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
- $I_y$ [cm⁴]: Moment of area about axis y-y
- $I_z$ [cm⁴]: Second moment of area about axis z-z
- $W_y$ [cm³]: Section modulus about axis y-y
- $W_z$ [cm³]: Section modulus about axis z-z
- $W_{py}$ [cm³]: Plastic section modulus about axis y-y
- $W_{pz}$ [cm³]: Plastic section modulus about axis z-z
- $i_y$ [cm]: Radius of gyration about y-y axis
- $i_z$ [cm]: Radius of gyration about z-z axis
- $A_{vz}$ [cm²]: Shear area parallel to web
- $A_{vy}$ [cm²]: Shear area parallel to flanges
- $I_t$ [cm⁴]: Torsional constant
- $I_w$ [cm⁶]: 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 (Llt) according to EN1993-1-1:2005 §6.3.2

**Symbols**

- $N_{tRd}$ [kN]: Tension resistance EN1993-1-1:2005 §6.2.3
- $N_{cRd}$ [kN]: Compression resistance EN1993-1-1:2005 §6.2.4
- $M_{crdy}$ [kNm]: Bending resistance about the strong y-y axis EN1993-1-1:2005 §6.2.5
- $M_{crdz}$ [kNm]: Bending resistance about the weak z-z axis EN1993-1-1:2005 §6.2.5
- $V_{crdy}$ [kN]: Shear resistance in the axis y-y parallel to flanges EN1993-1-1:1 §6.2.6
- $V_{crdz}$ [kN]: Shear resistance in the axis z-z parallel to web EN1993-1-1 §6.2.6
- $N_{brdy}$ [kN], $N_{brdz}$ [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
- $M_{brd1}$ [kNm]: Lateral torsional buckling resistance for various lengths between constrains
- $M_{brd2}$ [kNm]: Lateral torsional buckling resistance for constant (uniform) bending moment diagram along the beam
- $M_{brd1}$: Lateral torsional buckling resistance for parabolic bending moment diagram along the beam
Tables with dimensions and properties of user defined welded steel sections

Click 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 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

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

Coordinate system

Sections properties
Steel section types included in the program

<table>
<thead>
<tr>
<th>European I-beams</th>
<th>European wide flange beams</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPE</td>
<td>HE A (IPB1) Euro norm 53-62</td>
</tr>
<tr>
<td>IPE A</td>
<td>HE AA</td>
</tr>
<tr>
<td>IPE B</td>
<td>HE B (IPB) Euro norm 53-62</td>
</tr>
<tr>
<td>IPE V</td>
<td>HE M (IPEV) Euro norm 53-62</td>
</tr>
<tr>
<td>IPE 750</td>
<td>HE Euro norm 53-62</td>
</tr>
<tr>
<td>IPE A 80-600</td>
<td>HE A 100-1000</td>
</tr>
<tr>
<td>IPE O 180-600</td>
<td>HE B 100-1000</td>
</tr>
<tr>
<td>IPE V 400-600</td>
<td>HEM 100-1000</td>
</tr>
<tr>
<td>IPE 750</td>
<td>HE 400-1000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Beams with very wide flanges</th>
<th>HD 260x54.1 – 400x1086</th>
</tr>
</thead>
<tbody>
<tr>
<td>European standard beams</td>
<td>W 360x370x134</td>
</tr>
<tr>
<td>W 1 ASTM AE/A 6M</td>
<td>W 1100x400x499</td>
</tr>
<tr>
<td>W 2 ASTM AE/A 6M</td>
<td></td>
</tr>
<tr>
<td>W 3 ASTM AE/A 6M</td>
<td></td>
</tr>
<tr>
<td>American wide flange beams</td>
<td>UB 178x102x19</td>
</tr>
<tr>
<td>UB 1 BS 4 part 1-1993</td>
<td>UB 914x419x388</td>
</tr>
<tr>
<td>UB 2 BS 4 part 1-1993</td>
<td></td>
</tr>
<tr>
<td>UC BS 4 part 1-1993</td>
<td></td>
</tr>
</tbody>
</table>

