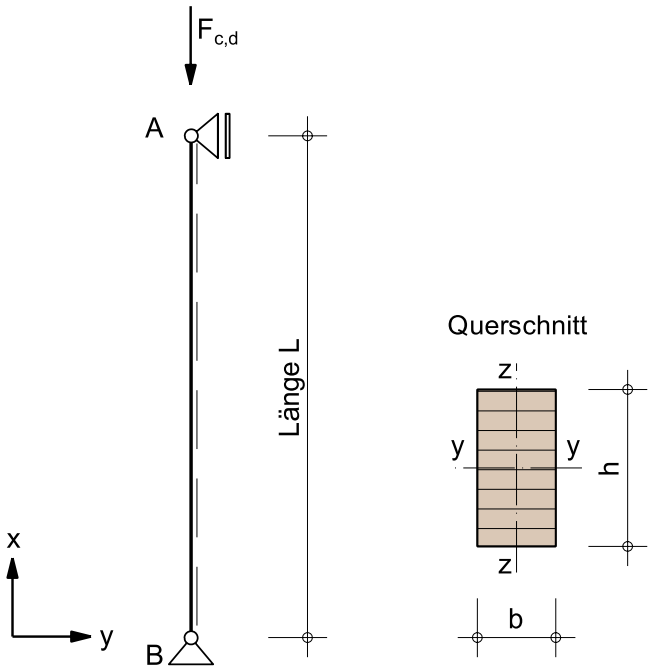
Nachweis Druckstab & Stütze

nach DIN EN 1995-1-1:2010-12 und Nationalem Anhang DIN EN 1995-1-1/NA:2013-08

Anschluss & Geometrie

Pendelstütze

Holzart:	Brettschichtholz
Festigkeit:	GL24c
Rohdichte ρ_k:	365 kg/m^3
Breite b:	160 mm
Höhe h:	200 mm
Länge L:	3.00 m

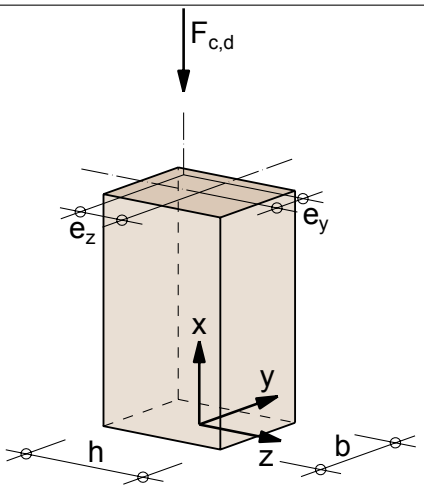


Beanspruchung

$F_{c,d}$:	95.00 kN
Nutzungsklasse:	NKL 1
KLED:	mittel
Ausmitte e_y:	50 mm
Ausmitte e_z:	-50 mm
$F_{c,d,fi}$:	57.00 kN
Brandschutz:	R30
Abbrand:	4-seitiger Abbrand (oben, unten, links, rechts)

Das Eigengewicht wurde mit ρ_{mean} = 5.00 kN/m³ (entspricht G_k = 0.48 kN) berücksichtigt.

Nachweis:	0.98 $\leq$ 1.00	**Nachweis erfüllt**



Bemessung

Schnittgrößen

Schnittgrößen am Auflager A (x = L = 3.00 m)

$$N_d = -F_{c,d} - 1.35 * G_k = -95.00 - 1.35 * 0.48 = -95.65 \text{ kN}$$

$$V_{z,d} = \frac{-F_{c,d} * e_z}{L} = \frac{-95.00 * -50}{3.00} * 10^{-3} = 1.58 \text{ kN}$$

$$V_{y,d} = \frac{-F_{c,d} * e_y}{L} = \frac{-95.00 * 50}{3.00} * 10^{-3} = -1.58 \text{ kN}$$

$M_{y,d} = -F_{c,d} * e_z = -95.00 * -50 * 10^{-3} = 4.75$ kNm

$M_{z,d} = -F_{c,d} * e_y = -95.00 * 50 * 10^{-3} = -4.75$ kNm

Festigkeits- und Steifigkeitswerte

$f_{c,0,k}$ =	21.50 N/mm²	$E_{0,mean}$ =	11000 N/mm²	k_{mod} :	0.80
$f_{m,k}$ =	24.00 N/mm²	$E_{0,05}$ =	9100 N/mm²	γ_M :	1.30

$$k_{h,z} = min \begin{cases} \left(\frac{600}{h}\right)^{0.1} = \left(\frac{600}{200}\right)^{0.1} = 1.10 \\ 1.1 \end{cases}$$

$$f_{c,0,d} = k_{mod} * \frac{f_{c,0,k}}{\gamma_M} = 0.80 * \frac{21.50}{1.30} = 13.23 \text{ N/mm}^2$$

$$f_{m,y,d} = k_{mod} * \frac{k_{h,z} * f_{m,k}}{\gamma_M} = 0.80 * \frac{1.10 * 24.00}{1.30} = 16.25 \text{ N/mm}^2$$

$$f_{m,z,d} = k_{mod} * \frac{f_{m,k}}{\gamma_M} = 0.80 * \frac{24.00}{1.30} = 14.77 \text{ N/mm}^2$$

