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Date: 14 March 2024

Origin: European

Latest date for receipt of comments: 13 May 2024

Project No. 2019/01854

Responsible committee: CB/203 Design & execution of steel structures

Interested committees:

Title: BS EN 1993-2 Eurocode 3 - Design of steel structures

Part 2: Steel Bridges

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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 Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.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.**
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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	Commend (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 2: Bridges

Eurocode 3 - Calcul des structures en acier - Partie 2:
Ponts

Eurocode 3 - Bemessung und konstruktion von
Stahlbauten - Teil 2: Brücken

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.

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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.

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COMITÉ EUROPÉEN DE NORMALISATION
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European foreword

This document (prEN 1993-2:2024) 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 1993-2:2006.

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 recognise 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.

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 EN 1993 (all parts)

EN 1993 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 — Basis of structural and geotechnical design.

EN 1993 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.

EN 1993 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*.

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.

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 1993-2

EN 1993-2 is the second part of EN 1993 — Design of Steel Structures and describes the principles and application rules for the safety and serviceability and durability of steel structures for bridges.

EN 1993-2 gives design rules which are supplementary to the generic rules in EN 1993-1.

EN 1993-2 is intended to be used with Eurocodes EN 1990, EN 1991 (all parts) and the parts 2 of EN 1992 to EN 1998 when steel structures or steel components for bridges are referred to.

Matters that are already covered in those documents are not repeated.

EN 1993-2 is intended for use by

- committees drafting design related product, 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 prEN 1993-2

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 prEN 1993-2 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 prEN 1993-2 through notes to the following clauses:

4.1.3(2)	4.3(2) – 2 choices	4.4(1)	4.4(2)
5.2.1(1) – 2 choices	5.2.3(2)	5.2.4(1)	5.3.1.2(1)
5.3.2(2)	5.4(1)	5.5(1)	5.6 (1)
5.7(1)	5.7(3)	6(3)	6(7)
7.4.1(2)	8.2.2.3(1)	8.2.2.5(1)	8.3.5(6)
9.1(3)	9.3(1)	9.4(1)	10.1.1(1)
10.1.1(3)	10.1.2(2)	10.1.2(3)	10.1.3(3)
10.2.2(1)	10.2.3(1)	10.4.2(1)	10.4.3 (2) – 2 choices
10.4.3(3)	10.5(1) – 2 choices	10.6(1)	11.1.2(1)

11.1.3(1)	11.1.5(1)	11.2.2(1)	11.2.3(1)
11.2.4(1)	11.2.6(1)	11.3(1)	11.4(1)
C.1(1)	C.3.1(2)	C.3.2.2(1)	C.3.2.2(2)
E.4(1)	F.1(2)		

National choice is allowed in EN 1993-2 on the application of the following informative annexes:

Annex C

Annex F

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 1993-2

- (1) EN 1993-2 provides rules for structural design of steel bridges and steel parts of steel-concrete composite bridges.
- (2) EN 1993-2 is applicable to the resistance, serviceability and durability of steel bridge structures.
- (3) The design of tension components and related parts is covered by EN 1993-1-11. For the design of hangers for tied-arch bridges, the additional provisions in Annex A apply.
- (4) Supplementary requirements for seismic design are given in EN 1998-2.

1.2 Assumptions

- (1) Unless specifically stated, EN 1990, EN 1991 (all parts), EN 1998 (all parts) and EN 1993-1 (all parts) apply.
- (2) The design methods given in EN 1993-2 are applicable if:
 - the execution quality is as specified in EN 1090-2 and EN 1090-4, and
 - the construction materials and products used are as specified in the relevant parts of EN 1993, or in the relevant material and product specifications.

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 1090-4, *Execution of steel structures and aluminium structures — Part 4: Technical requirements for cold-formed structural steel elements and cold-formed structures for roof, ceiling, floor and wall applications*

EN 1990:2023¹, *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*

EN 1998 (all parts), *Eurocode 8 — Design of structures for earthquake resistance*

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 terms and definitions given in EN 1990, EN 1993-1 (all parts) and the following apply.

3.1.1

breathing (of plates)

out-of-plane deformation of a plate caused by repeated application of in-plane loading

3.1.2

secondary structural elements

structural elements that do not form part of the main load-carrying structures of the bridge, such as guard rails, parapets, maintenance walkways, ladders and access covers

3.2 Symbols

3.2.1 General

For the purpose of this document, the symbols given in EN 1990, EN 1993-1 (all parts) and the following apply.

3.2.2 Latin upper-case symbols

A	cross-sectional area
A_{eff}	effective area
A_{wc}	area of the compression zone of the web
A_{1c}, A_{2c}	cross-section areas of a crossbeam submitted to local load from stiffeners
A_k, B_k	parameters for the calculation of the critical shear buckling factor
$A_{\chi}, B_{\chi}, C_{\chi}$	parameters for the calculation of the reduction factor for shear buckling
C_U	height of cope hole above base of stiffener
C_d	spring stiffness
C_L	height of cope hole below base of stiffener
C_{zf}	coefficient for the design buckling resistance of curved plate girders
D	hanger diameter
D_0	reference value of the hanger diameter
E	modulus of elasticity
F_{Ed}	additional lateral force
$F_{b,Rd}$	design bearing resistance for ultimate limit states verifications
$F_{v,\text{Ed},\text{ser}}$	shear force in a bolt under the characteristic load combination at serviceability limit state
F_i, F_{i+1}	loads introduced by the stiffeners at section i and section $i+1$

