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Eurocode 3 - Design of steel structures - Part 1-11: Design of structures with tension components

Eurocode 3 - Bemessung und Konstruktion von Stahlbauten - Teil 1-11: Bemessung und Konstruktion von Tragwerken mit Zuggliedern aus Stahl

Eurocode 3 - Calcul des structures en acier - Partie 1-11: Calcul des structures a câbles ou éléments tendus

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Eurocode 3 - Calcul des structures en acier - Partie 1-11: Calcul des structures à câbles ou éléments tendus

Eurocode 3 - Bemessung und Konstruktion von Stahlbauten - Teil 1-11: Bemessung und Konstruktion von Tragwerken mit Zuggliedern aus Stahl

This European Standard was approved by CEN on 13 January 2006.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

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Foreword

This European Standard EN 1993-1-11, Eurocode 3: Design of steel structures: Part 1-11 Design of structures with tension components, has been prepared by Technical Committee CEN/TC250 « Structural Eurocodes », the Secretariat of which is held by BSI. CEN/TC250 is responsible for all Structural Eurocodes.

This European Standard shall be given the status of a National Standard, either by publication of an identical text or by endorsement, at the latest by April 2007 and conflicting National Standards shall be withdrawn at latest by March 2010.

This Eurocode partially supersedes ENV 1993-2.

According to the CEN-CENELEC Internal Regulations, the National Standard Organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

National annex for EN 1993-1-11

This standard gives alternative procedures, values and recommendations with notes indicating where national choices may have to be made. The National Standard implementing EN 1993-1-11 should have a National Annex containing all Nationally Determined Parameters to be used for the design of tension components to be constructed in the relevant country.

National choice is allowed in EN 1993-1-11 through:

- 2.3.6(1)
- 2.3.6(2)
- 2.4.1(1)
- 3.1(1)
- 4.4(2)
- 4.5(4)
- 5.2(3)
- 5.3(2)
- 6.2(2)
- 6.3.2(1)
- 6.3.4(1)
- 6.4.1(1)P
- 7.2(2)
- A.4.5.1(1)
- A.4.5.2(1)
- B(6)

1 General

1.1 Scope

(1) prEN1993-1-11 gives design rules for structures with tension components made of steel, which, due to their connections with the structure, are adjustable and replaceable see Table 1.1.

NOTE: Due to the requirement of adjustability and replaceability such tension components are generally prefabricated products delivered to site and installed into the structure. Tension components that are not adjustable or replaceable, e.g. air spun cables of suspension bridges, or for externally post-tensioned bridges, are outside the scope of this part. However, rules of this standard may be applicable.

(2) This standard also gives rules for determining the technical requirements for prefabricated tension components for assessing their safety, serviceability and durability.

Table 1.1: Groups of tension components

Group	Main tension element	Component
A	rod (bar)	tension rod (bar) system, prestressing bar
B	circular wire	spiral strand rope
	circular and Z-wires	fully locked coil rope
	circular wire and stranded wire	strand rope
C	circular wire	parallel wire strand (PWS)
	circular wire	bundle of parallel wires
	seven wire (prestressing) strand	bundle of parallel strands

NOTE 1: Group A products in general have a single solid round cross section connected to end terminations by threads. They are mainly used as

- bracings for roofs, walls, girders
- stays for roof elements, pylons
- tensioning systems for steel-wooden truss and steel structures, space frames

NOTE 2: Group B products are composed of wires which are anchored in sockets or other end terminations and are fabricated primarily in the diameter range of 5 mm to 160 mm, see EN 12385-2.

Spiral strand ropes are mainly used as

- stay cables for aerials, smoke stacks, masts and bridges
- carrying cables and edge cables for light weight structures
- hangers or suspenders for suspension bridges
- stabilizing cables for cable nets and wood and steel trusses
- hand-rail cables for banisters, balconies, bridge rails and guardrails

Fully locked coil ropes are fabricated in the diameter range of 20 mm to 180 mm and are mainly used as

- stay cables, suspension cables and hangers for bridge construction
- suspension cables and stabilizing cables in cable trusses
- edge cables for cable nets
- stay cables for pylons, masts, aerials

Structural strand ropes are mainly used as

- stay cables for masts, aerials
- hangers for suspension bridges
- damper / spacer tie cables between stay cables
- edge cables for fabric membranes
- rail cables for banister, balcony, bridge and guide rails.

NOTE 3: Group C products need individual or collective anchoring and appropriate protection.

Bundles of parallel wires are mainly used as stay cables, main cables for suspension bridges and external tendons.

Bundles of parallel strands are mainly used as stay cables for composite and steel bridges.

