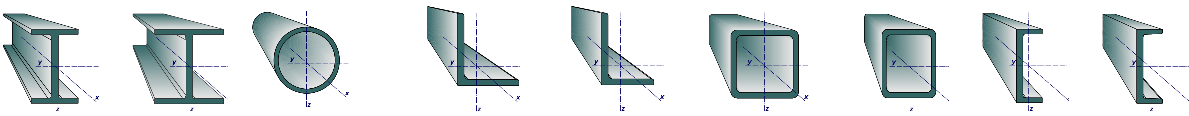
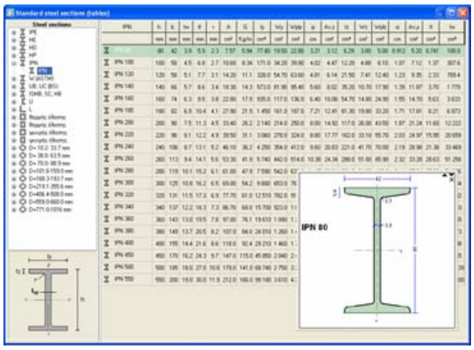
Design tables for Structural Steel Sections (Eurocode 3, EN1993-1-1:2005)

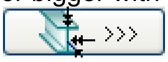
Tables with all the international steel sections, with their **dimensions**, **properties**, **classification**, **resistance and buckling resistance values** according to Eurocode 3, EN1993-1-1:2005. The tables are extended to welded section with dimensions given from the user.



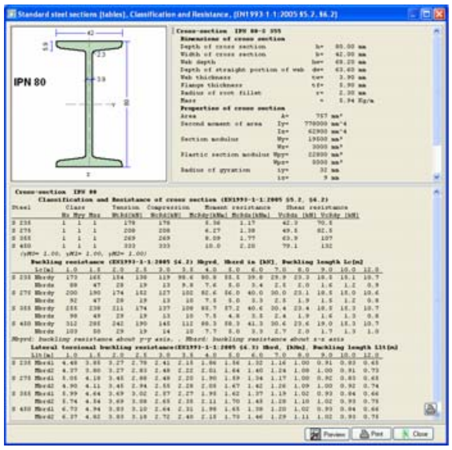
Tables with dimensions and properties of standard steel sections



From the left tree you select the section type e.g. IPE, HE etc. On the right the table shows all the standard sections for this group and their dimensions and properties. Moving up and down the table on the right the section drawing is shown in scale (you can grab and move the section drawing around the window and you can make it small or bigger with the arrows).

Click  or double click on a section and you obtain analytical report for the classification, resistance values and buckling resistance of the selected section.

Symbols



h [mm]:	Depth of cross section
b [mm]:	Width of cross section
hw [mm]:	Web depth
dw [mm]:	Depth of straight portion of web
tw [mm]:	Web thickness
tf [mm]:	Flange thickness
r [mm]:	Radius of root fillet
G [Kg/m]:	Mass
A [cm²]:	Area
Iy [cm^4]:	Moment of area about axis y-y
Iz [cm^4]:	Second moment of area about axis z-z
Wy [cm³]:	Section modulus about axis y-y
Wz [cm³]:	Section modulus about axis z-z
Wpy [cm]:	Plastic section modulus about axis y-y
Wpz [cm³]:	Plastic section modulus about axis z-z
iy [cm]:	Radius of gyration about y-y axis
iz [cm]:	Radius of gyration about z-z axis
Avz [cm²]:	Shear area parallel to web
Avy [cm²]:	Shear area parallel to flanges
It [cm^4]:	Torsional constant
Iw [cm^6]:	Warping constant

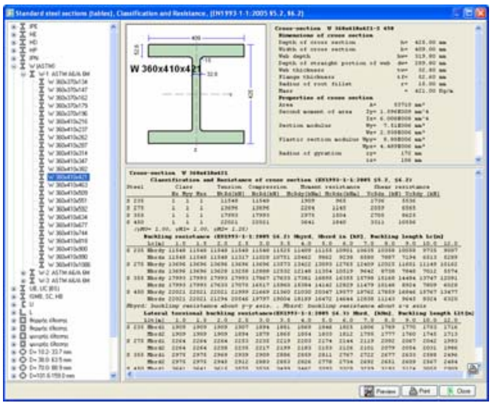
Classification and resistance of standard steel sections

Classification of cross section according to EN1993-1-1:2005 §5.5.
Resistance values of cross section according to EN1993-1-1:2005 §6.2.
Buckling resistance and lateral buckling resistance according to EN1993-1-1:2005 §6.3

From the tree on the left you select the section with its designation. On the right a drawing of the section profile is displayed together with the section dimensions and properties.

On the right window are also displayed:

- **Classification** (1,2,3,4) according to EN1993-1-1:2005 §5.5 for axial loading and loading with bending moments.
- **Resistances** of the section in compression, bending in y-y and z-z axis, and shear according to EN1993-1-1:2005 §6.2
- **Buckling resistance** for various buckling lengths (Lc) according to EN1993-1-1:2005 §6.3.1
- **Lateral torsional buckling resistance** for various lateral buckling lengths (L_{lt}) according to EN1993-1-1:2005 §6.3.2



Symbols

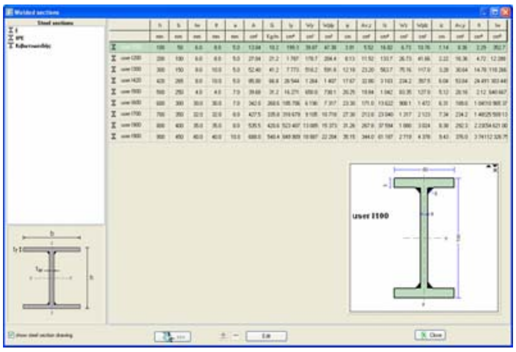
NtRd [kN]:	Tension resistance EN1993-1-1:2005 §6.2.3
NcRd [kN]:	Compression resistance EN1993-1-1:2005 §6.2.4
Mcrdy [kNm]:	Bending resistance about the strong y-y axis EN1993-1-1:2005 §6.2.5
Mcrdz [kNm]:	Bending resistance about the weak z-z axis EN1993-1-1:2005 §6.2.5
Vcrdz [kN]:	Shear resistance in the axis z-z parallel to web EN1993-1-1 §6.2.6
Vcrdy [kN]:	Shear resistance in the axis y-y axis parallel to flanges EN1993-1-1:2005 §6.2.6
Nbrdy [kN]: **Nbrdz [kN]:**	Buckling resistance in compression about the strong y-y or weak z-z axis, for various buckling lengths Lc (1.00,1.50…15 m) EN1993-1-1:2005 §6.3.1
Mbrd1 [kNm]: **Mbrd2 [kNm]:**	Lateral torsional buckling resistance for various lengths between constrains Llt (1.00,1.50 ….15 m) EN1993-1-1:2005 §6.3.2
Mbrd1:	Lateral torsional buckling resistance for constant (uniform) bending moment diagram along the beam
Mbrd2:	Lateral torsional buckling resistance for parabolic bending moment diagram along the beam

Tables of non-standard steel sections

Tables with steel sections organized as the standard sections, but the user can change the basic dimensions. Changes are activated with the [Edit]. As you change the dimensions the new geometric and strength properties are evaluated. These sections can be used as standard sections.

