NEMETSCHEK Scia

Theory

Steel Code Check

Scia Engineer

Introduction

Welcome to the Steel Code Check – Theoretical Background.

This document provides background information on the code checks according to different national and international regulations.

Version info

Documentation Title	Steel Code Check – Theoretical Background
Release	16.0
Revision	12/2015

TABLE OF CONTENTS

EC3 – ENV 1993

EC3 – ENV code check

The beam elements are checked according to the regulations given in

Eurocode 3
Design of steel structures
Part 1 - 1 : General rules and rules for buildings
ENV 1993-1-1:1992

Material properties

For standard steel grades, the yield strength fy and tensile strength fu are defined according to the thickness of the element (see Ref. [1], art.3.2.2.1.)

(fy, fu in N/mm², t in mm)

	t<=40	t<=40	40<t<=100	40<t<=100	100<t<=250	100<t<=250
	fy	fu	fy	fu	fy	fy
S235 S 235	235	360	215	340	175	320
S275 S 275	275	430	255	410	205	380
S355 S 355	355	510	335	490	275	450
S420 S 420	420	520	390	520		
S460 S 460	460	550	430	550		

Remark : For cold formed section, the values for fy and fu are not influenced by the previous table

Remark : For cold formed sections, the average yield strength f_{ya} can be used (by setting the proper data flag in the Cross Section input dialog).

The average yield strength is determined as follows:

$$f_{ya} = f_{yb} + \left(\frac{knt^2}{A_g}\right)\left(f_u - f_{yb}\right) \leq \min\left(f_u, 1.2f_{yb}\right)$$

with	f_{yb}	the tensile yield strength = f_y
	f_u	the tensile ultimate strength
	t	the material thickness
	A_g	the gross cross-sectional area
	k	is a coefficient depending on the type of forming : k = 0.7 for cold rolling k = 0.5 for other methods of forming
	n	the number of 90° bends in the section

Consulted articles

The cross-section is classified according to Table 5.3.1. (class 1,2,3 or 4). The section is checked for tension (art. 5.4.3.), compression (art. 5.4.4.), shear (art. 5.4.6.) and the combination of bending, shear and axial force (art. 5.4.9.).

For the stability check, the beam element is checked according to art.5.5.. The following criteria are considered :

- for compression : art. 5.5.1.
- for lateral torsional buckling : art. 5.5.2.
- for bending and axial compression : art. 5.5.4.

The shear buckling resistance is checked using the simple post-critical method from art. 5.6.3.

A more detailed overview for the used articles is given for part 5.3., 5.4., 5.5. and 5.6. in the following table. The chapters marked with “x” are consulted. The chapters marked with (*) have a supplementary explanation the following chapters.

5.3. Classification of cross sections	
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5.3.2. Classification	x
5.3.3. Cross-section requirements for plastic global analysis	
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5.3.5. Effective cross-section properties for class 4 cross-section	x (*)
5.3.6. Effects of transverse forces on webs	
5.4. Resistance of cross-sections	
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5.4.2. Section properties	(*)
5.4.3. Tension	x
5.4.4. Compression	x

5.4.5. Bending moment	x (*)
5.4.6. Shear	x
5.4.7. Bending and shear	x
5.4.8. Bending and axial force	x
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5.5.2. Lateral-torsional buckling	x (*)
5.5.3. Bending and axial tension	
5.5.4. Bending and axial compression	x (*)
5.6. Shear buckling resistance	
5.6.1. Basis	x
5.6.2. Design methods	
5.6.3. Simple post-critical method	x
5.6.4. Tension field method	
5.6.5. Intermediate transverse stiffeners	
5.6.6. Welds	
5.6.7. Interaction between shear force, bending moment and axial force	x
5.9. Built-up compression members	
5.9.3. Battened compression members	
5.9.3.1. Application	x(*)
5.9.3.2. Constructional details	
5.9.3.3. Second moment of inertia	x
5.9.3.4. Chord forces ar mid-length	x
5.9.3.5. Buckling resistance of chords	x
5.9.3.6. Moments and shear due to battening	x

Classification of sections

For each intermediary section, the classification is determined and the proper section check is performed. The classification can change for each intermediary point.

For each load case/combination, the critical section classification over the member is used to perform the stability check. So, the stability section classification can change for each load case/combination.

However, for non-prismatic sections, the stability section classification is determined for each intermediary section.

Effective cross-section properties for class 4 cross-section

The calculation of the effective area is performed with the direct method (sigma_d = fy,k).

For each intermediary section, the classification (and if necessary, the effective area) is determined and the proper section check is performed. The classification (and effective area) can change for each intermediary point. The most critical check is displayed on the screen.

For each load case and combination, the most critical effective area properties are saved :

Aeff is the effective area of the cross section when subject to uniform compression. Weff is the effective section modulus of the cross-section when subject only to moment about the relevant axis. eN is the shift of the relevant centroidal axis when the cross section is subject to uniform compression.

With these critical properties, the stability check is performed.

For non-prismatic elements, the effective area properties are calculated on each intermediary section, also for the stability check.

For angle sections, see chapter '**Error! Reference source not found.**'.

Section properties

5.4.2.2 : The net area properties are only taken into account in the Tension Check in case of lattice tower angle sections with bolted diagonal connections if the LTA functionality has been activated. For more information, reference is made to the Theoretical Background Bolted Diagonal Connections. In all other cases the net area properties are not taken into account.

5.4.2.3 : The shear lag effects are neglected .

Bending moment

5.4.5.3 : The holes for fasteners are neglected.

Bending, shear and axial force

The reduced design plastic resistance moment for the interaction of bending, shear and axial force, is taken from Table 5.17. Ref. [2]

Torsion check

For the cross section check inclusive torsion and warping, we refer to Chapter '**Error! Reference source not found.**'.

Built-in beams

For built-in beam sections (IFB, SFB, THQ sections), proper section checks are performed, taking into account the local plate bending. See Chapter '**Error! Reference source not found.**'

Compression members

5.5.1.5 For the calculation of the buckling length, we refer to chapter "**Error! Reference source not found.**"

The buckling properties for a VARH element are calculated by using the critical Euler force for this member (see chapter "**Error! Reference source not found.**").

The buckling curves for steel grade S420 and S460 are taken from Ref.[5], Annex D.

Lateral-torsional buckling

For I sections (symmetric and asymmetric), RHS (Rectangular Hollow Section) sections and CHS (Circular Hollow Section) sections, the elastic critical moment for LTB Mcr is given by the general formula F.2. Annex F Ref. [1]. For the calculation of the moment factors C1, C2 and C3 we refer to "**Error! Reference source not found.**".

For the other supported sections, the elastic critical moment for LTB Mcr is given by

$$M_{cr} = \frac{\pi^2 E I_z}{L^2} \sqrt{\frac{I_w}{I_z} + \frac{L^2 G I_t}{\pi^2 E I_z}}$$

with	E	the modulus of elasticity
	G	the shear modulus
	L	the length of the beam between points which have lateral restraint (= l_{LTB})
	Iw	the warping constant
	It	the torsional constant
	Iz	the moment of inertia about the minor axis

See also Ref. [3], part 7 and in particular part 7.7. for channel sections.

Haunched sections (I+Ivar, Iw+Plvar, Iw+Iwvar, Iw+Ivar, I+Iwvar) and composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

For advanced Lateral-torsional buckling analysis, see Annex D: Use of diaphragms.

Shear Buckling check

Composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

Shear buckling check for cold formed sections

See Ref.[4] 5.8 :

The shear resistance of the web $V_{w,Rd}$ shall be taken as the lesser of the shear buckling resistance $V_{b,Rd}$ and the plastic shear resistance $V_{pl,Rd}$.

The shear resistance of the web should be checked if:

$$\bar{\lambda}_w \leq 0.83 \cdot \frac{f_{yb}}{f_y} \frac{\gamma_{M0}}{\gamma_{M1}}$$

$$\bar{\lambda}_w = 0.346 \cdot \frac{s_w}{t} \sqrt{\frac{f_{yb}}{E}}$$

The shear buckling resistance $V_{b,Rd}$ is given by

$$V_{b,Rd} = \frac{s_w \cdot t \cdot f_{bv}}{\gamma_{M1}}$$

The plastic shear resistance $V_{pl,Rd}$ is given by

$$V_{pl,Rd} = \frac{s_w \cdot t \cdot f_y}{\gamma_{M0} \sqrt{3}}$$

with	$\bar{\lambda}_w$	the relative web slenderness
	f_{yb}	the basic yield strength
	f_y	the average yield strength
	s_w	the web length
	t	the web thickness
	E	the modulus of elasticity
	f_{bv}	the shear buckling strength
	γ_{M0}	the partial safety factor for resistance of cross-sections where failure is caused by yielding (=1.1)
	γ_{M1}	the partial safety factor for resistance of cross-sections where failure is caused by buckling (=1.1)

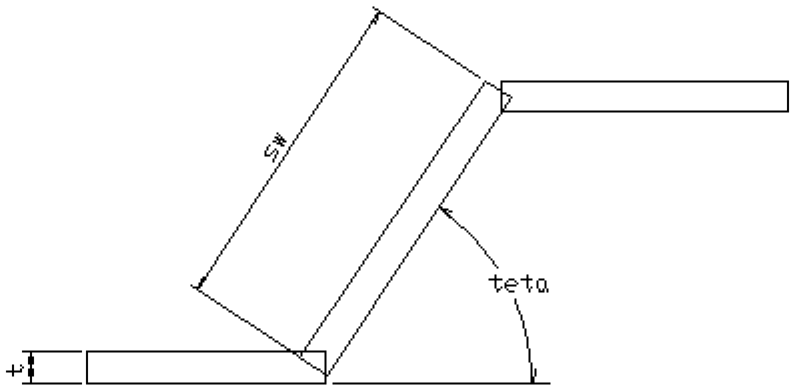
The value for f_{bv} is given by :

$\bar{\lambda}_w$	f_{bv}
<1.40	$0.48\,\dfrac{f_{yb}}{\bar{\lambda}_w}$
≥1.40	$0.67\,\dfrac{f_{yb}}{\bar{\lambda}_w^{\,2}}$

Remarks:

For an arbitrary composed section, the total Vb,Rd and Vpl,Rd is taken as the sum of resistance of each web, where the angle θ (teta) is larger than 45° (see figure)

The basic yield strength is taken equal to the average yield strength.



Stability check for torsional buckling and torsional-flexural buckling

See Ref.[4] 6.2.3.

The design buckling resistance $N_{b,Rd}$ for torsional or torsional-flexural buckling shall be obtained using buckling curve b, and with relative slenderness given by :

$$\bar{\lambda} = \sqrt{\frac{f_{yb}}{\sigma_{cr}}\beta_A}$$

$$\sigma_{cr} = \min(\sigma_{cr,T}, \sigma_{cr,TF})$$

$$\sigma_{cr,T} = \frac{1}{A_g i_0^2}\left(GI_t + \frac{\pi^2 EC_m}{l_T^2}\right)$$

$$i_0^2 = i_y^2 + i_z^2 + y_0^2$$

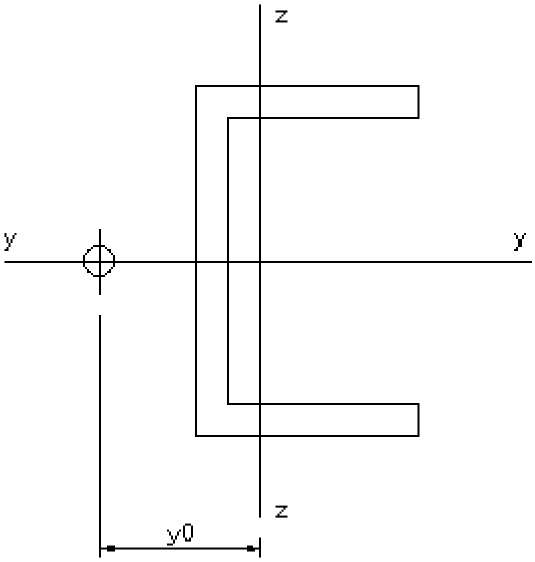
$$\sigma_{cr,TF} = \frac{1}{2\beta}\left[\left(\sigma_{cr,y} + \sigma_{cr,T}\right) - \sqrt{\left(\sigma_{cr,y} + \sigma_{cr,T}\right)^2 - 4\beta\sigma_{cr,y}\sigma_{cr,T}}\right]$$

$$\sigma_{cr,y} = \frac{\pi^2 E}{\left(\frac{l_y}{i_y}\right)^2}$$

$$\beta = 1 - \left(\frac{y_0}{i_0}\right)^2$$

with

β_A	the ratio A_{eff}/A (see Ref.[1] 5.5)
f_{yb}	the basic yield strength
σ_{cr}	the critical stress
$\sigma_{cr,T}$	the elastic critical stress for torsional buckling
$\sigma_{cr,TF}$	the elastic critical stress for torsional-flexural buckling
G	the shear modulus
E	the modulus of elasticity
I_T	the torsion constant of the gross section
C_M	the warping constant
i_y	the radius of gyration about yy-axis
i_z	the radius of gyration about zz-axis
l_T	the buckling length of the member for torsional buckling
y_0	the position of the shear center
l_y	the buckling length for flexural buckling about the yy-axis



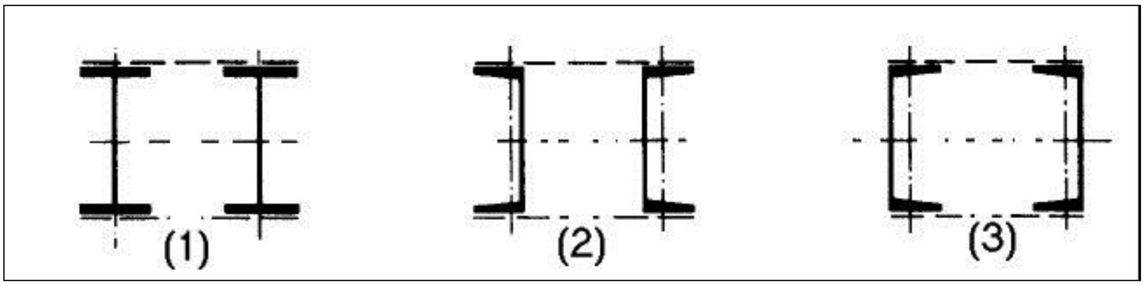
Bending and axial compression

When the torsional buckling and/or the torsional-flexural buckling is governing, the formula (6.12) from Ref.[4], article 6.5.2. is applied.

Battened compression members

The following section pairs are supported as battened compression member :

(1) 2I
(2) 2Uo
(3) 2Uc



Two links (battens) are used.