| British universal beams     | UC 152x152x23           |
| UC 356x406x634              |                        |

| British universal columns   | UPN 30-65               |
| UPN                        | UPN 80-400              |
| UAP NF A 45-255             | UPN 80-400              |
| UPE                       |                         |

| European standard channels  | UAP 80-300              |
| UP 80-400                  |                         |

| Channels with parallel flanges | L 20x20x3               |
| L 250x250x28                |                         |
| Equal angels                | L 30x20x3               |
| L 250x90x16                 |                         |
| Unequal angels              | Ø 10.2x1.0              |
| Ø 1016x400                  |                         |

| Cold formed                 |                         |
| Circular hollow sections    | 20x20x1.6               |
| 400x400x12.5                |                         |
| Square hollow sections      | 40x40x2.6               |
| 400x400x20.0                |                         |
| Square hollow sections hot  | 30x20x1.5               |
| rolled                     | 500x300x12.5             |
| Rectangular hollow sections | 50x30x2.6               |
| cold formed                | 400x260x17.5             |
| Rectangular hollow sections | hot rolled              |
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 based 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

<table>
<thead>
<tr>
<th>Class</th>
<th>Part subject to bending</th>
<th>Part subject to compression</th>
<th>Part subject to bending and compression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress distribution in parts (compression positive)</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
</tbody>
</table>
| 1     | c/t ≤ 72e               | c/t ≤ 33e                   | when $\alpha > 0.5$: $c/t \leq \frac{396e}{13\alpha - 1}$  
when $\alpha \leq 0.5$: $c/t \leq \frac{36e}{\alpha}$ |
| 2     | c/t ≤ 83e               | c/t ≤ 38e                   | when $\alpha > 0.5$: $c/t \leq \frac{456e}{13\alpha - 1}$  
when $\alpha \leq 0.5$: $c/t \leq \frac{41.5e}{\alpha}$ |
| 3     | c/t ≤ 124e              | c/t ≤ 42e                   | when $\psi > -1$: $c/t \leq \frac{42e}{0.67 + 0.33\psi}$  
when $\psi \leq -1$: $c/t \leq 62e(1 - \psi)^2(-\psi)$ |

<table>
<thead>
<tr>
<th>$e = \sqrt{\frac{235}{f_y}}$</th>
<th>$f_y$</th>
<th>235</th>
<th>275</th>
<th>355</th>
<th>420</th>
<th>460</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon$</td>
<td>1.00</td>
<td>0.92</td>
<td>0.81</td>
<td>0.75</td>
<td>0.71</td>
<td></td>
</tr>
</tbody>
</table>
Table 5.2 EN 1993-1-1:2005 – Outstanding flanges

<table>
<thead>
<tr>
<th>Class</th>
<th>Part subject to compression</th>
<th>Part subject to bending and compression</th>
<th>Tip in compression</th>
<th>Tip in tension</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tip in compression</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tip in tension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>c / t ≤ 9ε</td>
<td>c / t ≤ 10ε</td>
<td>c / t ≤ 10ε / α</td>
<td>c / t ≤ 10ε / α</td>
</tr>
<tr>
<td>2</td>
<td>c / t ≤ 10ε</td>
<td>c / t ≤ 10ε / α</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>c / t ≤ 14ε</td>
<td>c / t ≤ 21ε / k_o</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For k_o see EN 1993-1-5

| ε = √(235 / f_y) | f_y | 235 | 275 | 355 | 420 | 460 | ε | 1.00 | 0.92 | 0.81 | 0.75 | 0.71 |
|-----------------|-----|-----|-----|-----|-----|-----|---|-----|-----|-----|-----|-----|-----|
| ε²              | 1.00 | 0.85 | 0.66 | 0.56 | 0.51 |   |

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

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

Does not apply to angles in continuous contact with other components

<table>
<thead>
<tr>
<th>Class</th>
<th>Section in compression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stress distribution across section (compression positive)</td>
</tr>
<tr>
<td>3</td>
<td>h / t ≤ 15ε : b + h / 2t ≤ 11.5ε</td>
</tr>
</tbody>
</table>

