SLOVENSKI STANDARD

kSIST-TS FprCEN/TS 1993-1-101:2022

01-julij-2022

Evrokod 3: Projektiranje jeklenih konstrukcij - 1-101. del: Alternativna metoda interakcije za upogibne in tlačne elemente

Eurocode 3: Design of steel structures - Part 1-101: Alternative interaction method for members in bending and compression

Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 1 101: Alternative Interaktionsmethode für Bauteile unter Druck und Biegung

Eurocode 3: Calcul des structures en acier - Partie 1 101: Méthode de calcul pour la stabilité des barres en acier sollicitées en compression et flexion bi-axiale

Ta slovenski standard je istoveten z: FprCEN/TS 1993-1-101

ICS:

91.010.30	Tehnični vidiki	Technical aspects
91.080.13	Jeklene konstrukcije	Steel structures

kSIST-TS FprCEN/TS 1993-1-101:2022 en,fr,de

TECHNICAL SPECIFICATION

SPÉCIFICATION TECHNIQUE

TECHNISCHE SPEZIFIKATION

FINAL DRAFT
FprCEN/TS 1993-1-101

April 2022

ICS 91.010.30; 91.080.13

English Version

Eurocode 3: Design of steel structures - Part 1-101: Alternative interaction method for members in bending and compression

Eurocode 3: Calcul des structures en acier - Partie 1 101: Méthode de calcul pour la stabilité des barres en acier sollicitées en compression et flexion bi-axiale

Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 1 101: Alternative Interaktionsmethode für Bauteile unter Druck und Biegung

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

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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 Technical Specification. It is distributed for review and comments. It is subject to change without notice and shall not be referred to as a Technical Specification.

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

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Ref. No. FprCEN/TS 1993-1-101:2022 E

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European foreword

This document (FprCEN/TS 1993-1-101:2022) 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 design matters by CEN.

This document is currently submitted to the Vote on TS.

This document has been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

This document has 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 this document.

Introduction

0.1 Introduction to FprCEN/TS 1993-1-101

EN 1993-1-1:2005 'Design of Steel Structures — General rules and rules for buildings' included two methods for the determination of interaction factors used for the verification of the buckling resistance of members under bending and axial compression force, which were provided in two separate Annexes A and B.

During the revision of EN 1993-1-1:2005, the standardization committee CEN/TC 250/SC 3 took a decision to retain the method provided in Annex B in EN 1993-1-1:—[1] and to move the method of Annex A into a separate document, i.e. this document, for reasons of ease of use, without significant modifications.

This document is therefore to be considered as an alternative method to the one given in EN 1993-1-1:—[1]. Its applicability can be defined for each country, by the National Annex of EN 1993-1-1:—[1].

This document, which was prepared in line with the Eurocodes, is 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 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.

0.3 National annex for FprCEN/TS 1993-1-101

The applicability of this document can be defined for each country by the National Annex of EN 1993-1-1:—[1].

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] Under preparation. Current stage: FprEN 1993-1-1:2022.

1 Scope

(1) This document provides an alternative method for the stability verification of steel members under compression axial force and bending moment, with reference to EN 1993-1-1.

NOTE For the applicability of this document, see Clause 4.

(2) The method given in this document applies to uniform steel members with double symmetric cross-section under axial compression force and bi-axial bending.

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.

EN 1993-1-1:—[1], *Eurocode 3: Design of steel structures — Part 1-1: General rules and rules for buildings*

3 Terms, definitions and symbols

3.1 Terms and definitions

No terms and definitions are listed in this document.

3.2 Symbols

For the purposes of this document, the symbols given in EN 1993-1-1:—[1] apply.

4 Use of this Technical Specification

(1) This document provides an alternative method for the stability verification of steel members under compression axial force and bending moment, with reference to EN 1993-1-1.

NOTE National choice on the application of this document is given in the National Annex of EN 1993-1-1:—[1]. If the National Annex contains no information on the application of this informative annex, it can be used.

5 Methodology

(1) The notation is the same as the one in EN 1993-1-1.