The following additional checks are performed:

- buckling resistance check around weak axis of single chord with $N_{f,Sd}$
- section check of single chord, using internal forces :

$$N_G = N_{f,SD}$$

$$V_G = \frac{V_s}{2}$$

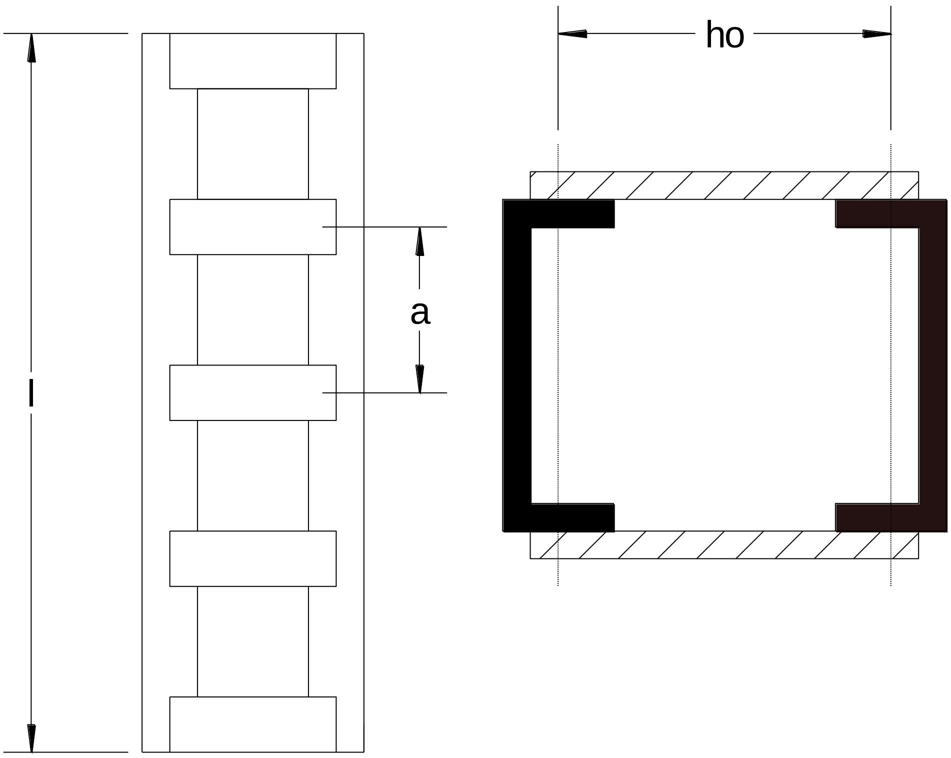
$$M_G = \frac{V_s a}{4}$$

- section check of single batten, using the internal forces :

$$T = \frac{V_s a}{h_0 2}$$

$$M = \frac{V_s a}{4}$$

For the calculation of V_s, the value of M_s is increased with the value of the internal force M_{zz}.



EC3 – ENV Fire Resistance

Fire actions effect E_{fi}

The design effects of actions for the fire situation $E_{fi,d,t}$ are taken from the results of the analysis. It is recommended to use the accidental combination rules, for calculating the internal forces used in the fire resistance check.

The accidental combination is given by

$$\Sigma\gamma_{GA}G_k + \psi_{1,1}Q_{k,1} + \Sigma\psi_{2,j}Q_{k,j} + \Sigma A_d(f)$$

with	G_k	characteristic values of permanent actions
	$Q_{k,1}$	characteristic value of the (main) variable action
	$Q_{k,j}$	characteristic values of the other variable actions
	$A_f(d)$	design values of actions from fire exposure
	γ_{GA}	partial safety factor for permanent actions in the accidental situation
	$\psi_{1,1}$ $\psi_{2,j}$	combination coefficients

Material properties

The material properties are depending on the steel temperature.

Strength and deformation properties :

$$k_{y,\theta} = f_{y,\theta}/f_y$$

$$k_{p,\theta} = f_{p,\theta}/f_y$$

$$k_{E,\theta} = E_{a,\theta}/E_a$$

The variation in function of the steel temperature of the value for yield strength $k_{y,\theta}$, proportional limit $k_{p,\theta}$ and modulus of elasticity $k_{E,\theta}$ is given by tables in Ref.[6], table 3.1.

For cold formed members $k_{y,\theta}$ is taken from Ref.[7], table III.2.5.

In the simplified calculation method, the following default properties are considered to be constant during the analysis:

unit mass	ρ_a	7850 kg/m³
thermal elongation	$\Delta l/l$	$14 \times 10^{-6} (\theta_a - 20)$
thermal conductivity	λ_a	45 W/mK

Temperature analysis - Thermal actions

In this part, the nominal temperature-time curves and the related net heat flux are described. See Ref.[8], Section 4, and Ref.[7], II.2.2.

Nominal temperature-time curve

The following temperature-time curves can be selected :

with t time in [min]

θ_g gas temperature in [°C]

α_c the coefficient of heat transfer by convection

- ISO 834 curve

$$\theta_g = 20 + 345 \log_{10}(8t + 1)$$
$$\alpha_c = [25] W/m^2K$$

- external fire curve

$$\theta_g = 660\left(1 - 0.687e^{-0.32t} - 0.313e^{-3.8t}\right) + 20$$
$$\alpha_c = [25] W/m^2K$$

- hydrocarbon curve

$$\theta_g = 1080\left(1 - 0.325e^{-0.167t} - 0.675e^{-2.5t}\right) + 20$$
$$\alpha_c = [50] W/m^2K$$

- smoldering fire curve

$$\theta_g = 154\sqrt[4]{t} + 20$$

during 21 minutes, followed by the standard ISO 834 curve

Net heat flux

$$h_{net,d} = \gamma_{n,c} h_{net,c} + \gamma_{n,r} h_{net,r}$$

with	$h_{net,d}$	the net heat flux
	$h_{net,c}$	the convective heat flux
	$h_{net,r}$	the radiative heat flux
	$\gamma_{n,c}$	factor depending on NAD [1.0]
	$\gamma_{n,r}$	factor depending on NAD [1.0]

$$h_{net,c} = \alpha_c\left(\theta_g - \theta_m\right)$$

$$h_{net,r} = \Phi\varepsilon_{res} 5.67 \cdot 10^{-8}\left(\left(\theta_r + 273\right)^4 - \left(\theta_m + 273\right)^4\right)$$

with	Φ	configuration factor [1.0]
	ε_{res}	resultant emissivity $= \varepsilon_f \varepsilon_m$
	ε_f	emissivity related to fire compartment = [0.800]
	ε_m	emissivity related to surface material = [0.625]
	θ_r	$= \theta_g$ gas temperature in [°C]
	θ_m	surface temperature of member in [°C]
	α_c	coefficient of heat transfer by convection

Steel Temperature

The increase of temperature $\Delta\theta_{a,t}$ in an unprotected steel member during a time interval Δt

$$\Delta\theta_{a,t} = \frac{A_m / V}{c_a \rho_a} h_{net,d} \Delta t$$

with	A_m	the exposed surface area per unit length [m²/m]
	V	the volume of the member per unit length [m³/m] The factor A_m/V should not be taken as less than $10m^{-1}$
	c_a	the specific heat of steel [J/kgK]
	$h_{net,d}$	the net heat flux per unit area [W/m²]
	Δt	the time interval [seconds] The value should not be taken as more than 5 seconds
	ρ_a	the unit mass of steel [kg/m³]

The increase of temperature $\Delta\theta_{a,t}$ in an insulated steel member during a time interval Δt

$$\Delta\theta_{a,t} = \frac{\lambda_p A_p / V}{d_p c_a \rho_a} \frac{(\theta_{g,t} - \theta_{a,t})}{\left(1 + \frac{\phi}{3}\right)} \Delta t - \left(e^{\phi/10} - 1\right) \Delta_{g,t}$$

$$\phi = \frac{c_p \rho_p}{c_a \rho_a} d_p A_p / V$$

with	A_p	the area of fire protection material per unit length [m²/m]
	V	the volume of the member per unit length [m³/m]
	c_a	the specific heat of steel [J/kgK]
	c_p	the specific heat of fire protection material [J/kgK]
	d_p	the thickness of the fire protection material [m]
	Δt	the time interval [seconds] The value should not be taken as more than 30 seconds
	ρ_a	the unit mass of steel [kg/m³]
	ρ_p	the unit mass of fire protection [kg/m³]
	$\theta_{a,t}$	the steel temperature at time t
	$\theta_{g,t}$	the ambient gas temperature at time t
	$\Delta\theta_{g,t}$	the increase of the ambient gas temperature during the time interval
	λ_p	the thermal conductivity of the fire protection material [W/mK]

The value $\Delta\theta_{a,t} \geq 0.0$

For the increase of temperature $\Delta\theta_{a,t}$ in an insulated steel member with intumescent coating, we refer to the NEN specifications, Chapter 'Steel Temperature'.

Calculation model

The calculation can be performed in 2 domains :

- strength domain
- temperature/time domain

In the strength domain, the strength $R_{fi,d,t}$(unity check) is calculated after a given time t (e.g. strength after 45 min). In the temperature/time domain, the critical steel temperature $\theta_{cr,d}$ is computed. From this critical temperature, the fire resistance time $t_{fi,d}$ is calculated (the time domain).

Code Check

The section and stability checks (buckling, lateral torsional buckling) are performed according to the regulations given in 'ENV 1993-1-2:1995' and/or 'Model Code on Fire Engineering - ECCS N° 111'. The checks are performed in the resistance domain or in the temperature/time domain..

Torsional buckling and shear buckling are not considered.

For each member, the classification of the cross section, the section check and the stability check are performed.

The following checks are executed :

EC3-1-2 :

- classification of cross section : art. 4.2.2.
- resistance for tension members : art. 4.2.3.1
- resistance for compression members (class 1,2 or 3) : art. 4.2.3.2.
- resistance for beams (class 1,2) : art. 4.2.3.3.
- resistance for beams (class 3) : art.4.2.3.4.
- resistance for members (class 1,2,3) subject to bending and compression : art. 4.2.3.5.
- critical temperature : art. 4.2.4.

ECCS Model Code on Fire Engineering

- resistance for tension members : art. III.5.2.
- resistance for compression members (class 1,2 or 3) : art. III.5.3.
- resistance for beams (class 1,2) : art. III.5.4.
- resistance for beams (class 3) : art. III.5.5.
- resistance for members (class 1,2,3) subject to bending and compression : art. III.5.6.
- resistance for members (class 4) : art. III.5.7.
- critical temperature : art. III.5.8.

Supported sections

I	Symmetric I shapes (IPE, HEA, HEB, ….)
RHS	Rectangular Hollow Section
CHS	Circular Hollow Section
L	Angle section
U	Channel section
T	T section
PPL	Asymmetric I shapes
Z	Z section
RS	Rectangular section
Σ	Cold formed section
COM	Composed section in PRIMAWIN
O	Solid tube
NUM	Numerical section

The necessary data conditions for these sections are described in Annex A: Profile Library Formcodes.

The COM and NUM sections are not read out of the profile library.

	I	RHS	CHS	L	U	T	PPL	RS	Z	Σ	O	COM	NUM
Classification	x	x	x	x	x	x	x	x	(1)	x	(1)	(1)	(1)
Section check class 1	x	x	x										
Section check class 2	x	x	x										
Section check class 3	x	x	x	x	x	x	x	x	x	x	x	x	x
Section check class 4	x	x		x	x		x			x			
Stability check class 1	x	x	x										
Stability check class 2	x	x	x										
Stability check class 3	x	x	x	x	x	x	x	x	x	x	x	x	x
Stability check class 4	x	x		x	x		x			x			
Shear buckling check	x				x		x			x			

(1) sections are classified as class 3 cross section by default.

References

[1] Eurocode 3
Design of steel structures
Part 1 - 1 : General rules and rules for buildings
ENV 1993-1-1:1992, 1992

[2] Essentials of Eurocode 3
Design Manual for Steel Structures in Building
ECCS - N° 65, 1991

[3] R. Maquoi
ELEMENTS DE CONSTRUCTIONS METALLIQUE
Ulg , Faculté des Sciences Appliquées, 1988

[4] ENV 1993-1-3:1996
Eurocode 3 : Design of steel structures
Part 1-3 : General rules
Supplementary rules for cold formed thin gauge members and sheeting
CEN 1996

[5] Eurocode 3
Design of steel structures
Part 1 - 1/ A1 : General rules and rules for buildings
ENV 1993-1-1:1992/A1, 1994

[6] Eurocode 3
Design of steel structures
Part 1 - 2 : General rules - Structural fire design
ENV 1993-1-2:1995, 1995

[7] Model Code on Fire Engineering
ECCS - N° 111
May 2001

[8] Eurocode 1
Basis of design and actions on structures
Part 2-2 : Actions on structures - Actions on structures exposed to fire
ENV 1991-2-2:1995

DIN18800

DIN18800 Code check

The beam elements are checked according to the regulations given in

DIN 18800 Teil 1
Stahlbauten
Bemessung und Konstruktion
DK 693.814.014.2, November 1990

DIN 18800 Teil 2
Stahlbauten
Stabilitätsfälle, Knicken von Stäben und Stabwerken
DK 693.814.074.5, November 1990

DIN 18800 Teil 3
Stahlbauten
Stabilitätsfälle, Plattenbeulen
DK 693.814.073.1, November 1990

Material properties

For standard steel grades, the yield strength fy and tensile strength fu are defined according to the thickness of the element (see Ref. [1], Tab.1)

The standard steel grades are :

(fy, fu in N/mm², t in mm)

	t<=40	t<=40	40<t<=80	40<t<=80
	fy	fu	fy	fu
S235 S 235 St 37-2	240	360	215	360
S275 S 275	280	430	255	430
S355 S 355 St 52-3	360	510	325	510

	t<=40	t<=40	40<t<=100	40<t<=100
	fy	fu	fy	fu
S420 S 420	420	520	390	520
S460 S 460	460	550	430	550

Consulted articles

For the section check, the cross section is classified according to DIN18800 Teil I, Table 12,13,14,15 and 18.. Depending on this classification, the section is checked as slender section, EL/EL (elastic/elastic), as EL/PL (elastic/plastic) or as PL/PL (plastic/plastic).

For the EL/EL check, DIN18800 Teil I, Element (746), (747), (748), (749), (750) are used.

The EL/PL check takes the rules from DIN18800 Teil I, Element (756), (757) and Table (16) ,(17). The PL/PL check is done according to DIN18800 Teil I, Element (758), Table (16),(17).

The slender cross section is checked according to DIN18800 Teil 2, Element (715).

For the stability check, the beam element is checked according to DIN18800 Teil 2 for buckling, lateral torsional buckling and bending and compression. The following criteria are used :

- compression : Element (304),(306)
- lateral torsional buckling : Element (311),(309)
- bending and axial compression : Element (313),(321),(322)
- bending (LTB) and compression : Element (320),(323)

For slender sections, the following criteria are used :

- calculation of effective area : Element (705),(706),(708),(709),(712),(713)
- buckling check : Element (715),(716),(718),(719)
- LTB check : Element (725),(726),(728),(729)

For the shear buckling check, the beam element is checked according to DIN18800 Teil 3. The following criteria are used : Element (113), (504), (602),(603)

A more detailed overview for the used articles is given for the relevant parts following table. The chapters marked with “x” are consulted. The chapters marked with (*) have a supplementary explanation the following chapters.

Teil 1	
7.5. Verfahren beim Tragsicherheitsnachweis Nachweise	(*)
7.5.1. Abgrenzungskriterien und Detailregelungen	(*)
7.5.2. Nachweis nach dem Verfahren Elastisch-Elastisch (745)…………………………………………………………………… (746) …………………………………………………………………… (747) …………………………………………………………………… (748) …………………………………………………………………… (749) …………………………………………………………………… (750) ……………………………………………………………………	x x x x x x x
Nachweis nach dem Verfahren Elastisch-Plastisch (753) …………………………………………………………………… (756) …………………………………………………………………… (757) ……………………………………………………………………	x x x x
Nachweis nach dem Verfahren Plastisch-Plastisch (758) ……………………………………………………………………	x x
Teil 2	
3.2. Planmässig mittiger Druck 3.2.1. Biegeknicken (304) ……………………………………………………………………	x x x (*)
3.2.2. Biegedrillknicken (306) ……………………………………………………………………	x x (*)
3.3. Einachsige Biegung ohne Normalkraft 3.3.1. Allgemeines (307) ……………………………………………………………………	x x x
3.3.2. Behinderung der Verformung (309) ……………………………………………………………………	x x (*)
3.3.3. Nachweis des Druckgurtes als Druckstab	
3.3.4. Biegedrillknicken (311) ……………………………………………………………………	x x (*)
3.4. Einachsige Biegung mit Normalkraft 3.4.1. Stäbe mit geringer Normalkraft (312) ……………………………………………………………………	x x x
3.4.2. Biegeknicken (314) ……………………………………………………………………	x x
3.4.3. Biegedrillknicken (320) ……………………………………………………………………	x x
3.5. Zweiachsige Biegung mit oder ohne Normalkraft 3.5.1. Biegeknicken (321) …………………………………………………………………… (322) ……………………………………………………………………	x x x x(*)
3.5.2. Biegedrillknicken (323) ……………………………………………………………………	x x

4. Mehrteilige, einfeldrige Stäbes 4.1. Allgemeines 4.2. Häufig verwendete Formelzeichnen (404) … 4.3. Ausweichen rechtwinklig zur stofffreien Achse (405) … (406)… (408)… (409)…	x(*) x x x x x
7. Planmässig gerade Stäbe mit ebenen dünnwandigen Quenschnittsteilen 7.1. Allgemeines (701) … (702) … (704) …	x x x x x
7.2. Berechnungsgrundlage (705) … (706) … (707) … (708) … (709) …	x x x x x x
7.3. Wirksame Breite beim Verfahren Elastisch-Elastisch (711) … (712) … (713) …	x x x (*) x
7.4. Wirksame Breite beim Verfahren Elastisch-Plastisch	
7.5. Biegeknicken 7.5.1. Spannungsnachweis beim Verfahren Elastisch-Elastisch (715) …	x x x
7.5.2. Vereinfachte Nachweise (716) … (718) … (719) … (721) …	x x x x x
7.6. Biegedrillknicken (722) … (723) … (725) … (726) … (728) … (729) …	x x x x x x x
Teil 3	
5. Nachweise (504) …	(*) x

6. Abminderungsfaktoren (601) .... (602)	x x x

Classification of sections

For each intermediary section, the classification is determined and the proper section check is performed. The classification can change for each intermediary point.