Tubular sections

<table>
<thead>
<tr>
<th>Class</th>
<th>Section in bending and/or compression</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>d / t ≤ 50ε²</td>
</tr>
<tr>
<td>2</td>
<td>d / t ≤ 70ε²</td>
</tr>
<tr>
<td>3</td>
<td>d / t ≤ 90ε²</td>
</tr>
</tbody>
</table>

NOTE: For d / t > 90ε² see EN 1993-1-6

| ε = √(235 / f_y) | f_y | 235 | 275 | 355 | 420 | 460 | ε | 1.00 | 0.92 | 0.81 | 0.75 | 0.71 |
|-----------------|-----|-----|-----|-----|-----|-----|---|-----|-----|-----|-----|-----|-----|
| ε²              | 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

\[
\frac{N_{Ed}}{N_{1,Rd}} \leq 1 \tag{EN 1993-1-1, 6.5}
\]

Design plastic resistance of the cross-section.

\[
N_{pl,Rd} = \frac{A \cdot f_y}{\gamma_{M0}} \tag{EN 1993-1-1, 6.6}
\]

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

\[
N_{u,Rd} = \frac{0.9 A_{net} \cdot f_u}{\gamma_{M2}} \tag{EN 1993-1-1, 6.7}
\]

- \( A \) 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
- \( \gamma_{M0}, \gamma_{M2} \) partial factors for material

### Compression EN 1993-1-1:2005 § 6.2.4

\[
\frac{N_{Ed}}{N_{c,Rd}} \leq 1 \tag{EN 1993-1-1, 6.9}
\]

\[
N_{c,Rd} = \frac{A \cdot f_y}{\gamma_{M0}} \quad \text{for class 1, 2, 3 cross-sections} \tag{EN 1993-1-1, 6.10}
\]

\[
N_{c,Rd} = \frac{A_{eff} \cdot f_y}{\gamma_{M0}} \quad \text{for class 4 cross-sections} \tag{EN 1993-1-1, 6.11}
\]

- \( A \) area of cross-section
- \( A_{eff} \) effective area of cross-section
- \( f_y \) yield strength of steel
- \( \gamma_{M0} \) 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.

\[
(1 - \rho) f_y, \quad \text{where} \quad \rho = \left( \frac{2V_{Ed}}{V_{pl,Rd}} - 1 \right)^2 \tag{EN 1993-1-1, 6.29}
\]
Bending moment EN 1993-1-1:2005 § 6.2.5

\[
\frac{M_{Ed}}{M_{c,Rd}} \leq 1 \quad \text{(EN 1993-1-1, 6.12)}
\]

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

\[
M_{y,Rd} = M_{pl,y,Rd} = \frac{W_{pl,y} \cdot fy}{\gamma_M} \quad \text{for class 1, 2 cross-sections} \quad \text{(EN 1993-1-1, 6.13)}
\]
\[
M_{z,Rd} = M_{pl,z,Rd} = \frac{W_{pl,z} \cdot fy}{\gamma_M} \quad \text{for class 1, 2 cross-sections}
\]
\[
M_{y,Rd} = M_{el,y,Rd} = \frac{W_{el,y} \cdot fy}{\gamma_M} \quad \text{for class 3 cross-sections} \quad \text{(EN 1993-1-1, 6.14)}
\]
\[
M_{z,Rd} = M_{el,z,Rd} = \frac{W_{el,z} \cdot fy}{\gamma_M} \quad \text{for class 3 cross-sections}
\]
\[
M_{y,Rd} = M_{el,y,Rd} = \frac{W_{eff,y} \cdot fy}{\gamma_M} \quad \text{for class 4 cross-sections} \quad \text{(EN 1993-1-1, 6.15)}
\]
\[
M_{z,Rd} = M_{el,z,Rd} = \frac{W_{eff,z} \cdot fy}{\gamma_M} \quad \text{for class 4 cross-sections}
\]
\[
W_{pl,y} \quad W_{pl,z} \quad \text{plastic section modulus about principal and secondary axis},
\]
\[
W_{el,y} \quad W_{el,z} \quad \text{elastic section modulus about principal and secondary axis},
\]
\[
W_{eff,y} \quad W_{eff,z} \quad \text{effective section modulus about principal and secondary axis},
\]
\[
fy \quad \text{yield strength of steel}
\]
\[
\gamma_M \quad \text{partial factors for material}
\]