Querschnittswerte

$$A = b * h = 160 * 200 * 10^{-2} = 320.00 \text{ cm}^2$$

$$W_y = \frac{b * h^2}{6} = \frac{160 * 200^2}{6} * 10^{-3} = 1066.67 \text{ cm}^3$$

$$W_z = \frac{h * b^2}{6} = \frac{200 * 160^2}{6} * 10^{-3} = 853.33 \text{ cm}^3$$

$$i_y = \frac{h}{\sqrt{12}} = \frac{200}{\sqrt{12}} = 57.74 \text{ mm}$$

$$i_z = \frac{b}{\sqrt{12}} = \frac{160}{\sqrt{12}} = 46.19 \text{ mm}$$

Schlankheit und Knicklängenbeiwerte

Stablänge $s = L = 3.00$ m

Knicklängenbeiwert $\beta = 1.00$ (DIN EN 1995-1-1/NA:2013-08, Tabelle NA. 24)

Ersatzstablänge $l_{ef} = \beta * s = 1.00 * 3.00 = 3.00$ m

Knicklänge $s_{ky} = l_{ef} = 3.00$ m

Knicklänge $s_{kz} = l_{ef} = 3.00$ m

Schlankheit

$$\lambda_y = \frac{s_{ky}}{i_y} = \frac{3.00 * 10^3}{57.74} = 51.96$$

$$\lambda_z = \frac{s_{kz}}{i_z} = \frac{3.00 * 10^3}{46.19} = 64.95$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} * \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} = \frac{51.96}{\pi} * \sqrt{\frac{21.50}{9100}} = 0.80 \quad \text{(Gl. 6.21)}$$

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} * \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} = \frac{64.95}{\pi} * \sqrt{\frac{21.50}{9100}} = 1.00 \quad \text{(Gl. 6.22)}$$

Knickbeiwerte

Imperfektionsbeiwert $\beta_c = 0.10$ (Gl. 6.29)

$$k_y = 0.5\left(1 + \beta_c * (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2\right) = 0.5\left(1 + 0.10 * (0.80 - 0.3) + 0.80^2\right) = 0.85 \quad \text{(Gl. 6.27)}$$

$$k_z = 0.5\left(1 + \beta_c * (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2\right) = 0.5\left(1 + 0.10 * (1.00 - 0.3) + 1.00^2\right) = 1.04 \quad \text{(Gl. 6.28)}$$

$$k_{c,y} = \frac{1}{k_y + \sqrt{k_y^2 - \lambda_{rel,y}^2}} = \frac{1}{0.85 + \sqrt{0.85^2 - 0.80^2}} = 0.88 \quad \text{(Gl. 6.25)}$$

$$k_{c,z} = \frac{1}{k_z + \sqrt{k_z^2 - \lambda_{rel,z}^2}} = \frac{1}{1.04 + \sqrt{1.04^2 - 1.00^2}} = 0.75 \quad \text{(Gl. 6.26)}$$

Beanspruchung

$$\sigma_{c,0,d} = \frac{N_d}{A} * 10 = \frac{-95.65}{320.00} * 10 = -2.99 \text{ N/mm}^2$$

$$\sigma_{m,y,d} = \frac{M_{y,d}}{W_y} * 10^3 = \frac{4.75}{1066.67} * 10^3 = 4.45 \text{ N/mm}^2$$

$$\sigma_{m,z,d} = \frac{M_{z,d}}{W_z} * 10^3 = \frac{-4.75}{853.33} * 10^3 = -5.57 \text{ N/mm}^2$$

Nachweise

Stabilitätsnachweis

Beiwert $k_m = 0.70$

$$\frac{|\sigma_{c,0,d}|}{k_{c,y} * f_{c,0,d}} + \frac{|\sigma_{m,y,d}|}{f_{m,y,d}} + k_m * \frac{|\sigma_{m,z,d}|}{f_{m,z,d}} = \frac{|-2.99|}{0.88 * 13.23} + \frac{|4.45|}{16.25} + 0.70 * \frac{|-5.57|}{14.77}$$
$$= 0.26 + 0.27 + 0.70 * 0.38$$
$$= 0.79 \quad \text{(Gl. 6.23)}$$

$$\frac{|\sigma_{c,0,d}|}{k_{c,z} * f_{c,0,d}} + k_m * \frac{|\sigma_{m,y,d}|}{f_{m,y,d}} + \frac{|\sigma_{m,z,d}|}{f_{m,z,d}} = \frac{|-2.99|}{0.75 * 13.23} + 0.70 * \frac{|4.45|}{16.25} + \frac{|-5.57|}{14.77}$$
$$= 0.3 + 0.70 * 0.27 + 0.38$$
$$= 0.87$$

