such a way that the PPWS is not damaged. In this respect, it is important to take into account the capacity of cranes and lifting equipment and possible loading restrictions on quays, roads, bridges, etc., and the shape of such elements. In addition, it shall be ensured that the PPWS cannot be displaced or start rolling during transportation and storage.

Annex A
(normative)

Cross-sectional layout of PPWS

Number of wires	61	91
Sectional area		

Number of wires	127
Sectional area