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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
- All comments should be submitted online at <https://standardsdevelopment.bsigroup.com/>. You will need to register in order to comment.

Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

English Version

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

Eurocode 3 - Calcul des structures en acier - Partie 1-
11 : Éléments tendus

Eurocode 3 - Bemessung und Konstruktion von
Stahlbauten - Teil 1-11: Zugglieder

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 250.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Warning : This document is not a European Standard. It is distributed for review and comments. It is subject to change without notice and shall not be referred to as a European Standard.



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

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European foreword

This document (prEN 1993-1-11:2024) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 1993-1-11:2006 and its corrigenda.

The first generation of EN Eurocodes was published between 2002 and 2007. This document forms part of the second generation of the Eurocodes, which have been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

The Eurocodes have been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by the Eurocodes.

The Eurocodes recognize the responsibility of each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level through the use of National Annexes.

0 Introduction

0.1 Introduction to the Eurocodes

The Structural Eurocodes comprise the following standards generally consisting of a number of Parts:

- EN 1990 Eurocode — Basis of structural and geotechnical design
- EN 1991 Eurocode 1 — Actions on structures
- EN 1992 Eurocode 2 — Design of concrete structures
- EN 1993 Eurocode 3 — Design of steel structures
- EN 1994 Eurocode 4 — Design of composite steel and concrete structures
- EN 1995 Eurocode 5 — Design of timber structures
- EN 1996 Eurocode 6 — Design of masonry structures
- EN 1997 Eurocode 7 — Geotechnical design
- EN 1998 Eurocode 8 — Design of structures for earthquake resistance
- EN 1999 Eurocode 9 — Design of aluminium structures
- New parts are under development, e.g. Eurocode for design of structural glass

The Eurocodes are intended for use by designers, clients, manufacturers, constructors, relevant authorities (in exercising their duties in accordance with national or international regulations), educators, software developers, and committees drafting standards for related product, testing and execution standards.

NOTE Some aspects of design are most appropriately specified by relevant authorities or, where not specified, can be agreed on a project-specific basis between relevant parties such as designers and clients. The Eurocodes identify such aspects making explicit reference to relevant authorities and relevant parties.

0.2 Introduction to the EN 1993 series

(1) The EN 1993 series applies to the design of buildings and civil engineering works in steel. It complies with the principles and requirements for the safety and serviceability of structures, the basis of their design and verification that are given in EN 1990 Eurocode — Basis of structural and geotechnical design.

(2) The EN 1993 series is concerned only with requirements for resistance, serviceability, durability and fire resistance of steel structures. Other requirements, e.g. concerning thermal or sound insulation, are not covered.

(3) The EN 1993 series is subdivided in various parts:

EN 1993-1, *Design of Steel Structures — Part 1: General rules and rules for buildings;*

EN 1993-2, *Design of Steel Structures — Part 2: Bridges;*

EN 1993-3, *Design of Steel Structures — Part 3: Towers, masts and chimneys;*

EN 1993-4, *Design of Steel Structures — Part 4: Silos and tanks;*

EN 1993-5, *Design of Steel Structures — Part 5: Piling;*

EN 1993-6, *Design of Steel Structures — Part 6: Crane supporting structures*;

EN 1993-7, *Design of steel structures — Part 7: Sandwich panels*.

(4) EN 1993-1 in itself does not exist as a physical document, but comprises the following 14 separate parts, the basic part being EN 1993-1-1:

EN 1993-1-1, *Design of Steel Structures — Part 1-1: General rules and rules for buildings*;

EN 1993-1-2, *Design of Steel Structures — Part 1-2: Structural fire design*;

EN 1993-1-3, *Design of Steel Structures — Part 1-3: Cold-formed members and sheeting*;

NOTE Cold formed hollow sections supplied according to EN 10219 are covered in EN 1993-1-1.

EN 1993-1-4, *Design of Steel Structures — Part 1-4: Stainless steel structures*;

EN 1993-1-5, *Design of Steel Structures — Part 1-5: Plated structural elements*;

EN 1993-1-6, *Design of Steel Structures — Part 1-6: Strength and stability of shell structures*;

EN 1993-1-7, *Design of Steel Structures — Part 1-7: Plate assemblies with elements under transverse loads*

EN 1993-1-8, *Design of Steel Structures — Part 1-8: Joints*;

EN 1993-1-9, *Design of Steel Structures — Part 1-9: Fatigue*;

EN 1993-1-10, *Design of Steel Structures — Part 1-10: Material toughness and through-thickness properties*;

EN 1993-1-11, *Design of Steel Structures — Part 1-11: Tension components*;

EN 1993-1-12, *Design of Steel Structures — Part 1-12: Additional rules for steel grades up to S960*;

EN 1993-1-13, *Design of Steel Structures — Part 1-13: Beams with large web openings*;

EN 1993-1-14, *Design of Steel Structures — Part 1-14: Design assisted by finite element analysis*.

