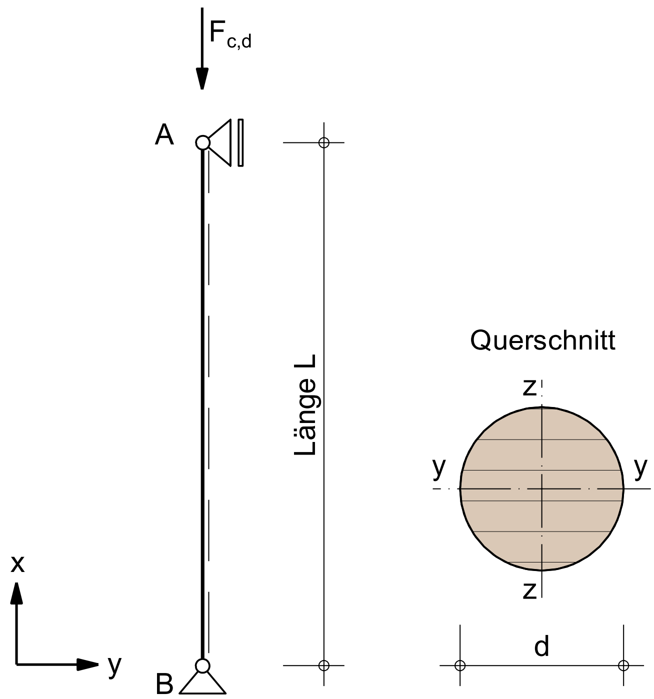
Nachweis Druckstab & Stütze

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:	GL24h
Rohdichte ρ_k:	385 kg/m^3
Durchmesser d:	160 mm
Länge L:	2.80 m

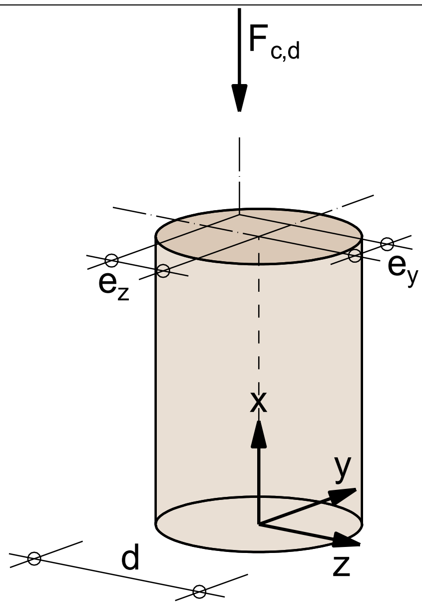


Beanspruchung

$F_{c,d}$:	35.00 kN
Nutzungsklasse:	NKL 1
KLED:	mittel
Ausmitte e_y:	50 mm
Ausmitte e_z:	-50 mm
$F_{c,d,fi}$:	21.00 kN
Brandschutz:	R30
Abbrand:	4-seitiger Abbrand (oben, unten, links, rechts)

Das Eigengewicht wurde mit ρ_{mean} = 5.00 kN/m³ (entspricht $G_k = 0.28$ kN) berücksichtigt.

Nachweis:	0.97 $\leq$ 1.00	**Nachweis erfüllt**



Bemessung

Schnittgrößen

Schnittgrößen am Auflager A (x = L = 2.80 m)

$$N_d = -F_{c,d} - 1.35 * G_k = -35.00 - 1.35 * 0.28 = -35.38 \text{ kN}$$

$$V_{z,d} = \frac{-F_{c,d} * e_z}{L} = \frac{-35.00 * -50}{2.80} * 10^{-3} = 0.63 \text{ kN}$$

$$V_{y,d} = \frac{-F_{c,d} * e_y}{L} = \frac{-35.00 * 50}{2.80} * 10^{-3} = -0.63 \text{ kN}$$

$$M_{y,d} = -F_{c,d} * e_z = -35.00 * -50 * 10^{-3} = 1.75 \text{ kNm}$$

$M_{z,d} = -F_{c,d} * e_y = -35.00 * 50 * 10^{-3} = -1.75$ kNm

Festigkeits- und Steifigkeitswerte

$f_{c,0,k}$ =	24.00 N/mm²	$E_{0,mean}$ =	11500 N/mm²	k_{mod} :	0.80
$f_{m,k}$ =	24.00 N/mm²	$E_{0,05}$ =	9600 N/mm²	γ_M :	1.30

$$f_{c,0,d} = k_{mod} * \frac{f_{c,0,k}}{\gamma_M} = 0.80 * \frac{24.00}{1.30} = 14.77 \text{ N/mm}^2$$