(Gl. 6.24)

Stabilitätsnachweis:	$0.87 \leq 1.00$	**Nachweis erfüllt**

brandschutztechnische Bemessung

Bemessungsverfahren nach DIN 1995-1-2:2010-12 nach der Methode mit reduziertem Querschnitt

Schnittgrößen

Schnittgrößen am Auflager A (x = L = 3.00 m)

$N_{d,fi} = -F_{c,d,fi} - 1.00 * G_k = -57.00 - 1.00 * 0.48 = -57.48$ kN

$V_{z,d,fi} = -F_{c,d,fi} * \frac{e_z}{L} = -57.00 * \frac{-50}{3.00} * 10^{-3} = 0.95$ kN

$V_{y,d,fi} = -F_{c,d,fi} * \frac{e_y}{L} = -57.00 * \frac{50}{3.00} * 10^{-3} = -0.95$ kN

$M_{y,d,fi} = -F_{c,d,fi} * e_z = -57.00 * -50 * 10^{-3} = 2.85$ kNm

$M_{z,d,fi} = -F_{c,d,fi} * e_y = -57.00 * 50 * 10^{-3} = -2.85$ kNm

Festigkeits- und Steifigkeitswerte

$k_{mod,fi}$: 1.00 k_{fi} : 1.15 $\gamma_{M,fi}$: 1.00

$f_{c,0,d,fi} = k_{mod,fi} * k_{fi} * \frac{f_{c,0,k}}{\gamma_{M,fi}} = 1.00 * 1.15 * \frac{21.50}{1.00} = 24.73$ N/mm²

$k_{h,z} = min \begin{cases} \left(\frac{600}{h}\right)^{0.1} = \left(\frac{600}{200}\right)^{0.1} = 1.10 \\ 1.1 \end{cases}$

$f_{m,y,d,fi} = k_{mod,fi} * k_{fi} * \frac{k_{h,z} * f_{m,k}}{\gamma_M, fi} = 1.00 * 1.15 * \frac{1.10 * 24.00}{1.00} = 30.36$ N/mm²

$f_{m,z,d,fi} = k_{mod,fi} * k_{fi} * \frac{f_{m,k}}{\gamma_M, fi} = 1.00 * 1.15 * \frac{24.00}{1.00} = 27.60$ N/mm²

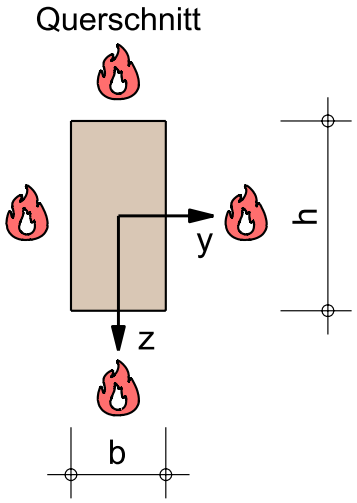
Querschnittswerte

Abbrandrate β_n: 0.70 mm/min d_0 : 7.00 mm Branddauer t : 30.00 min

$d_{char,n} = \beta_n * t = 0.70 * 30.00 = 21.00$ mm (DIN EN 1995-1-2:2010-12, Gl. 3.2)

$d_{ef} = d_{char,n} + k_0 * d_0 = 21.00 + 1.00 * 7.00 = 28.00$ mm (DIN EN 1995-1-2:2010-12, Gl. 4.1)

Brandschutz: R30, 4-seitiger Abbrand



$b_t = b - 2 * d_{ef} = 160 - 2 * 28.00 = 104.00$ mm

$h_t = h - 2 * d_{ef} = 200 - 2 * 28.00 = 144.00$ mm

$A_r = b_t * h_t = 104.00 * 144.00 * 10^{-2} = 149.76$ cm²

$W_{y,r} = \frac{b_t * h_t^2}{6} = \frac{104.00 * 144.00^2}{6} * 10^{-3} = 359.42$ cm³

$W_{z,r} = \frac{h_t * b_t^2}{6} = \frac{144.00 * 104.00^2}{6} * 10^{-3} = 259.58$ cm³