(5) All subsequent parts EN 1993-1-2 to EN 1993-1-14 treat general topics that are independent from the structural type like structural fire design, cold-formed members and sheeting, stainless steels, plated structural elements, etc.

(6) All subsequent parts numbered EN 1993-2 to EN 1993-7 treat topics relevant for a specific structural type like steel bridges, towers, masts and chimneys, silos and tanks, piling, crane supporting structures, etc. EN 1993-2 to EN 1993-7 refer to the generic rules in EN 1993-1 and supplement them.

0.3 Introduction to EN 1993-1-11

EN 1993-1-11 provides rules for structural design of tension components made of steel, in addition to other parts of EN 1993, for use in structures made of steel or other materials as e.g. concrete, steel-concrete composite and timber.

EN 1993-1-11 is intended for use by:

- committees drafting design related products, testing and execution standards,
- clients (e.g. for the formulation of their specific requirements),
- designers and constructors,
- relevant authorities.

Numerical values for partial factors and other reliability parameters are recommended as basic values that provide an acceptable level of reliability. They have been selected assuming that an appropriate level of workmanship and quality management applies.

0.4 Verbal forms used in the Eurocodes

The verb “shall” expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches could be used/adopted where technically justified.

The verb “may” expresses a course of action permissible within the limits of the Eurocodes.

The verb “can” expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.5 National annex for EN 1993-1-11

National choice is allowed in this standard where explicitly stated within notes. National choice includes the selection of values for Nationally Determined Parameters (NDPs).

The national standard implementing EN 1993-1-11 can have a National Annex containing all national choices to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

When no national choice is given, the default choice given in this standard is to be used.

When no national choice is made and no default is given in this standard, the choice can be specified by a relevant authority or, where not specified, agreed for a specific project by appropriate parties.

National choice is allowed in EN 1993-1-11 through notes to the following clauses:

4.3.6(1)	4.3.6(3)	4.4(3)	5.2.1(2)
5.3.1(2)	5.4.1(2)	8.2.2(1)	8.3(1)
8.4(1)	8.5.2.2(1)	8.5.3.2(1)	8.6.2(1)
10.3(1)	11(1)	C.3.1(1)	C.4.2(1)
C.4.3.2(1)	C.4.4.1 (1)		

National choice is allowed in EN 1993-1-11 on the application of the following informative annex:

Annex B

The National Annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

1.1 Scope of EN 1993-1-11

(1) EN 1993-1-11 provides rules for structural design of tension components made of steel, in addition to other parts of EN 1993, for use in structures made of steel or other materials such as concrete, steel-concrete composite and timber.

(2) EN 1993-1-11 covers the resistance, serviceability and durability of steel tension elements.

(3) The following items/aspects are outside the scope of EN 1993-1-11:

- pre- or post-tensioned systems in accordance with EN 1992-1-1 and EN 1992-2;
- reinforcing steel as part of a concrete structure in accordance with EN 1992-1-1;
- tension components in piling;
- detailed design of terminations.

1.2 Assumptions

(1) Unless specifically stated, EN 1990, EN 1991 and the EN 1993-1 series apply.

(2) The design methods given in EN 1993-1-11 are applicable if:

- execution quality is according to EN 1090-2; and
- the construction materials and products used are as specified in the relevant parts of the EN 1993 series, or in the relevant material and product specifications.

(3) EN 1993-1-11 is used in conjunction with ENs, EADs and ETAs for tension components.

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.

NOTE See the Bibliography for a list of other documents cited that are not normative references, including those referenced as recommendations (i.e. in 'should' clauses), permissions (i.e. through 'may' clauses), possibilities ('can' clauses), and in notes.

EN 1090-2, *Execution of steel structures and aluminium structures — Part 2: Technical requirements for steel structures*

EN 1990:2023,¹ *Eurocode — Basis of structural and geotechnical design*

EN 1991 (all parts), *Eurocode 1 — Actions on structures*

EN 1993 (all parts), *Eurocode 3 — Design of steel structures*

¹ As impacted by EN 1990:2023/prA1:2024

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1 Components and elements

3.1.1.1

tension component

tension element with terminations including accessories if applicable (e.g. corrosion protection, guiding, ...)