For each load case/combination, the critical section classification over the member is used to perform the stability check. So, the stability section classification can change for each load case/combination.

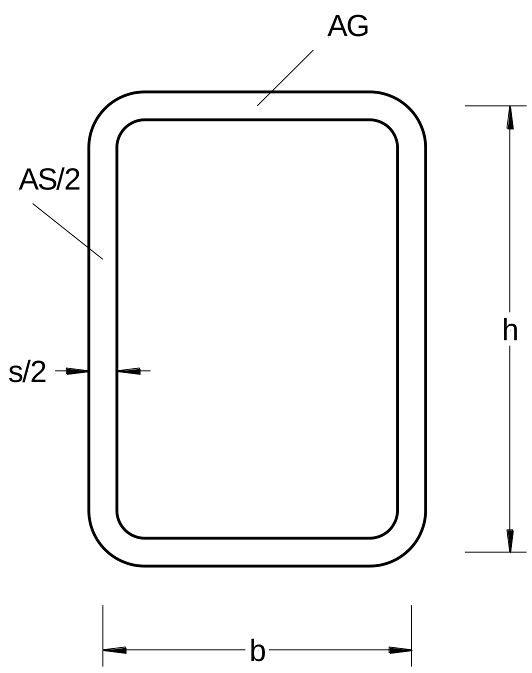
However, for non-prismatic sections, the stability section classification is determined for each intermediary section.

Net area properties

The net area properties are not taken into account .

The holes for fasteners are neglected.

Plastic interaction formula for RHS section



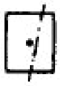
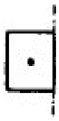
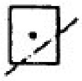
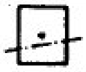
For RHS section, classified as Plastic-Plastic or Elastic-Plastic, the plastic interaction formula according to Ref.[13], can be selected.

- Used variable :

A	sectional area
$A_S = s\ h$	
$A_G = (A-A_S)/2.0$	
Wel,y	elastic section modulus around y axis
Wel,z	elastic section modulus around z axis
$f_{y,d}$	yield strength
$\tau_{y,d}$	shear strength
$V_{z,pl,Rd} = A_S\ \tau_{y,d}$	
$V_{y,pl,Rd} = 2A_G\ \tau_{y,d}$	
N_{Sd}	normal force
$M_{y,Sd}$	bending moment around y axis
$M_{z,Sd}$	bending moment around z axis
$V_{y,Sd}$	shear force in y direction
$V_{z,Sd}$	shear force in z direction
$M_{T,Sd}$	torsional moment
if $\left(\dfrac{V_{z,Sd} + \dfrac{M_{T,Sd}}{b}}{V_{z,pl,Rd}}\right) \le \dfrac{1}{4} \quad \eta_z = 1.0$ else $\eta_z = \sqrt{1 - \left(\dfrac{V_{z,Sd} + \dfrac{M_{T,Sd}}{b}}{V_{z,pl,Rd}}\right)^2}$	

if $\left(\dfrac{V_{y,Sd}+\dfrac{M_{T,Sd}}{h}}{V_{y,pl,Rd}}\right)\le\dfrac{1}{4}\quad \eta_y=1.0$ else $\eta_y=\sqrt{1-\left(\dfrac{V_{y,Sd}+\dfrac{M_{T,Sd}}{h}}{V_{y,pl,Rd}}\right)^2}$	
$A_r=\eta_z A_S+2\eta_y A_G$	
$\delta=\eta_z\dfrac{A_S}{A_r}$	
$N_{pl,Rd}=A_r\, f_{y,d}$	
$M_{y,pl,Rd}=\min\left(\dfrac{2-\delta}{4}hN_{pl,Rd},1.25W_{el,y}f_{yd}\right)$	
$M_{z,pl,Rd}=\min\left(\dfrac{1+\delta}{4}bN_{pl,Rd},1.25W_{el,z}f_{yd}\right)$	
$n=\dfrac{N_{Sd}}{N_{pl,Rd}}$	
$m_y=\dfrac{M_{y,Sd}}{M_{y,pl,Rd}}$	
$m_z=\dfrac{M_{z,Sd}}{M_{z,pl,Rd}}$	

- The following interaction formula are checked :

<table>
<tr><td></td><td>1</td><td>2</td><td>3</td></tr>
<tr><td></td><td>$0 \leq n \leq \delta$</td><td>$\delta \leq n \leq 1-\delta$</td><td>$1-\delta \leq n \leq 1$</td></tr>
<tr><td>1</td><td colspan="2"> $0 \leq m_y \leq m_1$
$m_z \leq 1 - \frac{n^2 + \left(\frac{2-\delta}{2} m_y\right)^2}{1-\delta^2}$</td><td> $0 \leq m_y \leq m_2$
$m_z \leq 2\frac{1-n}{1+\delta}$</td></tr>
<tr><td>2</td><td>$m_1 \leq m_y \leq m_3$</td><td>$m_1 \leq m_y \leq m_4$</td><td>$m_2 \leq m_y \leq m_4$</td></tr>
<tr><td></td><td colspan="3"> $m_z \leq 2\frac{(1-\delta)(1-n) - \left[1-n-\sqrt{\delta\left(1-n-\frac{2-\delta}{2} m_y\right)}\right]^2}{1-\delta^2}$</td></tr>
<tr><td>3</td><td> $m_3 \leq m_y \leq m_5$
$m_z \leq \frac{2\sqrt{\delta(2-\delta)(1-m_y)} - n^2}{1+\delta}$</td><td colspan="2">with
$m_1 = 2 - 2\frac{1+n}{2-\delta}$, $m_2 = \frac{\delta}{2(2-\delta)}\left[1-\left(1-2\frac{1-n}{\delta}\right)^2\right]$
$m_3 = 1 - \frac{n^2+(\delta-n)^2}{\delta(2-\delta)}$, $m_4 = 2\frac{1-n}{2-\delta}$, $m_5 = 1 - \frac{n^2}{\delta(2-\delta)}$</td></tr>
</table>

Plastic interaction formula for CHS section

For CHS section, classified as Plastic-Plastic or Elastic-Plastic, the plastic interaction formula according to Ref.[14], Tafel 6.74, is used :

$$\frac{M_v}{M_{pl,Q}} \frac{1}{\cos\left(\frac{N_v \pi}{N_{plQ} 2}\right)} \leq 1$$

$$Q_v = \sqrt{Q_y^2 + Q_z^2}$$

$$M_v = \sqrt{M_y^2 + M_z^2}$$

$$Q_{pl} = \frac{2dt\beta_s}{\sqrt{3}}$$

$$\frac{Q_v}{Q_{pl}} \leq \frac{1}{4} : \eta = 1$$

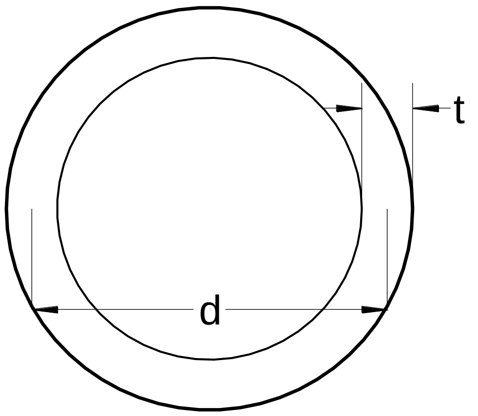
$$\frac{Q_v}{Q_{pl}} > \frac{1}{4} : \eta = \sqrt{1 - \left(\frac{Q_v}{Q_{pl}}\right)^2}$$

$$A_r = \eta \pi dt$$

$$N_{pl,Q} = A_r \beta_s$$

$$M_{pl,Q} = \min\left(\frac{d}{\pi} N_{pl,Q}, 1.25 W_{el} \beta_s\right)$$

with	Q_y,Q_z	internal shear force
	N_v	internal normal force
	M_y,M_z	internal bending moments
	β_s	yield strength
	d,t	dimensions from CHS
	W_{el}	elastic section modulus



Torsion check

For the cross section check inclusive torsion and warping, we refer to Chapter '**Error! Reference source not found.**'.

The stability check (DIN 18800 T2, formula 28 & 30) for doubly symmetric I section becomes (Ref.[9], pp. 259) :

$$\frac{N}{\kappa N_{pl,d}} + \frac{M_y}{M_{pl,y,d}} k_y + \frac{M_z + M_{z,w}}{M_{pl,z,d}} k_z \leq 1.0 \qquad (28)$$

$$\frac{N}{\kappa_z N_{pl,d}} + \frac{M_y}{\kappa_M M_{pl,y,d}} k_y + \frac{M_z + M_{z,w}}{M_{pl,z,d}} k_z \leq 1.0 \qquad (30)$$

with $M_{z,w}$ $= \frac{2M_w}{h}$

M_w bimoment (see chapter '**Error! Reference source not found.**')

k_z = 1.50 In case there is no compression force k_z is taken as 1.00 (Ref.[9], pp. 270).

Built-in beams

For built-in beam sections (IFB, SFB, THQ sections), proper section checks are performed, taking into account the local plate bending. See Chapter '**Error! Reference source not found.**'

Calculation of the buckling length

For the calculation of the buckling length, we refer to chapter "**Error! Reference source not found.**".

The buckling properties for a VARH element are calculated by using the critical Euler force for this member (see "**Error! Reference source not found.**").

The buckling curves for steel grade S420 and S460 are taken from Ref.[10], Annex D.

Torsional buckling

The slenderness for torsional buckling λ_{vi} is given by (see Ref.[6] , 7.5):

$$\lambda_{vi} = \frac{\beta_z l_z}{i_z} \sqrt{\frac{c^2 + i_M^2}{2c^2}\left\{1 + \sqrt{1 - \frac{4c^2\left[i_p^2 + 0.093\left(\frac{\beta_z^2}{\beta_0^2} - 1\right)z_M^2\right]}{\left(c^2 + i_M^2\right)^2}}\right\}}$$

with	l_0	the torsional buckling length, refers to the input value for the system length l_{yz}
	l_z	the system length for buckling around zz-axis
		Remark : the z-axis refers to the axis which goes through the shear force centre.
	β_z	refers to the buckling ratio around the zz-axis, taken as kz
		In case of an axis switch (Iz > Iy) this is taken as ky
	β_0	refers to end warping and is input by the value β_0
	z_M	the shear center
	i_y	the radius of gyration around major axis
	i_z	the radius of gyration around minor axis
	i_p^2	$= i_y^2 + i_z^2$
	i_M^2	$= i_p^2 + z_M^2$
	I_w	the warping constant
	I_z	the moment of inertia around minor axis
	I_t	the torsional constant

$$c^2 = \frac{I_w (\beta_z l_z)^2 / (\beta_0 l_0)^2 + 0.039\ (\beta_z l_z)^2 I_t}{I_z}$$

With this slenderness λ_{vi} and the buckling curve c, the reduction factor κ is calculated.

Use of diaphragms

(see also Ref.[7],3.5 and Ref.[8],3.3.4.)

The shear stiffness S for diaphragm is calculated as follows:

$$S = \frac{a.10^4}{K_1 + \frac{K_2}{L_s}}$$

with	a	the frame distance
	L_s	the length of diaphragm
	K_1	factor K1
	K_2	factor K2

The torsional constant It is adapted with the stiffness of the diaphragms:

$$I_{t,id} = I_t + vorhC_\vartheta \frac{l^2}{\pi^2 G}$$

with	l	the LTB length
	G	the shear modulus
	vorh C_θ	the actual rotational stiffness of diaphragm

LTB Check

For aysmmetric I sections, RHS (Rectangular Hollow Section) sections and CHS (Circular Hollow Section) sections, the elastic critical moment for LTB Mcr is given by the general formula F.2. Annex F Ref. [4]. For the calculation of the moment factors C1, C2 and C3 we refer to "**Error! Reference source not found.**".

Depending on the input of the basic data, Mcr for symmetric I sections is given by the general formula F.2. Annex F Ref. [4], by the DIN formula (19), or by formula according to Ref.[11] "Roik, Carl, Lindner, Biegetorsionsprobleme gerader dünnwandiger Stäbe, Verlag von Wilhelm Ernst & Sohn, 1972".

DIN formula (19) :

$$Mcr = \zeta N_{ki}\left(\sqrt{c^2 + 0.25\, z_p^{\,2}} + 0.5 z_p\right)$$

$$c^2 = \frac{I_w\,(\beta_z l)^2 / (\beta_0 l_0)^2 + 0.039\,(\beta_z l)^2 I_t}{I_z}$$

with	l, l_0	the LTB length
	β_z	refers to rotational end-restraint '*in plan*' (about the z-z local axis) and is input by the value β_z
	β_0	refers to end warping and is input by the value β_0
	z_p	the point of load application
	I_w	the warping constant
	I_z	the moment of inertia around minor axis
	I_t	the torsional constant
	A	the sectional area
	E	the modulus of elasticity
	λ_{vi}	the slenderness for torsional buckling (see above)
	ζ	the moment factor (equivalent for factor C1)

$$N_{ki} = \frac{\pi^2 E I_z}{(\beta_z l)^2}$$

Roik, Carl & Lindner

$$M_{ki,y} = M_{cr} = \zeta \frac{EI_z \pi^2}{l^2} \left[\sqrt{\left(\frac{5z_p}{\pi^2} \right)^2 + c^2} + \frac{5z_p}{\pi^2} \right]$$

$$c = \frac{I_w + 0.039 \cdot l^2 \cdot I_t}{I_z}$$

with

moment factor according to Roik, Carl, Lindner

modulus of elasticity

moment of inertia around weak axis zz

system length for LTB

application point for loading, negative value is on top and has negative influence

warping constant

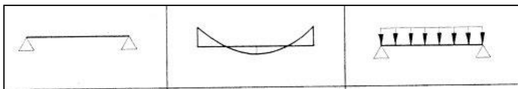
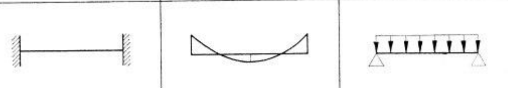
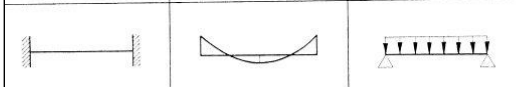
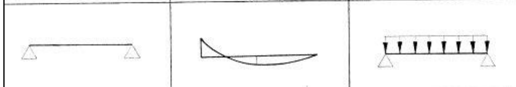
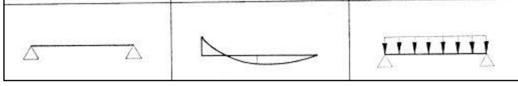
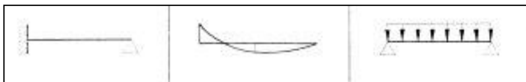
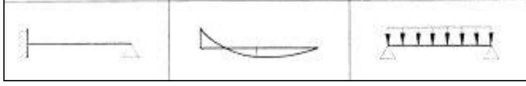
torsional constant

The factor ζ is supported for the following cases (described in Ref.[11], tables 5.13, 5.14, 5.15, 5.18, 5.19, 5.20, 5.21, 5.22, 5.23, 5.24, 5.25, 5.26, 5.27, 5.28, 5.29, 5.30, 5.33) :

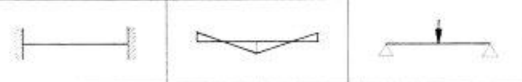
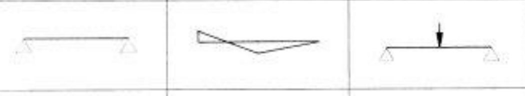
Linear moment distribution :

		–	–	5.13
		–	–	5.14
		–	–	5.15

Moment line according to distributed loading

	0	5.18
	$-\frac{h}{2}$	5.19
	0	5.20
	$-\frac{h}{2}$	5.21
	0	5.22
	$-\frac{h}{2}$	5.23
	0	5.24
	$-\frac{h}{2}$	5.25

Moment line according to concentrated loading

	0	5.26
	$-\frac{h}{2}$	5.27
	0	5.28
	$-\frac{h}{2}$	5.29
	0	5.30
	$-\frac{h}{2}$	5.31
	0	5.32
	$-\frac{h}{2}$	5.33

For the other supported sections, the elastic critical moment for LTB Mcr is given by

$$M_{cr} = \frac{\pi^2 E I_z}{L^2} \sqrt{\frac{I_w}{I_z} + \frac{L^2 G I_t}{\pi^2 E I_z}}$$

with	E	the modulus of elasticity
	G	the shear modulus
	L	the length of the beam between points which have lateral restraint (= l_{LTB})
	Iw	the warping constant
	It	the torsional constant
	Iz	the moment of inertia about the minor axis

See also Ref. [5], part 7 and in particular part 7.7. for channel sections.

