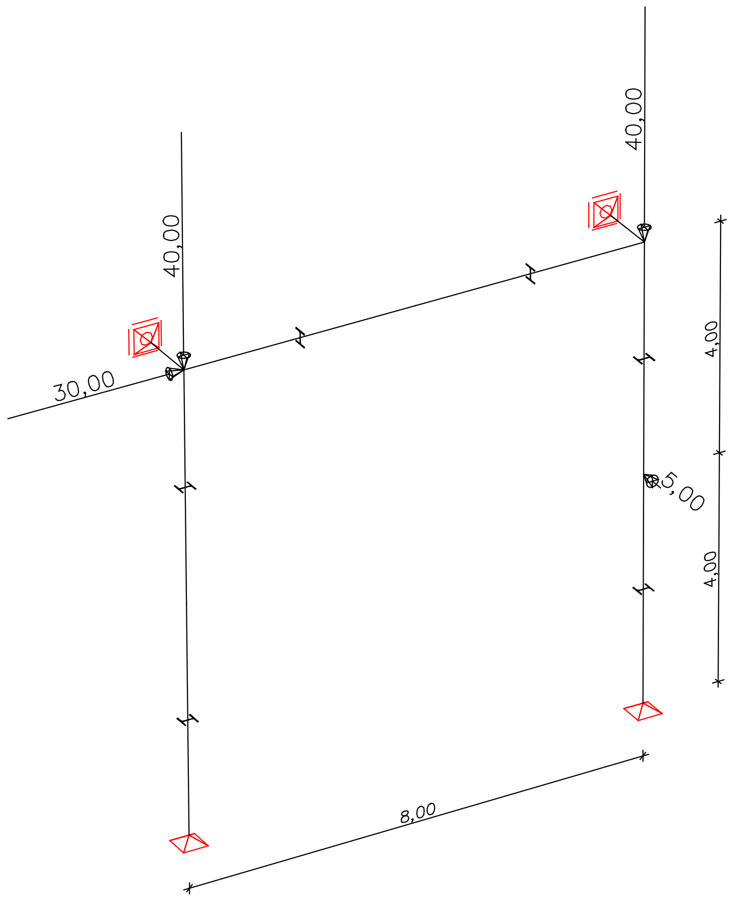
Rahmenstiel mit zweiachsiger Biegung und Normalkraft

Beispiel 7c aus:
Nachweispraxis Biegeknicken und Biegedrillknicknachweis, Jürgen Meister,
Verlag Ernst & Sohn 2002

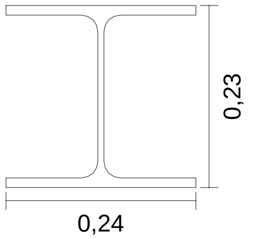


Es wird der rechte Rahmenstil nachgewiesen.

γ_M = 1,00 (Wird im Beispiel zur Vereinfachung angenommen)

Protokollausdruck:

Querschnitt: HEA 240



h = 230,0 mm
b = 240,0 mm
s = 7,5 mm
t = 12,0 mm
r = 21,0 mm

$A = 76{,}8\ cm^2$ $I_y = 7760{,}0\ cm^4$ $I_z = 2770{,}0\ cm^4$

$I_T = 41{,}7\ cm^4$ $I_\omega = 328500\ cm^6$

$i_z = 6{,}01\ cm$ $i_p = 11{,}71\ cm$ $i_M = 11{,}71\ cm$

Material: S235

$f_{y,k} = 240\ N/mm^2$

E-Modul = 210000 N/mm²

G-Modul = 81000 N/mm²

$\gamma_M = 1{,}00$

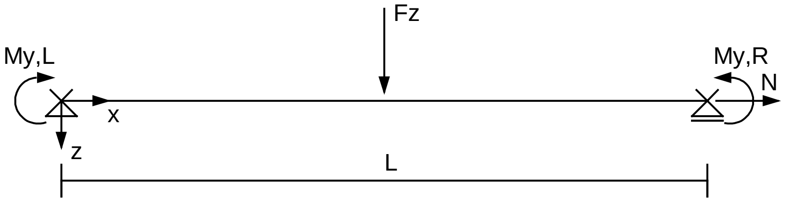
Einwirkungen in z-Richtung

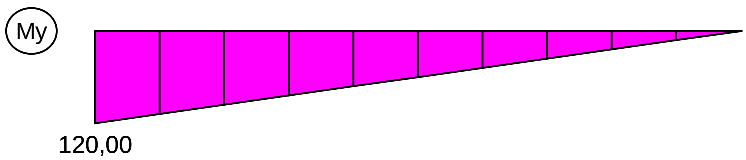
$L = 8{,}00\ m$ $N_d = -70{,}00\ kN$ $F_{z,d} = 0{,}00\ kN$