3.1.1.2

tension element

component to transfer tensile forces from one termination to the other

3.1.1.3

termination

component to transfer tensile forces from the tension element into the structure or into axially connected tension elements

3.1.1.4

rod

circular solid rods made of structural steel, stainless steel, concrete reinforcement steel or prestressing steel

3.1.1.5

wire

product manufactured by cold working of wire rod that is in a suitable metallurgical condition for cold working

3.1.1.6

strand

product made 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 wire

3.1.1.7

7-wire strand

product consisting of six cold drawn wires laid helically in the same direction and with the same lay length around a centre wire

3.1.1.8

spiral rope

product made of a minimum of two layers of wires laid helically around a centre wire

3.1.1.9

spiral strand rope

product comprising only round wires

3.1.1.10

stranded rope

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

3.1.1.11**full-locked coil rope**

product made of a core wire and of one or several layers of round wires stranded on top of this round wire core and one or several layers of shaped wires in alternating direction

3.1.1.12**parallel wire system**

PWS

product made of a bundle of parallel prestressing wires with terminations

3.1.1.13**parallel strand system**

PSS

product made of a bundle of parallel 7-wire strands with terminations

3.1.1.14**prefabricated parallel wire strands**

PPWS

products made of a bundle of parallel high strength steel wires with terminations at both ends

Note 1 to entry: The parallel wires in each PPWS are usually assembled in a hexagonal shape by means of special bands. Several PPWSs are usually assembled and compacted to form a circular cable which is wrapped with a mild steel wire.

3.1.1.15**air spun bundles**

tension elements made from arial spinning of parallel high strength wire

Note 1 to entry: Several bundles are usually compacted to a circular shape and wrapped by a mild steel wire.

3.1.1.16**saddle**

support between a continuous tension element and the structure, transferring deviation forces

3.1.1.17**clamp**

part that transfers the load from a secondary tension component to a continuous tension element

3.1.2 Material properties**3.1.2.1****modulus of deformation**

equivalent material property resulting from the axial deformation property of tension elements that can be a combination of the wire modulus and geometric assembly of the wires if arranged in helixes

3.1.2.2**creep**

time-dependant elongation (strain) of tension elements under permanent constant stress

3.1.2.3**relaxation**

time-dependant reduction of stress in tension elements under fixed strain

3.1.3 Manufacturing and installation

3.1.3.1

pre-stretching

several load cycles that are applied to a spiral rope as part of the manufacturing process

Note 1 to entry: Pre-stretching removes initial permanent elongation and makes the rope perform linear elastic.

3.1.3.2

prestressing

process of initial tensioning of a tension component by applying a controlled deformation or a controlled force

3.2 Symbols

3.2.1 General

(1) For the purposes of this document, the following symbols apply.

3.2.2 Latin upper-case symbols

A_m	nominal metallic cross-section of the tension element
E	modulus of elasticity of steel used in the tension component
E_{d1}	design value of the effect of the action with all tension components intact
E_{d2}	design value of the effect of the action with the relevant tension components removed
E_d	design value of the effect of the accidental loss of the tension component(s)
E_Q	modulus of deformation of group B tension element
E_t	effective modulus of elasticity of the tension component
$F_{c,min}$	calculated minimum breaking force of the tension element
F_{Ed}	design value of the tension element axial force
$F_{Ed }$	component of external design load parallel to the tension element
$F_{Ed\perp}$	component of the external design load perpendicular to the continuous tension element
F_{frict}	friction force measured in a clamp slippage test
F_m	characteristic value of maximal tensile strength for prestressing steel
$F_{p0,1}$	characteristic value of the strength for 0,1 % strain of prestressing steel
$F_{p,C}$	preloading force for a bolt
F_{Rd}	design value of the tension element resistance
F_r	clamping force
F_{ri}	initial clamping force, and equal to the initial preloading force in the bolts, summed over all bolts
$F_{r }$	slip resistant force measured in a slippage clamp test
F_{uk}	characteristic value of the tension element breaking force

F_{yk}	characteristic value of the tension element yield strength
L_1	total arc length of the saddle
L_2	arc length of the saddle between the two theoretical tangent points of the tension element under the most unfavourable characteristic combination of actions and the catenary effects
L_{clamp}	contact length of the clamp
L_h	horizontal projection length of the tension component between terminations
N	number of stress cycles during the design service life
N^*	reference value of the number of stress cycles for fatigue resistance $\Delta\sigma^*$
N_{Ed}	design value of the applied number of cycles
P	bound perimeter
P_k	characteristic value of the prestressing force
R	radius of curvature of the tension element inside the saddle
$R_{\min}$	minimum radius of curvature of the saddle of group C tension component

3.2.3 Latin lower-case symbols

d	nominal diameter of the rope, single wire, or strand
d'	contact width of the rope
f_{bpd}	bond strength in the ultimate limit state between strands and grout or between grout and saddle tube
f_{ctd}	design tensile strength of the grout
f_{pk}	characteristic tensile strength of prestressing steel
f_t	characteristic value of tensile strength of reinforcement steel
f_{uk}	characteristic value of the tensile strength of steel wires or (prestressing) strands
f_{yk}	characteristic value of 0,2 %-yield strength of reinforcement steel
n_w	number of individual wires or strands passing in the saddle
n_b	number of bolts of a clamp
n_s	number of activated surfaces for shear transfer
n_{sl}	number of strand's layers of a type 2 saddle of group C tension component
k	factor to account the dynamic effect of an accidental loss of a tension component(s)
m_1	slopes of fatigue resistance curve
m_2	
k_b	bending factor to consider measures to minimize bending stresses of the tension element at the termination