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

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

Querschnittswerte

$$A = \frac{\pi * d^2}{4} = \frac{\pi * 160^2}{4} * 10^{-2} = 201.06 \text{ cm}^2$$

$$W_y = \frac{\pi * d^3}{32} = \frac{\pi * 160^3}{32} * 10^{-3} = 402.12 \text{ cm}^3$$

$$W_z = \frac{\pi * d^3}{32} = \frac{\pi * 160^3}{32} * 10^{-3} = 402.12 \text{ cm}^3$$

$$i_y = \frac{d}{4} = \frac{160}{4} = 40.00 \text{ mm}$$

$$i_z = \frac{d}{4} = \frac{160}{4} = 40.00 \text{ mm}$$

Schlankheit und Knicklängenbeiwerte

Stablänge $s = L = 2.80$ m

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

Ersatzstablänge $l_{ef} = \beta * s = 1.00 * 2.80 = 2.80$ m

Knicklänge $s_{ky} = l_{ef} = 2.80$ m

Knicklänge $s_{kz} = l_{ef} = 2.80$ m

Schlankheit

$$\lambda_y = \frac{s_{ky}}{i_y} = \frac{2.80 * 10^3}{40.00} = 70.00$$

$$\lambda_z = \frac{s_{kz}}{i_z} = \frac{2.80 * 10^3}{40.00} = 70.00$$

$$\lambda_{rel,y} = \frac{\lambda_y}{\pi} * \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} = \frac{70.00}{\pi} * \sqrt{\frac{24.00}{9600}} = 1.11 \quad \text{(Gl. 6.21)}$$

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} * \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} = \frac{70.00}{\pi} * \sqrt{\frac{24.00}{9600}} = 1.11 \quad \text{(Gl. 6.22)}$$

Knickbeiwerte

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

$$k_y = 0.5\left(1 + \beta_c * (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2\right) = 0.5\left(1 + 0.10 * (1.11 - 0.3) + 1.11^2\right) = 1.16 \quad \text{(Gl. 6.27)}$$

$$k_z = 0.5\left(1 + \beta_c * (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2\right) = 0.5\left(1 + 0.10 * (1.11 - 0.3) + 1.11^2\right) = 1.16 \quad \text{(Gl. 6.28)}$$

$$k_{c,y} = \frac{1}{k_y + \sqrt{k_y^2 - \lambda_{rel,y}^2}} = \frac{1}{1.16 + \sqrt{1.16^2 - 1.11^2}} = 0.67 \quad \text{(Gl. 6.25)}$$

$$k_{c,z} = \frac{1}{k_z + \sqrt{k_z^2 - \lambda_{rel,z}^2}} = \frac{1}{1.16 + \sqrt{1.16^2 - 1.11^2}} = 0.67 \quad \text{(Gl. 6.26)}$$

Beanspruchung

$$\sigma_{c,0,d} = \frac{N_d}{A} * 10 = \frac{-35.38}{201.06} * 10 = -1.76 \text{ N/mm}^2$$

$$\sigma_{m,y,d} = \frac{M_{y,d}}{W_y} * 10^3 = \frac{1.75}{402.12} * 10^3 = 4.35 \text{ N/mm}^2$$

$$\sigma_{m,z,d} = \frac{M_{z,d}}{W_z} * 10^3 = \frac{-1.75}{402.12} * 10^3 = -4.35 \text{ N/mm}^2$$

