SLOVENSKI STANDARD

oSIST prEN 1993-1-5:2022

01-maj-2022

Evrokod 3 - Projektiranje jeklenih konstrukcij - 1-5. del: Elementi pločevinaste konstrukcije

Eurocode 3 - Design of steel structures - Part 1-5: Plated structural elements

Eurocode 3 - Bemessung und Konstruktion von Stahlbauten - Teil 1-5: Plattenförmige Bauteile

Eurocode 3 - Calcul des structures en acier - Partie 1-5: Plaques planes

Ta slovenski standard je istoveten z: **prEN 1993-1-5**

ICS:

91.010.30	Tehnični vidiki	Technical aspects
91.080.13	Jeklene konstrukcije	Steel structures

oSIST prEN 1993-1-5:2022 **en,fr,de**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

DRAFT prEN 1993-1-5

March 2022

ICS 91.010.30; 91.080.13

Will supersede EN 1993-1-5:2006

English Version

Eurocode 3 - Design of steel structures - Part 1-5: Plated structural elements

Eurocode 3 - Calcul des structures en acier - Partie 1-5: Plaques planes

Eurocode 3 - Bemessung und Konstruktion von Stahlbauten - Teil 1-5: Plattenförmige Bauteile

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.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

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

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No. prEN 1993-1-5:2022 E

Contents

Page

European foreword ... 4
0 Introduction ... 5
1 Scope ... 8
2 Normative references ... 9
3 Terms and definitions ... 9
3.1 Terms ... 9
3.2 Sign convention ... 10
3.3 Symbols ... 10
4 Basis of design ... 11
4.1 General rules ... 11
4.2 Partial factors ... 12
4.3 Effective width models for global analysis ... 12
4.4 Plate buckling effects on uniform members ... 13
4.5 Reduced stress method ... 14
4.6 Design assisted by finite element analysis ... 14
4.7 Non-uniform members ... 14
4.8 Members with corrugated webs ... 14
5 Shear lag in member design ... 14
5.1 General ... 14
5.2 Elastic shear lag ... 14
5.3 Shear lag at the ultimate limit state ... 18
6 Plate buckling effects due to direct stresses at the ultimate limit state ... 19
6.1 General ... 19
6.2 Resistance to direct stresses ... 20
6.3 Effective cross-section ... 20
6.4 Plate elements without longitudinal stiffeners ... 22
6.5 Stiffened plate elements with longitudinal stiffeners ... 27
6.6 Interpolation between plate and column buckling ... 32
6.7 Verification ... 37
7 Resistance to shear ... 39
7.1 General ... 39
7.2 Design resistance ... 40
7.3 Contribution from the web ... 41
7.4 Contribution from flanges ... 43
7.5 Verification ... 44
8 Resistance to patch loading ... 44
8.1 General ... 44
8.2 Design resistance ... 45
8.3 Length of stiff bearing ... 45
8.4 Reduction factor χ_F ... 45
8.5 Effective loaded length ... 46
8.6 Verification ... 47
9 Interaction ... 47

9.1 Interaction between shear force, bending moment and axial force 47
9.2 Interaction between transverse force, bending moment and axial force 48
9.3 Interaction between transverse force, bending moment and shear force 48

10 Flange induced buckling 49

11 Stiffeners and detailing 50
11.1 General 50
11.2 Direct stresses 50
11.3 Shear 55
11.4 Transverse loads 57

12 Reduced stress method 57
12.1 General 57
12.2 Buckling verification 58
12.3 Plate slenderness 59
12.4 Reduction factors 60

13 Plate girders with corrugated webs 63
13.1 General 63
13.2 Ultimate limit state 64

Annex A (informative) Calculation of critical stresses for stiffened plates 69

A.1 Use of this informative annex 69

A.2 Scope and field of application 69

A.3 Equivalent orthotropic plate for plates with at least three longitudinal stiffeners 69

A.4 Equivalent orthotropic plate for plates with one or two longitudinal stiffeners 70

A.5 Shear buckling coefficients 70

A.6 Buckling coefficient for patch loading 71

Annex B (informative) Non-uniform members 72

B.1 Use of this informative annex 72

B.2 Scope and field of application 72

B.3 General 72

B.4 Interaction of plate buckling and lateral torsional buckling 72

Bibliography 73

European foreword

This document (prEN 1993-1-5:2022) 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 matters by CEN.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 1993-1-5:2006 and its amendments and 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

0.2 Introduction to EN 1993 (all parts)

EN 1993 (all parts) 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 design.