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

\[
\frac{M_{Ed}}{M_{N,Rd}} \leq 1 \quad \text{(EN 1993-1-1, 6.31)}
\]
\[
M_{N,Rd} = M_{pl,Rd} \left[ 1 - \left( \frac{N_{Ed}}{N_{pl,Rd}} \right)^2 \right] \quad \text{(EN 1993-1-1, 6.32)}
\]

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

\[
(1 - \rho)fy \quad \text{where} \quad \rho = \left( \frac{2V_{Ed}}{V_{pl,Rd}} - 1 \right)^2 \quad \text{(EN 1993-1-1, 6.29)}
\]
Bi-axial bending EN 1993-1-1:2005 § 6.2.9

\[
\left( \frac{M_{y,Ed}}{M_{y,Rd}} \right)^\alpha + \left( \frac{M_{z,Ed}}{M_{z,Rd}} \right)^\beta \leq 1
\]

(EN 1993-1-1, 6.41)

For I and H sections: \( \alpha=2, \beta=5n, \beta \geq 1 \) (\( n=N_{Ed}/N_{pl,Rd} \))

For circular hollow sections: \( \alpha=2, \beta=2 \)

For rectangular hollow sections \( \alpha=\beta=1.66/(1-1.13 n^2) \)

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.

\[
V_{z,Rd} = V_{pl,z,Rd} = A_{z} \cdot f_y
\]

(EN 1993-1-1, 6.18)

Plastic shear resistance parallel to the cross-section flanges.

\[
V_{y,Rd} = V_{pl,y,Rd} = A_{y} \cdot f_y
\]

(EN 1993-1-1, 6.18)

\( A_{z}, A_{y} \) shear areas parallel to the cross-section web or flanges,

\( f_y \) yield strength of steel

\( \gamma_{M0} \) partial factors for material
Buckling resistance of uniform members in compression EN 1993-1-1:2005 § 6.3.1

Buckling resistance due to compression.

\[ \frac{N_{Ed}}{N_{b,Rd}} \leq 1 \] \hspace{1cm} (EN 1993-1-1, 6.46)

\[ N_{b,Rd} = \frac{X f_y}{\gamma_{M1}} \] for class 1, 2, 3 cross-sections \hspace{1cm} (EN 1993-1-1, 6.47)

\[ N_{b,Rd} = \frac{X_{eff} f_y}{\gamma_{M1}} \] for class 4 cross-sections \hspace{1cm} (EN 1993-1-1, 6.48)

The reduction factor \( \chi \) is determined from the non-dimensional slenderness \( \overline{\lambda} \)

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

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

\[ \overline{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}} ; \quad \overline{\lambda} = \frac{\pi^2 E A}{\lambda} ; \quad \lambda = \frac{l_{eff}}{i} ; \quad i = \sqrt{\frac{I}{A}} \]

\( \overline{\lambda} \) non-dimensional slenderness,

\( N_{cr} \) elastic critical buckling load,

\( \lambda \) slenderness,

\( i \) radius of gyration.