Nachweise

Stabilitätsnachweis

Beiwert $k_m = 1.00$

$$\begin{aligned}\frac{|\sigma_{c,0,d}|}{k_{c,y} * f_{c,0,d}} + \frac{|\sigma_{m,y,d}|}{f_{m,y,d}} + k_m * \frac{|\sigma_{m,z,d}|}{f_{m,z,d}} &= \frac{|-1.76|}{0.67 * 14.77} + \frac{|4.35|}{14.77} + 1.00 * \frac{|-4.35|}{14.77} \\ &= 0.18 + 0.29 + 1.00 * 0.29 \\ &= 0.77\end{aligned} \quad \text{(Gl. 6.23)}$$

$$\begin{aligned}\frac{|\sigma_{c,0,d}|}{k_{c,z} * f_{c,0,d}} + k_m * \frac{|\sigma_{m,y,d}|}{f_{m,y,d}} + \frac{|\sigma_{m,z,d}|}{f_{m,z,d}} &= \frac{|-1.76|}{0.67 * 14.77} + 1.00 * \frac{|4.35|}{14.77} + \frac{|-4.35|}{14.77} \\ &= 0.18 + 1.00 * 0.29 + 0.29 \\ &= 0.77\end{aligned} \quad \text{(Gl. 6.24)}$$

Stabilitätsnachweis:	$0.77 \leq 1.00$	**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 = 2.80 m)

$N_{d,fi} = -F_{c,d,fi} - 1.00 * G_k = -21.00 - 1.00 * 0.28 = -21.28$ kN

$V_{z,d,fi} = -F_{c,d,fi} * \frac{e_z}{L} = -21.00 * \frac{-50}{2.80} * 10^{-3} = 0.38$ kN

$V_{y,d,fi} = -F_{c,d,fi} * \frac{e_y}{L} = -21.00 * \frac{50}{2.80} * 10^{-3} = -0.38$ kN

$M_{y,d,fi} = -F_{c,d,fi} * e_z = -21.00 * -50 * 10^{-3} = 1.05$ kNm

$M_{z,d,fi} = -F_{c,d,fi} * e_y = -21.00 * 50 * 10^{-3} = -1.05$ kNm

Festigkeits- und Steifigkeitswerte

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

$f_{c,0,d,fi} = k_{mod,fi} * k_{fi} * \frac{f_{c,0,k}}{\gamma_{M,fi}} = 1.00 * 1.15 * \frac{24.00}{1.00} = 27.60$ N/mm²

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

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

$d_t = d - 2 * d_{ef} = 160 - 2 * 28.00 = 104.00$ mm

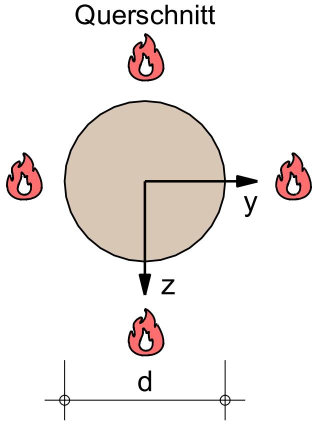
$A_r = \frac{\pi * d_t^2}{4} * 10^{-2} = \frac{\pi * 104.00^2}{4} * 10^{-2} = 84.95$ cm²

$W_{y,r} = \frac{(\pi * d_t^3)}{32} = \frac{(\pi * 104.00^3)}{32} * 10^{-3} = 110.43$ cm³

$W_{z,r} = \frac{(\pi * d_t^3)}{32} = \frac{(\pi * 104.00^3)}{32} * 10^{-3} = 110.43$ cm³