Haunched sections (I+Ivar, Iw+Plvar, Iw+Iwvar, Iw+Ivar, I+Iwvar) and composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

For full rectangular sections the value of n according to DIN 18800-2 tabelle 9 is taken as 1,5 according to Ref.[8] pp 175.

For advanced Lateral-torsional buckling analysis, see Annex D: Use of diaphragms.

Combined flexion for check method 2

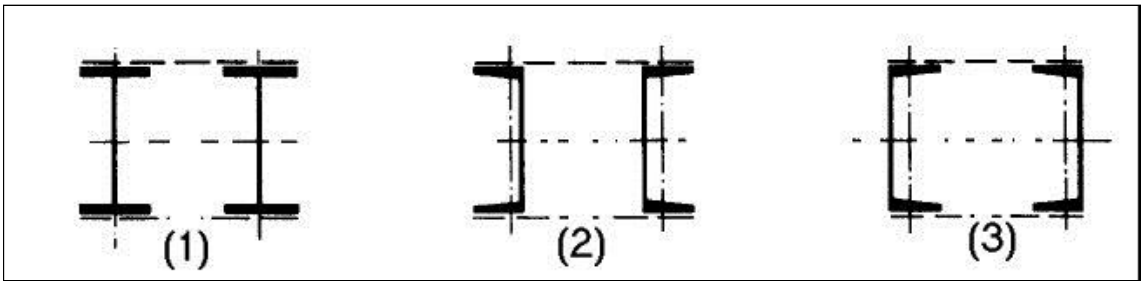
The value My is the maximum value of the bending moment around the strong axis in the member. The value Mz is the maximum value of the bending moment around the weak axis in the member.

For non-prismatic sections, the values My and Mz are the concurrent bending moments for each intermediary section.

Battened compression members

The following section pairs are supported as battened compression member :

(1) 2I
(2) 2Uo
(3) 2Uc



Two links (battens) are used.

The following additional checks are performed :

- buckling resistance check around weak axis of single chord with N_G
- section check of single chord, using internal forces (Ref.[7], pp.88-95) :

$$N_G = \frac{N}{2} + \max M_z \sin(\pi \frac{a}{l}) \frac{A_G}{W_z^*}$$

$$V_G = \frac{\max V_y}{2}$$

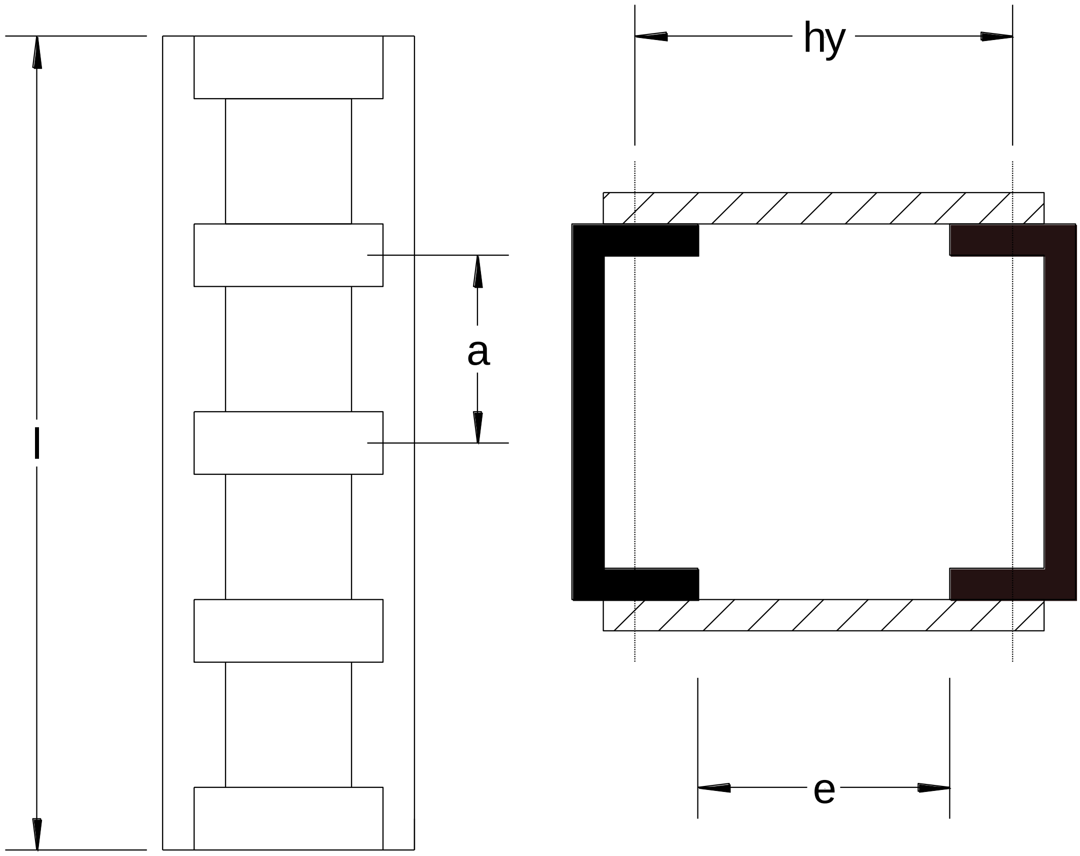
$$M_G = \frac{\max V_y a}{4}$$

- section check of single batten, using the internal forces (Ref.[7], pp.88-95) :

$$T = \frac{\max V_y a}{h_y 2}$$

$$M = \frac{Te}{2}$$

For the calculation of maxVy, the value of M_z is increased with the value of the internal force M_{zz}.



Effective area properties

The calculation of the effective area is performed with the direct method (sigma_d = fy,k) according to the El-El procedure (DIN18800 T2, 7.3.).

For each intermediary section, the classification (and if necessary, the effective area) is determined and the proper section check is performed. The classification (and effective area) can change for each intermediary point. The most critical check is displayed on the screen.

For each load case and combination, the most critical effective area properties are saved. The most critical effective area properties are the effective area properties on the position where the appropriate moment of inertia is the minimum.

With these critical properties, the stability check is performed.

For non-prismatic elements, the effective area properties are calculated on each intermediary section, also for the stability check.

Shear buckling check

Composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

Shear buckling check with buckling influence

The influence of the buckling effect into the shear buckling control, is neglected when there is a bending moment present.

It means that κ_k=1 if ψ<0.9. See also Ref.[3], Element 503.

Cold formed thin gauge members

The following table includes a list of DASt-Richtlinie 016 (Ref.[12]) elements which are implemented in Scia Engineer by using the related DIN18800 T2 (Ref.[2]) element.

Supported elements from DASt - Richtlinie 016	Covered by DIN 18800 T2 elements	Remarks
3.7.1. Grenzzustand der Tragfähigkeit		
328	Tab.26	
329	712	
330	712	
333	Tab.27	
335	706	
4.3.1. Biegemomententragfähigkeit		
404	715	
4.4. Biegedrillknicken biegebeanspruchter Bauteile 4.4.3. Allgemeiner Nachweis		
421	311	
422	311	
423	725, 726	
4.5. Druckbeanspruchte einteilige Stäbe 4.5.1. Allgemeines		
429	708-710	
430	708-710	
431	708-710	
432	708-710	

433	708-710	
434	708-710	
4.5.2. Planmäβig mittiger Druck		
435	716	A^{D}_{ef} is not used
436		manual input / input in profile library for KSL
437	723	
438	723	
4.5.3. Einachsige Biegung mit Druck		
440	707	
441	718	
442	728	
4.5.3. Zweiachsige Biegung mit Druck		
443	707	
444	721	A^{D}_{ef} is not used
445	729	

Supported sections

I	Symmetric I shapes (IPE, HEA, HEB, ….)
RHS	Rectangular Hollow Section (RHS)
CHS	Circular Hollow Section (CHS)
L	Angle section
U	Channel section
T	T section
PPL	Asymmetric I shapes
RS	Rectangular section
Σ	Cold formed section
COM	Composed section in PRIMAWIN
O	Solid tube
NUM	Numerical section

The necessary data conditions for these sections are described in Annex A: Profile Library Formcodes.

The COM and NUM sections are not read out of the profile library.

	I	RHS	CHS	L	U	T	PPL	RS	Σ	O	COM	NUM
Classification	x	x	x	x	x	x	x	x	x	(1)	(1)	(1)
Section check PL-PL	x	x										
Section check EL-PL	x	x										
Section check EL-EL	x	x	x	x	x	x	x	x	x	x	x	x
Section check slender section	x	x		x	x		x		x			
Stability check	x	x	x	x	x	x	x	x	x	x	x	x
Stability check slender section	x	x		x	x		x		x			
Shear buckling check	x	x			x		x					

(1) sections are classified as EL-EL cross section by default.

References

[1] DIN 18800 Teil 1
Stahlbauten
Bemessung und Konstruktion
DK 693.814.014.2, November 1990

[2] DIN 18800 Teil 2
Stahlbauten
Stabilitätsfälle, Knicken von Stäben und Stabwerken
DK 693.814.074.5, November 1990

[3] DIN 18800 Teil 3
Stahlbauten
Stabilitätsfälle, Plattenbeulen
DK 693.814.073.1, November 1990

[4] Eurocode 3
Design of steel structures
Part 1 - 1 : General rules and rules for buildings
ENV 1993-1-1:1992, 1992

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ELEMENTS DE CONSTRUCTIONS METALLIQUE
Ulg , Faculté des Sciences Appliquées, 1988

[6] G. Hünersen, E. Fritzsche
Stahlbau in Beispielen
Berechnungspraxis nach DIN 18 800 Teil 1 bis Teil 3 (11.90)
Werner-Verlag, Düsseldorf 1991

[7] E. Kahlmeyer
Stahlbau nach DIN 18 800 (11.90)
Werner-Verlag, Düsseldorf

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Stahlbauten
Erläuterungen zu DIN 18 800 Teil 1 bis Teil 4, 1.Auflage
Beuth Verlag, Berlin-Köln 1993

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Ernst & Sohn, 1999

[10] Eurocode 3
Design of steel structures
Part 1 - 1/ A1 : General rules and rules for buildings
ENV 1993-1-1:1992/A1, 1994

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Biegetorsionsprobleme gerader dünnwandiger Stäbe
Verlag von Wilhelm Ernst & Sohn
1972

[12] DASt-Richtlinie 016
Bemessung und konstruktive Gestaltung von Tragwerken aus dünnwandigen kaltgeformted Bauteilen
Stahlbau-Verlagsgesellschaft - 1992

[13] H. Rubin,
Interaktionsbeziehungen für doppeltsymmetrische I- und Kasten-Querschnitte bei zweiachsiger Biegung und Normalkraft
Der Stahlbau 5/1978, 6/1978

[14] Stahl im Hochbau
14. Auflage, Band I / Teil 2
1986, Verlag Stahleisen mbH, Düsseldorf

ONORM B 4300

ONORM B 4300 Code check

The beam elements are checked according to the regulations given in

ÖNORM B 4300-1
Stahlbau
Berechnung und Konstruktion der Tragwerke
Bemessung nach Grenzzuständen
DK 624.014.2.046, März 1994

ÖNORM B 4300-2
Stahlbau
Knicken von Stäben und Stabwerken
Bedingungen für die gemeinsame Anwendung von DIN 18 800 Teil 2 und ÖNORM B 4300-1
DK 624.014.2.075.2, April 1994

ÖNORM B 4300-3
Plattenbeulen
Bedingungen für die gemeinsame Anwendung von DIN 18 800 Teil 3 und ÖNORM B 4300-1
DK 624.014.2.075.4, April 1994

DIN 18800 Teil 1
Stahlbauten
Bemessung und Konstruktion
DK 693.814.014.2, November 1990

DIN 18800 Teil 2
Stahlbauten
Stabilitätsfälle, Knicken von Stäben und Stabwerken
DK 693.814.074.5, November 1990

DIN 18800 Teil 3
Stahlbauten
Stabilitätsfälle, Plattenbeulen
DK 693.814.073.1, November 1990

Material properties

For standard steel grades, the yield strength fy and tensile strength fu are defined according to the thickness of the element (see Ref. [1], 2.1. and Ref. [4], Tab.1)

The standard steel grades are:

(fy, fu in N/mm², t in mm)

	t<=40	t<=40	40<t<=80	40<t<=80
	fy	fu	fy	fu
St 360 S235 S 235	240	360	215	360
St 430 S275 S 275	280	430	255	430
St 510 S355 S 355	360	510	325	510

	t<=40	t<=40	40<t<=100	40<t<=100
	fy	fu	fy	fu
S420 S 420	420	520	390	520
S460 S 460	460	550	430	550

Consulted articles

For the section check, the cross section is classified according to ONORM B 4300-1 Tab.3,4,5 and to DIN18800 Teil I, Table 15,18. Depending on this classification, the section is checked as slender section, EL/EL (elastic/elastic), as EL/PL (elastic/plastic) or as PL/PL (plastic/plastic).

For the EL/EL check, ONORM B 4300-1 Art. 5.2. is used. (The 7% increase of the moment of inertia is taken into account for rolled I section - see Ref. [1], Art. 5.2.5.4.).

The EL/PL check takes the rules from DIN18800 Teil I, Element (756), (757) and Table (16) ,(17). The PL/PL check is done according to DIN18800 Teil I, Element (758), Table (16),(17).

The slender cross section is checked according to DIN18800 Teil 2, Element (715).

For the stability check, the beam element is checked according to DIN18800 Teil 2 for buckling, lateral torsional buckling and bending and compression. The following criteria are used :

- compression : Element (304),(306)
- lateral torsional buckling : Element (311),(309)
- bending and axial compression : Element (313),(321),(322)
- bending (LTB) and compression : Element (320),(323)

For slender sections, the following criteria are used :

- calculation of effective area : Element (705),(706),(708),(709),(712),(713)
- buckling check : Element (715),(716),(718),(719)
- LTB check : Element (725),(726),(728),(729)

For the shear buckling check, the beam element is checked according to DIN18800 Teil 3. The following criteria are used : Element (113), (504), (602),(603)

A more detailed overview for the used articles is given in "DIN18800 Code check".