EN 1993 (all parts) 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: Steel 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: Design of sandwich panels.*

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 steels;*

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: Strength and stability of planar plated structures transversely loaded;*

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

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

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

EN 1993-1-11, *Design of Steel Structures — Part 1-11: Design of structures with tension components made of steel;*

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 such as 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 such as 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, modify or supersede them.

0.3 Introduction to prEN 1993-1-5

prEN 1993-1-5 gives design requirements for unstiffened and stiffened plates that are subject to in-plane forces. It also covers plated structural elements like I-section girders or box girders, as well as plated components used in tanks and silos.

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 1993-1-5

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 1993-1-5 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 1993-1-5 through notes to the following:

4.6(2)	6.4.1(10)	7.1(2)

National choice is allowed in prEN 1993-1-5 on the application of the following informative annexes:

Annex A	Annex B

1 Scope

1.1 Scope of prEN 1993-1-5

(1) This document provides rules for structural design of stiffened and unstiffened nominally flat plates which are subject to in-plane forces.

(2) Effects due to shear lag, in-plane load introduction and plate buckling for I-section girders and box girders are covered. Also covered are plated structural components subject to in-plane loads as in tanks and silos. The effects of out-of-plane loading are outside the scope of this document.

NOTE 1 The rules in this part complement the rules for class 1, 2, 3 and 4 sections, see EN 1993-1-1.

NOTE 2 For the design of slender plates which are subject to repeated direct stress and/or shear and also fatigue due to out-of-plane bending of plate elements ("breathing"), see EN 1993-2 and EN 1993-6.

NOTE 3 For the effects of out-of-plane loading and for the combination of in-plane effects and out-of-plane loading effects, see EN 1993-2 and EN 1993-1-7.

(3) Single plate elements are considered as nominally flat where the curvature radius *r* in the direction perpendicular to the compression satisfies:

$$r \geq \frac{b^2}{t} \tag{1.1}$$

where

b is the panel width;

t is the plate thickness.

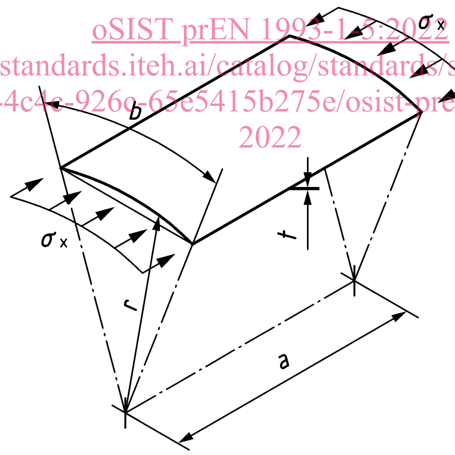

Figure 1.1 — Definition of plate curvature

1.2 Assumptions

(1) Unless specifically stated, EN 1990, EN 1991 (all parts) and EN 1993-1-1 apply.

(2) The design methods given in EN 1993-1-5 are applicable if

— the execution quality is as specified in EN 1090-2 and

— the construction materials and products used are as specified in the relevant parts of EN 1993 (all parts) or in the relevant material 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. through 'should' clauses) and permissions (i.e. through 'may' clauses).

EN 1090-2:2018, *Execution of steel structures and aluminium structures — Part 2: Technical requirements for steel structures*

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

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

prEN 1993-1-1:2020, *Eurocode 3: Design of steel structures — Part 1-1: General rules and rules for buildings*

3 Terms and definitions

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

3.1 Terms

3.1.1
plate
structural element that, in general, has two large dimensions a and b and a uniform much smaller dimension t, and is shaped such that the two large dimensions lie in a single plane

3.1.2
elastic critical stress
stress in a component at which the component becomes unstable when using small deflection elastic theory of a perfect structure

3.1.3
membrane stress
stress at mid-plane of the plate

3.1.4
gross cross-section
total cross-sectional area of a member but excluding discontinuous longitudinal stiffeners

3.1.5
effective cross-section and effective width
gross cross-section or width reduced for the effects of plate buckling or shear lag or both

Note 1 to entry: To distinguish between their effects the word "effective" is clarified as follows:

— "effective^{p}" denotes effects of plate buckling

— "effective^{s}" denotes effects of shear lag

— "effective" denotes effects of plate buckling and shear lag

3.1.6
plated structure
structure built up from nominally flat plates which are connected together

Note 1 to entry: The plates can be stiffened or unstiffened.