$M_{y,d,links} = 120{,}00\ kNm$ $M_{y,d,rechts} = 0{,}00\ kNm$

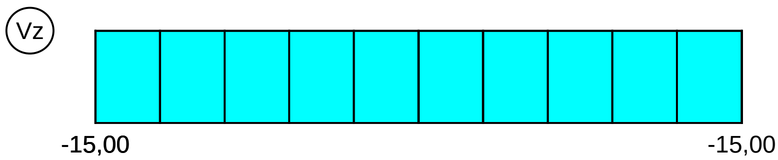
Lastangriffspunkt Schubmittelpunkt $\Rightarrow$ $z_p = 0{,}00\ cm$

Die Stabenden sind Gabelgelagert.

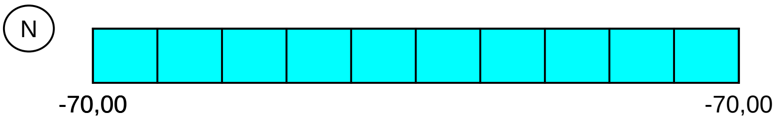




Max My,d = 120,00 kNm



Max Vz,d = -15,00 kN

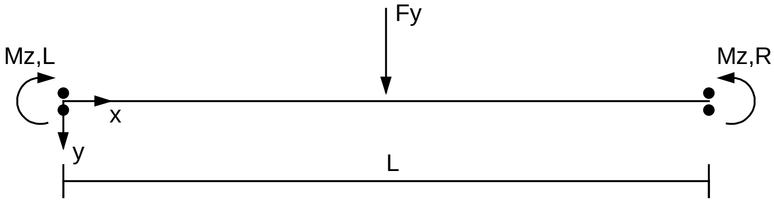


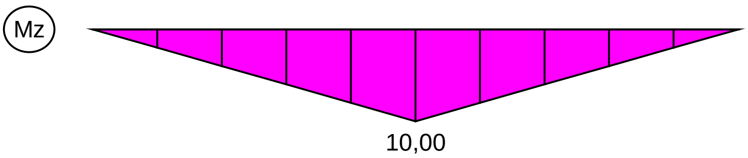
Min N,d = -70,00 kN

Einwirkungen in y-Richtung

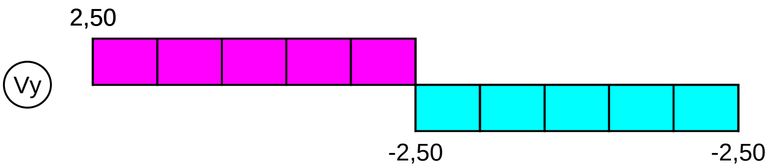
L = 8,00 m $F_{y,d}$ = 5,00 kN

$M_{z,d,links}$ = 0,00 kNm; $M_{z,d,rechts}$ = 0,00 kNm

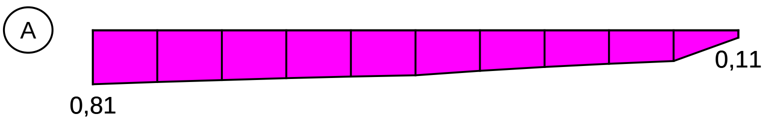




Max Mz,d = 10,00 kNm



Max Vy,d = 2,50 kN, Min Vy,d = -2,50 kN



Max Ausnutzung = 0,81

Knicklast $N_{Ki,z,d}$

$$N_{Ki,z,d} = \pi^2 \cdot (E \cdot I_z / \gamma_M) / L^2$$

mit I_z = 2770,0 cm^4 E = 210000 N/mm^2

L = 8,00 m γ_M = 1,0

$N_{Ki,z,d}$ = 897,05 kN

Verzweigungslastfaktor $\eta_{Ki,y}$ für $M_{Ki,y,d}$

$\eta_{Ki,y}$ = 3,03

Maßgebender Nachweis an der Stelle x = 0,00 m

Schnittgrößen:

N_d = -70,00 kN

$V_{z,d}$ = -15,00 kN

$M_{y,d}$ = 120,00 kNm

$V_{y,d}$ = 2,50 kN

$M_{z,d}$ = 0,00 kNm

Plastische Schnittgrößen:

$N_{pl,k} = \pm$ 1843,20 kN $N_{pl,d} = \pm$ 1843,20 kN

$V_{pl,z,k} = \pm$ 214,08 kN $V_{pl,z,d} = \pm$ 214,08 kN

$M_{pl,y,k} = \pm$ 178,71 kNm $M_{pl,y,d} = \pm$ 178,71 kNm

$V_{pl,y,k} = \pm$ 798,13 kN $V_{pl,y,d} = \pm$ 798,13 kN

$M_{pl,z,k} = \pm$ 84,41 kNm $M_{pl,z,d} = \pm$ 84,41 kNm

Abminderungsfaktor κ_z

$$\bar{\lambda}_{k,z} = \sqrt{N_{pl,d} / N_{Ki,z,d}}$$

mit $N_{pl,d}$ = 1843,20 kN $N_{Ki,z,d}$ = 897,05 kN

$\bar{\lambda}_{k,z}$ = 1,43 > 0,2

$$\kappa_z = 1/(k + \sqrt{k^2 - \bar{\lambda}_{k,z}^2}) \qquad k = 0{,}5 \cdot (1 + \alpha \cdot (\bar{\lambda}_{k,z} - 0{,}2) + \bar{\lambda}_{k,z}^2)$$

Knickspannungslinie c $\Rightarrow \alpha$ = 0,49

k = 1,83

κ_z = 0,34

Biegedrillknickmoment $M_{Ki,y,d}$

$$M_{Ki,y,d} = \frac{\eta_{Ki,y} \cdot M_{y,d}}{\gamma_M}$$

mit η_{Ki} = 3,03 $M_{y,d}$ = 120,00 kNm γ_M = 1,0

$M_{Ki,yd}$ = 363,60 kNm

Abminderungsfaktor κ_M

$\bar{\lambda}_M = \sqrt{M_{pl,y,d} / M_{Ki,y,d}}$

mit $M_{pl,y,d}$ = 178,71 kNm $M_{Ki,y,d}$ = 363,60 kNm

$\bar{\lambda}_M$ = 0,70 > 0,4

$\kappa_M = (1/(1+\bar{\lambda}_M^{2\cdot n}))^{1/n}$

Beiwert für gewalzte Träger n = 2,50

κ_M = 0,94

Beiwert k_y

$k_y = 1 - N_d / (\kappa_z \cdot N_{pl,d}) \cdot a_y \le 1 \qquad a_y = 0{,}15 \cdot \bar{\lambda}_{k,z} \cdot \beta_{M,y} - 0{,}15 \le 0{,}9$

mit N_d = 70,00 kN $N_{pl,d}$ = 1843,20 kN

κ_z = 0,34 $\bar{\lambda}_{k,z}$ = 1,43

Momentenverhältnis $\psi_{,y}$ = 0,00 $\Rightarrow$ $\beta_{M,y}$ = 1,80

a_y = 0,24

k_y = 0,97

Beiwert k_z

$k_z = 1 - N_d / (\kappa_z \cdot N_{pl,d}) \cdot a_z \le 1{,}5 \qquad a_z = \bar{\lambda}_{k,z} \cdot (2 \cdot \beta_{M,z} - 4) + (\alpha_{pl,z} - 1) \le 0{,}8$

mit N_d = 70,00 kN $N_{pl,d}$ = 1843,20 kN $\alpha_{pl,z}$ = 1,52

κ_z = 0,34 $\bar{\lambda}_{k,z}$ = 1,43

Momentenverhältnis $\psi_{,z}$ = 1,00 $\Rightarrow$ $\beta_{M,z}$ = 1,40

a_z = -1,20

k_z = 1,13

Nachweis

$$\frac{N_d}{\kappa_z \cdot N_{pl,d}} + \frac{M_{y,d}}{\kappa_M \cdot M_{ply,d}} \cdot k_y + \frac{M_{z,d}}{M_{plz,d}} \cdot k_z \le 1$$

N_d = 70,00 kN $M_{y,d}$ = 120,00 kNm $M_{z,d}$ = 0,00 kNm

$N_{pl,d}$ = 1843,20 kN $M_{ply,d}$ = 178,71 kNm $M_{plz,d}$ = 84,41 kNm

κ_z = 0,34 κ_M = 0,94 k_y = 0,97 k_z = 1,13

0,11 + 0,70 + 0,00 = 0,81 ≤ 1.0 Nachweis erfüllt !