The imperfection factor \( \alpha \) which corresponds to the appropriate buckling curve \( a_0, a, b, c, d \) should obtained from Table 6.2 of Eurocode 3, EN 1993-1-1:2005:

<table>
<thead>
<tr>
<th>Buckling curve</th>
<th>( a_0 )</th>
<th>a</th>
<th>b</th>
<th>C</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperfection factor ( \alpha )</td>
<td>0.13</td>
<td>0.21</td>
<td>0.34</td>
<td>0.49</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Equivalent buckling lengths \( L_{cr}/L \)
### Table 6.2 EN 1993-1-1:2005 Selection of buckling curve of a cross-section

<table>
<thead>
<tr>
<th>Cross section</th>
<th>Limits</th>
<th>Buckling about axis</th>
<th>$S_{235}$</th>
<th>$S_{275}$</th>
<th>$S_{355}$</th>
<th>$S_{420}$</th>
<th>$S_{460}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolled sections</td>
<td>$t_f \leq 40$ mm</td>
<td>$y$ - $y$</td>
<td>$a$</td>
<td>$a_0$</td>
<td>$a_0$</td>
<td>$a_0$</td>
<td>$a_0$</td>
</tr>
<tr>
<td></td>
<td>$40$ mm $&lt; t_f \leq 100$</td>
<td>$z$ - $z$</td>
<td>$b$</td>
<td>$a$</td>
<td>$a$</td>
<td>$a$</td>
<td>$a$</td>
</tr>
<tr>
<td></td>
<td>$t_f \leq 100$ mm</td>
<td>$y$ - $y$</td>
<td>$b$</td>
<td>$c$</td>
<td>$a$</td>
<td>$a$</td>
<td>$a$</td>
</tr>
<tr>
<td></td>
<td>$t_f &gt; 100$ mm</td>
<td>$z$ - $z$</td>
<td>$d$</td>
<td>$c$</td>
<td>$c$</td>
<td>$c$</td>
<td>$c$</td>
</tr>
<tr>
<td>Welded I-sections</td>
<td>$t_f \leq 40$ mm</td>
<td>$y$ - $z$</td>
<td>$b$</td>
<td>$c$</td>
<td>$b$</td>
<td>$b$</td>
<td>$c$</td>
</tr>
<tr>
<td></td>
<td>$t_f &gt; 40$ mm</td>
<td>$y$ - $z$</td>
<td>$c$</td>
<td>$d$</td>
<td>$c$</td>
<td>$d$</td>
<td>$d$</td>
</tr>
<tr>
<td>Hollow sections</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hot finished</td>
<td>any</td>
<td>a</td>
<td>a_0</td>
<td>a_0</td>
<td>a_0</td>
<td>a_0</td>
</tr>
<tr>
<td></td>
<td>Cold formed</td>
<td>any</td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>c</td>
</tr>
<tr>
<td>Welded box sections</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Generally (except as below)</td>
<td>any</td>
<td>b</td>
<td>b</td>
<td>b</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>Thick welds: $a &gt; 0.5t_f$</td>
<td>any</td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>c</td>
</tr>
<tr>
<td>U-, I- and solid sections</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Any</td>
<td>any</td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>c</td>
</tr>
<tr>
<td>L-sections</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Any</td>
<td>any</td>
<td>b</td>
<td>b</td>
<td>b</td>
<td>b</td>
<td>b</td>
</tr>
</tbody>
</table>
Lateral torsional buckling for uniform members EN 1993-1-1:2005 § 6.3.2

Lateral torsional buckling of uniform members in bending.

\[
\frac{M_{Ed}}{M_{b,Rd}} \leq 1 \quad \text{(EN 1993-1-1, 6.54)}
\]

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

- \( W_y = W_{pl,y} \) 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 \( \chi_{LT} \) is determined from the non-dimensional slenderness \( \bar{\lambda}_{LT} \)

\[
\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \lambda_{LT}^2}} \leq 1 \quad \text{(EN 1993-1-1, 6.56)}
\]

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

\[
\lambda_{LT} = \sqrt{\frac{W_y f_y}{M_{cr}}}
\]

The imperfection factor \( \alpha \) which corresponds to the appropriate buckling curve a,b,c,d:

<table>
<thead>
<tr>
<th>Imperfection curve</th>
<th>( \alpha_{LT} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>0.21</td>
</tr>
<tr>
<td>b</td>
<td>0.34</td>
</tr>
<tr>
<td>c</td>
<td>0.49</td>
</tr>
<tr>
<td>d</td>
<td>0.76</td>
</tr>
</tbody>
</table>