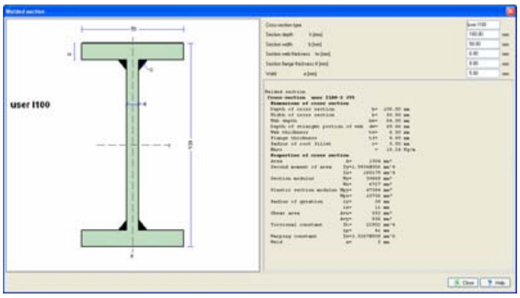
Tables with dimensions and properties of user defined welded steel sections

Click Edit and you enter the window where you can enter the basic dimensions of a welded steel section. The strength properties of the section are listed at the same time.
For adding new section or deleting existing click + − . Click Stop edit to stop editing.



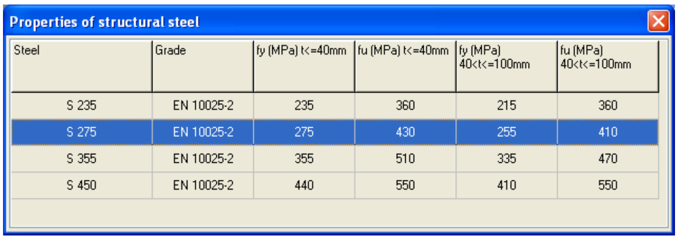
Classification and resistance of user defined welded steel sections

See standard sections.



Parameters

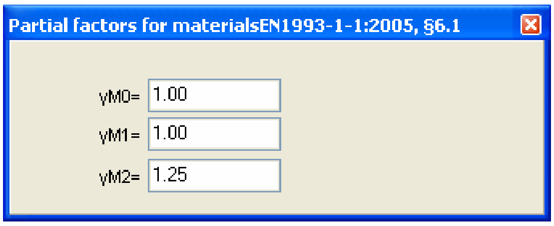
The classification of the sections the strength and buckling resistances are produced for four steel grades, S235, S275, S355 and S450. The names and the basic values of steel grades can be changed from Parameters/Structural steel.
To do changes first click to unlock Locked



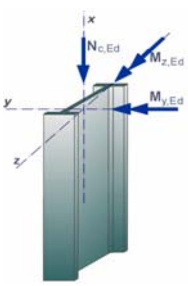
Properties of structural steel

Steel	Grade	fy (MPa) t<=40mm	fu (MPa) t<=40mm	fy (MPa) 40<t<=100mm	fu (MPa) 40<t<=100mm
S 235	EN 10025-2	235	360	215	360
S 275	EN 10025-2	275	430	255	410
S 355	EN 10025-2	355	510	335	470
S 450	EN 10025-2	440	550	410	550

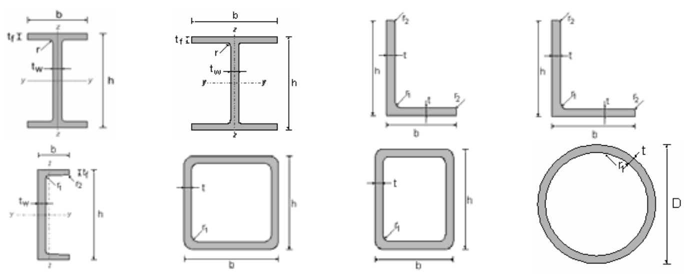
The partial factors for materials γ_{M0}, γ_{M1}, γ_{M2} which are use for the classification and resistance can be changed from Parameters/ Partial factors for materials.
To do changes first click to unlock Locked