Nachweis an der Stelle x = 4,00 m

Schnittgrößen:

N_d = -70,00 kN

$V_{z,d}$ = -15,00 kN

$M_{y,d}$ = 60,00 kNm

$V_{y,d}$ = -2,50 kN

$M_{z,d}$ = 10,00 kNm

Plastische Schnittgrößen:

$N_{pl,k} = \pm$ 1843,20 kN $N_{pl,d} = \pm$ 1843,20 kN

$V_{pl,z,k} = \pm$ 214,08 kN $V_{pl,z,d} = \pm$ 214,08 kN

$M_{pl,y,k} = \pm$ 178,71 kNm $M_{pl,y,d} = \pm$ 178,71 kNm

$V_{pl,y,k} = \pm$ 798,13 kN $V_{pl,y,d} = \pm$ 798,13 kN

$M_{pl,z,k} = \pm$ 84,41 kNm $M_{pl,z,d} = \pm$ 84,41 kNm

Abminderungsfaktor κ_z

$$\bar{\lambda}_{k,z} = \sqrt{N_{pl,d} / N_{Ki,z,d}}$$

mit $N_{pl,d}$ = 1843,20 kN $N_{Ki,z,d}$ = 897,05 kN

$\bar{\lambda}_{k,z}$ = 1,43 > 0,2

$$\kappa_z = 1/(k + \sqrt{k^2 - \bar{\lambda}_{k,z}^2}) \qquad k = 0,5 \cdot (1 + \alpha \cdot (\bar{\lambda}_{k,z} - 0,2) + \bar{\lambda}_{k,z}^2)$$

Knickspannungslinie c $\Rightarrow \alpha$ = 0,49

k = 1,83

κ_z = 0,34

Biegedrillknickmoment $M_{Ki,yd}$

$$M_{Ki,y,d} = \frac{\eta_{Ki} \cdot M_{y,d}}{\gamma_M}$$

mit η_{Ki} = 3,03 $M_{y,d}$ = 60,00 kNm γ_M = 1,0

$M_{Ki,yd}$ = 181,80 kNm

Abminderungsfaktor κ_M

$\bar{\lambda}_M = \sqrt{M_{pl,y,d} / M_{Ki,y,d}}$

mit $M_{pl,y,d}$ = 178,71 kNm $M_{Ki,y,d}$ = 181,80 kNm

$\bar{\lambda}_M$ = 0,99 > 0,4

$\kappa_M = (1/(1+\bar{\lambda}_M^{2\cdot n}))^{1/n}$

Beiwert für gewalzte Träger n = 2,50

κ_M = 0,76

Beiwert k_y

$k_y = 1 - N_d / (\kappa_z \cdot N_{pl,d}) \cdot a_y \leq 1 \qquad a_y = 0{,}15 \cdot \bar{\lambda}_{k,z} \cdot \beta_{M,y} - 0{,}15 \leq 0{,}9$

mit N_d = 70,00 kN $N_{pl,d}$ = 1843,20 kN

κ_z = 0,34 $\bar{\lambda}_{k,z}$ = 1,43

Momentenverhältnis $\psi_{,y}$ = 0,00 $\Rightarrow$ $\beta_{M,y}$ = 1,80

a_y = 0,24

k_y = 0,97

Beiwert k_z

$k_z = 1 - N_d / (\kappa_z \cdot N_{pl,d}) \cdot a_z \leq 1{,}5 \qquad a_z = \bar{\lambda}_{k,z} \cdot (2 \cdot \beta_{M,z} - 4) + (\alpha_{pl,z} - 1) \leq 0{,}8$

mit N_d = 70,00 kN $N_{pl,d}$ = 1843,20 kN $\alpha_{pl,z}$ = 1,52

κ_z = 0,34 $\bar{\lambda}_{k,z}$ = 1,43

Momentenverhältnis $\psi_{,z}$ = 1,00 $\Rightarrow$ $\beta_{M,z}$ = 1,40

a_z = -1,20

k_z = 1,13

Nachweis

$$\frac{N_d}{\kappa_z \cdot N_{pl,d}} + \frac{M_{y,d}}{\kappa_M \cdot M_{ply,d}} \cdot k_y + \frac{M_{z,d}}{M_{plz,d}} \cdot k_z \leq 1$$

N_d = 70,00 kN $M_{y,d}$ = 60,00 kNm $M_{z,d}$ = 10,00 kNm

$N_{pl,d}$ = 1843,20 kN $M_{ply,d}$ = 178,71 kNm $M_{plz,d}$ = 84,41 kNm

κ_z = 0,34 κ_M = 0,76 k_y = 0,97 k_z = 1,13

0,11 + 0,43 + 0,13 = 0,67 $\leq$ 1.0 Nachweis erfüllt !