(2) Unless a second order analysis is carried out using the imperfections given in EN 1993-1-1:—[1], 7.5, members which are subjected to combined bending and axial compression should satisfy the criteria given in Formulae (4.1) and (4.2):

$$\frac{N_{\mathrm{Ed}}}{\dfrac{\chi_{\mathrm{y}} N_{\mathrm{Rk}}}{\gamma_{\mathrm{M1}}}} + k_{\mathrm{yy}} \frac{M_{\mathrm{y,Ed}} + \Delta M_{\mathrm{y,Ed}}}{\dfrac{\chi_{\mathrm{LT}} M_{\mathrm{y,Rk}}}{\gamma_{\mathrm{M1}}}} + k_{\mathrm{yz}} \frac{M_{\mathrm{z,Ed}} + \Delta M_{\mathrm{z,Ed}}}{\dfrac{M_{\mathrm{z,Rk}}}{\gamma_{\mathrm{M1}}}} \leq 1{,}0 \tag{4.1}$$

$$\frac{N_{\mathrm{Ed}}}{\dfrac{\chi_{\mathrm{z}} N_{\mathrm{Rk}}}{\gamma_{\mathrm{M1}}}} + k_{\mathrm{zy}} \frac{M_{\mathrm{y,Ed}} + \Delta M_{\mathrm{y,Ed}}}{\dfrac{\chi_{\mathrm{LT}} M_{\mathrm{y,Rk}}}{\gamma_{\mathrm{M1}}}} + k_{\mathrm{zz}} \frac{M_{\mathrm{z,Ed}} + \Delta M_{\mathrm{z,Ed}}}{\dfrac{M_{\mathrm{z,Rk}}}{\gamma_{\mathrm{M1}}}} \leq 1{,}0 \tag{4.2}$$

where

N_{Ed} is the design value of the compression axial force;

N_{Rk} is the characteristic value of the resistance to the axial force according to EN 1993-1-1:—[1], 8.2.2.6;

$M_{y,Ed}$ and $M_{z,Ed}$ are the design values of the maximum bending moments about the y-y and z-z axes respectively, along the member;

$\Delta M_{y,Ed}$, $\Delta M_{z,Ed}$ are the moments due to the shift of the centroidal axis according to EN 1993-1-1:—[1], 8.2.2.5 for Class 4 sections;

$M_{y,Rk}$ and $M_{z,Rk}$ are the characteristic values of the resistance to the bending moment about the y-y axis and z-z axis respectively, according to EN 1993-1-1:—[1], 8.2.2.6;

χ_y and χ_z are the reduction factors due to flexural buckling according to EN 1993-1-1:—[1], 8.3.1;

χ_{LT} is the reduction factor due to lateral torsional buckling according to EN 1993-1-1:—[1], 8.3.2;

k_{yy}, k_{yz}, k_{zy}, k_{zz} are the interaction factors according to Table 4.1.

(3) As a simplification for uniform members subjected to axial compression and bending about the strong axis, the condition given in Formula (4.3) may be used when out-of-plane buckling (flexural buckling and lateral torsional buckling) is prevented:

$$\frac{1{,}1\,N_{Ed}}{\frac{\chi_y N_{Rk}}{\gamma_{M1}}}+C_{my,0}\frac{1{,}1\left(M_{y,Ed}+\Delta M_{y,Ed}\right)}{\frac{M_{y,Rk}}{\gamma_{M1}}}\le 1{,}0 \qquad (4.3)$$

where

γ_{M1} is the partial factor according to the appropriate part of EN 1993:

Part 1-1 for buildings;

Part 2 for bridges.

$C_{my,0}$ is the equivalent uniform moment factor according to Table 4.2.