$k_{c,s}$	clamping force coefficient to account for the relationship between the bolt force and the integral contact pressure between clamp and the tension element, for each surface
k_e	loss factor for the termination
$k_{ef,s}$	external load coefficient
k_F	consequence factor applicable to actions for reliability differentiation
$k_{p,B}$	phase factor to consider the design situation for group B tension components
$k_{p,C}$	phase factor to consider the design situation for group C tension components
k_r	bolt force reduction coefficient due to long term effects
q_{Ed}	transverse pressure due to the clamping force
q_{lim}	limiting value of the transverse pressure for clamps and saddles
r_1	radius of the saddle at the contact surface with the tension element
r_2	rounding radius at the saddle ends
w	unit weight of the tension component

3.2.4 Greek upper-case symbols

ΔE_d	additional action effect due to the accidental loss of the tension component(s)
ΔL_2	additional arc length of the saddle
$\Delta \alpha$	imposed tension element rotations of the test specimen
$\Delta \sigma$	stress range
$\Delta \sigma^*$	reference value of the fatigue resistance at N^* cycles
$\Delta \sigma_c$	reference value of the fatigue resistance at $N_c = 2$ million stress cycles (detail category)
$\Delta \sigma_{Ed}$	design value of the applied stress range according to EN 1993-1-9
$\Delta \sigma_t$	axial stress range of the test specimen
ΔT	Temperature variation of the test specimen

3.2.5 Greek lower-case symbols

α	arc angle in radians between theoretical tangent points (deviation angle) of the tension element passing over the saddle
γ_E	Partial factor applied to the effects of actions accounting for the uncertainties covered by γ_f and γ_{Rd}
γ_F	Partial factor for actions, accounting for the uncertainties covered by γ_f and γ_{Rd}
γ_G	partial factor for permanent actions
$\gamma_{G,fav}$	partial factor for a permanent action that produces favourable effects
γ_{Mf}	partial factor for fatigue resistance

$\gamma_{M,fr,B1}$	partial factor for friction between group B tension element and the saddle resulting from the deviation force of the tension element
$\gamma_{M,fr,B2}$	partial factor for friction between group B tension element and a clamp or saddle resulting from the clamping force
$\gamma_{M,fr,B3}$	partial factor for friction between group B tension element and a clamp resulting from the component of the external design load perpendicular to the continuous tension element
$\gamma_{M,fr,B4}$	partial factor for friction between group B tension element and a clamp resulting from the clamping force
$\gamma_{M,fr,C1}$	partial factor for friction between group C tension element and the saddle resulting from the deviation force of the tension element
$\gamma_{M,fr,D1}$	partial factor for friction between group D tension element and the saddle resulting from the deviation force of the tension element
$\gamma_{M,fr,D3}$	partial factor for friction between group D tension element and a clamp resulting from the component of the external design load perpendicular to the continuous tension element
$\gamma_{M,fr,D4}$	partial factor for friction between group D tension element and a clamp resulting from the clamping force
$\gamma_{Mt,A}$	partial factor for group A tension elements
$\gamma_{Mt,B}$	partial factor for group B tension elements
$\gamma_{Mt,C}$	partial factor for group C tension elements
$\gamma_{Mt,D}$	partial factor for group D tension elements
γ_{PT}	partial factor for prestressing actions of the tension component
$\gamma_{PT,fav}$	partial factor for prestressing actions of the tension component that produces favourable effects
γ_s	partial factor for reinforcing or prestressing steel
μ	friction coefficient
η_{p2}	coefficient that takes into account the type of tendon and the bond situation at the saddle
σ	stress in the tension component
σ_{cst}	constant axial stress of the test specimen
σ_{max}	maximum axial stress of the test specimen
σ_{min}	minimum axial stress of the test specimen
$\sigma_{sup,Cd}$	maximum stress as a function of the fatigue detail category
$\sigma_{sup,Ed}$	maximal stress caused by the frequent combinations of actions
$\sigma_{u,k}$	characteristic value of the breaking strength of the steel used in the tension element

3.3 Groups

(1) Tension components are classified into groups A, B and C according to Table 3.1.

Table 3.1 — Groups of tension components

Group	Tension element	Tension component
A	rod	tension rod system made of structural steel or stainless steel
		tension rod system made of concrete reinforcement steel
		tension rod system made of prestressing steel
B	rope made of circular wire	spiral strand rope with terminations
	rope made of circular wire and stranded wire	stranded rope (type IWRC or WSC) with terminations
	rope made of circular and Z-shaped wires	full-locked coil rope with terminations
C	bundle made of circular prestressing wires	parallel wire system (PWS)
	bundle made of 7-wire prestressing strands	parallel strand system (PSS)

NOTE 1 In addition, Group D tension components are defined in Annex C – Parallel wire tension components for suspended structures.