3.1.7
stiffener
flat plate or prismatic section attached to a plate to resist buckling or to strengthen the plate

Note 1 to entry: A stiffener is denoted:

— longitudinal if its direction is parallel to the member constituted of the assembled plates;

— transverse if its direction is perpendicular to the member constituted of the assembled plates.

3.1.8
stiffened plate
plate with transverse or longitudinal stiffeners or both

3.1.9
subpanel
unstiffened plate portion surrounded by flanges and/or stiffeners

3.1.10
hybrid girder
girder with flanges and web(s) made of different steel grades

3.1.11
direct stresses
normal stresses acting in the direction of the longitudinal axis of the member

3.1.12
patch loading
local introduction of in-plane forces

3.2 Sign convention

Unless otherwise stated, compression is taken as positive.

3.3 Symbols

For the purposes of this document, the symbols in EN 1990, EN 1993-1-1 and the following apply.

$A_{s\ell}$	total gross cross-sectional area of all the longitudinal stiffeners of a stiffened plate without contributing plating;
A_{st}	gross cross-sectional area of one transverse stiffener;
A_{eff}	effective cross-sectional area;
$A_{c,eff}$	effective[p] cross-sectional area;
$A_{c,eff,loc}$	effective[p] cross-sectional area for local buckling;
a	length of a stiffened or unstiffened plate;
b	width of a stiffened or unstiffened plate;

b_0 gross width of the flange outstand or half the width of an internal element;

b_g gross width of the compression zone corresponding to $A_{c,eff}$;

b_{eff} effective[s] width for elastic shear lag;

F_{Ed} design transverse force;

h_w clear web depth between flanges;

L_{eff} effective length for resistance to transverse forces;

$M_{f,Rd}$ design plastic moment of resistance of the cross-section consisting of the effective area of the flanges only;

$M_{f,Rk}$ characteristic plastic moment of resistance of the cross-section consisting of the effective area of the flanges only;

$M_{f,eff,Rd}$ design plastic moment of resistance of the cross section consisting of the effective area of the flanges and the fully effective web irrespective of its section class;

$M_{pl,Rd}$ design value of the plastic moment resistance (irrespective of cross-section class);

M_{Ed} design bending moment;

N_{Ed} design axial force;

t thickness of the plate;

V_{Ed} design shear force including shear from torque;

W_{eff} effective elastic section modulus;

β effective[s] width factor for shear lag;

Additional symbols are defined where they first occur.

4 Basis of design

4.1 General rules

4.1.1 Basic requirement

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

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

(3) The effects of shear lag and plate buckling shall be taken into account at the ultimate, serviceability and fatigue limit states.

4.2 Partial factors

(1) The partial factors as defined in EN 1993-1-1 should be applied to the characteristic values of the following resistances:

— Resistance to direct stresses	γ_{M0}
— Resistance to shear	γ_{M1}
— Resistance to patch loading	γ_{M1}
— Resistance of transverse stiffeners	γ_{M1}
— Resistance according to the reduced stress method	γ_{M1}
— Resistance of compression flanges of girder with corrugated webs where lateral torsional buckling governs	γ_{M1}

(2) Partial factors γ_{M0} and γ_{M1} have the value assigned to them in the National Annex to the relevant parts of EN 1993-1 to EN 1993-6.

4.3 Effective width models for global analysis

(1) The effects of shear lag and of plate buckling on the stiffness of members and joints shall be taken into account in the global analysis.

(2) The effects of shear lag of flanges in global analysis may be taken into account by the use of an effective^{s} width. For simplicity this effective^{s} width may be assumed to be uniform over the length of the span.

(3) For each span of a member the effective^{s} width of flanges should be taken as the lesser of the gross width and $L/8$ per side of the web, where L is the span or twice the distance from the support to the end of a cantilever.

(4) The effects of plate buckling in elastic global analysis may be taken into account by effective^{p} cross-sectional areas of the elements in compression, see 6.3.