F_1, F_2	point loads
I	moment of inertia (second moment of area)
I_B	Moment of inertia (second moment of area) of the stiffeners including deck plate
L	span length
L_{cr}	buckling length
L_E	embedded length
L_F	clear height of gusset plate
L_i	span length of the span i
L_R	spacing of the centres of rigid lateral restraints to the compression flange
L_w	half wavelength of buckling
$L_{w,i}$	effective correlation length
L_1	modified span length of an arch
L_λ	critical length of the influence line or area
M_{cr}	elastic critical moment for lateral torsional buckling
$M_{c,Rd}$	design value of the bending moment resistance about one principal axis of a cross-section
M_{Ed}	design value of the bending moment
$M_{rw,max}$	calculated bending moment due to rain-wind-induced vibration
$M_{w,max}$	calculated bending moment
M_1, M_2	end moments
N_E	reference elastic critical axial force
N_{Ed}	design value of the axial force
N_{cr}	elastic critical axial force for the relevant buckling mode based on the gross cross-sectional properties
$N_{c,Rd}$	design value of the resistance to axial force of the cross-section for uniform compression
N_{Ed}	design value of the axial force
N_i	number of lorries per year in lane i
N_{obs}	total number of lorries per year in the slow lane
N_0	reference number of cycles
Q_{mi}	average gross weight of the lorries in lane i
Q_i	gross weight of the lorry i
Q_0	reference weight
R	radius of cope hole

R_B	radius of the beam in plan
R_{eH}	yield strength taken from the relevant product standard
R_m	ultimate strength taken from the relevant product standard
St	Strouhal number
$V_{b,Rd}$	design value of the shear buckling resistance
$V_{bw,Rd}$	design value of the shear buckling resistance considering the contribution of the web
V_{Ed}	design value of the shear force
W_{el}	elastic section modulus
$W_{el,com}$	elastic modulus which corresponds to the fibre where the limiting compressive stress is obtained
$W_{el,min}$	elastic modulus which corresponds to the fibre with the maximum stress (tension or compression).
Z_{Ed}	required design Z-value resulting from the magnitude of strains from restrained metal shrinkage under the weld beads

3.2.3 Latin lower-case symbols

a_R	spacing of the rigid transverse stiffeners
a_σ	ratio of stress ranges
a	weld size
a_0, b_0, c_0	stability values for galloping oscillations in the bending mode
b_c	width of the compression flange
b	plate width
b_{eff}	effective width
b_F	width at cope hole level
b_p	width of unstiffened panel
b_{st}	width of stiffener
b_u	maximum width of plate
b_w	width of weld
b_{1c}, b_{2c}	width of a crossbeam submitted to local load from stiffeners
c	stiffness parameter
c	exciting coefficient
c_{lat}	exciting power coefficient
d	plate thickness of flat steel plate hanger
d_c	distance between adjacent crossbeams

d_s	distance between springs
e	spacing of the supports of the deck plate
e_{crossb}	spacing of crossbeams
e_E	edge distance of crossbeams
e_{LS}	spacing between stiffeners
e_Q, e_s	eccentricities in a forged hanger
e_0	equivalent geometrical imperfection
f	natural frequency
f_i	natural frequency of the relevant mode
f_u	ultimate tensile strength
f_{ub}	nominal tensile strength of bolts
f_y	yield strength
f_{yb}	nominal yield strength for bolts
f_{yw}	yield strength of the web
f_0	reference frequency
h_{crossb}	height of crossbeam
h	height of stiffener
h_{stiff}	height of stiffener
h_w	height of the web
k	number of lanes with heavy traffic
k_d	factor to take account of the continuous reduction of the excitation risk due to rain-wind induced vibrations
$k_{F,i}$	factor to take account of a continuous reduction in the level of excitation as the natural frequencies increase
$k_{H,i}$	reduction factor to take account of frequency
k_s	stress modification factor
$k_{T,i}$	reduction factor to take account of turbulence
$k_{V,i}$	factor to take account of the continuous decrease in the excitation at wind velocities in excess of 20 m/s
k_α	amplification factor for taking into account second order sway effects
$k_{\tau,za}$	critical shear buckling factor for the web of a curved girder
m	amplification factor applied to the reference elastic critical axial force
m_L	mass per unit length
n	percentage of traffic

n_i	number of lorries of gross weight Q_i in the slow lane
q	lateral load for the effects of oscillations due to vortex shedding
$q_{\max}$	maximum value of the equivalent lateral load
q_{red}	reduced value of the equivalent lateral load for the effects of oscillations due to vortex shedding
q_0	reference value of the lateral load
r	radius
r_g	root gap or root reset
r_w, r_1	radius in a cope hole
s	length of a arch
s	gap width
t	thickness
t_D	thickness of deck plate
$t_{f,cb}$	flange thickness of crossbeam
t_{stiff}	thickness of stiffener
t_{Ld}	design service life of the bridge in years
t_w	web thickness
$t_{w,cb}$	web thickness of a crossbeam
$t_{w,st}$	plate thickness of stiffeners
v	imperfection of forged hanger end
$v_{cr,i}$	critical wind velocity of the relevant mode
V_m	mean value of the wind velocity at mid height of the hangers
v_0	reference value of the critical wind velocity
z_a	curvature parameter for shear resistance
z_f	curvature parameter for bending resistance

3.2.4 Greek upper-case symbols

Φ	non dimensional factor depending on ratios of shear forces and bending moments
Φ_{LT}	value to determine the reduction factor for lateral torsional buckling
Φ_R	Diameter of rope hangers
Φ_2	damage equivalent impact factor
$\Delta b_1, \Delta b_2$	imperfections in forged hanger end
$\Delta\sigma$	stress range