(4) The types of termination dealt with in this part for Group B and C products are

- metal and resin sockets, see EN 13411-4
- sockets with cement grout
- ferrules and ferrule securing, see EN 13411-3
- swaged sockets and swaged fitting
- U-bolt wire rope grips, see EN 13411-5
- anchoring for bundles with wedges, cold formed button heads for wires and nuts for bars.

NOTE: For terminology see Annex C.

1.2 Normative references

(1) This European Standard incorporates dated and undated reference to other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments or revisions to any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 10138 *Prestressing steels*

Part 1 General requirements

Part 2 Wires

Part 3 Strands

Part 4 Bars

EN 10244 *Steel wire and wire products – Non-ferrous metallic coatings on steel wire*

Part 1 General requirements

Part 2 Zinc and zinc alloy coatings

Part 3 Aluminium coatings

EN 10264 *Steel wire and wire products – Steel wire for ropes*

Part 1 General requirements

Part 2 Cold drawn non-alloyed steel wire for ropes for general applications

Part 3 Cold drawn and cold profiled non alloyed steel wire for high tensile applications

Part 4 Stainless steel wires

EN 12385 *Steel wire ropes – safety*

Part 1 General requirements

Part 2 Definitions, designation and classification

Part 3 Information for use and maintenance

Part 4 Stranded ropes for general lifting applications

Part 10 Spiral ropes for general structural applications

EN 13411 *Terminations for steel wire ropes – safety*

Part 3 Ferrules and ferrule-securing

Part 4 Metal and resin socketing

Part 5 U-bolt wire rope grips

1.3 Terms and definitions

(1) For the purpose of this European Standard the following terms and definitions apply.

1.3.1
strand
an element of rope normally consisting of an assembly of wires of appropriate shape and dimensions laid helically in the same or opposite direction in one or more layers around a centre

1.3.2
strand rope
an assembly of several strands laid helically in one or more layers around a core (single layer rope) or centre (rotation-resistant or parallel-closed rope)

1.3.3
spiral rope
an assembly of a minimum of two layers of wires laid helically over a central wire

1.3.4
spiral strand rope
spiral rope comprising only round wires

1.3.5
fully locked coil rope
spiral rope having an outer layer of fully locked Z-shaped wires

1.3.6
fill factor *f*
the ratio of the sum of the nominal metallic cross-sectional areas of all the wires in a rope (A) and the circumscribed area (A_u) of the rope based on its nominal diameter (d)

1.3.7
spinning loss factor *k*
reduction factor for rope construction included in the breaking force factor K

1.3.8

breaking force factor (*K*)
an empirical factor used in the determination of minimum breaking force of a rope and obtained as follows:

$$K = \frac{\pi\ f\ k}{4}$$

where f is the fill factor for the rope

k is the spinning loss factor

NOTE: *K*-factors for the more common rope classes and constructions are given in the appropriate part of EN 12385.

1.3.9

minimum breaking force (F_{min})

minimum breaking force which should be obtained as follows:

$$F_{min} = \frac{d^2 \ R_r \ K}{1000} \ [kN]$$

where d is the diameter of the rope in mm

K is the breaking force factor

R_r is the rope grade in N/mm²

1.3.10

rope grade (R_r)

a level of requirement of breaking force which is designated by a number (e.g. 1770 [N/mm²], 1960 [N/mm²])

NOTE: Rope grades do not necessarily correspond to the tensile strength grades of the wires in the rope.

1.3.11

unit weight (w)

the self weight of rope based on the metallic cross-section (A_m) and the unit length taking account of the densities of steel and the corrosion protection system

1.3.12

cable

main tension component in a structure (e.g. a stay cable bridge) which may consist of a rope, strand or bundles of parallel wires or strands

1.4 Symbols

(1) For this standard the symbols given in 1.6 of EN 1993-1-1 and 1.6 of EN 1993-1-9 apply.

(2) Additional symbols are defined where they first occur.

NOTE: Symbols may have various meanings.

2 Basis of design

2.1 General

(1)P The design of structures with tension components shall be in accordance with the general rules given in EN 1990.

(2) The supplementary provisions for tension components given in this standard should also be applied.

(3) For improved durability the following exposure classes may be applied:

Table 2.1: Exposure classes

Fatigue action	Corrosion action	
	not exposed externally	exposed externally
no significant fatigue action	class 1	class 2
mainly axial fatigue action	class 3	class 4
axial and lateral fatigue actions (wind & rain)	–	class 5

(4) Connections of tension components to the structure should be replaceable and adjustable.

2.2 Requirements

(1)P The following limit states shall be considered in designing tension components:

1. ULS: Applied axial loads shall not exceed the design tension resistance, see section 6.

2. SLS: Stress and strain levels in the component shall not exceed the limiting values, see section 7.

NOTE: For durability reasons, serviceability checks may govern over ULS-verifications.