$i_{y,r} = \frac{d_t}{4} = \frac{104.00}{4} = 26.00$ mm

$i_{z,r} = \frac{d_t}{4} = \frac{104.00}{4} = 26.00$ mm



Schlankheit und Knicklängenbeiwerte

Schlankheit

$$\lambda_{y,fi} = \frac{s_{ky}}{i_{y,r}} = \frac{2.80 * 10^3}{26.00} = 107.69$$

$$\lambda_{z,fi} = \frac{s_{kz}}{i_{z,r}} = \frac{2.80 * 10^3}{26.00} = 107.69$$

$$\lambda_{rel,y,fi} = \frac{\lambda_{y,fi}}{\pi} * \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} = \frac{107.69}{\pi} * \sqrt{\frac{24.00}{9600}} = 1.71 \qquad \text{(Gl. 6.21)}$$

$$\lambda_{rel,z,fi} = \frac{\lambda_{z,fi}}{\pi} * \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} = \frac{107.69}{\pi} * \sqrt{\frac{24.00}{9600}} = 1.71 \qquad \text{(Gl. 6.22)}$$

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

Knickbeiwerte

$$k_{y,fi} = 0.5\left(1 + \beta_c * (\lambda_{rel,y,fi} - 0.3) + \lambda^2_{rel,y,fi}\right) = 0.5\left(1 + 0.10 * (1.71 - 0.3) + 1.71^2\right) = 2.03 \qquad \text{(Gl. 6.27)}$$

$$k_{z,fi} = 0.5\left(1 + \beta_c * (\lambda_{rel,z,fi} - 0.3) + \lambda^2_{rel,z,fi}\right) = 0.5\left(1 + 0.10 * (1.71 - 0.3) + 1.71^2\right) = 2.03 \qquad \text{(Gl. 6.28)}$$

$$k_{c,y,fi} = \frac{1}{k_{y,fi} + \sqrt{k^2_{y,fi} - \lambda^2_{rel,y,fi}}} = \frac{1}{2.03 + \sqrt{2.03^2 - 1.71^2}} = 0.32 \qquad \text{(Gl. 6.25)}$$

$$k_{c,z,fi} = \frac{1}{k_{z,fi} + \sqrt{k^2_{z,fi} - \lambda^2_{rel,z,fi}}} = \frac{1}{2.03 + \sqrt{2.03^2 - 1.71^2}} = 0.32 \qquad \text{(Gl. 6.26)}$$

Beanspruchung

$$\sigma_{c,0,d,fi} = \frac{N_{d,fi}}{A_r} = \frac{-21.28}{84.95} * 10 = -2.51 \text{ N/mm}^2$$

$$\sigma_{m,y,d,fi} = \frac{M_{y,d,fi}}{W_{y,r}} = \frac{1.05}{110.43} * 10^3 = 9.51 \text{ N/mm}^2$$

$$\sigma_{m,z,d,fi} = \frac{M_{z,d,fi}}{W_{z,r}} = \frac{-1.05}{110.43} * 10^3 = -9.51 \text{ N/mm}^2$$

Nachweise

Stabilitätsnachweis

Beiwert $k_m = 1.00$

$$\frac{|\sigma_{c,0,d,fi}|}{k_{c,y,fi} * f_{c,0,d,fi}} + \frac{|\sigma_{m,y,d,fi}|}{f_{m,y,d,fi}} + k_m * \frac{|\sigma_{m,z,d,fi}|}{f_{m,z,d,fi}} = \frac{|-2.51|}{0.32 * 27.60} + \frac{|9.51|}{27.60} + 1.00 * \frac{|-9.51|}{27.60}$$

$$= 0.28 + 0.34 + 1.00 * 0.34 \qquad \text{(Gl. 6.23)}$$

$$= 0.97$$

$$\frac{|\sigma_{c,0,d,fi}|}{k_{c,z,fi} * f_{c,0,d,fi}} + k_m * \frac{|\sigma_{m,y,d,fi}|}{f_{m,y,d,fi}} + \frac{|\sigma_{m,z,d,fi}|}{f_{m,z,d,fi}} = \frac{|-2.51|}{0.32 * 27.60} + 1.00 * \frac{|9.51|}{27.60} + \frac{|-9.51|}{27.60}$$

$$= 0.28 + 0.34 + 1.00 * 0.34 \quad \text{(Gl. 6.24)}$$

$$= 0.97$$

Stabilitätsnachweis im Brandfall:	$0.97 \leq 1.00$	**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)