$\Delta\sigma_c$	characteristic reference value of fatigue resistance in terms of normal stress, at 2×10^6 cycles
$\Delta\sigma_{e,2}$	damage equivalent normal stress range related to 2×10^6 cycles
$\Delta\sigma_{fre}$	nominal stress range due to the frequent load combination
$\Delta\sigma_p, \Delta\sigma_{loc}, \Delta\sigma_{glo}$	stress ranges from load p
$\Delta\sigma_{rw}$	stress range due to rain-wind-induced vibrations
$\Delta\sigma_{w,e,2}$	stress range at the points likely to be affected by fatigue
$\Delta\sigma_1$	stress range at the section due to load model 71 on one track
$\Delta\sigma_{1+2}$	stress range at the section to be checked due to load model 71 on any two tracks
$\Delta\tau_{e,2}$	damage equivalent shear stress range related to 2×10^6 cycles
$\Delta\tau_c$	characteristic reference value of fatigue resistance in terms of shear stress, at 2×10^6 cycles
θ	mass moment of inertia
Φ_{glo}	damage equivalent impact factor for global effects
Φ_{loc}	damage equivalent impact factor for local effects
Φ_2	damage equivalent impact factor

3.2.5 Greek lower-case symbols

α	angle between flange and web
α_{cr}	factor by which the design loading would have to be increased to cause elastic instability in a global mode
α_m	reduction factor for the number of piers in a row
α_w	aspect ratio of a web panel
δ	logarithmic decrement of damping
δ_{meas}	logarithmic decrement of damping obtained by measurements
δ_T	logarithmic decrement of damping of the first torsional mode
ε	material parameter depending on the yield strength
γ	stiffness ratio
γ_{Ff}	partial factor for the fatigue action effect
γ_{Mf}	partial factor for the fatigue resistance
$\gamma_{M,ser}$	partial factor for serviceability limit states
γ_{M0}	partial factor for resistance of cross-sections
γ_{M1}	partial factor for resistance of members to instability assessed by member checks

γ_{M2}	partial factor for resistance of cross-sections in tension to fracture, for resistance of bolts, for resistance of rivets, for resistance of pins, for resistance of welds for resistance of plates in bearing
γ_{M3}	partial factor for slip resistance of joints at ultimate limit state (Category C)
$\gamma_{M3,ser}$	partial factor for slip resistance of joints at serviceability limit state
γ_{M4}	partial factor for bearing resistance in an injection bolt
γ_{M5}	partial factor for resistance of joints in hollow section lattice girders
$\gamma_{M6,ser}$	partial factor for resistance of pins at serviceability limit states
γ_{M7}	partial factor for preload of high strength bolts
γ_c	partial factor for resistance of concrete
$\gamma_{sl,i}^*$	relative stiffness of a longitudinally stiffened web panel
η_i	value of the influence line for the internal force that produces the stress range in the middle of lane i
λ_{glo}	damage equivalent factor for global effects
λ_{loc}	damage equivalent factor for local effects
$\lambda, \lambda_1, \lambda_2, \lambda_3, \lambda_4$	damage equivalent factors
$\bar{\lambda}_{LT}$	relative slenderness for lateral torsional buckling
$\bar{\lambda}_w$	relative slenderness for shear buckling of the web
$\bar{\lambda}_{w0}$	limit of relative slenderness for susceptibility to shear buckling of the web
λ_{max}	maximum λ -value taking account of the fatigue limit
λ_{max}^*	maximum λ -value taking account of the fatigue limit
μ	ratio of shear forces
ρ	density of the air
$\rho_{c,x}$	reduction factor
$\sigma_{cr,p}$	longitudinal critical stress of a web panel or sub-panel
σ_{Ed}	design value of a normal stress
$\sigma_{Ed,ser}$	normal stress at serviceability limit states
$\sigma_{p,max}$	maximum normal stress for the calculation of the reference stress range
$\sigma_{p,min}$	minimum normal stress for the calculation of the reference stress range
$\tau_{Ed,ser}$	shear stress at serviceability limit states
σ_G	stress due to the axial force acting on the hangers under permanent actions
$\sigma_{glob,Ed}$	design value of stress in the stiffener due to bridge loads comprising one or more heavy vehicles
σ_{limit}	limiting stress of the weakest part of the cross-section in compression

$\sigma_{loc,Ed}$	design value of stress in a stiffener due to local wheel or tyre load from a single heavy vehicle
$\sigma_{net,Rd}$	design value of the tensile strength at cope hole level
$\sigma_{p,max}$	maximum stress
$\sigma_{p,min}$	minimum stress
σ_Q	stress due to the axial force and bending moment of the hanger as a result of frequent traffic loads
σ_{Rd}	design value of the tensile strength of a hanger
σ_{rw}	maximum stress amplitude due to rain-wind-induced vibration
$\sigma_{x,Ed}$	design value of longitudinal stress
$\sigma_{x,Ed,ser}$	longitudinal stress at serviceability limit states
σ_1, σ_2	direct stresses
σ_{1b}, σ_{2b}	stresses due to bending
σ_{1c}, σ_{2c}	compressive stresses due to local load from stiffeners
τ_{cr}	elastic critical shear stress
τ_{Rd}	design value of the shear strength at cope hole level
$\tau_{Ed,ser}$	shear stress at serviceability limit states
$\Phi_A, \Phi_B, \Phi_R, \Phi_H$	diameters of hanger components
Φ_s, Φ_w, Φ_0	angles of imperfection of forged hanger end
χ_w	reduction factor for shear buckling
ψ	combination factor

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

4 Basis of design

4.1 General rules

4.1.1 Basic requirements

(1) The design of steel bridges and steel parts of steel-concrete composite bridges shall be in accordance with the general rules given in EN 1990, EN 1991 (all parts) and EN 1998 (all parts) and the specific design provisions for steel structures given in EN 1993-1 (all parts).

(2) Steel bridges and steel parts of steel-concrete composite bridges designed according to this document shall be executed according to EN 1090-2 and EN 1090-4, with construction materials and products used as specified in the relevant parts of EN 1993, or in the relevant material and product specifications.

NOTE Additional guidance is given in Annex C for orthotropic decks.

4.1.2 Structural reliability

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

(2) The choice of the execution classes may be specified by the relevant authority or, where not specified, as agreed for a specific project by the relevant parties.