NOTE 2 Examples of tension components for groups A, B, C and D are illustrated in Annex B.

(2) For the design of Group D, parallel wires tension components for suspended structures (i.e. for suspension bridges and other suspended structures), use the additional provisions in Annex C (normative).

(3) For hangers of tied-arch bridges using rod tension elements, the rules from prEN 1993-2:2024, Annex A should additionally apply.

4 Basis of design

4.1 General rules

4.1.1 Basic requirements

(1) The design of tension components shall be in accordance with the general rules given in EN 1990:2023 and the EN 1991 series and the specific design provisions for steel structures given in the other relevant parts of the EN 1993-1 series.

(2) Tension components designed according to this document shall be executed according to EN 1090-2.

(3) Tension components designed according to this document shall comprise construction materials and products used as specified in the relevant parts of EN 1993, or in the relevant material and product specifications.

4.1.2 Structural reliability

(1) The rules in EN 1993-1-1 apply.

4.2 Principle of limit state design

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

- 1) Ultimate Limit States (ULS): Applied axial loads shall not exceed the design tension resistance in accordance with Clause 8.

Fatigue stress ranges from axial load shall not exceed the limiting values in accordance with Clause 10.

Effects from transverse loads shall be addressed by adequate structural details in accordance with Clause 8 and Clause 10.

- 2) Serviceability Limit States (SLS): Stress levels and deflection in the tension component shall be in accordance with Clause 9.

4.3 Basic variables for actions

4.3.1 Self-weight of tension components

(1) The characteristic value of the self-weight of tension components should be determined from their geometry and the density of the materials, including corrosion protection system and casing if applicable.

(2) For tension elements of group B data for self-weight may be in accordance with EN 12385-2, EN 12385-4 and EN 12385-10.

4.3.2 Wind actions

(1) The wind effects should include:

- the static effects of wind drag on the tension component in accordance with EN 1991-1-4, including deflections and bending effects near the ends of the tension component,
- aerodynamic and other excitation causing possible oscillation of the tension components in accordance with 7.4 and 7.5 and EN 1991-1-4.

4.3.3 Ice loading

(1) The ice loading should be in accordance with EN 1991-1-9.

4.3.4 Thermal actions

(1) The thermal actions in accordance with EN 1991-1-5 should include temperature changes and the effects of differential temperatures between the tension components and the structure.

4.3.5 Prestressing

(1) Prestressing of a tension component should be performed either by applying a controlled deformation or a controlled force.

(2) The design value of prestress may be based on the characteristic value of the prestressing force, P_k , in accordance with EN 1990:2023, 6.1.3.

4.3.6 Replacement and accidental loss of tension components

(1) Where required, the replacement of a tension component should be taken into account in the design as a transient design situation. For structures under fatigue actions or for structures with an assumed working life exceeding the life span of the tension component itself, it is recommended to consider such loading conditions.

NOTE The transient loading conditions can be set by the National Annex.

(2) Where required, the accidental loss of tension component(s) should be taken into account in the design, considering an accidental design load combination.

NOTE EN 1990 provides additional information about accidental loss of tension components and robustness criteria.

(3) The dynamic effect in the structure from the accidental loss of the relevant tension elements(s) should be defined based on experience, nonlinear dynamic time history analysis or measurements, as specified by the relevant authority or, where not specified, agreed for a specific project by the relevant parties.

(4) In absence of a dynamic time history analysis, the dynamic effect in the structure ΔE_d may be considered by a dynamic factor k applied to the differential effect of the action resulting from the removal of the relevant tension elements(s).

NOTE 1 The value of k is 2,0 unless the National Annex gives a different value.

NOTE 2 A lower k factor can be defined based on experience, nonlinear dynamic time history analysis or measurements.

(5) The analysis may be performed by applying opposing forces, including dynamic amplification, at both terminations of the lost tension component(s) or, in case of linear system behaviour, by superposition of design values, including the dynamic amplification, as per the following formulae:

$$\Delta E_d = k (E_{d2} - E_{d1}) \quad (4.1)$$

$$E_d = E_{d1} + \Delta E_d \quad (4.2)$$

where

- ΔE_d represents the dynamic effect of an accidental loss of the tension component(s);
- E_{d1} represents the design value of the effect of the action with all tension component(s) intact;
- E_{d2} represents the design value of the effect of the action with the relevant tension component(s) removed;
- E_d represents the resulting design value of the effect of the accidental loss of the tension component(s);
- k is a dynamic factor.

4.3.7 Fatigue loads

(1) Fatigue stress in tension components results from traffic load and wind induced or otherwise induced vibrations.