(5) For the calculation of effective areas for stiffness, the serviceability limit state slenderness $\bar{\lambda}_{p,ser}$ may be calculated from:

$$\bar{\lambda}_{p,ser} = \bar{\lambda}_{p} \sqrt{\frac{\sigma_{com,Ed,ser}}{f_y}} \tag{4.1}$$

where

$\sigma_{com,Ed,ser}$ is defined as the maximum compressive stress (calculated on the basis of the effective cross-section) in the relevant element under loads at serviceability limit state.

(6) The second moment of area at serviceability limit state may be calculated by an interpolation of the gross cross-section and the effective cross-section for the relevant load combination using the formula:

$$I_{eff} = I_{gr} - \frac{\sigma_{gr}}{\sigma_{com,Ed,ser}}\left(I_{gr} - I_{eff}\left(\sigma_{com,Ed,ser}\right)\right) \tag{4.2}$$

where

I_{gr} is the second moment of area of the gross cross-section;

σ_{gr} is the maximum compressive bending stress at serviceability limit states based on the gross cross-section;

$I_{eff}(\sigma_{com,Ed,ser})$ is the second moment of area of the effective cross-section with allowance for local buckling according to 6.4.1(7) calculated for the maximum stress $\sigma_{com,Ed,ser} \geq \sigma_{gr}$ within the span length considered, using the reduced slenderness obtained from Formula (4.1).

(7) The effective second moment of area I_{eff} may be taken as variable along the span according to the most severe locations. Alternatively, a uniform value may be used based on the maximum absolute sagging moment under serviceability loading.

(8) The calculations described in (5) and (6) require iterations, but as a conservative approximation they may be carried out as a single calculation at a stress level equal to or higher than $\sigma_{com,Ed,ser}$.

(9) For global analysis, the effect of plate buckling on the stiffness may be ignored when the effective[p] cross-sectional area of an element in compression at ultimate limit state is greater than 0,5 times the gross cross-sectional area of the same element. The criterion applies for all individual plates of the cross-section.

4.4 Plate buckling effects on uniform members

(1) Effective[p] width models for direct stresses, resistance models for shear buckling and buckling due to transverse loads as well as interactions between these models for determining the resistance of uniform members at the ultimate limit state may be used when the following conditions apply:

— panels are rectangular and flanges are parallel;

— the diameter of any unstiffened open hole or cut out does not exceed 0,05b, where b is the width of the panel.

(2) If the panel is non-rectangular but with an angle ϕ (see Figure 4.1) equal to or less than 10°, the panel may be considered as a rectangular panel to calculate the relevant reduction factors, using as reference width b the larger of b_1 and b_2 (according to Figure 4.1).

(3) If the panel is non-rectangular with an angle ϕ greater than 10° but less than or equal to 17,5°, the rules for non-rectangular panels should be applied.

NOTE The elastic buckling load factor α_{cr} can be calculated either based on a rectangular panel with the larger width or based in the real tapered shape and corresponding edge stresses. The reduction factor is calculated uniquely for each cross-section based on its local critical stress. See 6.4.1(1) for the definition of the reduction factor and 12.3(1) for the definition of α_{cr}.

(4) For non-rectangular panels with an angle ϕ greater than 17,5°, see 4.7.

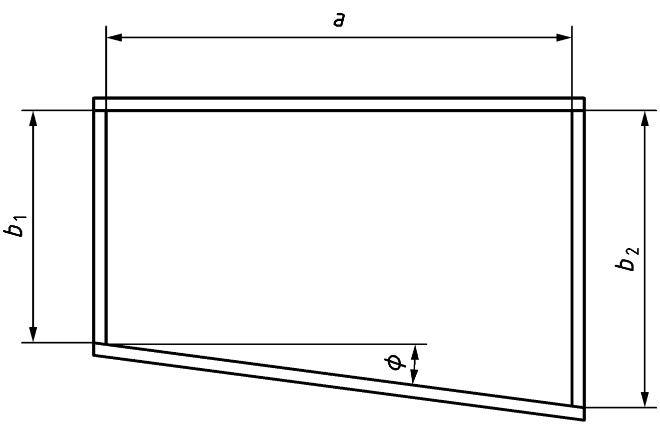

Figure 4.1 — Definition of angle ϕ