Supported sections

I	Symmetric I shapes (IPE, HEA, HEB, ….)
RHS	Rectangular Hollow Section (RHS)
CHS	Circular Hollow Section (CHS)
L	Angle section
U	Channel section
T	T section
PPL	Asymmetric I shapes
RS	Rectangular section
Σ	Cold formed section
COM	Composed section in PRIMAWIN
O	Solid tube
NUM	Numerical sections

The necessary data conditions for these sections are described in Annex A: Profile Library Formcodes.

The COM and NUM sections are not read out of the profile library.

	I	RHS	CHS	L	U	T	PPL	RS	Σ	O	COM	NUM
Classification	x	x	x	x	x	x	x	x	x	(1)	(1)	(1)
Section check PL-PL	x											
Section check EL-PL	x											
Section check EL-EL	x	x	x	x	x	x	x	x	x	x	x	x
Section check slender section	x	x		x	x		x		x			
Stability check	x	x	x	x	x	x	x	x	x	x	x	x
Stability check slender section	x	x		x	x		x		x			
Shear buckling check	x	x			x		x					

(1) sections are classified as EL-EL cross section by default.

References

[1] ÖNORM B 4300-1
Stahlbau
Berechnung und Konstruktion der Tragwerke
Bemessung nach Grenzzuständen
DK 624.014.2.046, März 1994

[2] ÖNORM B 4300-2
Stahlbau
Knicken von Stäben und Stabwerken
Bedingungen für die gemeinsame Anwendung von DIN 18 800 Teil 2 und ÖNORM B 4300-1
DK 624.014.2.075.2, April 1994

[3] ÖNORM B 4300-3
Plattenbeulen
Bedingungen für die gemeinsame Anwendung von DIN 18 800 Teil 3 und ÖNORM B 4300-1
DK 624.014.2.075.4, April 1994

[4] DIN 18800 Teil 1
Stahlbauten
Bemessung und Konstruktion
DK 693.814.014.2, November 1990

[5] DIN 18800 Teil 2
Stahlbauten
Stabilitätsfälle, Knicken von Stäben und Stabwerken
DK 693.814.074.5, November 1990

[6] DIN 18800 Teil 3
Stahlbauten
Stabilitätsfälle, Plattenbeulen
DK 693.814.073.1, November 1990

NEN

NEN6770/6771 Code check

The beam elements are checked according to the regulations given in

Staalconstructies TGB 1990 Basiseisen en basisrekenregels voor overwegend statisch belaste constructies NEN 6770, december 1991
Staalconstructies TGB 1990 Stabiliteit NEN 6771, december 1991-januari 2000

Material properties

For standard steel grades, the yield strength fy and tensile strength fu are defined according to the thickness of the element (see Ref. [1], art.9.1.2.1.1.)

The standard steel grades are :

(fy, fu in N/mm², t in mm)

	t<=40	t<=40	40<t<=100	40<t<=100	100<t<=250	100<t<=250
	fy	fu	fy	fu	fy	fy
S235 S 235	235	360	215	340	175	320
S275 S 275	275	430	255	410	205	380
S355 S 355	355	510	335	490	275	450
S420 S 420	420	520	390	520		
S460 S 460	460	550	430	550		

Remark : For cold formed section, the values for fy and fu are not influenced by the previous table.

Consulted articles

The cross section is classified according to NEN 6771 Table 1. (Class 1, 2, 3 or 4).

The section is checked on following criteria:

- Tension: NEN 6770 Art. 11.2.1., NEN 6771 Art. 11.2.1.
- Compression: NEN 6770 Art. 11.2.2., NEN 6771 Art. 11.2.2.
- Shear: NEN 6770 Art. 11.2.4., NEN 6771 Art. 11.2.4.
- Bending, shear and axial force: NEN 6770 Art. 11.3., NEN 6771 Art. 11.3.

For the stability check, the element is checked on following criteria:

- Compression: NEN 6771 Art.12.1.1.1/ 12.1.2./12.1.3.
- Lateral torsional buckling : NEN 6771 Art.12.2.
- Bending and axial compression: NEN 6771 Art.12.3.
- Shear buckling : NEN 6771 Art.13.8. / 13.9.

A more detailed overview for the used articles is given for NEN6770 part 11,12 and NEN6771 part 10,11,12,13. The chapters marked with “x” are consulted. The chapters marked with (*) have a supplementary explanation the following chapters.

NEN6770	
11.Toetsing van de doorsnede 11.1. Algemeen	x x
11.2. Enkelvoudige krachten en momenten 11.2.1. Axiale trek	x x
11.2.2. Axiale druk	x
11.2.3. Buiging	
11.2.4. Afschuiving	x
11.2.5. Torsie	x
11.3. Combinaties van krachten en momenten 11.3.1. Enkele buiging met normaalkracht en afschuiving	x x
11.3.2. Dubbele buiging met normaalkracht en afschuiving	x
11.4. Vloeicriterium	x
11.5. De invloed van de boutgaten	(*)
NEN6771	
10.2.4. Doorsneden	x (*)
11.Toetsing van de doorsnede 11.1. Algemeen	x x
11.2. Enkelvoudige krachten en momenten 11.2.1. Axiale trek	x x
11.2.2. Axiale druk	x

11.2.3. Buiging	
11.2.4. Afschuiving	x
11.2.5. Torsie	
11.3. Combinaties van krachten en momenten	x
12. Toetsing van de stabiliteit 12.1. Op druk belaste staven 12.1.1. Knikstabiliteit	x x x (*)
12.1.2. Torsiestabiliteit	x
12.1.3. Torsieknikstabiliteit	x
12.1.4. Verend gesteunde staven	
12.1.5. Staven in vakwerken	
12.1.6. Samengestelde staven 12.1.6.1 Algemeen 12.1.6.2. Benodigde grootheden 12.1.6.3. Toetsing van het middenveld van de samengestelde staaf 12.1.6.4. Toetsing van de eindvelden van de samengestelde staaf 12.1.6.4.2 Staven met raamwerkverband	x(*) x x x x x
12.2. Op buiging belaste staven(kipstabiliteit) 12.2.1. Toepassingsgebied	xx x
12.2.2. Toetsingsregel	x
12.2.3. Ongesteunde lengte	
12.2.4. Opleggingen en zijdelingse steunen	
12.2.5. Het theoretisch elastische kipmoment	x (*)
12.3. Op druk en buiging belaste staven 12.3.1. Knikstabiliteit	x x
12.3.2. Torsiestabilteit	x
12.3.3. Torsieknikstabiliteit	x
12.4. Op trek en buiging belaste staven	
13. Toetsing van de plooistabiliteit 13.1. Algemeen	x x
13.2. Geometrie van het verstijfde en onverstijfde plaatveld	x
13.3. Geometrie van de verstijvingen	
13.4. Belasting in het vlak van het plaatveld 13.4.1. Normaalspanning in langsrichting	x x
13.4.2. Schuifspanningen	x
13.4.3. Normaalspanningen in dwarsrichting	
13.4.4. Platen in en loodrecht op hun vlak belast	
13.5. Belasting op verstijvingen	
13.6. Ideële kritieke plooispanning van een onverstijfd plaatveld	x
13.7. De plooispanning van een onverstijfd plaatveld 13.7.1. Bepaling van de relatieve slankheid van het plaatveld	x x

13.7.2. De plooispanning voor een onverstijfd plaatveld met als opleggingen dwarsverstijving(en) en/of randen	x
13.7.3. De plooispanning voor een onverstijfd plaatveld met ten minste een langsverstijving als oplegging	
13.8. Eisen waaraan plaatvelden en verstijvingen moeten voldoen 13.8.1. Onverstijfd plaatveld	x x
13.8.2. Dwarsverstijvingen	
13.8.3. Langsverstijvingen	
13.8.4. Stijfheidseisen te stellen aan langs- en dwarsverstijvingen	
13.8.5. Doorsnedecontrole voor langs- en dwarsverstijvingen	
13.9. Interactie tussen plooi en knik 13.9.1. Algemeen	x (*) x
13.9.2. Constructies opgebouwd uit plaatvelden al of niet verstijfd met dwarsverstijvingen	x
13.9.3. Constructies opgebouwd uit plaatvelden verstijfd met langsverstijvingen en/of niet verstijfd met dwarsverstijvingen	
13.9.4. Berekeningen van de dwarsverstijvingen	

Section properties

The influence of the bore hole is neglected.

Classification of sections

For each intermediary section, the classification is determined and the proper section check is performed. The classification can change for each intermediary point.

For each load case/combination, the critical section classification over the member is used to perform the stability check. So, the stability section classification can change for each load case/combination.

However, for non-prismatic sections, the stability section classification is determined for each intermediary section.

Effective cross-section properties for class 4 cross-section

The calculation of the effective area is performed with the direct method (sigma_d = fy,k).

For each intermediary section, the classification (and if necessary, the effective area) is determined and the proper section check is performed. The classification (and effective area) can change for each intermediary point. The most critical check is displayed on the screen.

For each load case and combination, the most critical effective area properties are saved :

Aeff is the effective area of the cross section when subject to uniform compression. Weff is the effective section modulus of the cross-section when subject only to moment about the relevant axis. eN is the shift of the relevant centroidal axis when the cross section is subject to uniform compression.

With these critical properties, the stability check is performed.

For non-prismatic elements, the effective area properties are calculated on each intermediary section, also for the stability check.

For angle sections, see chapter '**Error! Reference source not found.**'.

Torsion check

For the cross section check inclusive torsion and warping, we refer to Chapter '**Error! Reference source not found.**'.

Built-in beams

For built-in beam sections (IFB, SFB, THQ sections), proper section checks are performed, taking into account the local plate bending. See Chapter '**Error! Reference source not found.**

Buckling length

For the calculation of the buckling length, we refer tochapter "**Error! Reference source not found.**".

The buckling properties for a VARH element are calculated by using the critical Euler force for this member (see "**Error! Reference source not found.**").

The buckling curves for steel grade S420 and S460 are taken from Ref.[5], Annex D.

Lateral-torsional buckling

For symmetric I sections and RHS (Rectangular Hollow Section) sections, the elastic critical moment for LTB Mcr is given by the formula of Ref [2], part 12.2.5.. When the factor α > 5000, the elastic critical moment for LTB Mcr is given by the general formula in EC3, Annex F, F.2. Ref [3]. For asymmetric I sections, the elastic critical moment for LTB Mcr is given by the general formula in EC3, Annex F, F.2. Ref [3].

For the calculation of the moment factors C1, C2 and C3 we refer to Ref.[7], tables 9 (case 1), 10 and 11.

For the other supported sections, the elastic critical moment for LTB Mcr is given by

$$M_{cr} = \frac{\pi^2 E I_z}{L^2} \sqrt{\frac{I_w}{I_z} + \frac{L^2 G I_t}{\pi^2 E I_z}}$$

with	E	the modulus of elasticity
	G	the shear modulus
	L	the length of the beam between points which have lateral restraint (= l_{LTB})
	Iw	the warping constant
	It	the torsional constant
	Iz	the moment of inertia about the minor axis

See also Ref. [4], part 7 and in particular part 7.7. for channel sections.

Haunched sections (I+Ivar, Iw+Plvar, Iw+Iwvar, Iw+Ivar, I+Iwvar) and composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

For advanced Lateral-torsional buckling analysis, see Annex D: Use of diaphragms.

Use of diaphragms

See Chapter '**Error! Reference source not found.**'.

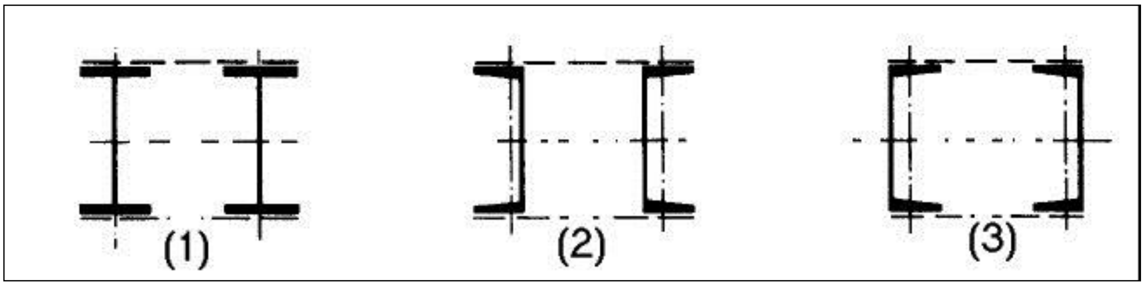
Battened compression members

The following section pairs are supported as battened compression member :

(1) 2I

(2) 2Uo

(3) 2Uc



Two links (battens) are used.

The following additional checks are performed :

- buckling resistance check around weak axis of single chord with $N_{f,s;d}$
- section check of single chord, using internal forces :

$$N_G = N_{f;s;d}$$

$$V_G = \frac{Q_{f;s;d}}{2}$$

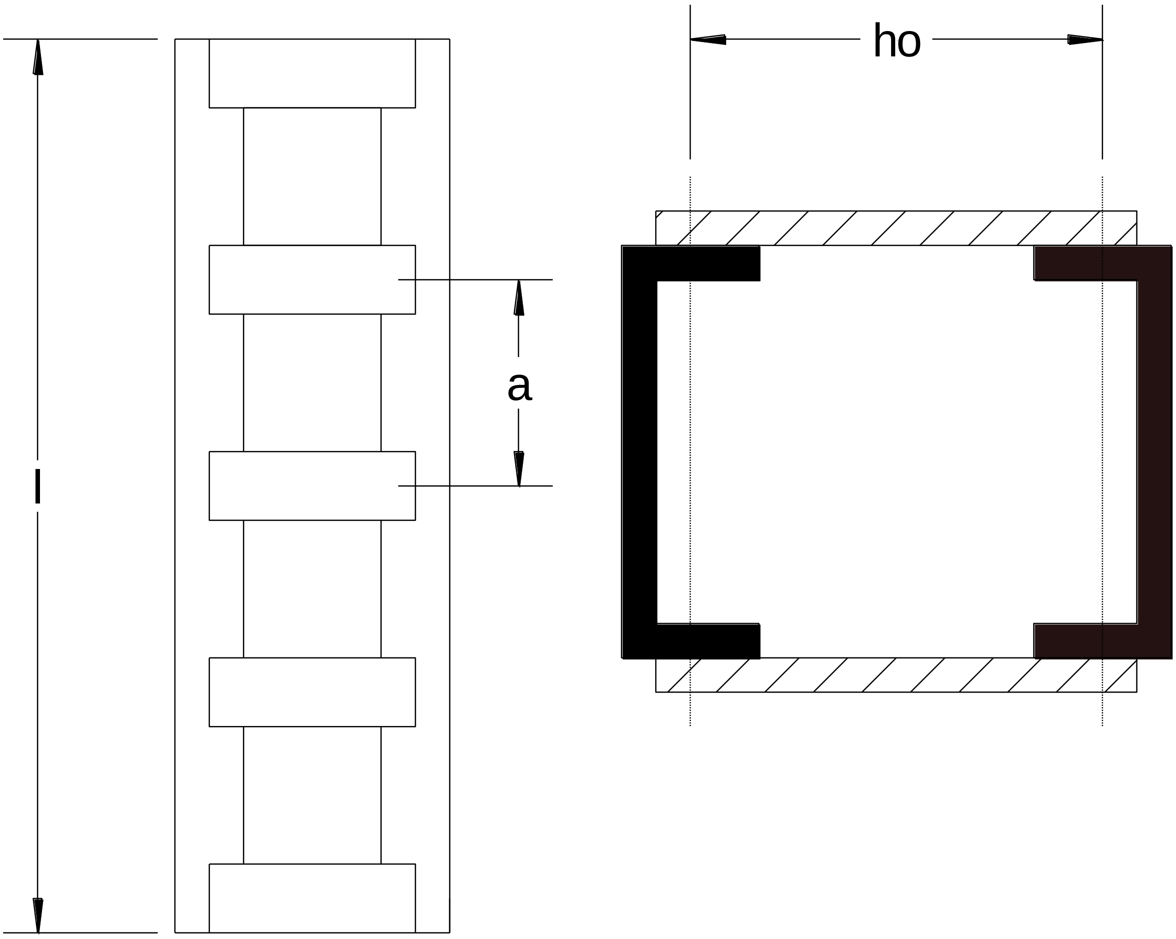
$$M_G = \frac{Q_{f;s;d}a}{4}$$

- section check of single batten, using the internal forces :

$$V_{k;s;d} = \frac{Q_{f;s;d}a}{h_0 2}$$

$$M_{k;s;d} = \frac{Q_{f;s;d}a}{4}$$

For the calculation of $Q_{f;s;d}$, the value of $M_{y;s;d}$ is increased with the value of the internal force M_{zz}.



