Lateral Torsional Buckling (sections class 1-3) - Column Item COx

according to EN 1993-1-1:2005 (EC3)
section and eqn. numbers refer to this code

(Form EC3-LTB_06-04-18.mcd - adopted)

Profile chosen

Profile := "HEA240"

Yield limit

$f_{y.k} := 355 \frac{N}{mm^2}$

Partial safety factor for material

$\gamma_M := 1.1$

Design strength

$f_{y.d} := \frac{f_{y.k}}{\gamma_M}$ $\quad f_{y.d} = 323 \frac{N}{mm^2}$

Young's modulus

$E := 2.1 \cdot 10^5 \frac{N}{mm^2}$

Section Properties

$h_{profile} := 230 \cdot mm$ $\quad I_y := 7763 \cdot cm^4$ $\quad W_y := 675 \cdot cm^3$

$b_{profile} := 240 \cdot mm$ $\quad I_z := 2769 \cdot cm^4$ $\quad W_z := 231 \cdot cm^3$

$A_{profile} := 76.8 \cdot cm^2$ $\quad I_T := 42 \cdot cm^4$ $\quad I_\omega := 328500 \cdot cm^6$

Select CLASS of cross-section

CLASS := 2

Factor from elastic to plastic section modulus
if CLASS = 3 only elastic properties may be used

$\alpha_{pl.y} := wenn(CLASS = 3, 1, 1.14)$ $\quad \alpha_{pl.y} = 1.14$

$\alpha_{pl.z} := wenn(CLASS = 3, 1, 1.50)$ $\quad \alpha_{pl.z} = 1.50$

Design resistances of cross section

$N_{pl.d} := A_{profile} \cdot f_{y.d}$ $\quad N_{pl.d} = 2479\,kN$

$M_{pl.y.d} := \alpha_{pl.y} \cdot W_y \cdot f_{y.d}$ $\quad M_{pl.y.d} = 248\,kNm$

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$$M_{pl.z.d} := \alpha_{pl.z} \cdot W_z \cdot f_{y.d} \qquad M_{pl.z.d} = 112\,\text{kNm}$$

System length - distance of gable ends

$L := 6.00\text{m}$ $\qquad L = 6.00\ \text{m}$

Actions

from excentrically connected beam:
(the moment from offset will be carried to the upper and lower parts of the member to equal parts) $V_{y.Ed} := 200\text{kN}$

Moments about major axis

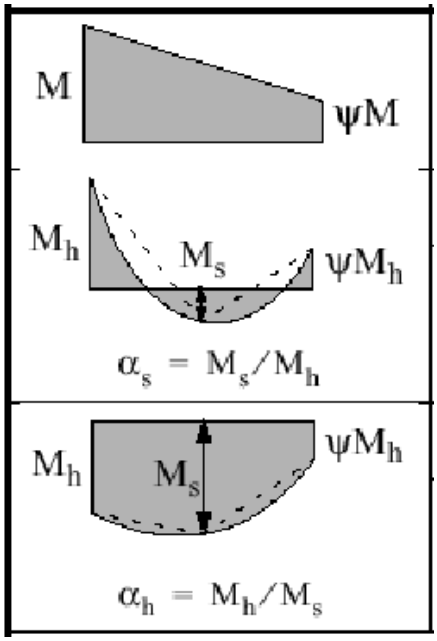

bild1

End moment M_1 (+/-):

$$M_{1.y} := 0.5 \cdot V_{y.Ed} \cdot \left(\frac{h_{profile}}{2} + 20\text{mm} \right)$$

$M_{1.y} = 14\,\text{kNm}$

End moment $M_2 < M_1$ (+/-): $M_{2.y} := 0\text{kNm}$

Relation of end moments

$$\psi_y := \frac{M_{2.y}}{M_{1.y}} \qquad \psi_y = 0.000$$

Moment from transverse loads (positive only)

$M_{3.y} := 150\text{kNm}$

Position of Maximum (dist. from M2) $a_y := 1.5\text{m}$ $\qquad a_y = 1500\,\text{mm}$

$$M_{y.s} := M_{2.y} + \frac{a_y}{L} \cdot \left(M_{1.y} - M_{2.y} \right) + M_{3.y} \qquad M_{y.s} = 153.4\,\text{kNm}$$