(2) Fatigue actions due to traffic should be in accordance with EN 1991-2. They may cause variable axial and transverse loads and, where there is a flexural constraint at a termination, bending moments. Bending moments may be reduced by appropriate structural detailing.

(3) Fatigue actions due to wind should be in accordance with EN 1991-1-4. Wind induced or otherwise induced vibrations cause primarily variable transverse loads and bending moments.

4.4 Verification by the partial factor method

(1) Partial factors γ_{Mt} should be in accordance with:

- Clause 8 except for fatigue verification;
- EN 1993-1-9 for fatigue verification.

(2) For ULS – and SLS – verifications, the actions self-weight “G” and prestress “P” should be included in the relevant combinations of actions.

(3) For ULS verifications, the partial factor γ_{PT} should be applied to the forces of the tension elements.

NOTE The value of the partial factor γ_{PT} is given in Table 4.1 unless the National Annex gives different values.

- a) If there is a direct correlation between the stress in the tension elements and the self-weight (e.g. suspension bridges or cable stayed bridges), a single partial factor γ_{PT} is applied to “G+P” ($\gamma_{PT} = \gamma_G$) with γ_G and k_F according to EN 1990.
- b) If there is no correlation between the stress in the tension elements and the self-weight (e.g. prestress acting against the structural stiffness provided by other structural members, such as masts, cable net facades, spokes wheel roof structures), a partial factor γ_G is applied to “G” according to EN 1990 and a partial factor γ_{PT} is applied to “P”. Values are given in Table 4.1 for qualified stressing procedures (ETA or equivalent) or in combination with a direct monitoring of the stressing forces. For other applications variations can be considered.

Table 4.1 (NDP) — Partial factors γ_{PT} (persistent and transient) design situations

Action or effect				Partial factors γ_F and γ_E		
Type	Analysis	Symbol	Resulting effect	Structural resistance	Static equilibrium and uplift	
Design case (DC) ^e				DC1	DC2(a)	DC2(b)
a) Prestress correlated to self-weight ($P_{k,G}$)	linear and nonlinear	γ_{PT}	unfavourable	γ_G	γ_G	γ_G
		$\gamma_{PT,fav}$	favourable	$\gamma_{G,fav}$	$\gamma_{G,fav}$	$\gamma_{G,fav}$
b) Prestress against stiffness (not correlated to self-weight) ($P_{k,E}$)	linear ^b	γ_{PT}	unfavourable	1,0	1,1 k_F^d	1,0
		$\gamma_{PT,fav}$	favourable	1,0	0,9	1,0
	nonlinear ^c	γ_{PT}	unfavourable	1,1 ^a k_F^d	1,1 k_F^d	1,0
		$\gamma_{PT,fav}$	favourable	0,9 ^a	0,9	1,0
^a Partial factor considers variations of prestress up to $\pm 5\%$, due to the prestressing method, marking and cutting to length (according to A.4.4) and/or accuracy of stressing procedure and method of force measurement.						
^b i) γ_F as per EN 1990:2023, 8.3.2.1(3) when applying factors to actions, in case of linear analysis in accordance with EN 1990:2023, 7.2.1, or nonlinear analysis in accordance with EN 1990:2023, 7.2.2. ii) γ_E as per EN 1990:2023, 8.3.2.1(4) when applying factors to the effects of actions, in case of nonlinear analysis, in accordance with EN 1990:2023, 8.3.2.1(4).						
^c γ_F as per EN 1990:2023, 8.3.2.2 when applying factors to actions, in case of nonlinear analysis in accordance with EN 1990:2023, 7.2.2 and 8.3.2.1(4).						
^d k_F in accordance with EN 1990.						
^e Geotechnical design cases SC3 and DC4 should follow the selections in EN 1990.						

(4) The selections in Table 4.1 should follow the used combination of actions in EN 1990:2023, 8.3.4.2(2).

5 Material

5.1 General

(1) The characteristic values of the material properties for tension elements should be in accordance with 5.2, 5.3 and 5.4.

(2) The characteristic values of the material properties for terminations should be taken from the relevant technical specifications.

(3) The coefficient of linear thermal expansion for steel should be taken from EN 1993-1-1 and for other materials from prEN 1991-1-5:2023, Annex C.

NOTE Characteristic values are also referred to as nominal values.

5.2 Group A tension elements

5.2.1 Nominal tensile strength and nominal yield strength

(1) The nominal values of the tensile strength and yield strength should be taken from the references given in Table 5.1.

Table 5.1 — Nominal tensile strength and yield strength – references

Structural steel	EN 1993-1-1, EN 10343, EN 1993-1-8
Structural stainless steel	EN 1993-1-4
Casting steel	EN 10340
Prestressing steel	EN 1992-1-1, EN 10138-3
Concrete reinforcement steel	EN 1992-1-1, EN 10080

(2) A maximum value for the nominal tensile strength should be given for durability reasons.