Coordinate system



Sections properties



Steel section types included in the program

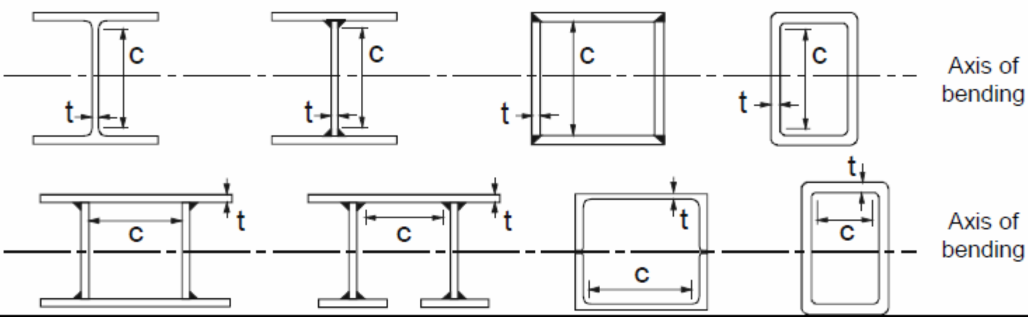
Types in the program	Description	Range
IPE: IPE Euronorm 19-57; IPE A; IPE O; IPE V; IPE 750	European I-beams	IPE 80-600 IPE A 80-600 IPE O 180-600 IPE V 400-600 IPE 750
HE: HE A (IPB1) Euronorm 53-62; HE AA; HE B (IPB) Euronorm 53-62; HE M (IPBv) Euronorm 53-62; HE Euronorm 53-62	European wide flange beams	HE A 100-1000 HE AA 100-1000 HE B 100-1000 HEM 100-1000 HE 400-1000
HL	Beams with very wide flanges	HL 1000/1100
HD: HD-1; HD-2 ASTM A6/A 6M	Wide flange columns	HD 260x54.1 – 400x1086
HP	Wide flange bearing piles	HP 200x57.2 – 400x231
IPN	European standard beams	IPN 80-550 Flabge slope: 14%
W (ASTM): W-1 ASTM A6/A 6M; W-2 ASTM A6/A 6M; W-3 ASTM A6/A 6M	American wide flange beams	W 360x370x134 W 1100x400x499
UB, UC (BS): UB-1 BS 4 part 1-1993; UB-2 BS 4 part 1-1993	British universal beams	UB 178x102x19 UB 914x419x388
UC BS 4 part 1-1993	British universal columns	UC 152x152x23 UC 356x406x634
ISMB, SC, HB: ISMB Indian Standard; ISSC Indian Standard; ISHB Indian Standard		
I GOST: No10..No60 GOST 8239-89; 10B1..45B2 GOST 26020-83; 50B1..100B4 GOST 26020-83; 20SH1..70SH1 GOST 26020-83; 20K1..40K5 GOST 26020-83; 24DB1..50DH1 GOST 26020-83	Russian standards	
U: UPN	European standard channels	UPN 30-65 UPN 80-400
UAP NF A 45-255; UPE	Channels with parallel flanges	UAP 80-300 UPE 80-400
5Y..40Y GOST 8240-89; 5P..40P GOST 8240-89		
L: L20x20x3..80x80x8 Euronorm 56-77; L100x100x8..160x160x19 Euronorm 56-77; L180x180x16..250x250x28 Euronorm 56-77	Equal angels	L 20x20x3 L 250x250x28
La: L30x20x3..80x40x8 Euronorm 57-78; L90x60x6..130x40x12 Euronorm 57-78; L150x75x9..250x90x16 Euronorm 57-78	Unequal angels	L 30x20x3 L 250x90x16
hot rolled	Square hollow sections hot rolled	40x40x2.6 400x400x20.0
hot rolled	Rectangular hollow sections hot rolled	50x30x2.6 400x260x17.5
cold formed	Rectangular hollow sections cold formed	20x20x1.6 400x400x12.5
cold formed	Rectangular hollow sections cold formed	30x20x1.5 500x300x12.5
D= 10.2 – 1016 mm	Circular hollow sections	Ø 10.2x1.0 Ø 1016x400
C: Steadman C140-C300; Ruukki C100-C350; Albion C125-Z226; Albion C246-Z401; Dimond DHS150-DHS400		
Z: Steadman Z140-Z300; Ruukki Z100-Z350; Albion Z125-Z226; Albion Z246-Z401; Metsec Z142-Z202; Metsec Z232-Z342; ICS Z152-Z254		

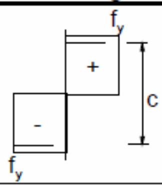
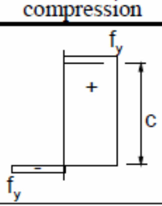
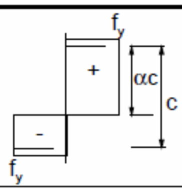
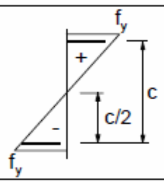
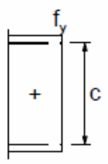
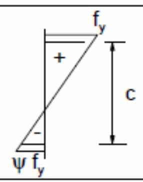
Classification of cross sections EN 1993-1-1:2005 § 5.5

The design of steel elements can be done with elastic or plastic analysis depending on the class of the cross section.
The design of sections of classes 1 and 2 is based on the plastic resistance, the design of cross-sections of class 3 is base on elastic resistance and the design of cross-sections of class 4 is based on elastic resistance and effective cross section properties.
The classification of cross sections in 1, 2, 3 and 4 classes depends on the ratios of thickness to width of the parts of the cross-section which are in compression according to tables 5.2 of EN 1993-1-1:2005.

Table 5.2 EN 1993-1-1:2005 – Internal compression parts

Internal compression parts

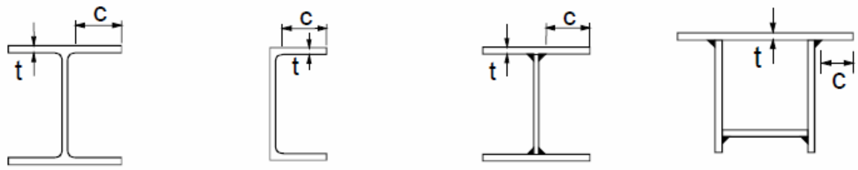


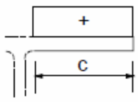
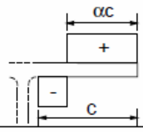
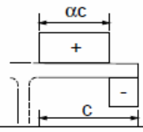
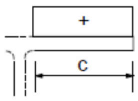
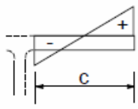
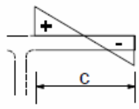
Class	Part subject to bending	Part subject to compression	Part subject to bending and compression
Stress distribution in parts (compression positive)			
1	$c/t \le 72\varepsilon$	$c/t \le 33\varepsilon$	when $\alpha > 0{,}5$: $c/t \le \frac{396\varepsilon}{13\alpha - 1}$ when $\alpha \le 0{,}5$: $c/t \le \frac{36\varepsilon}{\alpha}$
2	$c/t \le 83\varepsilon$	$c/t \le 38\varepsilon$	when $\alpha > 0{,}5$: $c/t \le \frac{456\varepsilon}{13\alpha - 1}$ when $\alpha \le 0{,}5$: $c/t \le \frac{41{,}5\varepsilon}{\alpha}$
Stress distribution in parts (compression positive)			
3	$c/t \le 124\varepsilon$	$c/t \le 42\varepsilon$	when $\psi > -1$: $c/t \le \frac{42\varepsilon}{0{,}67 + 0{,}33\psi}$ when $\psi \le -1^{*)}$: $c/t \le 62\varepsilon(1-\psi)\sqrt{(-\psi)}$

$\varepsilon = \sqrt{235/f_y}$	f_y	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71

Table 5.2 EN 1993-1-1:2005 – Outstanding flanges

Outstand flanges



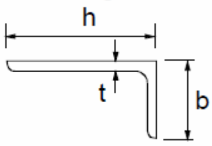
Class	Part subject to compression	Part subject to bending and compression: Tip in compression	Part subject to bending and compression: Tip in tension
Stress distribution in parts (compression positive)			
1	$c/t \le 9\varepsilon$	$c/t \le \frac{9\varepsilon}{\alpha}$	$c/t \le \frac{9\varepsilon}{\alpha\sqrt{\alpha}}$
2	$c/t \le 10\varepsilon$	$c/t \le \frac{10\varepsilon}{\alpha}$	$c/t \le \frac{10\varepsilon}{\alpha\sqrt{\alpha}}$
Stress distribution in parts (compression positive)			
3	$c/t \le 14\varepsilon$	$c/t \le 21\varepsilon\sqrt{k_\sigma}$ For k_σ see EN 1993-1-5	