Shear buckling check

Composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

Shear buckling check with buckling influence

The influence of the buckling effect into the shear buckling control, is neglected when there is a bending moment present, i.e. if ψ<0.9.

NEN6072 - Fire Resistance

For more info, reference is made to to Ref.[8], Ref.[9].

Fire actions effect

The design effects of actions for the fire situation are taken from the results of the analysis. It is recommended to use the special combination rules according to Ref.[10], NEN6702 6.2.2., for calculating the internal forces used in the fire resistance check.

This special combination is given by

$$\gamma_{f;g} G_{rep} + \Sigma \gamma_{f;q} \psi_i Q_{i;rep} + \gamma_{f;a} F_{a;rep}$$

with	G_{rep}	characteristic values of permanent actions
	Q_i	characteristic value of the variable action
	$F_{a;rep}$	design values of special action (from fire exposure)
	$\gamma_{f;g}$	partial safety factor for permanent actions in the special combination =1.0
	$\gamma_{f;q}$	partial safety factor for variable actions in the special combination =1.0
	$\gamma_{f;a}$	partial safety factor for special actions in the special combination =1.0
	ψ_I	the 'momentaaan' factor for the variable action

Material properties

The yield strength is depending on the steel temperature :

$$f_{y;\theta;d} = \psi f_{y;d}$$

The variation in function of the steel temperature of the value for yield strength ψ is given by :

- ψ=1.0 when $\theta_a \leq 400°$ C
- $$\psi = \frac{1.03}{\left(e^{\beta} + 1\right)^{0.26}}$$ when 400°C < $\theta_a \leq 1200°$ C

with β $= \frac{\theta_a - 482}{39.2}$

θ_a steel temperature in °C

$f_{y;d}$ design value for yield strength at room temperature

$f_{y;\theta;d}$ design value for yield strength at increased temperature

The following default properties are considered to be constant during the analysis :

unit mass	ρ_a	7850 kg/m³
thermal elongation	$\Delta l/l$	14×10^{-6} (θ_a-20)
thermal conductivity	λ_a	45 W/mK

Nominal temperature-time curve

The standard temperature-time (ISO 834) curve is used :

$$\theta_g = 20 + 345 \log_{10}(8t + 1)$$

with t time in [min]

θ_g gas temperature in [°C]

Steel Temperature

The increase of temperature $\Delta\theta_a$ in an unprotected steel member during a time interval Δt

$$\Delta\theta_a = \frac{\alpha}{c_a \rho_a} P(\theta_t - \theta_a)\Delta t$$

$$\alpha = \alpha_c + \alpha_r$$

$$\alpha_r = \frac{\varepsilon_r 5.67}{(\theta_t - \theta_a)}\left(\left(\frac{\theta_t + 273}{100}\right)^4 - \left(\frac{\theta_a + 273}{100}\right)^4\right)$$

with A_m the exposed surface area per unit length [m²/m]

V the volume of the member per unit length [m³/m]

P $= A_m/V$

θ_t gas temperature in [°C]

θ_a	steel temperature [°C]
c_a	the specific heat of steel [J/kgK]
Δt	the time interval [seconds]
ρ_a	the unit mass of steel [kg/m³]
ε_r	resultant emissivity = 0.5
α_c	coefficient of heat transfer by convection = 25 W/(m²K)

The increase of temperature $\Delta\theta_a$ in an insulated (non intumescent coating) steel member during a time interval Δt

$$\Delta\theta_a = \frac{K_{ef}}{c_a\rho_a} P_i \kappa_M(\theta_t - \theta_a)\Delta t - \left(e^{\xi/5} - 1\right)\Delta\theta_t$$

$$K_{ef} = \frac{\lambda_{i;d;ef}}{d_i}$$

$$\kappa_M = \frac{1}{1 + \frac{2}{3}\xi}$$

$$\xi = \frac{c_i\rho_i}{2c_a\rho_a} d_i P_i$$

with

A_p	the area of fire protection material per unit length [m²/m]
V	the volume of the member per unit length [m³/m]
P_i	$= A_p/V$
c_a	the specific heat of steel [J/kgK]
c_i	the specific heat of fire protection material [J/kgK]
d_i	the thickness of the fire protection material [m]
Δt	the time interval [seconds] The value should not be taken as more than 30 seconds
ρ_a	the unit mass of steel [kg/m³]
ρ_i	the unit mass of fire protection [kg/m³]
θ_a	the steel temperature at time t
θ_t	the ambient gas temperature at time t
$\Delta\theta_t$	the increase of the ambient gas temperature during the time interval
$\lambda_{i;d;ef}$	the thermal conductivity of the fire protection material [W/mK]

The increase of temperature $\Delta\theta_a$ in an insulated (intumescent coating) steel member during a time interval Δt

$$\Delta\theta_a = \frac{K_{d;ef}}{c_a \rho_a} P_i \left(\theta_t - \theta_a\right) \Delta t$$

with	A_p	the area of fire protection material per unit length [m²/m]
	V	the volume of the member per unit length [m³/m]
	P_i	$= A_p/V$
	c_a	the specific heat of steel [J/kgK]
	$K_{d;ef}$	coefficient of heat transfer of the intumescent coating
	Δt	the time interval [seconds] The value should not be taken as more than 30 seconds
	ρ_a	the unit mass of steel [kg/m³]
	θ_a	the steel temperature at time t
	θ_t	the ambient gas temperature at time t
	$\lambda_{i;d;ef}$	the thermal conductivity of the fire protection material [W/mK]

Calculation model

The calculation can be performed in 2 domains :

- strength domain
- temperature/time domain

In the strength domain, the strength (unity check) is calculated after a given time t (e.g. strength after 45 min). In the temperature/time domain, the critical steel temperature $\theta_{a,cr}$ is computed. From this critical temperature, the fire resistance time is calculated (the time domain).

The critical steel temperature $\theta_{a,cr}$ is given by :

$$\theta_{a,cr} = 39.2 \ln\left[\frac{1}{0.8925(\kappa\eta)^{3.846}} - 1\right] + 482$$

with	η	degree of utilization at time t=0
	κ	correction factor = 1.00 for tension elements = 1.00 for beams, statically determined, 4 side exposure = 0.70 for beams, statically determined, 3 side exposure = 0.85 for beams, statically undetermined, 4 side exposure = 0.60 for beams, statically undetermined, 3 side exposure = 1.20 for compression elements (inclusive the buckling check) = 1.20 for compression and bending elements (inclusive the buckling and LTB check)

Code Check

The section and stability checks (buckling, lateral torsional buckling) are performed according to the regulations given in NEN6770/6771, adapted with the yield strength for the increased temperature and the correction factor. The checks are performed in the resistance domain or in the temperature/time domain. Shear buckling is not considered.

Supported sections

I	Symmetric I shapes (IPE, HEA, HEB, ….)
RHS	Rectangular Hollow Section (RHS)
CHS	Circular Hollow Section (CHS)
L	Angle section
U	Channel section
T	T section
PPL	Asymmetric I shapes
Z	Z section
RS	Rectangular section
Σ	Cold formed section
COM	Composed section in PRIMAWIN
O	Solid tube
NUM	Numerical section

The necessary data conditions for these sections are described in Annex A: Profile Library Formcodes.

The COM and NUM sections are not read out of the profile library.

	I	RHS	CHS	L	U	T	PPL	RS	Z	Σ	O	COM	NUM
Classification	x	x	x	x	x	x	x	x	(1)	x	(1)	(1)	(1)
Section check class 1	x	x	x										
Section check class 2	x	x	x										
Section check class 3	x	x	x	x	x	x	x	x	x	x	x	x	x
Section check class 4	x	x		x	x		x			x			
Stability check class 1	x	x	x										
Stability check class 2	x	x	x										
Stability check class 3	x	x	x	x	x	x	x	x	x	x	x	x	x
Stability check class 4	x	x		x	x		x			x			
Shear buckling check	x	x			x		x						

(1) Sections are classified as class 3 cross section by default.

References

[1] Staalconstructies TGB 1990
Basiseisen en basisrekenregels voor overwegend statisch belaste constructies
NEN 6770, december 1991

[2] Staalconstructies TGB 1990
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NEN 6771, december 1991

[3] Eurocode 3
Design of steel structures
Part 1 - 1 : General rules and rules for buildings
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[4] R. Maquoi
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Ulg , Faculté des Sciences Appliquées, 1988

[5] Eurocode 3
Design of steel structures
Part 1 - 1/ A1 : General rules and rules for buildings
ENV 1993-1-1:1992/A1, 1994

[6] ENV 1993-1-3:1996
Eurocode 3 : Design of steel structures
Part 1-3 : General rules
Supplementary rules for cold formed thin gauge members and sheeting
CEN 1996

[7] Staalconstructies TGB 1990
Stabiliteit
NEN 6771, januari 2000

[8] NEN 6072
Rekenkundige bepaling van de brandwerendheid van bouwdelen
Staalconstructies
December 1991

[9] NEN 6072/A2 - Wijzigingsblad
Rekenkundige bepaling van de brandwerendheid van bouwdelen
Staalconstructies
December 2001

[10] NEN 6702
Belastingen en vervormingen TGB 1990
December 1991

CM66

CM66 Code check

The beam elements are checked according to the regulations given in

Règles de calcul des constrcutions en acier
ITBTP / CTICM
Régles CM Decembre 1966
Editions Eyrolles 1982

Consulted articles

The cross-section is checked for tension (art. 3,1), bending (art. 3,2.) and shear (art. 3,3.).

For the stability check, the following criteria are considered:

- for compression : art. 3,4.
- for compression and bending : art. 3,5
- for lateral torsional buckling : art. 3,6.
- for double bending and axial compression : art. 3,7.
- for shear buckling : art 5,212

A more detailed overview for the used articles is given for the relevant parts in the following table. The chapters marked with "x" are consulted. The chapters marked with (*) have a supplementary explanation the following chapters.

3 Règles générales concernant les calculs de résistance et de déformation	
3,0 Données numériques	x
3,1 Pièces soumises à traction simple	x (*)
3,2 Pièces soumises à flexion simple ou déviée	x
3,21 Flexion simple	x(*)
3,22 Flexion déviée	
3,3 Effet de l'effort tranchant dans les pièces fléchies	x

3,4 Pièces soumises à la compression – flambement simple	
3,40 Généralités	x(*)
3,41 Pièces comprimées a parois pleines	x
3,42 Pièces composées a treilis	
3,43 Pièces composées a traverses de liaison	
3,44 Conditions spéciales imposées aux éléments comprimés a parois minces	x
3,5 Pièces soumises à compression avec flexion dans le plan de flambement	
3,50 Principe	x
3,51 Coefficient d'amplification des contraintes de flexion	x (*)
3,52 Vérfication des pièces a parois pleines	x
3,53 Vérification des pièces composées à treilis	
3,54 Vérification des pièces composées à traverses de liaison	
3,6 Déversement en flexion simple	
3,60 Généralités	x
3,61 Pièces symétriquement chargées et appuyées	
3,611 Poutres à äme pleine	x(*)
3,612 Poutres à treilis	
3,62 Cas des piéces soumises à deux moments différents au droit des appuis	x(*)
3,63 Cas des poutrelles en console parfaitement encastrées	
3,64 Coeffcients utilisés pour la détermination de kd	
3,641 Coefficient D	x
3,642 Coefficient C	x(*)
3,643 Coefficient B	x(*)
3,7 Flexion composée	
3,70 Domaine d'application	x
3,71 Notations	x
3,72 Principe des vérifications	x
3,73 Formules enveloppes pour les pièces à parois pleines	x (*)
3,8 Flambement dans les systémes hyperstatiques	
3,9 Déformations	x
5 Règles spéciales à certains éléments	
5,212 Poutres composées à âme pleine – âmes	x

Section properties

The net area properties are not taken into account .

Plastic coefficient

The plastic coefficients are calculated according to the Ref.[1], 13,212 (Valeurs du coefficient ψ d'adaptation plastique).

Compression members

For the calculation of the buckling length, we refer to "**Error! Reference source not found.**".

The buckling properties for a VARH element are calculated by using the critical Euler force for this member (see "**Error! Reference source not found.**").

Factor kf

The factor kf is calculated using the formula given in Ref[1], 3,516

$$k_f = \frac{\mu + 0.25 - 1.72\left(1 - \frac{A_M}{M_{med}}\right)^2}{\mu - 1;3}$$

If Mmed ≈ 0.0, the formula 3,513 is used : $k_f = \frac{\mu + 0.25}{\mu - 1.3}$

LTB Check

The LTB check is performed for symmetric I sections. For other cross sections the factor kd=1.0.

For the calculation of the coefficient C, we refer to "**Error! Reference source not found.**".

The coefficient B is calculated by interpolating the table for B given in Ref[1] 3,643, and using the calculated C value with table for C given in Ref[1] 3,642.

Haunched sections (I+Ivar, Iw+Plvar, Iw+Iwvar, Iw+Ivar, I+Iwvar) and composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

Use of diaphragms

See Chapter '**Error! Reference source not found.**'.

Combined flexion

The values σ_{fx} is the maximum value of the bending stress in the member for the bending around the strong axis. The value σ_{fy} is the maximum value of the bending stress in the member for the bending around the weak axis.

For non-prismatic sections the values σ_{fx} and σ_{fy} are the local (i.e. in each intermediary section) bending stresses.

Shear buckling check

Composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

Supported sections

I	Symmetric I shapes (IPE, HEA, HEB, ….)
RHS	Rectangular Hollow Section (RHS)
CHS	Circular Hollow Section (CHS)
L	Angle section
U	Channel section
T	T section
PPL	Asymmetric I shapes
RS	Rectangular section
Σ	Cold formed section
COM	Composed section in PRIMAWIN
O	Solid tube
NUM	Numerical section

The necessary data conditions for these sections are described in Annex A: Profile Library Formcodes.

The COM and NUM sections are not read out of the profile library.

	I	RHS	CHS	L	U	T	PPL	RS	Σ	O	COM	NUM
Section check	x	x	x	x	x	x	x	x	x	x	x	x
Buckling check	x	x	x	x	x	x	x	x	x	x	x	x
Slender section buckling check	x	x		x	x	x	x	x	x			
LTB Check	x											
Shear buckling check	x	x			x		x					

References

[1] Règles de calcul des constrcutions en acier
ITBTP / CTICM
Régles CM Decembre 1966
Editions Eyrolles 1982

CM66 - Additif 80

CM66 - Additif 80 Code check

The beam elements are checked according to the regulations given in Additif 80

Consulted articles

The cross-section is classified according to art. 5,12. (classification 'plastic' or 'elastic').

The section is checked for tension and compression (art. 4,2), bending (art 4,3), shear force (art. 4,4), the combination of bending and axial force (art. 4,5 and art 4.6).