4.1.3 Robustness

(1) EN 1993-1-1:2022, 4.1.3, applies.

(2) For robustness, the design of the bridge should ensure that when the damage of a component due to accidental actions occurs, the remaining structure can sustain at least the accidental load combination.

NOTE 1 EN 1990 provides additional information about accidental design situations and robustness criteria.

NOTE 2 The National Annex can define components that are subject to accidental design situations and also details for assessments. Examples of such components are hangers, tension components, bearings.

4.1.4 Design service life for bridges

(1) The design service life of bridges should be taken in accordance with EN 1990:2023, Table A.2.2.

(2) The required design service life should be achieved through design for fatigue, see Clause 10, and/or appropriate detailing, see Annex C, and by serviceability checks, see Clause 9.

(3) For structural elements that cannot be designed for the total design service life of the bridge, 6(5) and 6(6) should be considered.

4.1.5 Durability

(1) EN 1993-1-1:2022, 4.1.5, applies.

(2) For durability, see Clause 6.

4.2 Basic variables

4.2.1 Actions and environmental influences

(1) EN 1993-1-1:2022, 4.3.1, applies.

(2) Actions for the design of bridges should be taken from EN 1991 (all parts). For the combination of actions and partial factors for actions, see EN 1990:2023, A.2.

(3) For the determination of combinations of effects from local and global loading on steel bridge decks of road bridges use Annex E.

(4) For actions not defined in EN 1991 (all parts), additional rules may be specified by the relevant authority or, where not specified, agreed for a specific project by the relevant parties.

NOTE For actions on bearings, see EN 1990.

4.2.2 Material and product properties

(1) See Clause 5 and EN 1993-1-1.

4.3 Verification by the partial factor method

(1) EN 1993-1-1:2022, 4.4, applies.

(2) The partial factors γ_{Mi} in Table 4.1 should be applied to the characteristic values of resistance in ultimate and serviceability limit states.

Table 4.1 — Partial factors

a) resistance of members and cross-section:	
— resistance of cross-sections to excessive yielding including local buckling	γ_{M0}
— resistance of members to instability assessed by member checks	γ_{M1}
— resistance of cross-sections in tension to fracture	γ_{M2}
b) resistance of joints	
— resistance of bolts	γ_{M2}
— resistance of rivets	γ_{M2}
— resistance of pins	γ_{M2}
— resistance of welds	γ_{M2}
— resistance of plates in bearing	γ_{M2}
— slip resistance	
— at ultimate limit state (Category C)	γ_{M3}
— at serviceability limit state	$\gamma_{M3,ser}$
— bearing resistance of an injection bolt	γ_{M4}
— resistance of joints in hollow section lattice girders	γ_{M5}
— resistance of pins at serviceability limit state	$\gamma_{M6,ser}$
— partial factor for resistance of components when verifying structural integrity (tying resistance)	γ_{Mu}

— resistance of tension components	see prEN 1993-1-11:2 024
— resistance of concrete	γ_c see EN 1992 (all parts)
c) Serviceability	
— stress limitation (see 9.3)	$\gamma_{M,ser}$

NOTE 1 The numerical values for partial factors γ_{Mi} for bridges for non-accidental design situations are the following, unless the National Annex gives different values:

- $\gamma_{M0} = 1,00$;
- $\gamma_{M1} = 1,10$;
- $\gamma_{M2} = 1,25$;
- $\gamma_{M3} = 1,25$;
- $\gamma_{M3,ser} = 1,10$;
- $\gamma_{M4} = 1,10$;
- $\gamma_{M5} = 1,10$;
- $\gamma_{M6,ser} = 1,00$;
- $\gamma_{Mu} = 1,10$;
- $\gamma_{M,ser} = 1,00$.

NOTE 2 The numerical values for partial factors γ_{Mi} for bridges for accidental design situations are the following, unless the National Annex gives different values:

- $\gamma_{M0} = 1,00$;
- $\gamma_{M1} = 1,00$;
- $\gamma_{M2} = 1,15$.

For all other partial factors, the values are as given in Note 1, unless the National Annex gives different values.

4.4 Partial factors for fatigue verifications

(1) The partial factor for fatigue loads should be taken as γ_{Ff} .

NOTE The value of the partial factor is $\gamma_{Ff} = 1,0$ according to EN 1990:2023, A.2 unless the National Annex gives a different value.

(2) The partial factor for fatigue resistance should be taken as γ_{Mf} .

NOTE The values of the partial factor γ_{Mf} are given in EN 1993-1-9 unless the National Annex gives different values.

4.5 Design assisted by testing

(1) EN 1993-1-1:2022, 4.5 applies.

(2) Testing should be used to verify the design of a bridge under the effects of wind where the calculation or the use of established results do not provide sufficient assurance of the structural safety during either the erection stage or the design service life.

NOTE prEN 1991-1-4:2024, Annex K gives guidance on derivation of design parameters from wind tunnel tests and numerical simulations.

5 Materials

5.1 General

(1) EN 1993-1-1:2022, 5.1 applies.

5.2 Structural steel

5.2.1 Material properties

(1) The nominal values of the yield strength f_y and the ultimate strength f_u for structural steel should be obtained:

- a) either by adopting the values $f_y = R_{eH}$ and $f_u = R_m$ (as lower bound of the given range) directly from the product standard;
- b) or by using the values given in EN 1993-1-1:2022, Table 5.1 for steel conforming to EN 10025 (all parts), EN 10210 (all parts), EN 10219 (all parts), and in EN 1993-1-1:2022, Table 5.2 for steel conforming to EN 10149 (all parts) and considering the availability of the material in the thickness range according to the product standard.

NOTE 1 The choice for option a) or b) can be set by the National Annex, considering the effects on partial factors (see Table 4.1) and their calibration according to EN 1993-1-1:2022, Annex E and EN 1990.