Table 4.1 — Interaction factors k_{ij}

Interaction factors	Design assumptions	
	Elastic cross-sectional properties For Class 3 with $W_i = W_{el,i}$ and Class 4	Plastic cross-sectional properties for Class 1 and Class 2 ($W_i = W_{pl,i}$) or Elasto-plastic cross-sectional properties for Class 3 (with $W_i = W_{ep,i}$ according to EN 1993-1-1:—[1], Annex B)
k_{yy}	$C_{my}C_{mLT}\frac{\mu_y}{1-\frac{N_{Ed}}{N_{cr,y}}}$	$C_{my}C_{mLT}\frac{\mu_y}{1-\frac{N_{Ed}}{N_{cr,y}}}\frac{1}{C_{yy}}$
k_{yz}	$C_{mz}\frac{\mu_y}{1-\frac{N_{Ed}}{N_{cr,z}}}$	$C_{mz}\frac{\mu_y}{1-\frac{N_{Ed}}{N_{cr,z}}}\frac{1}{C_{yz}}0{,}6\sqrt{\frac{w_z}{w_y}}$

Interaction factors	Design assumptions	
	Elastic cross-sectional properties **For Class 3 with $W_i = W_{el,i}$ and Class 4**	**Plastic cross-sectional properties for Class 1 and Class 2 ($W_i = W_{pl,i}$) or Elasto-plastic cross-sectional properties for Class 3 (with $W_i = W_{ep,i}$ according to EN 1993-1-1:—[1], Annex B)**
k_{zy}	$C_{my} C_{mLT} \dfrac{\mu_z}{1 - \dfrac{N_{Ed}}{N_{cr,y}}}$	$C_{my} C_{mLT} \dfrac{\mu_z}{1 - \dfrac{N_{Ed}}{N_{cr,y}}} \dfrac{1}{C_{zy}} 0{,}6 \sqrt{\dfrac{w_y}{w_z}}$
k_{zz}	$C_{mz} \dfrac{\mu_z}{1 - \dfrac{N_{Ed}}{N_{cr,z}}}$	$C_{mz} \dfrac{\mu_z}{1 - \dfrac{N_{Ed}}{N_{cr,z}}} \dfrac{1}{C_{zz}}$

Auxiliary terms:

$$\mu_y = \frac{1 - \dfrac{N_{Ed}}{N_{cr,y}}}{1 - \chi_y \dfrac{N_{Ed}}{N_{cr,y}}}$$

$$\mu_z = \frac{1 - \dfrac{N_{Ed}}{N_{cr,z}}}{1 - \chi_z \dfrac{N_{Ed}}{N_{cr,z}}}$$

$$w_y = \frac{W_y}{W_{el,y}} \le 1{,}5$$

$$w_z = \frac{W_z}{W_{el,z}} \le 1{,}5$$

$$n_{pl} = \frac{N_{Ed}}{N_{Rk} / \gamma_{M0}}$$

$$a_{LT} = 1 - \frac{I_T}{I_y} \ge 0$$

$$C_{yy} = 1 + (w_y - 1)\left[\left(2 - \frac{1{,}6}{w_y} C_{my}^2 \bar{\lambda}_{max} - \frac{1{,}6}{w_y} C_{my}^2 \bar{\lambda}_{max}^2\right) n_{pl} - b_{LT}\right] \ge \frac{W_{el,y}}{W_y}$$

with: $b_{LT} = 0{,}5 a_{LT} \bar{\lambda}_0^2 \dfrac{M_{y,Ed}}{\chi_{LT} M_{y,Rk} / \gamma_{M1}} \dfrac{M_{z,Ed}}{M_{z,Rk} / \gamma_{M1}}$

$$C_{yz} = 1 + (w_z - 1)\left[\left(2 - 14 \frac{C_{mz}^2 \bar{\lambda}_{max}^2}{w_z^5}\right) n_{pl} - c_{LT}\right] \ge 0{,}6 \sqrt{\frac{w_z}{w_y}} \frac{W_{el,z}}{W_z}$$

with: $c_{LT} = 10 a_{LT} \dfrac{\bar{\lambda}_0^2}{5 + \bar{\lambda}_z^4} \dfrac{M_{y,Ed}}{C_{my} \chi_{LT} M_{y,Rk} / \gamma_{M1}}$

$$C_{zy} = 1 + (w_y - 1)\left[\left(2 - 14 \frac{C_{my}^2 \bar{\lambda}_{max}^2}{w_y^5}\right) n_{pl} - d_{LT}\right] \ge 0{,}6 \sqrt{\frac{w_y}{w_z}} \frac{W_{el,y}}{W_y}$$