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).

\[
M_{cr} = C_1 \frac{\pi^2 EI_z}{(kL)^2} \left[ \frac{k}{k_w} \right]^2 \left[ \frac{I_z}{L^2} + \frac{(kL)^3 GI_z}{\pi^2 EI_z} + \left( C_2 Z_g - C_3 Z_j \right)^2 \right] - \left( C_2 Z_g - C_3 Z_j \right)
\]

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 \( C1=1.132, C2=0.459, C3=0.525 \)

- \( I_z \) 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

\[
\frac{N_{Ed}}{x_{v} N_{Rk} / \gamma_{M1}} + k_{yy} \frac{M_{Y,Ed}}{x_{LT} M_{y, Rk} / \gamma_{M1}} + k_{yz} \frac{M_{Z,Ed}}{M_{z, Rk} / \gamma_{M1}} \leq 1
\]  
(EN 1993-1-1, 6.61)

\[
\frac{N_{Ed}}{x_{z} N_{Rk} / \gamma_{M1}} + k_{zy} \frac{M_{Y,Ed}}{x_{LT} M_{y, Rk} / \gamma_{M1}} + k_{zz} \frac{M_{Z,Ed}}{M_{z, Rk} / \gamma_{M1}} \leq 1
\]  
(EN 1993-1-1, 6.62)

\[N_{Rk} = A f_{y}\]

\[M_{y, Rk} = W_{pl, y} f_{y}\] for class 1, 2 cross-sections
\[M_{y, Rk} = W_{el, y} f_{y}\] for class 3 cross-sections,
\[M_{z, Rk} = W_{eff, y} f_{y}\] 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** \(k_{yy}\), \(k_{yz}\), \(k_{zy}\), \(k_{zz}\)

<table>
<thead>
<tr>
<th>Interaction factors</th>
<th>Type of sections</th>
<th>Design assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>(k_{yy})</td>
<td>I-sections</td>
<td>(C = 1 + 0.6 \frac{N_{Ed}}{x_{y} N_{Rk} / \gamma_{M1}})</td>
</tr>
<tr>
<td>(k_{zy})</td>
<td>RHS-sections</td>
<td>(C = \frac{1}{1 + 0.6 \frac{N_{Ed}}{x_{z} N_{Rk} / \gamma_{M1}}})</td>
</tr>
<tr>
<td>(k_{zz})</td>
<td>I-sections</td>
<td>(0.6 k_{yy})</td>
</tr>
<tr>
<td>(k_{xx})</td>
<td>RHS-sections</td>
<td>(0.6 k_{yy})</td>
</tr>
</tbody>
</table>

For I- and H-sections and rectangular hollow sections under axial compression and uniaxial bending \(M_{y,Ed}\), the coefficient \(k_{xx}\), may be \(k_{xx} = 0\).
Table B.2

<table>
<thead>
<tr>
<th>Interaction factors</th>
<th>Design assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>elastic cross-sectional properties</td>
</tr>
<tr>
<td></td>
<td>class 3, class 4</td>
</tr>
<tr>
<td>$k_{yy}$</td>
<td>$k_{yy}$ from Table B.1</td>
</tr>
<tr>
<td>$k_{yz}$</td>
<td>$k_{yz}$ from Table B.1</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
 k_{yy} & = \begin{cases} 
 1 - \frac{0.05\bar{\lambda}_z}{(C_{mLT} - 0.25) \chi_x N_{Ed}/\gamma_{MI}} & \text{if } \bar{\lambda}_z > 0.4, \\
 1 - \frac{0.05\bar{\lambda}_z}{(C_{mLT} - 0.25) \chi_x N_{Ed}/\gamma_{MI}} & \text{if } \bar{\lambda}_z < 0.4 \\
 \end{cases} \\
 k_{yz} & = \begin{cases} 
 1 - \frac{0.1\bar{\lambda}_z}{(C_{mLT} - 0.25) \chi_x N_{Ed}/\gamma_{MI}} & \text{if } \bar{\lambda}_z > 0.4, \\
 1 - \frac{0.1\bar{\lambda}_z}{(C_{mLT} - 0.25) \chi_x N_{Ed}/\gamma_{MI}} & \text{if } \bar{\lambda}_z < 0.4 \\
 \end{cases} 
\end{align*}
\]

for $\bar{\lambda}_z < 0.4$:

\[
k_{yz} = 0.6 + \bar{\lambda}_z \leq 1 - \frac{0.1\bar{\lambda}_z}{(C_{mLT} - 0.25) \chi_x N_{Ed}/\gamma_{MI}}
\]