$\varepsilon = \sqrt{235/f_y}$						
	f_y	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71

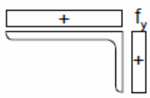
Table 5.2 EN 1993-1-1:2005 - Angles

Angles

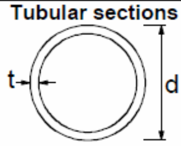
Refer also to “Outstand flanges” (see sheet 2 of 3)



Does not apply to angles in continuous contact with other components

Class	Section in compression
Stress distribution across section (compression positive)	
3	$h/t \le 15\varepsilon : \frac{b+h}{2t} \le 11{,}5\varepsilon$

Tubular sections



Class	Section in bending and/or compression
1	$d/t \le 50\varepsilon^2$
2	$d/t \le 70\varepsilon^2$
3	$d/t \le 90\varepsilon^2$ **NOTE** For $d/t > 90\varepsilon^2$ see EN 1993-1-6.

$\varepsilon = \sqrt{235/f_y}$						
	f_y	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71
	ε^2	1,00	0,85	0,66	0,56	0,51

Ultimate limit states EN 1993-1-1:2005 § 6.2

Tension EN 1993-1-1:2005 § 6.2.3

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1$$ (EN 1993-1-1, 6.5)

Design plastic resistance of the cross-section.

$$N_{pl,Rd} = \frac{A \cdot f_y}{\gamma_{M0}}$$ (EN 1993-1-1, 6.6)

Design ultimate resistance of net cross-section at holes for fasteners.

$$N_{u,Rd} = \frac{0.9 A_{net} \cdot f_u}{\gamma_{M2}}$$ (EN 1993-1-1, 6.7)

A *area of cross-section*
A_{net} *area of net cross-section (minus holes)*
f_y *yield strength of steel*
f_u *ultimate strength of steel*
γ_{M0} , γ_{M2} *partial factors for material*

Compression EN 1993-1-1:2005 § 6.2.4

$$\frac{N_{Ed}}{N_{c,Rd}} \leq 1$$ (EN 1993-1-1, 6.9)

$$N_{c,Rd} = \frac{A \cdot fy}{\gamma_{M0}}$$ for class 1, 2, 3 cross-sections (EN 1993-1-1, 6.10)

$$N_{c,Rd} = \frac{A_{eff} \cdot fy}{\gamma_{M0}}$$ for class 4 cross-sections (EN 1993-1-1, 6.11)

A *area of cross-section*
A_{eff} *effective area of cross-section*
fy *yield strength of steel*
γ_{M0} *partial factors for material*

In case the design value of shear is $V_{Ed} > 0.50 V_{pl,Rd}$ the reduced yield strength is used.

$(1-\rho) fy$, where ρ = $\left(\frac{2V_{Ed}}{V_{pl,Rd}} - 1 \right)^2$ (EN 1993-1-1, 6.29)

Bending moment EN 1993-1-1:2005 § 6.2.5

$$\frac{M_{Ed}}{M_{c,Rd}} \leq 1$$ (EN 1993-1-1, 6.12)

Design resistance of cross section for bending about the principal (y-y) or secondary (z-z) axis.

$$M_{y,Rd} = M_{pl,y,Rd} = \frac{W_{pl,y} \cdot fy}{\gamma_{M0}}$$ for class 1, 2 cross-sections (EN 1993-1-1, 6.13)

$$M_{z,Rd} = M_{pl,z,Rd} = \frac{W_{pl,z} \cdot fy}{\gamma_{M0}}$$ for class 1, 2 cross-sections

$$M_{y,Rd} = M_{el,y,Rd} = \frac{W_{el,y} \cdot fy}{\gamma_{M0}}$$ for class 3 cross-sections (EN 1993-1-1, 6.14)

$$M_{z,Rd} = M_{el,z,Rd} = \frac{W_{el,z} \cdot fy}{\gamma_{M0}}$$ for class 3 cross-sections

$$M_{y,Rd} = M_{c,y,Rd} = \frac{W_{eff,y} \cdot fy}{\gamma_{M0}}$$ for class 4 cross-sections (EN 1993-1-1, 6.15)

$$M_{z,Rd} = M_{c,z,Rd} = \frac{W_{eff,z} \cdot fy}{\gamma_{M0}}$$ for class 4 cross-sections

$W_{pl,y}$ $W_{pl,z}$ *plastic section modulus about principal and secondary axis,*
$W_{el,y}$ $W_{el,z}$ *elastic section modulus about principal and secondary axis,*
$W_{eff,y}$ $W_{eff,z}$ *effective section modulus about principal and secondary axis,*
fy *yield strength of steel*
γ_{M0} *partial factors for material*

When bending moment acts together with axial force design check is performed according to :

$$\frac{M_{Ed}}{M_{N,Rd}} \leq 1$$ (EN 1993-1-1, 6.31)

$$M_{N,Rd} = M_{pl,Rd}\left[1 - \left(\frac{N_{Ed}}{N_{pl,Rd}}\right)^2\right]$$ (EN 1993-1-1, 6.32)

In case the design value of shear is $V_{Ed} > 0.50 V_{pl,Rd}$ the reduced yield strength is used.

$(1-\rho)fy$, where ρ = $\left(\frac{2V_{Ed}}{V_{pl,Rd}} - 1\right)^2$ (EN 1993-1-1, 6.29)

Bi-axial bending EN 1993-1-1:2005 § 6.2.9

$$\left(\frac{M_{y,Ed}}{M_{y,Rd}}\right)^{\alpha}+\left(\frac{M_{z,Ed}}{M_{zRd}}\right)^{\beta}\leq 1$$ (EN 1993-1-1, 6.41)

For I and H sections: α=2, β=5n, β≥1 ($n=N_{Ed}/N_{pl,Rd}$)
For circular hollow sections: α=2, β=2
For rectangular hollow sections α=β=1.66/(1-1.13 n^2)

Shear EN 1993-1-1:2005 § 6.2.6

$$\frac{V_{Ed}}{V_{c,Rd}}\leq 1$$ (EN 1993-1-1, 6.17)

Plastic shear resistance parallel to the cross-section web.

$$V_{z,Rd}=V_{pl,z,Rd}=\frac{A_{vz}\cdot f_y}{\sqrt{3}\gamma_{M0}}$$ (EN 1993-1-1, 6.18)

Plastic shear resistance parallel to the cross-section flanges.

$$V_{y,Rd}=V_{pl,y,Rd}=\frac{A_{vy}\cdot f_y}{\sqrt{3}\gamma_{M0}}$$ (EN 1993-1-1, 6.18)

A_{vy} A_{vz} *shear areas parallel to the cross-section web or flanges,*
fy *yield strength of steel*
γ_{M0} *partial factors for material*

Buckling resistance of uniform members in compression EN 1993-1-1:2005 § 6.3.1

Buckling resistance due to compression.