with: $d_{LT} = 2 a_{LT} \dfrac{\bar{\lambda}_0}{0{,}1 + \bar{\lambda}_z^4} \dfrac{M_{y,Ed}}{C_{my} \chi_{LT} M_{y,Rk} / \gamma_{M1}} \dfrac{M_{z,Ed}}{C_{mz} M_{z,Rk} / \gamma_{M1}}$

$$C_{zz} = 1 + (w_z - 1)\left[2 - \frac{1{,}6}{w_z} C_{mz}^2 \bar{\lambda}_{max} \left(1 + \bar{\lambda}_{max}\right) - e_{LT}\right] n_{pl} \ge \frac{W_{el,z}}{W_z}$$

with: $e_{LT} = 1{,}7 a_{LT} \dfrac{\bar{\lambda}_0}{0{,}1 + \bar{\lambda}_z^4} \dfrac{M_{y,Ed}}{C_{my} \chi_{LT} M_{y,Rk} / \gamma_{M1}}$

where

$M_{y,Rk}$ and $M_{z,Rk}$ are defined in EN 1993-1-1:—[1], 8.2.2.6;

W_y and W_z are defined in EN 1993-1-1:—[1], Table 8.1.

$\bar{\lambda}_{max} = \max \begin{cases} \bar{\lambda}_y \\ \bar{\lambda}_z \end{cases}$

$\bar{\lambda}_0 =$ relative slenderness for lateral-torsional buckling due to uniform bending moment, i.e. $\psi_y = 1{,}0$ in Table 4.2;

$\bar{\lambda}_{LT} =$ relative slenderness for lateral-torsional buckling.

Interaction factors	**Design assumptions**	
	Elastic cross-sectional properties For Class 3 with $W_i = W_{el,i}$ and Class 4	**Plastic cross-sectional properties for Class 1 and Class 2 ($W_i = W_{pl,i}$) or Elasto-plastic cross-sectional properties for Class 3 (with $W_i = W_{ep,i}$ according to EN 1993-1-1:—[1], Annex B)**
If : $\bar{\lambda}_0 \leq 0{,}2\sqrt{C_1}\sqrt[4]{\left(1-\frac{N_{Ed}}{N_{cr,z}}\right)\left(1-\frac{N_{Ed}}{N_{cr,T}}\right)}$		$C_{my} = C_{my,0}$ $C_{mz} = C_{mz,0}$ $C_{mLT} = 1{,}0$
If $\bar{\lambda}_0 > 0{,}2\sqrt{C_1}\sqrt[4]{\left(1-\frac{N_{Ed}}{N_{cr,z}}\right)\left(1-\frac{N_{Ed}}{N_{cr,T}}\right)}$		$C_{my} = C_{my,0} + \left(1-C_{my,0}\right)\frac{\sqrt{\varepsilon_y}\, a_{LT}}{1+\sqrt{\varepsilon_y}\, a_{LT}}$ $C_{mz} = C_{mz,0}$ $C_{mLT} = C_{my}^2 \frac{a_{LT}}{\sqrt{\left(1-\frac{N_{Ed}}{N_{cr,z}}\right)\left(1-\frac{N_{Ed}}{N_{cr,T}}\right)}} \geq 1{,}0$
C_1	factor depending on the loading and end conditions. It may be taken as: $C_1 = k_c^{-2}$ where k_c is to be taken from EN 1993-1-1:—[1], Table 8.6.	
$C_{mi,0}$	equivalent uniform moment factors to be determined according to Table 4.2	
$\varepsilon_y = \frac{M_{y,Ed}}{N_{Ed}}\frac{A}{W_{el,y}}$	for Class 1, 2 and 3 cross-sections	
$\varepsilon_y = \frac{M_{y,Ed}}{N_{Ed}}\frac{A_{eff}}{W_{eff,y}}$	for Class 4 cross-sections	
$N_{cr,y}$	elastic critical axial force for flexural buckling about y-y axis	
$N_{cr,z}$	elastic critical axial force for flexural buckling about z-z axis	
$N_{cr,T}$	elastic critical axial force for torsional buckling	
I_T	St Venant torsional constant	
I_y	second moment of area about the y-y axis	