NOTE 2 Rules for the use of the steels according to EN 1993-1-1:2022, Table 5.1 and Table 5.2 can be set by the National Annex.

5.2.2 Ductility requirements

(1) EN 1993-1-1:2022, 5.2.2 applies.

5.2.3 Fracture toughness

(1) The material shall have the required material toughness to prevent brittle fracture within the intended design service life of the structure.

(2) The rules in EN 1993-1-10 for fracture toughness apply.

NOTE The National Annex can specify conditions of application of EN 1993-1-10 to bridges and can give additional requirements.

5.2.4 Through thickness properties

(1) Steel with improved through thickness properties conforming to EN 10164 should be used where required, see EN 1993-1-10.

NOTE Where Z_{Ed} values have been determined in accordance with EN 1993-1-10, the required quality class according to EN 10164 is given in Table 5.2, unless the National Annex gives different values.

Table 5.2 (NDP) — Quality class conforming to EN 10164

Target value Z_{Ed}	Quality class
$Z_{Ed} \leq 10$	—
$10 < Z_{Ed} \leq 20$	Z15
$20 < Z_{Ed} \leq 30$	Z25
$Z_{Ed} > 30$	Z35

5.2.5 Values of other material properties

(1) EN 1993-1-1:2022, 5.2.5, applies.

5.3 Connecting devices

5.3.1 Fasteners

5.3.1.1 Bolts, nuts and washers

(1) Bolts, nuts and washers should conform to the rules given in FprEN 1993-1-8:2023, 5.1.

(2) Bolt grades 4.8 and 5.8 should not be used in bridges.

5.3.1.2 Rivets

(1) Rivets should conform to the rules given in FprEN 1993-1-8:2023, 5.2.

NOTE The material properties, dimensions and tolerances of steel rivets can be given in the National Annex.

5.3.1.3 Anchor bolts

(1) Anchor bolts should conform to the rules given in FprEN 1993-1-8:2023, 5.3.

5.3.2 Welding consumables

(1) All welding consumables should conform to the rules given in FprEN 1993-1-8:2023, 6.2.

(2) The filler metal should be selected according to the rules given in EN 1993-1-8.

NOTE Restrictions to the use of undermatched filler metals can be set by the National Annex.

5.4 Cables and other tension elements

(1) Cables and other tension elements should be designed according to EN 1993-1-11.

NOTE The National Annex can specify the types of cables appropriate to the specific bridge types.

(2) Use the additional provisions according to Annex A for certain types of hangers in tied-arch bridges.

5.5 Bearings

(1) Bearings should conform to EN 1337 (all parts).

NOTE The National Annex can give requirements for the installation and the use of bearings applicable to bridges.

(2) Bearings should be designed according to EN 1990:2023, Annex G.

5.6 Dampers and lock-up devices

(1) Dampers and lock-up devices should conform to EN 15129 and to the relevant technical specifications.

NOTE The National Annex can give requirements for the installation and the use of dampers and lock-up devices applicable to bridges.

5.7 Other bridge components

(1) Expansion joints, guardrails, parapets and other ancillary items should conform to the relevant technical specifications.

NOTE The National Annex can give requirements for the installation and the use of expansion joints, guardrails, parapets and other ancillary items applicable to bridges.

(2) Expansion joints should be designed according to EN 1990:2023, A.2.10.4.

(3) The bridge deck surfacing system, the products used and the method of application should conform to the relevant technical specification.

NOTE The National Annex can give requirements for the bridge deck surfacing system, the products used and the method of application for bridges.

6 Durability

(1) EN 1993-1-1:2022, Clause 6, applies.

(2) The effects of corrosion or fatigue of components and material should be taken into account by appropriate detailing. The effects of fatigue should be taken into account in accordance with Clause 10, EN 1993-1-9 and EN 1993-1-10.

(3) Elements or parts of elements that cannot be inspected should be avoided where possible. Where they are unavoidable, appropriate corrosion allowances should be provided.

NOTE The National Annex can give requirements for sealing against corrosion, measures to ensure air tightness of box girders or the provisions of extra steel thickness for inaccessible surfaces.

(4) Permanent connections of structural parts of the bridge should be made with preloaded bolts in a Category B or C connection. Alternatively, closely fitted bolts, rivets or welding may be used to prevent slipping.

NOTE Injection bolts can also be used if permitted by 11.1.2.

(5) For components, such as tension components, bearings and expansion joints, that cannot be designed with sufficient reliability to achieve the design service life of the bridge, the rules in EN 1990:2023, A.2.3(2) and (3) apply.

(6) Structural parts of a bridge to which guardrails or parapets are connected, should be designed according to EN 1990:2023, A.2.6.8(3).

(7) The design service life of the bridge and its components according to 4.1.4 should be attained by:

- fatigue design of details in accordance with (2), (3) and EN 1993-1-9 and with serviceability checks carried out in accordance with Clause 9;
- appropriate structural detailing (e.g. orthotropic decks);
- material chosen in accordance with Clause 5;
- fabrication conforming to EN 1090-2 and EN 1090-4.

NOTE Recommendations for structural detailing of orthotropic steel decks are given in Annex C. Alternatively, orthotropic steel decks can be designed according to CEN/TS 1993-1-901². The National Annex can provide additional information on the use of these two possibilities.

² Under preparation.

7 Structural analysis

7.1 Structural modelling for analysis

7.1.1 Basic assumptions

- (1) EN 1993-1-1:2022, 7.1.1, applies.
- (2) For the analysis of cable supported structures, EN 1993-1-11 applies.

7.1.2 Joint modelling

- (1) EN 1993-1-1:2022, 7.1.2 applies.
- (2) For bridges, the type of joint and its modelling should be chosen to ensure that the required fatigue life will be attained.