For the stability check, the following criteria are considered:

- for lateral torsional buckling : art. 5,2.
- for compression : art. 5,31.
- for compression and bending : art. 5,32

A more detailed overview for the used articles is given in the following table. The chapters marked with “x” are consulted. The chapters marked with (*) have a supplementary explanation in the following chapters.

4 Resistance des sections	
4,1 Règle générale	(*)
4,2 Effort normale	x
4,3 Moment de flexion	x
4,4 Effort tranchant	x
4,5 Moment de flexion et effort normal	x
4,6 Momens de flexion, effort normal et effort tranchant	x
5 Stabilité des éléments	
5,1 Conditions de non voilement local	x (*)
5,2 Résistance au déversement des poutre fléchies	
5,21 Règles de contreventement latéral au voisinage des sections plastifiées	
5,22 Moment ultime de déversement en flexion simple	x (*)
5,23 Dimensionnement des entretoises	
5,24 Résistance au déversement en flexion déviée	x
5,3 Résistance au flambement	
5,31 Eléments simplement comprimés	x
5,32 Eléments comprimés et fléchis	x
5,33 Longueur de flambement	(*)

Classification of sections

For each intermediary section, the classification is determined and the proper section check is performed. The classification can change for each intermediary point.

For each load case/combination, the critical section classification over the member is used to perform the stability check. So, the stability section classification can change for each load case/combination.

However, for non-prismatic sections, the stability section classification is determined for each intermediary section.

Section check

If the sections are not according to the conditions specified in art. 5,1, the sections are checked according to the regulations given in Ref.[2].

If a torsional moment is present, the sections are checked according to the regulations given in Ref.[2].

Compression members

For the calculation of the buckling length, we refer to "**Error! Reference source not found.**".

The buckling properties for a VARH element are calculated by using the critical Euler force for this member (see "**Error! Reference source not found.**").

Lateral-torsional buckling

For the calculation of the moment factors C1 and C2, we refer to "**Error! Reference source not found.**", using the EC3 values.

Haunched sections (I+Ivar, Iw+Plvar, Iw+Iwvar, Iw+Ivar, I+Iwvar) and composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

Use of diaphragms

See Chapter '**Error! Reference source not found.**'.

Supported sections

I	Symmetric I shapes (IPE, HEA, HEB, ….)
RHS	Rectangular Hollow Section (RHS)
CHS	Circular Hollow Section (CHS)
L	Angle section
U	Channel section
T	T section
PPL	Asymmetric I shapes
RS	Rectangular section
Σ	Cold formed section
COM	Composed section in PRIMAWIN
O	Solid tube
NUM	Numerical section

The necessary data conditions for these sections are described in Annex A: Profile Library Formcodes.

The COM and NUM sections are not read out of the profile library.

	I	RHS	CHS	L	U	T	PPL	RS	Σ	O	COM	NUM
Classification Add 80	x	x										
Plastic section check Add 80	x	x										
Buck:ling check Add 80	x	x										
LTB check Add 80	x	x										
Compression + bending Add 80	x	x										

References

[1] Additif 80

[2] Règles de calcul des constrcutions en acier
ITBTP / CTICM
Régles CM Decembre 1966
Editions Eyrolles 1982

BS5950-1:1990

BS5950-1:1990 Code Check

The beam elements are checked according to the regulations given in:

British Standard BS 5950
Structural use of steelwork in building
Part1. Code of practice for design in simple
and continuous construction:hot rolled section
British Standard distribution BS5950 Part1 1990 revised in 1992

Material properties

For standard steel grades, the yield strength py is defined according to the thickness of the element (see Table 6 Art.3.1.1.). The standard steel grades are :

Grade 43 : yield strength defined between 245 and 275 N/mm²
Grade 50 : yield strength defined between 325 and 355 N/mm²
Grade 55 : yield strength defined between 415 and 450 N/mm²

(p_Y in N/mm², t in mm)

Steel grade	Thickness limits	P_Y
Grade 43	t≤16 mm	275 N/Mm²
	t≤40 mm	265 N/mm²
	t≤63 mm	255 N/mm²
	t≤100 mm	245 N/mm²
	t≤16 mm	355 N/mm²

Grade 50	t≤40 mm	345 N/mm²
	t≤63 mm	340 N/mm²
	t≤100 mm	325 N/mm²
Grade 55	t≤16 mm	450 N/mm²
	t≤25 mm	430 N/mm²
	t≤40 mm	415 N/mm²
	t≤63 mm	400 N/mm²

Remark: For cold-formed section, values for Py are not influenced by the previous table.

Remark : The reduction rules from previous table are only valid when the used material is defined as material for the selected code.

Consulted articles

According to Art. 3.5. and table 7, cross sections are classified in 4 types:

- Plastic
- Compact
- Semi-compact
- Slender

A reduction factor is applied to the design strength of the material in use for slender sections by following the rules described in Art. 3.6 and in Table 8. Partial safety factor of design strength is included in py value.

The section is checked for bending (Art.4.2.), tension (Art.4.6.), compression (Art.4.7.), shear (Art.4.2.3.), combined moment and axial force (Art. 4.8.) and biaxial moments (Art.4.9.). For the stability check, the beam element is checked for lateral torsional buckling, shear buckling, compression and bending with axial compression. Articles used for this stability check are the following:

- for lateral torsional buckling : Art. 4.3.
- shear buckling : Art. 4.4.5.
- for compression : Art. 4.7.
- for bending and axial compression : Art. 4.8.

A more detailed overview of used articles is given in the following table.

Part. 3 Section properties	
3.5. Limiting proportions of cross sections	Art. 3.5.1.
	Art. 3.5.2.
	Art. 3.5.4.
	Table 7
	Fig.3
3.6. Slender cross section	Art. 3.6.1.
	Art. 3.6.2.-3.6.3.
	Art. 3.6.4.
	Table 8
Part. 4 Design of structural elements	
4.2. Member in bending	Art. 4.2.1.3. (a) (c)
Shear capacity	Art. 4.2.3.
Moment capacity with low shear	Art. 4.2.5.
Moment capacity with high shear	Art. 4.2.6.
4.3. Lateral torsional buckling	
Member in bending	Art. 4.3.7.
LTB factor	
General	Art. 4.3.7.1.
Equivalent uniform moment	Art. 4.3.7.2.
Buckling Resistance	Art. 4.3.7.3.
Bending strength p_b	Art. 4.3.7.4.
Equivalent slenderness λ_{LT}, ϕ, η, u, v	Art. 4.3.7.5. Appendix B.
Factors m, n	Art. 4.3.7.6.
Equal flanged rolled section	Art. 4.3.7.7.
Buckling resistance moment for single angle	Art.4.3.8.
4.4. Plate Girders	
General	Art. 4.4.1.
Dimensions of webs and flanges	Art. 4.4.2.2. Art. 4.4.2.3.
Moment capacity	Art. 4.4.4.
Section with slender webs	Art. 4.4.4.2. (a)
Shear buckling resistance of thin webs	Art. 4.4.5.1.
Design without using tension field action	Art. 4.4.5.3. and Appendix H.1.
4.6. Axially loaded tension members	

Tension capacity	Art. 4.6.1.
Effective Area of simple tension members	Art. 4.6.3.1. Art. 4.6.3.3.
4.7. Compression member	
Slenderness	Art. 4.7.3.2.
Compression resistance	Art. 4.7.4.
Compressive strength	Art. 4.7.5. Appendix C
4.8. Axially loaded members with moments	
Tension members with moments	Art. 4.8.2. + EC3 5.4.9.&Annex F
Compression members with moments	Art. 4.8.3.
Local capacity check	Art. 4.8.3.2.
Buckling check with exact approach	Art. 4.8.3.3.2.
4.9. Members with biaxial moments	See 4.8.

Classification of sections

For each intermediary section, the classification is determined and the proper section check is performed. The classification can change for each intermediary point.
For each load case/combination, the critical section classification over the member is used to perform the stability check.

So, the stability section classification can change for each load case/combination.
However, for non-prismatic sections, the stability section classification is determined for each intermediary section.

Slender cross-section

Slender sections are particularly sensitive to local buckling. British Standard code (Art. 3.6.) defines stress reduction factor to prevent this phenomenon. For webs subject to moments and axial load and for circular hollow sections, the design strength py should be assumed such that the limiting proportions for semi-compact section are met. For other sections, where a slender outstand is in compression, the design strength should be reduced by the factor given in Table 8.

Section properties

The net area of a section is taken as its gross section neglecting the deduction due to fastener holes: Art. 3.3. Shear area of a cross-section is calculated by using Art. 4.2.3.

Bending moment

Before any calculation of members in bending, it's necessary to determine the shear capacity. For plastic and compact section with high shear load, moment capacity is calculated with the plastic modulus only for I and PLL sections (Art. 4.2.6. and 4.8.). For other cross-section, with plastic or compact section classification, characterised or not by a low shear load, we assumed that the moment capacity is calculated by using the same approach than for semi-compact section: the elastic modulus (elastic calculation).

Bending, shear, axial force

For plastic and compact sections, BS5950 Art. 4.8.2. & 4.8.3.2. (b) prescribes a detailed approach to determine the unity check of axially loaded members with moments. The detailed relationship allows a greater economy for plastic and compact section . In this expression, we use a reduced moment capacity Mr respectively about the major and the minor axis. Those values are determined by using EC3 Art.5.4.9. (see Ref.[5]). For semi-compact and slender section, the simplified approach is applied following Art. 4.8.2.and Art. 4.8.3.2. (a).

Lateral torsional buckling

For I sections (symmetric and asymmetric PPL), rectangular sections (solid and hollow), T sections, channel sections and angle section, the critical lateral torsional buckling moment is given by the general formula Art. 4.3.7. and Annex B2&3. For other sections, we follow conservative recommendation described in Art. 4.3.7.5. and calculation proposed in EC3 to determine the elastic critical moment Mcr EC3 Annex F1.1. Formula (F.1.) see Ref [5].

The condition to be satisfied in all the cases is that

$$\overline{M} \leq M_{LTB}$$

with

Mb=Sxpb

and

$$\overline{M} = mM_A$$

(m is an equivalent uniform moment factor)

pb is the bending strength and is related to the equivalent slenderness :

$$\lambda_{LT} = n \cdot u \cdot v \cdot \lambda$$

in which n is an equivalent slenderness factor.

For beam without loading point between points of lateral restraint, n=1 and m depends on the ratio of the end moments at the points of restraint.

For beam loaded between point of lateral restraint, m=1 and n depend on the ratio of the end moments at the points of restraint and on the ratio of the larger moment to the mid-span free moment.

There are thus two methods for dealing with lateral torsional buckling namely:

'm approach' i.e. the 'equivalent uniform moment method' with n=1

'n approach' i.e. the 'equivalent slenderness method' with m=1

In any given situation, only one method will be admissible, taking into account that it is always conservative to use m=n=1. Since the publication of BS5950 Part 1 1990, doubt has been cast on the correctness of using n factors less than 1 in combination with an effective length L_{LTB} less than the length of the member L in the calculation of λ_{LTB}. However, as a interim measure, pending clarification ina future version of BS5950, it is recommended that λ_{LTB} is taken as the smaller of the two following values:

$$\lambda_{LTB} = uv\frac{L_{LTB}}{r_y}$$

$$\lambda_{LTB} = nuv\frac{L}{r_y}$$

By using the settings of BS5950, the user can define which method correspond to his situation or define his choice as the conservative method m=n=1.

Haunched sections (I+Ivar, Iw+Plvar, Iw+Iwvar, Iw+Ivar, I+Iwvar) and composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

Use of diaphragms

See Chapter '**Error! Reference source not found.**'.

Compression member

For member submitted to compression, we applied the recommendations given in BS 5950 and Appendix C to determine the compressive strength.

Shear buckling check

Composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

Supported sections

I	Symmetric I shapes (IPE, HEA, HEB, ….)
RHS	Rectangular Hollow Section (RHS)
CHS	Circular Hollow Section (CHS)
L	Angle section
U	Channel section
T	T section
PPL	Asymmetric I shapes
RS	Rectangular section
Σ	Cold formed section
COM	Composed section in PRIMAWIN
O	Solid tube
NUM	Numerical section

The necessary data conditions for these sections are described in Annex A: Profile Library Formcodes.

The COM and NUM sections are not read out of the profile library.

	I	RHS	CHS	L	U	T	PPL	RS	Σ	O	COM	NUM
Classification	x	x	x	x	x	x	x	(1)	x	(1)	(1)	(1)
Section check class 1	x	x	x	x	x	x	x		x			
Section check class 2	x	x	x	x	x	x	x		x			
Section check class 3	x	x	x	x	x	x	x	x	x	x	x	x
Section check class 4	x	x	x	x	x	x	x		x			
Stability check class 1	x	x	x	x	x	x	x		x			
Stability check class 2	x	x	x	x	x	x	x		x			
Stability check class 3	x	x	x	x	x	x	x	x	x	x	x	x
Stability check class 4	x	x	x	x	x	x	x		x			
Shear buckling check	x				x		x					

(1)sections are classified as class 3 cross section by default

References

[1] British Standard BS5950 Part 1 : 1990+Revised text 1992
Structural use of steel work in building
Part1 Code of practice for design in simple and continuous construction: hot rolled sections

[2] Plastic design to BS5950
J.M. Davies & B.A. Brown
The steel Construction institute

[3] Steelwork design
Guide to BS5950: Part 1: 1990
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[4] Essentials of Eurocode 3
Design Manual for Steel Structures in Building
ECCS - N° 65, 1991

[5] Eurocode 3
Design of steel structures
Part 1 - 1 : General rules and rules for buildings
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[6] R. Maquoi
ELEMENTS DE CONSTRUCTIONS METALLIQUE
Ulg , Faculté des Sciences Appliquées, 1988

BS5950-1:2000

BS5950-1:2000 Code Check

The background to this code check can be found within the document “BS 5950-1:2000 steel code check Theory”

IS 800

IS:800 Code check

The beam elements are checked according to the regulations given in

IS 800 Draft version (for 3rd Revision)

Material properties

The following steel grades are supported :

Grade/ Classification	Yield stress(Mpa)	Ultimate tensile stress(Mpa)
A/Fe410WA	250(<20mm), 240(20mm to 40mm), 230(>40mm)	410
B/Fe410WB	250(<20mm), 240(20mm to 40mm), 230(>40mm)	410
C/Fe410WC	250(<20mm), 240(20mm to 40mm), 230(>40mm)	410
Fe440	300(<16mm), 290(16mm to 40mm), 280(>41mm to 63mm)	440
Fe440B	300(<16mm), 290(16mm to 40mm), 280(>41mm to 63mm)	440
Fe490	350(<16mm), 330(16mm to 40mm), 320(>41mm to 63mm)	490
Fe490B	350(<16mm), 330(16mm to 40mm), 320(>41mm to 63mm)	490
Fe540	410(<16mm), 390(16mm to 40mm), 380(>41mm to 63mm)	540
Fe540B	410(<16mm), 390(16mm to 40mm), 380(>41mm to 63mm)	540

The string in the column 'Grade/Classification' is used to determine the proper yield stress reduction.

Consulted articles

The cross-section is classified according to Table 3.1.

The section is checked for tension (Section 6), compression (Section 7), bending (Section 8) and the combination of forces (Section 9).

A more detailed overview for the used articles is given in the following table. The chapters marked with “x” are consulted. The chapters marked with (*) have a supplementary explanation in the following chapters.

3.7. Classification of Cross Section	x(*)
6.1. Tension members	x
6.2. Design strength due to Yielding of Gross section	
7.1. Design Strength	x
8.2. Design strength in bending	x
8.2.1. Laterally supported beam	
8.2.1.1. Section with slender webs	x
8.2.1.2. When factored shear force < 0.6 Vd	x
8.2.1.3. When factored shear force > 0.6 Vd	x
8.2.2. Laterally unsupported beam	x
8.2.2.1. Elastic Lateral Torsional Buckling moment	x
8.4. Shear	x
8.4.1. The nominal plastic shear resistance	x
8.4.2. Resistance to shear buckling	x
9.1. General	x
9.2. Combined Shear and bending	x
9.3. Combined Axial Force and Bending Moment	x
Appendix F	x

Remarks

- the design of slender compression elements is outside the scope of this implementation
- the shear buckling check is only using the Simple Post Critical Method

Classification of sections

For each intermediary section, the classification is determined and the proper section check is performed. The classification can change for each intermediary point.