NOTE The maximum values of the nominal tensile strength are in accordance with Table 5.2 unless the National Annex gives different values.

Table 5.2 — (NDP) Nominal tensile strength: recommended maximum values

Prestressing steel	$f_{pk} = 1\,050 \text{ N/mm}^2$
Concrete reinforcement steel	$f_t = 600 \text{ N/mm}^2$

(3) Detailing of terminations of prestressing steel tension elements should consider that prestressing steel has lower ductility than concrete reinforcement steel and structural steel.

5.2.2 Modulus of elasticity

(1) The value of the modulus of elasticity should be taken from the references given in Table 5.3. For prestressing steel and concrete reinforcement steel, these are recommended values. More precise values may be obtained from manufacturers' data.

Table 5.3 — Modulus of elasticity E for group A tension elements – references

Structural steel	In accordance with EN 1993-1-1
Structural stainless steel	In accordance with EN 1993-1-4
Prestressing steel	In accordance with EN 1992-1-1
Concrete reinforcement steel	In accordance with EN 1992-1-1

5.2.3 Creep and relaxation

(1) For group A tension components made of prestressing steel, creep and/or relaxation should be taken into account where the related increase of length and/or loss of force are of relevance.

(2) Creep and/or relaxation of the group A tension components may be ignored if the tensile force caused by the quasi-permanent combination of actions does not exceed 50 % of F_{uk} .

(3) For group A tension components made of prestressing steel, if the tensile force caused by the quasi-permanent combination of actions exceeds 50 % of F_{uk} , EN 1992-1-1:2023, Annex B should be applied.

5.3 Group B tension elements

5.3.1 Nominal tensile strength grade of steel wires

(1) The value of the tensile strength grade of steel wires f_{uk} should be taken from the references given in Table 5.4.

Table 5.4 — Nominal tensile strength grade of steel wires – references

Non-alloyed steel wire	EN 10264, Part 1 to Part 3
Stainless steel wires	EN 10264, Part 1 and Part 4

(2) A maximum value for the nominal tensile strength grade f_{uk} should be given for durability reasons.

NOTE The maximum values for f_{uk} are in accordance with Table 5.5 unless the National Annex gives different values.

Table 5.5 — (NDP) Nominal tensile strength grade of steel wires: recommended maximum values

Round steel wires	1 770 N/mm ²
Z-shaped steel wires	1 570 N/mm ²
Round stainless steel wires	1 570 N/mm ²
Z-shaped stainless steel wires	1 350 N/mm ²

(3) Stranded ropes should comply to EN 12385-4.

(4) Spiral strand ropes and full locked coil ropes should comply to EN 12385-10.

5.3.2 Modulus of deformation

(1) The modulus of deformation E_Q should be used as the modulus of elasticity for structural analysis.

(2) Nominal values of modulus of deformation E_Q for use as first estimates are in accordance with Table 5.6.

Table 5.6 — Nominal modulus of deformation E_Q for group B tension elements

Tension elements	E_Q N/mm ²	
	Steel wires	Stainless steel wires
Spiral strand ropes	160 000 ± 10 000	130 000 ± 10 000
Stranded ropes (type IWRC or WSC)	100 000 ± 10 000	90 000 ± 10 000
Full-locked coil ropes	160 000 ± 10 000	130 000 ± 10 000

(1) The actual value of the modulus of deformation should be measured. The measuring procedure described in Annex A should be applied. The impact of the actual value on the structure should be assessed in comparison to the nominal value used as first estimate.

(2) For fully pre-stretched tension components, a constant modulus of deformation may be assumed. The procedure described in Annex A should be applied to achieve fully pre-stretching of the tension components.

(3) Non or partially pre-stretched group B tension components exhibit both elastic and permanent deformations which should be taken into account.

5.3.3 Creep and relaxation

(1) For group B tension components creep and/or relaxation should be taken into account where the related increase of length and/or loss of force are of relevance.

NOTE Group B tension members are used in both: a) structures with a prestress state driven by dead load, thus experiencing mainly creep and, b) structures prestressed against the elasticity of other structural members – thus experiencing mainly relaxation. For group B tension components typically creep tests are executed according to Annex A. Creep characteristics derived from creep tests can also be used to consider the effect of relaxation provided the reduction of prestress does not exceed 20 %.

(2) Values for creep should be based on test results or data from similar structures.

For fully pre-stretched, galvanized full-locked coil ropes a typical result from a creep test according to Annex A is 0,035 % at 1 000 hours. Higher design values are recommended for longer service periods.

NOTE Non or partially pre-stretched ropes have a higher creep value than fully pre-stretched ropes.

(3) Where the creep value is determined by testing according to Annex A and Clause 11 (e.g. as part of the quality control plan), it should reflect project specific requirements (e.g. pre-stretch condition, loads).