NOTE Fatigue categories given in EN 1993-1-9 are appropriate for rigid joints between members of bridges except for bearings, pinned connections and cables.

7.2 Global analysis

7.2.1 Consideration of second order effects

- (1) EN 1993-1-1:2022, 7.2.1, applies assuming the rules for sway modes apply to global modes for bridges.

7.2.2 Methods of analysis for ultimate limit state design checks

- (1) EN 1993-1-1:2022, 7.2.2, applies.
- (2) Where the behaviour of a bridge or its components is governed by the first buckling mode, on the basis of elastic global analysis, the second order bending moment M_{II} due to the applied axial force may be calculated by increasing the imperfections and other deformations according to the first order theory by the factor k_α calculated from the Formula (7.1):

$$k_\alpha = \frac{1}{1 - \frac{1}{\alpha_{cr}}} \quad \text{provided that: } 3 \leq \alpha_{cr} < 10 \quad (7.1)$$

where

α_{cr} is the factor by which the design loading would have to be increased to cause elastic instability in a global mode.

- (3) For $\alpha_{cr} < 3$, a more accurate second order analysis should be applied.
- (4) For $\alpha_{cr} \geq 10$, the second order effects may be neglected, see EN 1993-1-1.

7.3 Imperfections

7.3.1 Basis

- (1) EN 1993-1-1:2022, 7.3.1, applies.

7.3.2 Sway imperfections

(1) EN 1993-1-1:2022, 7.3.2, applies.

NOTE For piers, α_m is applicable if cumulative effects from contributions of various piers occur (e.g. for piers forming a frame with the superstructure).

(2) For arched bridges, use the rules in Annex D.

7.3.3 Equivalent bow imperfection for global and member analysis

7.3.3.1 Flexural buckling

(1) EN 1993-1-1:2022, 7.3.3.1 applies.

7.3.3.2 Lateral torsional buckling

(1) EN 1993-1-1:2022, 7.3.3.2 applies.

7.3.4 Combination of sway and equivalent bow imperfections

(1) EN 1993-1-1:2022, 7.3.4 applies.

7.3.5 Imperfections for analysis of bracing systems

(1) EN 1993-1-1:2022, 7.3.5 applies.

7.3.6 Imperfection based on elastic critical buckling modes

(1) EN 1993-1-1:2022, 7.3.6 applies.

7.4 Methods of analysis

7.4.1 General

(1) Elastic global analysis should be used to determine the internal forces and moments for all persistent and transient design situations.

(2) Plastic global analysis according to EN 1993-1-1:2022, 7.4.3, may be used for accidental design situations.

NOTE The National Annex can give restrictions on the use of plastic global analysis.

(3) If a finite element model (FEM) analysis is used, EN 1993-1-14 should be applied.

7.4.2 Elastic global analysis

(1) EN 1993-1-1:2022, 7.4.2, applies.

(2) If all cross-sections are class 1 and member resistance is not reduced by buckling, the effects of differential temperature, shrinkage and settlement at the ultimate limit state may be neglected.

7.5 Classification of cross-sections

(1) EN 1993-1-1:2022, 7.5, applies.

8 Ultimate limit states

8.1 Partial factors

(1) The partial factors on resistance should be taken from 4.3.

8.2 Resistance of cross-sections

8.2.1 General

(1) EN 1993-1-1:2022, 8.2.1, applies.

8.2.2 Section properties

8.2.2.1 Gross cross-section

(1) EN 1993-1-1:2022, 8.2.2.1, applies.

8.2.2.2 Net area

(1) EN 1993-1-1:2022, 8.2.2.2, applies.

8.2.2.3 Shear lag effects

(1) EN 1993-1-1:2022, 8.2.2.3, and EN 1993-1-5 apply.

NOTE The National Annex can give restrictions on the method to consider shear lag effects at the ultimate limit state.

8.2.2.4 Effective properties of cross-section with class 3 webs and class 1 or 2 flanges

(1) EN 1993-1-1:2022, 8.2.2.4 applies.

8.2.2.5 Effective cross-section properties of class 4 cross-sections

(1) The effects of local plate buckling should be considered using one of the following two methods specified in EN 1993-1-5:

- a) effective cross-section properties of class 4 sections in accordance with EN 1993-1-5
- b) limiting the stress levels on the gross cross-section in accordance with FprEN 1993-1-5:2023, Clause 12.

NOTE The National Annex can specify the methods to be used. In case of the use of the method b), the National Annex can give further guidance.

(2) For class 4 circular hollow sections, the effects of local buckling should be considered using one of the following two methods:

- a) effective cross-section properties of class 4 sections in accordance with EN 1993-1-1
- b) limiting the stress levels on the gross cross-section in accordance with EN 1993-1-6.

8.2.2.6 Section properties for the characteristic resistance

(1) EN 1993-1-1:2022, 8.2.2.6 applies.

8.2.3 Tension

(1) EN 1993-1-1:2022, 8.2.3 applies.

(2) For the design of steel tension components comprising rods, ropes and bundles of wires, EN 1993-1-11 applies.

(3) For certain types of hangers in tied-arch bridges, additional rules according to Annex A should apply.

8.2.4 Compression

(1) EN 1993-1-1:2022, 8.2.4 applies.

(2) As an alternative for class 4 cross-sections, the design resistance may be calculated using Formula (8.1):

$$N_{c,Rd} = \frac{A\sigma_{\text{limit}}}{\gamma_{M1}} \quad (8.1)$$

where

$\sigma_{\text{limit}} = \rho_{c,x} f_y$ is the limiting stress of the weakest part of the cross-section in compression

$\rho_{c,x}$ is the reduction factor according to FprEN 1993-1-5:2023, 12.4.

8.2.5 Bending

(1) EN 1993-1-1:2022, 8.2.5 applies.