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1$$ (EN 1993-1-1, 6.46)

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}}$$ for class 1, 2, 3 cross-sections (EN 1993-1-1, 6.47)

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}}$$ for class 4 cross-sections (EN 1993-1-1, 6.48)

The reduction factor χ is determined from the non-dimensional slenderness $\overline{\lambda}$

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \overline{\lambda}^2}} \leq 1$$ (EN 1993-1-1, 6.49)

$$\Phi = 0.5\left[1 + \alpha\left(\overline{\lambda} - 0.2\right) + \overline{\lambda}^2\right]$$

$$\overline{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}} ; N_{cr} = \frac{\pi^2 \mathrm{EA}}{\lambda^2} ; \lambda = \frac{l_{eff}}{i} ; i = \sqrt{\frac{I}{A}}$$

$\overline{\lambda}$ *non-dimensional slenderness,*
N_{cr} *elastic critical buckling load,*
Lcr equivalent buckling length,
λ slenderness,
i radius of gyration.

The imperfection factor α which corresponds to the appropriate buckling curve ao,a,b,c,d should obtained from Table 6.2 of Eurocode 3, EN 1993-1-1:2005:

Buckling curve	a_o	a	b	C	d
Imperfection factor α	0.13	0.21	0.34	0.49	0.76

Equivalent buckling lengths Lcr/L

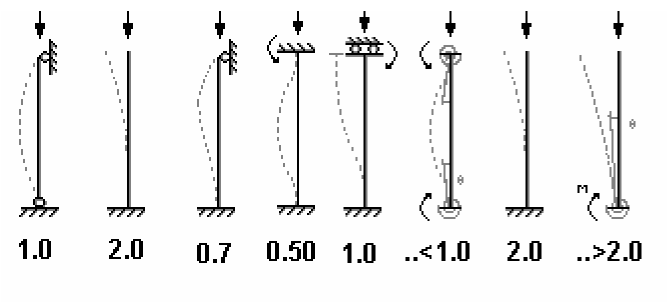
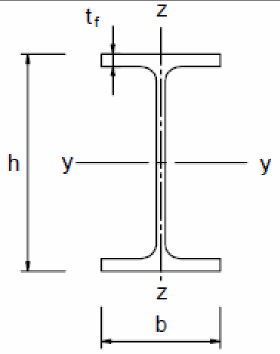
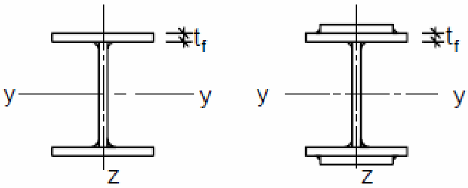
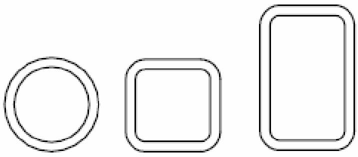
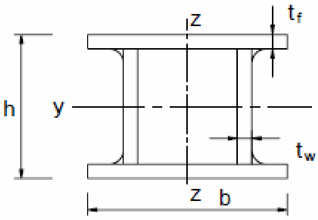
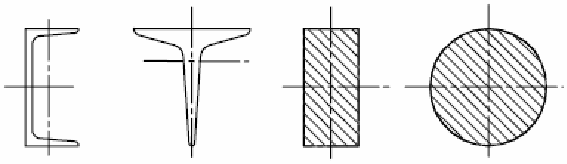
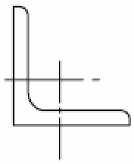


Table 6.2 EN 1993-1-1:2005 Selection of buckling curve of a cross-section

Cross section		Limits		Buckling about axis	Buckling curve S 235 S 275 S 355 S 420	Buckling curve S 460
Rolled sections		$h/b > 1{,}2$	$t_f \le 40$ mm	y – y z – z	a b	a_0 a_0
			40 mm $< t_f \le 100$	y – y z – z	b c	a a
		$h/b \le 1{,}2$	$t_f \le 100$ mm	y – y z – z	b c	a a
			$t_f > 100$ mm	y – y z – z	d d	c c
Welded I-sections		$t_f \le 40$ mm		y – y z – z	b c	b c
		$t_f > 40$ mm		y – y z – z	c d	c d
Hollow sections		hot finished		any	a	a_0
		cold formed		any	c	c
Welded box sections		generally (except as below)		any	b	b
		thick welds: $a > 0{,}5t_f$ $b/t_f < 30$ $h/t_w < 30$		any	c	c
U-, T- and solid sections				any	c	c
L-sections				any	b	b

Lateral torsional buckling for uniform members EN 1993-1-1:2005 § 6.3.2

Lateral torsional buckling of uniform members in bending.

$$\frac{M_{Ed}}{M_{b,Rd}} \leq 1 \qquad \text{(EN 1993-1-1, 6.54)}$$

$$M_{b,Rd} = \frac{\chi_{LT} W_y f_y}{\gamma_{M1}} \qquad \text{(EN 1993-1-1, 6.55)}$$

$W_y = W_{pl,y}$ for class 1, 2 cross-sections,

$W_y = W_{el,y}$ for class 3 cross-sections,

$W_y = W_{eff,y}$ for class 4 cross-sections.