**Factor** | **Bending axis** | **Points braced in direction**  
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{mny}$</td>
<td>$y-y$</td>
<td>$z-z$</td>
</tr>
<tr>
<td>$C_{mnz}$</td>
<td>$z-z$</td>
<td>$y-y$</td>
</tr>
<tr>
<td>$C_{mLT}$</td>
<td>$y-y$</td>
<td>$y-y$</td>
</tr>
</tbody>
</table>

Table B.3

<table>
<thead>
<tr>
<th>Moment Diagram</th>
<th>Range</th>
<th>$C_{mny}$, $C_{mnz}$, $C_{mLT}$ under loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M$</td>
<td>-1 $\leq \psi \leq 1$</td>
<td>$0.6 + 0.4 \psi \geq 0.4$</td>
</tr>
<tr>
<td>$(-) M_h$</td>
<td>$0 \leq \alpha_h &lt; 1$</td>
<td>$0.2 + 0.8 \alpha_h \geq 0.4$</td>
</tr>
<tr>
<td>$(-) M_i$</td>
<td>$-1 \leq \alpha_i &lt; 0$</td>
<td>$0 \leq \psi \leq 1$</td>
</tr>
<tr>
<td>$\alpha_i = M_i/M_h$</td>
<td>$-1 \leq \alpha_i &lt; 0$</td>
<td>$0 \leq \psi \leq 1$</td>
</tr>
<tr>
<td>$(-) M_h$</td>
<td>$0 \leq \alpha_h &lt; 1$</td>
<td>$-1 \leq \psi \leq 1$</td>
</tr>
<tr>
<td>$(-) M_i$</td>
<td>$-1 \leq \alpha_i &lt; 0$</td>
<td>$0 \leq \psi \leq 1$</td>
</tr>
<tr>
<td>$\alpha_i = M_i/M_h$</td>
<td>$-1 \leq \alpha_i &lt; 0$</td>
<td>$0 \leq \psi \leq 1$</td>
</tr>
</tbody>
</table>

**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: Ly = 5.20 m, Lz = 5.20 m

In the main program screen, click [Diagram].

- 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 6.0 m), 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 6.0 m > 5.20 m, 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 \( g = 18 \text{ kN/m} \).
Variable load \( q = 24 \text{ kN/m} \).
Steel S 355.

Design load:
\[
q_{ed} = 1.35 \times 18.0 + 1.50 \times 24.0 = 60.30 \text{ kN/m}
\]
Maximum design bending moment:
\[
M_{y,ed} = 60.30 \times 5.80^2 / 8 = 253.6 \text{ kNm}
\]
Maximum design shearing force:
\[
V_{z,ed} = 60.30 \times 5.80 / 2 = 174.9 \text{ kN}
\]

In the main program screen, click:

- 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 \( L_l = 5.80 \text{ m} \) (table 6.0m), check \( M_{brd2} \) (parabolic bending moment diagram) to be greater than the maximum bending moment acting on the beam \( M_{y,ed} = 253.6 \text{ kNm} \).

Section IPE 500 is OK.

For lateral buckling length \( 6.0m > 5.80 \text{ m} \), has resistance in bending moment due to lateral buckling \( M_{brd2} = 288 \text{ kNm} \) > 253.6 kNm

From the table above you can check the resistances in shear and bending.
Shear resistance \( V_{c,rdz} = 1227 \text{ kN} \), bending resistance \( M_{c,rdy} = 779 \text{ kNm} \).