(2) As an alternative for class 4 cross-sections, the design resistance may be calculated using Formula (8.2):

$$M_{c,Rd} = \text{Min} \left(\frac{W_{el,com} \sigma_{\text{limit}}}{\gamma_{M1}}; \frac{W_{el,min} f_y}{\gamma_{M0}} \right) \quad (8.2)$$

where

$\sigma_{\text{limit}} = \rho_{c,x} f_y$ is the limiting compressive stress of the weakest part of the cross-section;

$\rho_{c,x}$ is the reduction factor according to FprEN 1993-1-5:2023, 12.4;

$W_{el,com}$ is the elastic modulus which corresponds to the fibre where the limiting compressive stress is obtained;

$W_{el,min}$ is the elastic modulus which corresponds to the fibre with the maximum stress (tension or compression).

8.2.6 Shear

(1) EN 1993-1-1:2022, 8.2.6 and EN 1993-1-5 apply.

8.2.7 Torsion

8.2.7.1 General

- (1) Torsional and distortional effects should be taken into account for members subject to torsional loading.
- (2) An appropriate elastic model (such as a grillage model, a shell model, a higher-order beam model or a beam on elastic foundation model), taking into account the member cross-section and the stiffness and the location of any diaphragms or cross-bracings present, should be used to determine the combined effect of bending, torsion and distortion.
- (3) Distortional effects in box-girder members may be disregarded where the longitudinal stresses at any cross-section created by distortion under the governing eccentric ULS combination of actions do not exceed either 10 % of the longitudinal stresses caused by the longitudinal bending moment or $0,05 f_{yd}$, whichever is greater, due to the same combination of actions and at the same cross-section.
- (4) Diaphragms or cross-bracings should be designed taking into account the torsional and distortional effects.

8.2.7.2 Torsion for which distortional effects may be neglected

- (1) EN 1993-1-1:2022, 8.2.7 applies.

8.2.8 Combined bending and shear

- (1) EN 1993-1-1:2022, 8.2.8 applies.

8.2.9 Combined bending and axial force

8.2.9.1 Class 1 and class 2 cross-sections

- (1) EN 1993-1-1:2022, 8.2.9.1 applies.

8.2.9.2 Class 3 cross-sections

- (1) EN 1993-1-1:2022, 8.2.9.2 applies.

8.2.9.3 Class 4 cross-sections

- (1) EN 1993-1-1:2022, 8.2.9.3 applies.

- (2) When using the limiting stress method according to 8.2.4(2) or 8.2.5(2), the criterion in Formula (8.3) should be met:

$$\sigma_{x,Ed} \leq \frac{\sigma_{\text{limit}}}{\gamma_{M1}} \leq \frac{f_y}{\gamma_{M0}} \quad (8.3)$$

where σ_{limit} should be determined from 8.2.4 or 8.2.5.

8.2.10 Combined bending, shear and axial force

- (1) EN 1993-1-1:2022, 8.2.10 applies.

8.2.11 Combined bending, shear, axial force and transverse loads

(1) The interaction between bending, shear, axial force and transverse loads may be determined using one of the following two methods:

a) Interaction methods given in 8.2.8 to 8.2.10.

NOTE For plate buckling effects, see FprEN 1993-1-5:2023, Clause 6 to Clause 9.

b) Interaction of stresses using the yielding criterion given in 8.2.1

NOTE For plate buckling effects, see FprEN 1993-1-5:2023, Clause 12.

8.3 Buckling resistance of members

8.3.1 Uniform members in compression

8.3.1.1 Buckling resistance

(1) EN 1993-1-1:2022, 8.3.1.1 applies.

8.3.1.2 Slenderness of compression members

(1) EN 1993-1-1:2022, 8.3.1.2 applies.

8.3.1.3 Buckling reduction factor for flexural buckling

(1) EN 1993-1-1:2022, 8.3.1.3 applies.

8.3.1.4 Buckling reduction factors for torsional and torsional-flexural buckling

(1) EN 1993-1-1:2022, 8.3.1.4 applies.

8.3.1.5 Use of class 3 section properties with stress limits

(1) As an alternative to using class 4 cross-section properties, class 3 cross-section properties may be used in conjunction with stress limits in accordance with FprEN 1993-1-5:2023, Clause 12.

8.3.2 Uniform members in bending

(1) EN 1993-1-1:2022, 8.3.2 applies.

8.3.3 Uniform members in bending and axial compression

(1) EN 1993-1-1:2022, 8.3.3 applies.

(2) As an alternative to Formulae (8.88) and (8.89) in EN 1993-1-1:2022, 8.3.3, the simplified method of CEN/TS 1993-1-101 may be used.

8.3.4 General method for lateral and lateral torsional buckling of structural components

(1) EN 1993-1-1:2022, 8.3.4, applies.

8.3.5 Simplified method for lateral and lateral torsional buckling of structural components

(1) Truss chords and flanges in compression that are subject to lateral buckling may be verified by modelling the elements as a column subject to the compression force N_{Ed} and supported by continuous or discrete elastic restraint modelled as springs.

NOTE 1 Guidance for determining the stiffness of the restraint in the form of U-frames is given in CEN/TR 1993-1-103³.

NOTE 2 Where truss flanges and/or chords are restrained by U-frames, the U-frame members are subjected to forces induced by the restraint and the interaction of the U-frame and the flanges or chords.

NOTE 3 This method cannot verify the resistance of beams braced together where a mode of overall buckling involving two or more beams can occur, such as the combined rotation of paired beams in the absence of plan bracing or a deck plate or slab. In such cases, the elastic critical bending moment and slenderness for buckling is obtained from an elastic critical buckling analysis or from literature.

(2) The buckling mode and the elastic critical buckling load N_{cr} may be determined from an elastic critical buckling analysis. If continuous springs are used to represent the restraints which are basically discrete, the buckling length used to calculate the elastic critical buckling should not be less than the spacing of the restraints.