The reduction factor χ_{LT} is determined from the non-dimensional slenderness $\overline{\lambda}_{LT}$

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \overline{\lambda}_{LT}^2}} \leq 1 \qquad \text{(EN 1993-1-1, 6.56)}$$

$$\Phi_{LT} = 0.5\left[1 + \alpha_{LT}\left(\overline{\lambda}_{LT} - 0.2\right) + \overline{\lambda}_{LT}^2\right]$$

$$\overline{\lambda}_{LT} = \sqrt{\frac{W_y f_y}{M_{cr}}}$$

The imperfection factor α which corresponds to the appropriate buckling curve a,b,c,d:

Buckling curve	a	b	C	d
Imperfection factor α_{LT}	0.21	0.34	0.49	0.76

Recommended values for torsional buckling curves:
Rolled Sections h/b<2 buckling curve a, h/b>2 buckling curve b
Welded sections h/b<2 buckling curve c, h/b>2 buckling curve d

The critical elastic moment for lateral torsional buckling is computed according to Annex F of Eurocode 3-1-1 (1992).

$$M_{cr} = C_1 \frac{\pi^2 E I_z}{(kL)^2}\left[\sqrt{\left(\frac{k}{k_w}\right)^2 \frac{I_w}{I_z} + \frac{(kL)^2 G I_t}{\pi^2 E I_z} + \left(C_2 Z_g - C_3 Z_j\right)^2} - \left(C_2 Z_g - C_3 Z_j\right)\right]$$

C1, C2, C3, coefficients depending on the loading conditions and support conditions,
for a beam with uniform bending moment diagram C1=1.000, C2=0.000, C3=1.000
for a beam with parabolic bending moment diagram C1=1.132, C2=0.459, C3=0.525

I_t *St. Venant torsional constant,*

I_w *warping constant,*

I_z *second moment of inertia about the weak axis,*

L *beam length between the support points,*

k , k_w *coefficients depending on the support conditions,*

Z_g *distance of shear center from point of load application*

Uniform members in bending and compression EN 1993-1-1:2005 § 6.3.4

$$\frac{N_{Ed}}{x_y N_{Rk}/\gamma_{M1}} + k_{yy}\frac{M_{Y,Ed}}{\chi_{LT} M_{y,Rk}/\gamma_{M1}} + k_{yz}\frac{M_{z,Ed}}{M_{z,Rk}/\gamma_{M1}} \le 1 \qquad \text{(EN 1993-1-1, 6.61)}$$

$$\frac{N_{Ed}}{x_z N_{Rk}/\gamma_{M1}} + k_{zy}\frac{M_{Y,Ed}}{\chi_{LT} M_{y,Rk}/\gamma_{M1}} + k_{zz}\frac{M_{z,Ed}}{M_{z,Rk}/\gamma_{M1}} \le 1 \qquad \text{(EN 1993-1-1, 6.62)}$$

$N_{Rk} = Af_y$

$M_{y,Rk} = W_{pl,y} f_y$ for class 1, 2 cross-sections

$M_{y,Rk} = W_{el,y} f_y$ for class 3 cross-sections,

$M_{y,Rk} = W_{eff,y} f_y$ for class 4 cross-sections,

$M_{z,Rk} = W_{pl,z} f_y$ for class 1, 2 cross-sections

$M_{z,Rk} = W_{el,z} f_y$ for class 3 cross-sections,

$M_{z,Rk} = W_{eff,z} f_y$ for class 4 cross-sections.

The interaction coefficients k_{yy} , k_{yz} , k_{zy} , k_{zz} are determined from tables B.1 and B.2

Table B.1 interaction coefficients k_{yy} , k_{yz} , k_{zy} , k_{zz}

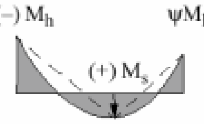
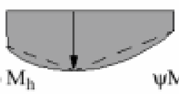
Interaction factors	Type of sections	Design assumption: elastic cross-sectional properties class 3, class 4	Design assumption: plastic cross-sectional properties class 1, class 2
k_{yy}	I-sections RHS-sections	$C_{my}\left(1+0,6\bar{\lambda}_y \frac{N_{Ed}}{\chi_y N_{Rk}/\gamma_{M1}}\right) \le C_{my}\left(1+0,6 \frac{N_{Ed}}{\chi_y N_{Rk}/\gamma_{M1}}\right)$	$C_{my}\left(1+(\bar{\lambda}_y-0,2)\frac{N_{Ed}}{\chi_y N_{Rk}/\gamma_{M1}}\right) \le C_{my}\left(1+0,8 \frac{N_{Ed}}{\chi_y N_{Rk}/\gamma_{M1}}\right)$
k_{yz}	I-sections RHS-sections	k_{zz}	$0,6\ k_{zz}$
k_{zy}	I-sections RHS-sections	$0,8\ k_{yy}$	$0,6\ k_{yy}$
k_{zz}	I-sections	$C_{mz}\left(1+0,6\bar{\lambda}_z \frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}}\right) \le C_{mz}\left(1+0,6 \frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}}\right)$	$C_{mz}\left(1+(2\bar{\lambda}_z-0,6)\frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}}\right) \le C_{mz}\left(1+1,4 \frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}}\right)$
	RHS-sections		$C_{mz}\left(1+(\bar{\lambda}_z-0,2)\frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}}\right) \le C_{mz}\left(1+0,8 \frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}}\right)$
For I- and H-sections and rectangular hollow sections under axial compression and uniaxial bending $M_{y,Ed}$ the coefficient k_{zy} may be $k_{zy} = 0$.			

Table B.2

Interaction factors	Design assumptions	
	elastic cross-sectional properties class 3, class 4	plastic cross-sectional properties class 1, class 2
k_{yy}	k_{yy} from Table B.1	k_{yy} from Table B.1
k_{yz}	k_{yz} from Table B.1	k_{yz} from Table B.1
k_{zy}	$\left[1-\frac{0{,}05\bar{\lambda}_z}{(C_{mLT}-0{,}25)}\frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}}\right] \geq \left[1-\frac{0{,}05}{(C_{mLT}-0{,}25)}\frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}}\right]$	$\left[1-\frac{0{,}1\bar{\lambda}_z}{(C_{mLT}-0{,}25)}\frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}}\right] \geq \left[1-\frac{0{,}1}{(C_{mLT}-0{,}25)}\frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}}\right]$ for $\bar{\lambda}_z < 0{,}4$: $k_{zy} = 0{,}6+\bar{\lambda}_z \leq 1-\frac{0{,}1\bar{\lambda}_z}{(C_{mLT}-0{,}25)}\frac{N_{Ed}}{\chi_z N_{Rk}/\gamma_{M1}}$
k_{zz}	k_{zz} from Table B.1	k_{zz} from Table B.1

Factor	Bending axis	Points braced in direction
Cmy	y-y	z-z
Cmz	z-z	y-y
CmLT	y-y	y-y