5.3.4 Friction coefficients

(1) The friction coefficient should be used to calculate the friction force between the tension element and the steel attachments.

(2) Values for the friction coefficient may be based on test results or data from similar structures.

(3) Tests for determining the friction coefficient should be carried out according to Annex A and Clause 11.

(4) For full-locked coil ropes in contact with steel attachments via soft metal or thermally sprayed zinc according to 8.5.2.1(3), the friction coefficient $\mu = 0,1$ may be applied without testing, or $\mu = 0,15$ with confirmation by suitability testing according to Table 8.6.

(5) For spiral strand ropes in contact with steel attachments via soft metal or thermally sprayed zinc according to 8.5.2.1(3), the friction coefficient $\mu = 0,1$ may be applied without testing.

5.4 Group C tension elements

5.4.1 Nominal tensile strength grade of steel wires and strands

(1) References for the nominal tensile strength grade f_{uk} are in accordance with Table 5.7

Table 5.7 — Nominal tensile strength grade of steel wires and strands – references

Steel wires	EN 10138-1 ^a
Strands	EN 10138-2
^a Relaxation class R1 only	

(2) A maximum value for the nominal tensile strength grade f_{uk} should be given for durability reasons.

NOTE The maximum values for f_{uk} are in accordance with Table 5.8 unless the National Annex gives different values.

Table 5.8 — (NDP) Nominal tensile strength grade of steel wires and strands: recommended maximum values

Steel wires	1 770 N/mm ²
Strands	1 860 N/mm ²

5.4.2 Modulus of elasticity

(1) The modulus of elasticity for group C tension elements may be taken from Table 5.9 in accordance with EN 10138-1 for wires and EN 10138-2 for strands. Alternatively, values may be obtained from manufacturers' data.

Table 5.9 — Nominal modulus of elasticity E for group C tension elements

Tension element	E N/mm ²
Bundle of parallel wires	205 000
Bundle of parallel 7-wire strands	195 000 ± 10 000

5.4.3 Creep and relaxation

(1) For group C tension components, creep and/or relaxation should be taken into account where the related increase of length and/or loss of force are of relevance.

(2) Creep and/or relaxation of group C tension components may be ignored if the tensile force caused by the quasi-permanent combination of actions does not exceed 50 % of F_{uk} .

(3) If the tensile force caused by the quasi-permanent combination of actions exceeds 50 % of F_{uk} , EN 1992-1-1:2023, Annex B should be applied.

5.4.4 Friction coefficients

(1) The friction coefficient should be used to calculate the friction force between the tension element and the attachments (including saddles).

(2) Values for the friction coefficient should be based on test results or data from similar structures.

(3) Tests for verifying the friction coefficient should be carried out according to Annex A and Clause 11.

6 Durability

(1) A corrosion protection system should be selected based on:

- the design service life, in accordance with EN 1990:2023, 4.6,
- the corrosive impact, described by the exposure classes C1 to C5 according to EN ISO 12944-2,
- the accessibility for inspection and the maintenance intervals, and
- the type of tension element or termination.

NOTE The durability of tension elements and terminations is mainly affected by effects of corrosion, the choice of corrosion protection system, and choices made in design, execution and maintenance.

(2) For durability, the tension component of the groups A, B and C should comply with the rules given in Annex A.

(3) All components of the corrosion protection system should be compatible with each other.

(4) The durability of terminations, saddles and clamps should be in general at least equivalent to the durability of the connected tension element.

7 Structural analysis

7.1 General

(1) The analysis shall be carried out for the limit states considered for the transient execution or maintenance phase and the persistent service life phase after completion of construction works.

(2) The design analysis for the transient execution phase should be based on the specified stage-by-stage programme of erection sequence and control measures.

(3) The material behaviour (e.g. creep, shrinkage and cracking, etc.) of the structure itself, incorporating the tension components, should be as defined in the relevant material specific design codes. If applicable, the structural analysis should consider upper and lower design limits of material properties.

(4) For compliance with control measures throughout the construction works (e.g. measurements of shape, gradients, deformations, frequencies or forces), all calculations should be re-checked using actual values of permanent loads, imposed deformations and any imposed actions.

(5) Where applicable, the effects of dynamic interactions between the tension component and the structure should be considered.

(6) Where applicable, the effects of creep and / or relaxation should be considered.

7.2 Nonlinear effects from deformations

(1) Nonlinear behaviour of structures with tension components should be included in the structural analysis when required by 7.2.2 of EN 1990:2023.

(2) Nonlinear analysis should be based on the geometry defined by the permanent loading “ $G + P$ ” and the initial temperature T_0 according to EN 1991-1-5.

(3) Appropriate assumptions for the imperfection of the structure should be taken into account. Values should be taken from the relevant Eurocodes.