Design moment, maximum by absolute value

$$M_{y.Ed} := \max\left(\left|M_{1.y}\right| , \left|M_{2.y}\right| , \left|M_{y.s}\right| \right) \qquad M_{y.Ed} = 153\,\text{kNm}$$

see Table B.3

$$\alpha_{y.s} := \text{wenn}\left(\left|M_{y.s}\right| < \left|M_{1.y}\right| , \frac{M_{y.s}}{M_{1.y}} , 0 \right) \qquad \alpha_{y.s} = 0.000$$

$$\alpha_{y.h} := \text{wenn}\left(\left|M_{y.s}\right| > \left|M_{1.y}\right| , \frac{M_{1.y}}{M_{y.s}} , 0 \right) \qquad \alpha_{y.h} = 0.088$$

Flexural buckling about minor axis

Factor for buckling length $\beta_z := 1.0$

buckling length $L_{cr.z} := \beta_z \cdot L$ $\qquad L_{cr.z} = 6.00\ \text{m}$

Bifurcation load $N_{cr.z.d} := \frac{\pi^2}{L_{cr.z}^2} \cdot \frac{E \cdot I_z}{\gamma_M}$ $\qquad N_{cr.z.d} = 1449\,\text{kN}$

normalised Slenderness $\lambda_{bar.z} := \sqrt{\frac{N_{pl.d}}{N_{cr.z.d}}}$ $\qquad \lambda_{bar.z} = 1.308$

$$\eta_p := \frac{h_{profile}}{b_{profile}} \qquad \eta_p = 0.96$$

Buckling curve (table 6.2) - ONLY rolled sections and t,f =< 40 mm

$$BC_z := \begin{cases} \text{"b"} & \text{if } \eta_p > 1.2 \\ \text{"c"} & \text{if } \eta_p \le 1.2 \end{cases} \qquad BC_z = \text{"c"}$$

Imperfection factor (table 6.1)

$$\alpha_z := \begin{cases} 0.34 & \text{if } BC_z = \text{"b"} \\ 0.49 & \text{if } BC_z = \text{"c"} \end{cases} \qquad \alpha_z = 0.49$$

Reduction factor according to eq. (6.49)

$$\Phi_z := 0.5 \cdot \left[1 + \alpha_z \cdot \left(\lambda_{bar.z} - 0.2 \right) + \lambda_{bar.z}^2 \right] \qquad \Phi_z = 1.627$$

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$$\chi_z := \begin{cases} 1 & \text{if } \lambda_{bar.z} \le 0.2 \\ \dfrac{1}{\Phi_z + \sqrt{\Phi_z^2 - \lambda_{bar.z}^2}} & \text{if } \lambda_{bar.z} > 0.2 \end{cases} \qquad \chi_z = 0.386$$

Design buckling resistance under normal compression

$$N_{b.z.Rd} := \chi_z \cdot N_{pl.d} \qquad N_{b.z.Rd} = 956\,\text{kN}$$

Elastic critical moment for lateral-torsional buckling according to DIN 18800-2 Element 311, eq. 19:

$$c := \sqrt{\frac{I_\omega + 0.039 \cdot L_{cr.z}^2 \cdot I_T}{I_z}} \qquad c = 18.2\,\text{cm}$$

Distance of centroid from attack of transverse forces;
positive, if a torsion about the centroid produces a restoring force

input "t" for top, "m" for middle, "b" for bottom

z := "t"

$$z_p := \begin{cases} -\dfrac{h_{profile}}{2} & \text{if } z = \text{"t"} \\ 0\text{mm} & \text{if } z = \text{"m"} \\ \dfrac{h_{profile}}{2} & \text{if } z = \text{"b"} \end{cases} \qquad z_p = -115\,\text{mm}$$

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Tabelle 10. Momentenbeiwerte ζ

Zeile	Momentenverlauf	ζ
1	max M	1,00
2	max M	1,12
3	max M	1,35
4	max M, $-1 \le \psi \le 1$, ψ max M	1,77 – 0,77 ψ