3. Fatigue: Stress ranges from axial load fluctuations and wind and rain induced oscillations shall not exceed the limiting values, see sections 0 and 0.

NOTE: Due to the difficulties in modelling the excitation characteristics of tension elements, SLS checks should be carried out in addition to fatigue checks.

(2) To prevent the likely de-tension of a tension component (i.e. the stress reaching below zero and causing uncontrolled stability or fatigue or damages to structural or non structural parts) and for certain types of structures, the tension components are preloaded by deformations imposed on the structure (prestressing).

In such cases permanent actions, which should consist of actions from gravity loads “G” and prestress “P”, should be considered as a single permanent action “G+P” to which the relevant partial factors γ_{Gi} should be applied, see section 5.

NOTE: For other materials and methods of construction other rules for the combination of “G” and “P” may apply.

(3) Any attachments to prefabricated tension components, such as saddles or clamps, should be designed for ultimate limit states and serviceability limit states using the breaking strength or proof strength of cables as actions, see section 6. For fatigue see EN 1993-1-9.

NOTE: Fatigue action on the ropes is governed by the radius in the saddle or anchorage area (see Figure 6.1 for minimum radius).

2.3 Actions

2.3.1 Self weight of tension components

(1) The characteristic value of the self weight of tension components and their attachments should be determined from the cross-sectional area and the density of the materials unless data are given in the relevant parts of EN 12385.

(2) For spiral strands, locked coil strands or structural wire ropes the nominal self weight g_k may be calculated as follows:

$$g_k = w\, A_m \qquad (2.1)$$

where A_m is the cross-section in mm² of the metallic components

w [N/(mm³)] is the unit weight taking into account the density of steel including the corrosion protection system, see Table 2.2

(3) A_m may be determined from

$$A_m = \frac{\pi\, d^2}{4} f \qquad (2.2)$$

where d is the external diameter of rope or strand in mm, including any sheathing for corrosion protection

f is the fill-factor, see Table 2.2

Table 2.2: Unit weight w and fill-factors f

		Fill factor f							unit weight $w \times 10^{-7}$ $\left[\frac{N}{mm^3}\right]$
		Core wires + 1 layer z-wires	Core wires + 2 layer z-wires	Core wires + >2 layer z-wires	Number of wire layers around core wire: 1	2	3-6	>6	
1	Spiral strand ropes				0,77	0,76	0,75	0,73	830
2	Fully locked coil ropes	0,81	0,84	0,88					830
3	Circular wire strand ropes				0,56				930

(4) For parallel wire ropes or parallel strand ropes the metallic cross-section may be determined from

$$A_m = n\, a_m \qquad (2.3)$$

where n is the number of identical wires or strands of which the rope is made

a_m is the cross-section of a wire (derived from its diameter) or a (prestressing) strand (derived from the appropriate standard)

(5) For group C tension components the self weight should be determined from the steel weight of the individual wires or strands and the weight of the protective material (HDPE, wax etc.)

2.3.2 Wind actions

(1) The wind effects to be taken into account should include:

- the static effects of wind drag on the cables, see EN 1991-1-4, including deflections and bending effects near the ends of the cable,
- aerodynamic and other excitation causing possible oscillation of the cables, see section 8.

2.3.3 Ice loads

(1) For ice loading see Annex B to EN 1993-3-1.

2.3.4 Thermal actions

(1) The thermal actions to be taken into account should include the effects of differential temperatures between the cables and the structure.

(2) For cables exposed externally the actions from differential temperature should be taken into account, see EN 1991-1-5.

2.3.5 Prestressing

(1) The preloads in cables should be such that, when all the permanent actions are applied, the structure adopts the required geometric profile and stress distribution.

(2) Facilities for prestressing and adjusting the cables should be provided and the characteristic value of the preload should be taken as that required to achieve the required profile in (1) at the limit state under consideration.

(3) If adjustment of the cables is not intended to be carried out the effects of the variation of preloads should be considered in the design of the structure.

2.3.6 Replacement and loss of tension components

(1) The replacement of at least one tension component should be taken into account in the design as a transient design situation.

NOTE: The National Annex may define the transient loading conditions and partial factors for replacement.

(2) Where required a sudden loss of any one tension component should be taken into account in the design as an accidental design situation.

NOTE 1: The National Annex may define where such an accidental design situation should apply and also give the protection requirements and loading conditions, e.g. for hangers of bridges.

NOTE 2: In the absence of a rigorous analysis the dynamic effect of a sudden removal may conservatively be allowed for by using the additional action effect E_d:

$$E_d = k\, E_{d2} - E_{d1} \tag{2.4}$$

where $k = 1{,}5$

E_{d1} represents the design effects with all cables intact;

E_{d2} represents the design effects with the relevant cable removed.

2.3.7 Fatigue loads

(1) For fatigue loads see EN 1991.