Table B.3

Moment Diagram	Range		C_{my}, C_{mz} и C_{mLT} under loading	
			Distributed	Concentrated
M  ψM	$-1 \leq \psi \leq 1$		$0{,}6 + 0.4\,\psi \geq 0{,}4$	
(−) M_h  ψM_h, (+) M_s, $\alpha_s = M_s/M_h$	$0 \leq \alpha_s \leq 1$	$-1 \leq \psi \leq 1$	$0{,}2 + 0.8\,\alpha_s \geq 0{,}4$	$0{,}2 + 0.8\alpha_s \geq 0{,}4$
	$-1 \leq \alpha_s < 0$	$0 \leq \psi \leq 1$	$0{,}1 - 0.8\,\alpha_s \geq 0{,}4$	$-0.8\alpha_s \geq 0{,}4$
		$-1 \leq \psi < 0$	$0{,}1(1-\psi) - 0.8\,\alpha_s \geq 0{,}4$	$0{,}2(-\psi) - 0.8\,\alpha_s \geq 0{,}4$
(+) M_s  (+) M_h, ψM_h, $\alpha_h = M_h/M_s$	$0 \leq \alpha_h \leq 1$	$-1 \leq \psi \leq 1$	$0{,}95 + 0{,}05\,\alpha_h$	$0{,}90 + 0{,}10\,\alpha_h$
	$-1 \leq \alpha_h < 0$	$0 \leq \psi \leq 1$	$0{,}95 + 0{,}05\,\alpha_h$	$0{,}90 + 0{,}10\,\alpha_h$
		$-1 \leq \psi < 0$	$0{,}95 + 0{,}05\,\alpha_h(1+2\psi)$	$0{,}90 - 0{,}10\,\alpha_h(1+2\psi)$

Bibliography

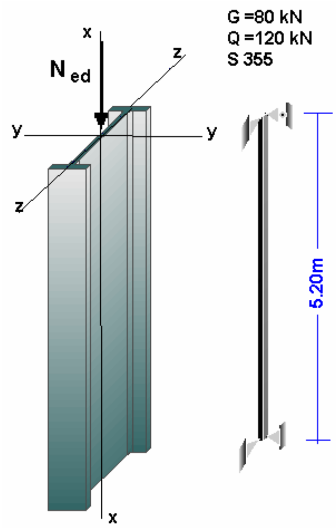
Eurocode 3, EN1993-1-1:2005

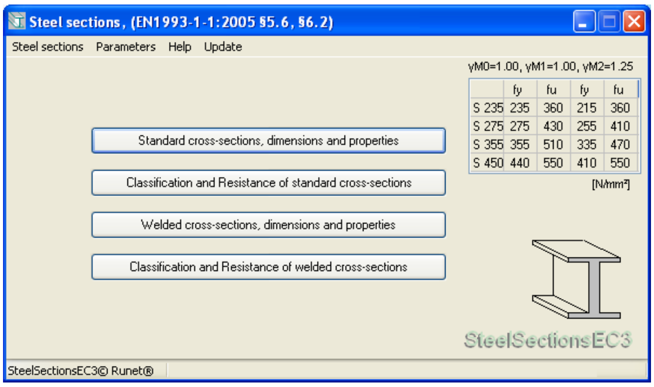
Examples

The following examples show how you can choose the right steel sections using the tables in the program.

Example 1

Steel column 5.20 m.
Axial load G = 80 kN, variable axial load Q = 120 kN.
Steel S 355.
Total axial design load:
Ned =1.35xG+1.50xQ=1.35x80+1.50x120 = 288 kN
Buckling lengths: Liy=5.20 m, Liz=5.20 m



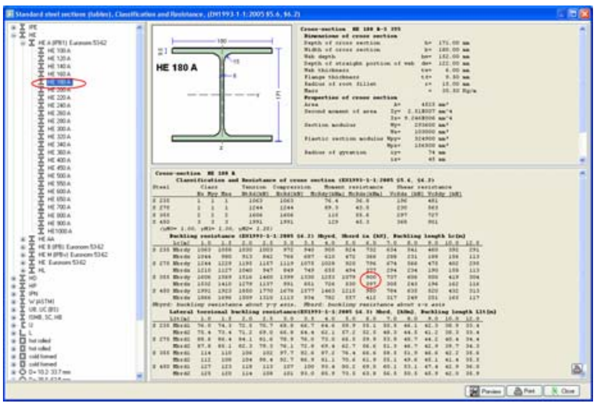


	fy	fu	fy	fu
S 235	235	360	215	360
S 275	275	430	255	410
S 355	355	510	335	470
S 450	440	550	410	550

In the main program screen, click **Classification and Resistance of standard cross-sections**.

- From the tree control on the left select section type **HEA**.
- Click + and all the sections of type HEA are displayed.

For steel grade **S 355** and buckling length **5.20 m** (table values between 5.0 m and 6.0m), check Nbyrd and Nbzrd (buckling resistances in compression in y-y and z-z axis) to be greater than the design load of the column Ned=288 kN.

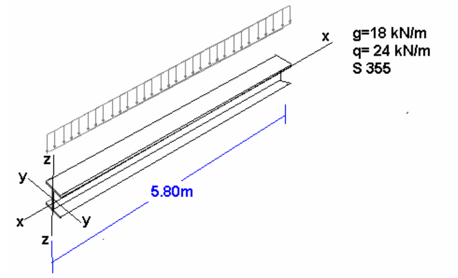


Section **HE 180 A** is OK.

For buckling length **6.0m**>5.20m, the section has, buckling resistances in compression **Nbyrd = 900 kN** > 288 kN and **Nbzrd = 397 kN** >288 kN.

Example 2

Beam 5.80 m with loads.
Permanent load g = 18 kN/m.
Variable load q = 24 kN/m.
Steel S 355.
Design load:
qed = 1.35x18.0+1.50x24.0 = 60.30 kN/m
Maximum design bending moment:
My,ed = 60.30x5.80^2/8 = 253.6 kNm
Maximum design shearing force:
Vz,ed = 60.30x5.80/2 = 174.9 kN