Moment coefficient according to DIN 18800-2 Table 10

$\zeta := 1.77$

bild3

Critical Moment for LTB (DIN 18800-2 Element 311, eq. 19):

$$M_{cr.y.d} := \zeta \cdot N_{cr.z.d} \cdot \left(\sqrt{c^2 + 0.25 \cdot z_p^{\,2}} + 0.5 \cdot z_p \right) \qquad M_{cr.y.d} = 342\,\text{kNm}$$

normalised slenderness (eq. (6.56))

$$\lambda_{bar.LT} := \sqrt{\frac{M_{pl.y.d}}{M_{cr.y.d}}} \qquad \lambda_{bar.LT} = 0.852$$

Buckling curve (table 6.5) - ONLY rolled sections

$$BCLT := \begin{cases} \text{"b"} & \text{if } \eta_p \le 2 \\ \text{"c"} & \text{if } \eta_p > 2 \end{cases} \qquad BCLT = \text{"b"}$$

Imperfection factor (table 6.3)

$$\alpha_{LT} := \begin{cases} 0.34 & \text{if } BCLT = \text{"b"} \\ 0.49 & \text{if } BCLT = \text{"c"} \end{cases} \qquad \alpha_{LT} = 0.34$$

Reduction factor according to eq. (6.57)

Parameters

$\lambda_{bar.LT.0} := 0.4$

$\beta := 0.75$

According to 6.3.2.2 (4) LTB may be ignored, if λ,LT / λ,LT,0 <=1

$$\frac{\lambda_{bar.LT}}{\lambda_{bar.LT.0}} = 2.129$$

According to 6.3.2.2 (4) LTB may be ignored, if M,Ed / (Mcr.y * (λ,LT,0)^2) <=1

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$$\frac{M_{y.Ed}}{M_{cr.y.d}\cdot\gamma_M}\cdot\frac{1}{\lambda_{bar.LT.0}^{\,2}} = 2.545$$

$$\Phi_{LT} := 0.5\cdot\left[1 + \alpha_{LT}\cdot\left(\lambda_{bar.LT} - \lambda_{bar.LT.0}\right) + \beta\cdot\lambda_{bar.LT}^{\,2}\right] \qquad \Phi_{LT} = 0.849$$

$$\chi_{LT} := \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^{\,2} - \beta\cdot\lambda_{bar.LT}^{\,2}}} \qquad \chi_{LT} = 0.788$$

checking limits

$$\chi_{LT} := \min\left(\chi_{LT}, 1.0, \frac{1}{\lambda_{bar.LT}^{\,2}}\right) \qquad \chi_{LT} = 0.788$$

Table 6.6: Correction factors k_c

Moment distribution	k_c
$\psi = 1$	1,0
$-1 \le \psi \le 1$	$\frac{1}{1{,}33 - 0{,}33\psi}$
	0,94
	0,90
	0,91
	0,86
	0,77
	0,82

Correction factor from table 6.6

$k_c := 0.82$

Modification factor eq. (6.58)

$$f := 1 - 0.5\cdot\left(1 - k_c\right)\cdot\left[1 - 2.0\cdot\left(\lambda_{bar.LT} - 0.8\right)^2\right]$$

$$f := \min(f, 1) \qquad f = 0.91$$

Modified reduction factor

$$\chi_{LT.mod} := \min\left(\frac{\chi_{LT}}{f}, 1\right) \qquad \chi_{LT.mod} = 0.866$$

bild2

Design buckling resistance in bending

$$M_{b.Rd} := \chi_{LT.mod}\cdot M_{pl.y.d} \qquad M_{b.Rd} = 215\,kNm$$

$$k_{zy} := 1 \qquad k_{yy} := 1$$

Stability check according to eq. (6.61)

utilisation of flexural buckling about major axis by N

utilisation of LTB by My $\eta_{1.My} := \frac{M_{y.Ed}}{M_{b.Rd}} \cdot k_{yy}$ $\eta_{1.My} = 0.713$

Stability check according to eq. (6.62)

utilisation of LTB by My $\eta_{2.My} := \frac{M_{y.Ed}}{M_{b.Rd}} \cdot k_{zy}$ $\eta_{2.My} = 0.713$

Utilisation in cross section check (without interaction):

utilisation by My: $\eta_{My} := \frac{M_{y.Ed}}{M_{pl.y.d}}$ $\eta_{My} = 0.618$

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