(3) The verification to lateral torsional buckling may be carried out in accordance with 8.3.2 using Formula (8.4):

$$\bar{\lambda}_{LT} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}} \quad (8.4)$$

where

A_{eff} is the effective area of the chord;

N_{cr} is the elastic critical load determined with the gross cross-section of the chord.

(4) For chords in compression or the bottom flanges of continuous girders between rigid supports, the effect of initial imperfections and second order effects on a supporting spring may be taken into account by a first order calculation, by applying an additional lateral force F_{Ed} at the connection of the chord to the spring according to the Formulae (8.5):

$$F_{Ed} = \begin{cases} \frac{N_{Ed}}{100} & \text{if } L_{cr} \leq 1,2 d_s \\ \frac{N_{Ed}}{N_{cr} - N_{Ed}} \times \frac{C_d L_w}{500} & \text{if } L_{cr} > 1,2 d_s \end{cases} \quad (8.5)$$

where

$$L_{cr} = \pi \sqrt{\frac{EI}{N_{cr}}}$$

L_w is the half wavelength of buckling determined by taking L_R/L_w as the next integer below L_R/L_{cr} but not less than unity;

³ Under preparation.

L_R is the span length between the rigid supports, for example by rigid cross-frames;

d_s is the distance between the springs;

C_d is the spring stiffness, see (1), NOTE 1.

(5) If the design value of the compression force N_{Ed} is constant over the length of the chord, the critical axial load N_{cr} may be calculated using Formula (8.6):

$$N_{cr} = mN_E \quad (8.6)$$

where

$$N_E = \pi^2 \frac{EI}{L_R^2}$$

$$m = \frac{2}{\pi^2} \sqrt{\gamma} \text{ but not less than } 1,0$$

$$\gamma = \frac{c_s L_R^4}{EI}$$

$$c_s = \frac{C_d}{d_s}$$

A lateral support to a compressed flange may be assumed to be rigid if its stiffness C_d satisfies the condition in Formula (8.7):

$$C_d > \frac{4N_E}{L_R} \quad (8.7)$$

where N_E is the elastic critical load which is determined assuming hinged ends. If there are no rigid lateral supports at girder ends to define the length L_R , either the slenderness should be determined in accordance with (2) or the value of m should be modified in the last half wavelength of buckling to allow for the end restraint flexibility in accordance with elastic buckling theory.

(6) The procedure given in (1) to (5) may also be applied to the flanges of girders in compression when A_{eff} in (3) is substituted by the Formula (8.8):

$$A_{eff} + \frac{A_{wc}}{3} \quad (8.8)$$

where A_{wc} is the area of the compression zone of the web. In the case of a class 4 section the areas should be taken as the effective areas.

For the case where the compressive force N_{Ed} is not constant over the length of the chord, the approach in (7) and (8) is recommended.

NOTE The National Annex can give further guidance or a different approach for the case where the compressive force N_{Ed} is not constant over the length of the chord.

(7) For the bottom flange of a continuous girder with rigid lateral supports at a distance L_R (see Figure 8.1), m in Formula (8.6) may be taken as the minimum value obtained from the Formulae (8.9) and (8.10):

$$m = 1 + 0,44(1 + \mu)\Phi^{1,5} + (3 + 2\Phi)\gamma/(350 - 50\mu) \quad (8.9)$$

$$m = 1 + 0,44(1 + \mu)\Phi^{1,5} + (0,195 + (0,05 + \mu/100)\Phi)\gamma^{0,5} \quad (8.10)$$

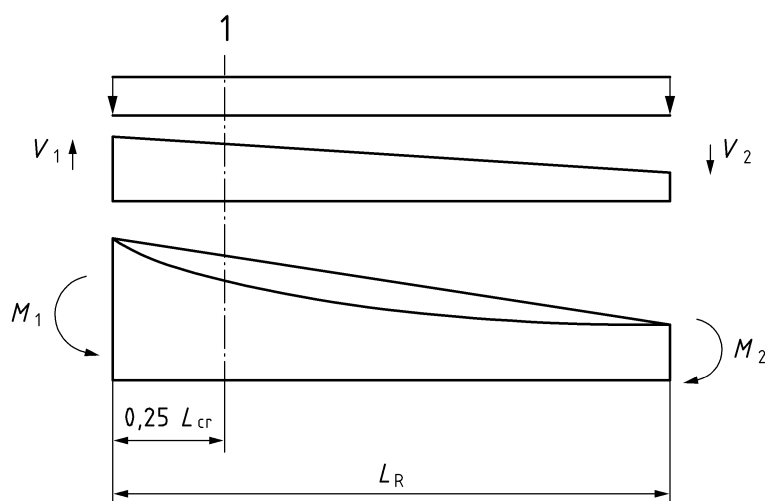
where

$$\mu = \frac{V_2}{V_1} \quad \text{see Figure 8.1}$$

$$\Phi = \frac{2\left(1 - \frac{M_2}{M_1}\right)}{1 + \mu} \quad \text{for } M_2 > 0$$

Where the bending moment changes signs, Formulae (8.9) and (8.10) may be used as a conservative estimate by inserting $M_2 = 0$.

(8) The verification of resistance to lateral torsional buckling in accordance with 8.3.2 may be carried out at a distance $0,25 L_{cr}$ from the support with the largest moment as shown in Figure 8.1, provided that the cross-sectional resistance is also checked at the section with the largest moment, where $L_{cr} = L_R/\sqrt{m}$.



Key

1 design section

Figure 8.1 — Segment of beam between rigid lateral supports with bending moment varying as a parabola

8.3.6 Plate girders curved in plan

- (1) The effects of any curvature in plan should be considered on the resistances of plate girders.
- (2) Unless an advanced approach considering the nonlinear behaviour directly is used, use the rules of Annex B.