$i_{y,r} = \frac{h_t}{\sqrt{12}} = \frac{144.00}{\sqrt{12}} = 41.57$ mm

$i_{z,r} = \frac{b_t}{\sqrt{12}} = \frac{104.00}{\sqrt{12}} = 30.02$ mm

Schlankheit und Knicklängenbeiwerte

Schlankheit

$\lambda_{y,fi} = \frac{s_{ky}}{i_{y,r}} = \frac{3.00 * 10^3}{41.57} = 72.17$

$\lambda_{z,fi} = \frac{s_{kz}}{i_{z,r}} = \frac{3.00 * 10^3}{30.02} = 99.93$

$\lambda_{rel,y,fi} = \frac{\lambda_{y,fi}}{\pi} * \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} = \frac{72.17}{\pi} * \sqrt{\frac{21.50}{9100}} = 1.12$ (Gl. 6.21)

$\lambda_{rel,z,fi} = \frac{\lambda_{z,fi}}{\pi} * \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} = \frac{99.93}{\pi} * \sqrt{\frac{21.50}{9100}} = 1.55$ (Gl. 6.22)

Imperfektionsbeiwert $\beta_c = 0.10$ (Gl. 6.29)

Knickbeiwerte

$k_{y,fi} = 0.5\left(1 + \beta_c * (\lambda_{rel,y,fi} - 0.3) + \lambda_{rel,y,fi}^2\right) = 0.5\left(1 + 0.10 * (1.12 - 0.3) + 1.12^2\right) = 1.17$ (Gl. 6.27)

$k_{z,fi} = 0.5\left(1 + \beta_c * (\lambda_{rel,z,fi} - 0.3) + \lambda_{rel,z,fi}^2\right) = 0.5\left(1 + 0.10 * (1.55 - 0.3) + 1.55^2\right) = 1.76$ (Gl. 6.28)

$k_{c,y,fi} = \frac{1}{k_{y,fi} + \sqrt{k_{y,fi}^2 - \lambda_{rel,y,fi}^2}} = \frac{1}{1.17 + \sqrt{1.17^2 - 1.12^2}} = 0.66$ (Gl. 6.25)

$k_{c,z,fi} = \frac{1}{k_{z,fi} + \sqrt{k_{z,fi}^2 - \lambda_{rel,z,fi}^2}} = \frac{1}{1.76 + \sqrt{1.76^2 - 1.55^2}} = 0.39$ (Gl. 6.26)

Beanspruchung

$$\sigma_{c,0,d,fi} = \frac{N_{d,fi}}{A_r} = \frac{-57.48}{149.76} * 10 = -3.84 \text{ N/mm}^2$$

$$\sigma_{m,y,d,fi} = \frac{M_{y,d,fi}}{W_{y,r}} = \frac{2.85}{359.42} * 10^3 = 7.93 \text{ N/mm}^2$$

$$\sigma_{m,z,d,fi} = \frac{M_{z,d,fi}}{W_{z,r}} = \frac{-2.85}{259.58} * 10^3 = -10.98 \text{ N/mm}^2$$

Nachweise

Stabilitätsnachweis

Beiwert $k_m = 0.70$

$$\frac{|\sigma_{c,0,d,fi}|}{k_{c,y,fi} * f_{c,0,d,fi}} + \frac{|\sigma_{m,y,d,fi}|}{f_{m,y,d,fi}} + k_m * \frac{|\sigma_{m,z,d,fi}|}{f_{m,z,d,fi}} = \frac{|-3.84|}{0.66 * 24.73} + \frac{|7.93|}{30.36} + 0.70 * \frac{|-10.98|}{27.60}$$
$$= 0.24 + 0.26 + 0.70 * 0.4$$
$$= 0.77 \quad \text{(Gl. 6.23)}$$

$$\frac{|\sigma_{c,0,d,fi}|}{k_{c,z,fi} * f_{c,0,d,fi}} + k_m * \frac{|\sigma_{m,y,d,fi}|}{f_{m,y,d,fi}} + \frac{|\sigma_{m,z,d,fi}|}{f_{m,z,d,fi}} = \frac{|-3.84|}{0.39 * 24.73} + 0.70 * \frac{|7.93|}{30.36} + \frac{|-10.98|}{27.60}$$
$$= 0.4 + 0.26 + 0.70 * 0.4$$
$$= 0.98 \quad \text{(Gl. 6.24)}$$

Stabilitätsnachweis im Brandfall:	$0.98 \leq 1.00$	**Nachweis erfülltt**

verwendete Normen

DIN EN 14080:2013-09	Holzbauwerke - Brettschichtholz und Balkenschichtholz
DIN EN 1995-1-1:2010-12	Eurocode 5: Bemessung und Konstruktion von Holzbauteilen, Teil 1-1
DIN EN 1995-1-1/A2:2014-07	Änderung A2 zu EC5
DIN EN 1995-1-1/NA:2013-08	Nationaler Anhang (EC5)