For each load case/combination, the critical section classification over the member is used to perform the stability check. So, the stability section classification can change for each load case/combination.

However, for non-prismatic sections, the stability section classification is determined for each intermediary section

The cross sections are classified as

- class 1 : plastic
- class 2 : compact
- class 3 : semi-compact
- class 4 : slender section

The class 4 (slender) section check is not supported. For this sections a class 3 (semi-compact) section check is performed.

Section properties

The net area properties are not taken into account .

Section check

In the case of high shear for class 3 section, the allowable normal stress is reduced with a factor (1-ρ). When torsional shear stress is present, the VonMisis criterium is checked.

Compression members

For the calculation of the buckling length, we refer to "**Error! Reference source not found.**". The buckling properties for a VARH element are calculated by using the critical Euler force for this member (see "**Error! Reference source not found.**") .

Stability check for torsional buckling and torsional-flexural buckling

The design buckling resistance $N_{b,Rd}$ for torsional or torsional-flexural buckling shall be obtained using buckling for buckling around the weak axis, and with relative slenderness given by :

$$\bar{\lambda} = \sqrt{\frac{f_{yb}}{\sigma_{cr\ A}}}$$

$$\sigma_{cr} = \min(\sigma_{cr,T}; \sigma_{cr,TF})$$

$$\sigma_{cr,T} = \frac{1}{A_g i_0^2}\left(GI_t + \frac{\pi^2 EC_m}{l_T^2}\right)$$

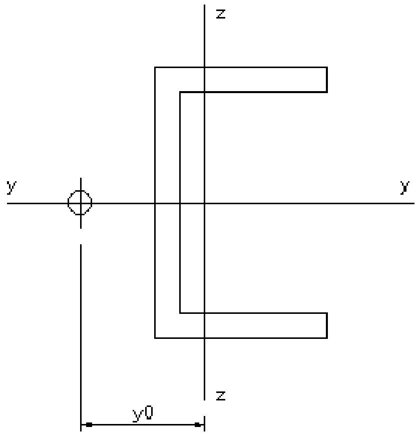
$$i_0^2 = i_y^2 + i_z^2 + y_0^2$$

$$\sigma_{cr,TF} = \frac{1}{2\beta}\left[\left(\sigma_{cr,y} + \sigma_{cr,T}\right) - \sqrt{\left(\sigma_{cr,y} + \sigma_{cr,T}\right)^2 - 4\beta\sigma_{cr,y}\sigma_{cr,T}}\right]$$

$$\sigma_{cr,y} = \frac{\pi^2 E}{\left(\frac{l_y}{i_y}\right)^2}$$

$$\beta = 1 - \left(\frac{y_0}{i_0}\right)^2$$

with	f_{yb}	the basic yield strength
	σ_{cr}	the critical stress
	$\sigma_{cr,T}$	the elastic critical stress for torsional buckling
	$\sigma_{cr,TF}$	the elastic critical stress for torsional-flexural buckling
	G	the shear modulus
	E	the modulus of elasticity
	I_T	the torsion constant of the gross section
	C_M	the warping constant
	i_y	the radius of gyration about yy-axis
	i_z	the radius of gyration about zz-axis
	l_T	the buckling length of the member for torsional buckling
	y_0	the position of the shear center
	l_y	the buckling length for flexural buckling about the yy-axis



Lateral-torsional buckling

The elastic critical moment for LTB Mcr for I sections (symmetric and asymmetric), RHS (Rectangular Hollow Section) sections and CHS (Circular Hollow Section) sections, can be calculated using the formula given by Annex F.

For the calculation of the moment factors C1, C2 and C3 we refer to "**Error! Reference source not found.**".

For the other supported sections, the elastic critical moment for LTB Mcr is given by

$$Mcr = \frac{\pi^2 EI_z}{L^2}\sqrt{\frac{Iw}{I_z} + \frac{L^2 GI_t}{\pi^2 EI_z}}$$

with	E	the modulus of elasticity
	G	the shear modulus
	L	the length of the beam between points which have lateral restraint (= l_{LTB})
	Iw	the warping constant
	It	the torsional constant
	Iz	the moment of inertia about the minor axis

Haunched sections (I+Ivar, Iw+Plvar, Iw+Iwvar, Iw+Ivar, I+Iwvar) and composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

For advanced Lateral-torsional buckling analysis, see Annex D: Use of diaphragms.

Use of diaphragms

See Chapter '**Error! Reference source not found.**'.

Supported sections

The following standard sections are defined :

I	Symmetric I shapes (IPE, HEA, HEB, ….)
RHS	Rectangular Hollow Section
CHS	Circular Hollow Section
L	Angle section
U	Channel section
T	T section
PPL	Asymmetric I shapes
Z	Z section
RS	Rectangular section
Σ	Cold formed section
COM	Composed section (sheet welded, section pairs, …)
O	Solid tube
NUM	Numerical section

The necessary data conditions for these sections are described in Annex A: Profile Library Formcodes.

The COM and NUM sections are not read out of the profile library.

In the following matrix is shown which sections are supported for the different analysis parts in the Indian steel Code check :

	I	RHS	CHS	L	U	T	PPL	RS	Z	Σ	O	COM	NUM
Section Classification	x	x	x	x	x	x	x	x	(1)	x	(1)	(1)	(1)
Section check class 1	x	x	x										
Section check class 2	x	x	x										
Section check class 3	x	x	x	x	x	x	x	x	x	x	x	x	x
Section check class 4													
Stability check class 1	x	x	x										
Stability check class 2	x	x	x										
Stability check class 3	x	x	x	x	x	x	x	x	x	x	x	x	x
Stability check class 4													
Shear buckling check	x				x		x						

(1) sections are classified as class 3 cross section by default.

References

[1] IS:800 2005

EAE

The beam elements are checked according to the regulations given in

Instrucción EAE
Documento 0 de la Instrucción de Acero Estructural
Comisión Permanente de Estructuras de Acero
November 2004

Material properties

For standard steel grades, the yield strength fy and tensile strength fu are defined according to Capítulo VI of Ref. [1].

Steel Grade	fy (N/mm²)	fu (N/mm²)
S 235	235	360
S 275	275	430
S 355	355	510
S 275 N/NL	275	390
S 355 N/NL	355	490
S 420 N/NL	420	540
S 460 N/NL	460	570
S 275 M/ML	275	380
S 355 M/ML	355	470
S 420 M/ML	420	520
S 460 M/ML	460	550
S 460 Q/QL/QL1	460	570
S 235 W	235	360
S 355 W	355	510
S 235 H	235	360
S 275 H	275	430
S 355 H	355	510
S 275 NH/NLH	275	370
S 355 NH/NLH	355	470
S 460 NH/NLH	460	550
S 275 MH/MLH	275	360
S 355 MH/MLH	355	470
S 420 MH/MLH	420	500
S 460 MH/MLH	460	530

The name of the steel grade (e.g. 'S 355 W') is used to identify the steel grade.

Remark : For cold formed section, the values for fy and fu are not influenced by the previous table

Remark : For cold formed sections, the average yield strength f_{ya} can be used (by setting the proper data flag in the Cross Section input dialog) according to Ref.[4].

The average yield strength is determined as follows :

$$f_{ya} = f_{yb} + \left(\frac{knt^2}{A_g} \right) (f_u - f_{yb}) \leq \min(f_u, 1.2 f_{yb})$$

with	f_{yb}	the tensile yield strength = f_y
	f_u	the tensile ultimate strength
	t	the material thickness
	A_g	the gross cross-sectional area
	k	is a coefficient depending on the type of forming : k = 0.7 for cold rolling k = 0.5 for other methods of forming
	n	the number of 90° bends in the section

Consulted articles

The beam elements are checked according to the regulations given in " Instrucción EAE, Documento 0 de la Instrucción de Acero Estructural, Comisión Permanente de Estructuras de Acero, November 2004".

The cross-sections are classified according to Artículo 20 of Capítulo V. All classes of cross-sections are included. For class 4 sections (slender sections) the effective section is calculated in each intermediary point, according to Artículo 20 of Capítulo V.

The member check is executed according to Capítulo IX. The stress check is taken from art. 34.: the section is checked for tension (art. 34.2.), compression (art. 34.3.), bending (art. 34.4.), shear (art. 34.5.), torsion (art. 34.6.) and combined bending, shear and axial force (art. 34.7.1., art. 34.7.2. and art. 34.7.3.).

The stability check is taken from art. 35.: the beam element is checked for buckling (art. 35.1.), lateral torsional buckling (art. 35.2.), and combined bending and axial compression (art. 35.3.).

The shear buckling is checked according to prEN 1993-1-5:2003, Chapter 5.

For I sections, U sections and cold formed sections warping can be considered.

A check for critical slenderness and torsion moment is also included.

For integrated beams, the local plate bending is taken into account for the plastic moment capacity and the bending stresses in the section. The out-of-balance loading is checked.

A more detailed overview for the used articles is given in the following table. The chapters marked with “x” are consulted. The chapters marked with (*) have a supplementary explanation the following chapters.

Instrucción EAE

20. Clasificación de las secciones transversales	(*)
20.2. Clasificación de las secciones transversales metálicas	x
20.3. Criterios de asignación de Clase en secciones metálicas no rigidizadas	x
20.7. Características de la sección reducida en secciones transversales esbeltas	x
34. Estado límite de resistencia de las secciones	
34.1. Principios generales del cálculo	x
34.1.2. Características de las secciones transversales	x(*)
34.2. Esfuerzo axil de tracción	x
34.3. Esfuerzo axil de compresión	x
34.4. Momento flector	x
34.5. Esfuerzo cortante	x
34.6. Torsión	x(*)
34.7. Interacción de esfuerzos	
34.7.1. Flexión y cortante	x
34.7.2. Flexión y esfuerzo axil	x
34.7.3. Flexión, cortante y esfuerzo axil	x
35. Estado límite de inestabilidad	
35.1. Elementos sometidos a compresión	x(*)
35.2. Elementos sometidos a flexión	x
35.3. Elementos sometidos a compresión y flexión	x(*)
35.5. Abolladura del alma a cortante	x
35.7. Interacción	
35.7.1. Cortante, flexión y esfuerzo axil	x

For cold formed sections EN 1993-1-3 is applied.

6.1.2. Axial tension	
6.1.3. Axial compression	
6.1.5. Shear force	
6.1.6. Torsional moment	

Classification of sections

For each intermediary section, the classification is determined and the proper section check is performed. The classification can change for each intermediary point.

For each load case/combination, the critical section classification over the member is used to perform the stability check. So, the stability section classification can change for each load case/combination.

However, for non-prismatic sections, the stability section classification is determined for each intermediary section.

Effective cross-section properties for class 4 cross-section

The calculation of the effective area is performed with the direct method (sigma_d = fy,k).

For each intermediary section, the classification (and if necessary, the effective area) is determined and the proper section check is performed. The classification (and effective area) can change for each intermediary point. The most critical check is displayed on the screen.

For each load case and combination, the most critical effective area properties are saved :

Aeff is the effective area of the cross section when subject to uniform compression. Weff is the effective section modulus of the cross-section when subject only to moment about the relevant axis. eN is the shift of the relevant centroidal axis when the cross section is subject to uniform compression.

With these critical properties, the stability check is performed.

For non-prismatic elements, the effective area properties are calculated on each intermediary section, also for the stability check.

Section properties

The net area properties are not taken into account .

The shear lag effects are neglected .

Torsion check

For the cross section check inclusive torsion and warping, we refer to Chapter '**Error! Reference source not found.**'.

Built-in beams

For built-in beam sections (IFB, SFB, THQ sections), proper section checks are performed, taking into account the local plate bending. See Chapter '**Error! Reference source not found.**'.

Compression members

For the calculation of the buckling length, we refer to chapter "**Error! Reference source not found.**"

The buckling properties for a VARH element are calculated by using the critical Euler force for this member (see chapter "**Error! Reference source not found.**").

Lateral-torsional buckling

For I sections (symmetric and asymmetric), RHS (Rectangular Hollow Section) sections and CHS (Circular Hollow Section) sections, the elastic critical moment for LTB Mcr is given by the general formula F.2. Annex F Ref. [5]. For the calculation of the moment factors C1, C2 and C3 we refer to "**Error! Reference source not found.**".

For the other supported sections, the elastic critical moment for LTB Mcr is given by

$$Mcr = \frac{\pi^2 EI_z}{L^2} \sqrt{\frac{Iw}{I_z} + \frac{L^2 GI_t}{\pi^2 EI_z}}$$

with	E	the modulus of elasticity
	G	the shear modulus
	L	the length of the beam between points which have lateral restraint (= l_{LTB})
	Iw	the warping constant
	It	the torsional constant
	Iz	the moment of inertia about the minor axis

See also Ref. [3], part 7 and in particular part 7.7. for channel sections.

Haunched sections (I+Ivar, Iw+Plvar, Iw+Iwvar, Iw+Ivar, I+Iwvar) and composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

For advanced Lateral-torsional buckling analysis, see Annex D: Use of diaphragms.

Combined bending and axial compression

For prismatic members the value $M_{y,Ed}$ is the maximum value of the bending moment around the strong axis in the member. The value $M_{z,Ed}$ is the maximum value of the bending moment around the weak axis in the member.

For non-prismatic sections, the values $M_{y,Ed}$ and $M_{z,Ed}$ are the concurrent bending moments for each intermediary section.

Interaction Method Calculation of C_{zz}

By default for C_{zz} the formula given in Ref.[1] is used:

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

In this formula however the position of the factor e_{LT} is incorrect. For exact analysis the formula according to Ref.[9] can be used:

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

Shear buckling check

Composed rail sections (Iw+rail, Iwn+rail, I+rail, I+2PL+rail, I+PL+rail, I+2L+rail, I+Ud+rail) are considered as equivalent asymmetric I sections.

Supported sections

I	Symmetric I shapes (IPE, HEA, HEB, ….)
RHS	Rectangular Hollow Section
CHS	Circular Hollow Section
L	Angle section
U	Channel section
T	T section
PPL	Asymmetric I shapes
Z	Z section
RS	Rectangular section
Σ	Cold formed section
COM	Composed section in PRIMAWIN
O	Solid tube
NUM	Numerical section

The necessary data conditions for these sections are described in Annex A: Profile Library Formcodes.

The COM and NUM sections are not read out of the profile library.

	I	RHS	CHS	L	U	T	PPL	RS	Z	Σ	O	COM	NUM
Classification	x	x	x	x	x	x	x	x	(1)	x	(1)	(1)	(1)
Section check class 1	x	x	x										
Section check class 2	x	x	x										
Section check class 3	x	x	x	x	x	x	x	x	x	x	x	x	x
Section check class 4	x	x		x	x		x			x			
Stability check class 1	x	x	x										
Stability check class 2	x	x	x										
Stability check class 3	x	x	x	x	x	x	x	x	x	x	x	x	x
Stability check class 4	x	x		x	x		x			x			
Shear buckling check	x				x		x			x			

(1) Sections are classified as class 3 cross section by default.

References

[1] Instrucción EAE
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Comisión Permanente de Estructuras de Acero
November 2004

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[3] R. Maquoi
ELEMENTS DE CONSTRUCTIONS METALLIQUE
Ulg , Faculté des Sciences Appliquées, 1988

[4] ENV 1993-1-3:1996
Eurocode 3 : Design of steel structures
Part 1-3 : General rules
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CEN 1996

[5] Eurocode 3
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Part 1 - 1/ A1 : General rules and rules for buildings
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[8] Eurocode 1
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