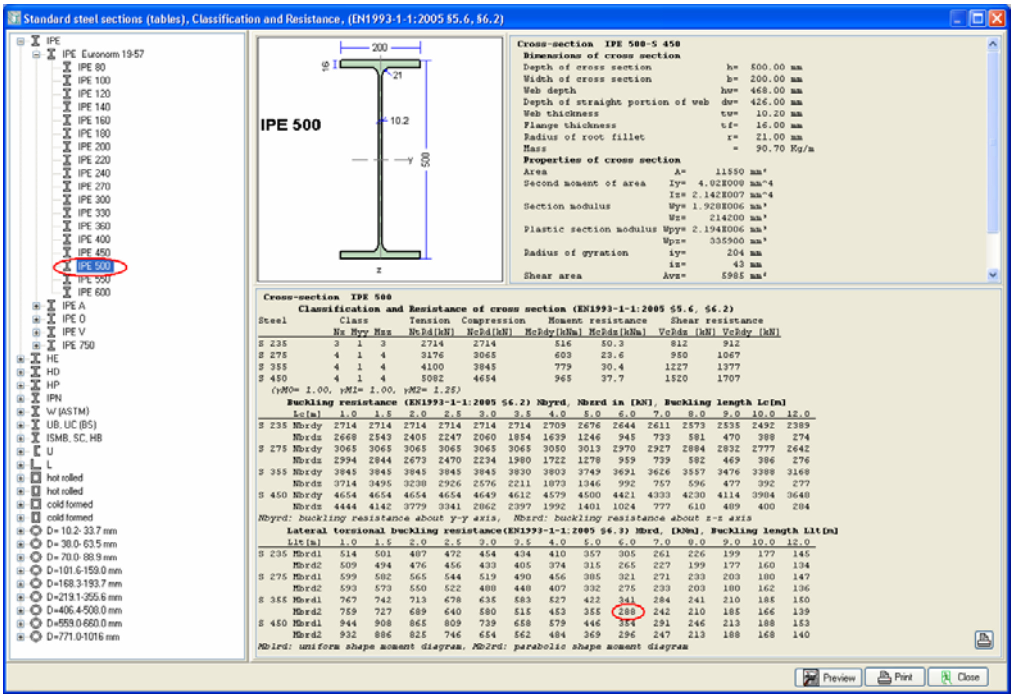
In the main program screen, click [Classification and Resistance of standard cross-sections].

- From the tree control on the left select section type **IPE**.
- Click + and all the sections of type IPE are displayed.

For steel grade **S 355** and lateral buckling length L_{Lt}=**5.80 m** (table 6.0m), check Mbrd2 (parabolic bending moment diagram) to be greater than the maximum bending moment acting on the beam My,ed = 253.6 kNm.

Section **IPE 500** is OK.

For lateral buckling length **6.0m**>5.80 m, has resistance in bending moment due to lateral buckling **Mbrd2 = 288** kNm>253.6 kNm
From the table above you can check the resistances in shear and bending.
Shear resistance **Vc,rdz = 1227 kN**, bending resistance **Mc,rdy = 779 kNm**.



Standard steel sections (tables), Classification and Resistance, (EN1993-1-1:2005 §5.6, §6.2)

IPE 500

Cross-section IPE 500-S 450

Dimensions of cross section

Depth of cross section	h=	500.00	mm
Width of cross section	b=	200.00	mm
Web depth	hw=	468.00	mm
Depth of straight portion of web	dw=	426.00	mm
Web thickness	tw=	10.20	mm
Flange thickness	tf=	16.00	mm
Radius of root fillet	r=	21.00	mm
Mass	=	90.70	Kg/m

Properties of cross section

Area	A=	11550	mm²
Second moment of area	Iy=	4.82E008	mm^4
	Iz=	2.142E007	mm^4
Section modulus	Wy=	1.928E006	mm³
	Wz=	214200	mm³
Plastic section modulus	Wpy=	2.194E006	mm³
	Wpz=	335900	mm³
Radius of gyration	iy=	204	mm
	iz=	43	mm
Shear area	Avz=	5985	mm²

Cross-section IPE 500

Classification and Resistance of cross section (EN1993-1-1:2005 §5.6, §6.2)

Steel	Class			Tension	Compression	Moment resistance		Shear resistance	
	Nx	Myy	Mzz	NtRd[kN]	NcRd[kN]	McRdy[kNm]	McRdz[kNm]	VcRdz [kN]	VcRdy [kN]
S 235	3	1	3	2714	2714	516	50.3	812	912
S 275	4	1	4	3176	3065	603	23.6	950	1067
S 355	4	1	4	4100	3845	779	30.4	1227	1377
S 450	4	1	4	5082	4654	965	37.7	1520	1707

(γM0= 1.00, γM1= 1.00, γM2= 1.25)

Buckling resistance (EN1993-1-1:2005 §6.2) Nbyrd, Nbzrd in [kN], Buckling length Lc[m]

	Lc[m]	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	10.0	12.0
S 235	Nbrdy	2714	2714	2714	2714	2714	2714	2709	2676	2644	2611	2573	2535	2492	2389
	Nbrdz	2668	2543	2405	2247	2060	1854	1639	1246	945	733	581	470	388	274
S 275	Nbrdy	3065	3065	3065	3065	3065	3065	3050	3013	2970	2927	2884	2832	2777	2642
	Nbrdz	2994	2844	2673	2470	2234	1980	1722	1278	959	739	582	469	386	276
S 355	Nbrdy	3845	3845	3845	3845	3845	3830	3803	3749	3691	3626	3557	3476	3388	3168
	Nbrdz	3714	3495	3238	2926	2576	2211	1873	1346	992	757	596	477	392	277
S 450	Nbrdy	4654	4654	4654	4654	4649	4612	4579	4500	4421	4333	4230	4114	3984	3648
	Nbrdz	4444	4142	3779	3341	2862	2397	1992	1401	1024	777	610	489	400	284

Nbyrd: buckling resistance about y-y axis, Nbzrd: buckling resistance about z-z axis

Lateral torsional buckling resistance(EN1993-1-1:2005 §6.3) Mbrd, [kNm], Buckling length Llt[m]

	Llt[m]	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	10.0	12.0
S 235	Mbrd1	514	501	487	472	454	434	410	357	305	261	226	199	177	145
	Mbrd2	509	494	476	456	433	405	374	315	265	227	199	177	160	134
S 275	Mbrd1	599	582	565	544	519	490	456	385	321	271	233	203	180	147
	Mbrd2	593	573	550	522	488	448	407	332	275	233	203	180	162	136
S 355	Mbrd1	767	742	713	678	635	583	527	422	341	284	241	210	185	150
	Mbrd2	759	727	689	640	580	515	453	355	288	242	210	185	166	139
S 450	Mbrd1	944	908	865	809	739	658	579	446	354	291	246	213	188	153
	Mbrd2	932	886	825	746	654	562	484	369	296	247	213	188	168	140

Mb1rd: uniform shape moment diagram, Mb2rd: parabolic shape moment diagram