

# Tragwerksentwurf I+II

## Formeln und Tabellen

### Legende / Legend

#### Kräfte (innere und äussere) / Forces

N = Normalkraft / Axial force [kN]  
V = Querkraft / Shear force [kN]  
M = Moment / Moment [kNm]

#### Lasten / Loads

F = Einwirkung (Einzellast) [kN]  
Action (applied load / single load)  
G = Einzellast, ständig / Dead point load [kN]  
Q = Einzellast, veränderlich / Live point load [kN]  
s = Linienlast allgemein / Line load general [kN/m]  
 $\bar{s}$  = Flächenlast allgemein / Area load general [kN/m<sup>2</sup>]  
g = Linienlast ständig / Dead line load [kN/m]  
q = Linienlast veränderlich / Live line load [kN/m]  
 $\bar{g}$  = Flächenlast ständig / Dead area load [kN/m<sup>2</sup>]  
 $\bar{q}$  = Flächenlast veränderlich / Live area load [kN/m<sup>2</sup>]

#### Sicherheitsfaktoren für Lasten / Safety factors for loads:

Ständige Lasten/ Dead load:  $\gamma_G = 1.35$   
Veränderliche Lasten/ Live load:  $\gamma_Q = 1.50$

#### Geometrie / Geometry

A = Querschnittsfläche / Cross-sectional area [mm<sup>2</sup>]  
W = Widerstandsmonent / Section modulus [mm<sup>3</sup>]  
I = Trägheitsmoment / Moment of inertia [mm<sup>4</sup>]  
 $\ell$  = Länge / Length [mm]  
r = Radius/ Radius [mm]  
d = Durchmesser/ Diameter [mm]  
t = Wandstärke / Thickness [mm]  
b = Breite / Width [mm]  
h = Höhe / Height [mm]  
 $\Delta \ell$  = Längenänderung / Length variation [mm]

#### Index / Indices

k = Charakteristischer Wert / Characteristic value  
d = Wert auf Bemessungsniveau / Design value  
q = veränderliche Last / Live load  
g = ständige Last / Dead load  
allow = Zulässige ... / Allowable ...  
cr = Kritische Knicklast / Critical buckling load  
req = erforderliche ... / Required ...  
ef = effektive ... / Effective ...  
t = Zug ... / Tension ...  
c = Druck ... / Compression ...  
m = Moment ... / Moment ...

### Materialkennwerte / Material properties

Holz Timber	Elastizitätsmodul E Modulus of Elasticity E [N/mm <sup>2</sup> ]	Zugfestigkeit $f_{tk}$ Allowable tensile stress $f_{tk}$ [N/mm <sup>2</sup> ]	Druckfestigkeit $f_{tk}$ Allowable compressive stress $f_{tk}$ [N/mm <sup>2</sup> ]	Biegezugfestigkeit $f_{mk}$ Allowable bending strength $f_{mk}$ [N/mm <sup>2</sup> ]	Raumlast $\gamma_k$ Material density $\gamma_k$ [kN/m <sup>3</sup> ]	Widerstandsbeiwert $\gamma_m$ Material safety factor $\gamma_m$
Fichte Spruce	11'000	14	20	24	3.5	1.3
Buche Beech	11'000	24	26	30	5	
Eiche Oak	11'000	26	26	40	5.5	
BSH Glulam	11'000	18	22	29	4	

Stahl Steel	Elastizitätsmodul E Modulus of elasticity E [N/mm <sup>2</sup> ]	Zugfestigkeit $f_{tk}$ Allowable tensile stress $f_{tk}$ [N/mm <sup>2</sup> ]	Druckfestigkeit $f_{tk}$ Allowable compressive stress $f_{tk}$ [N/mm <sup>2</sup> ]	Biegezugfestigkeit $f_{mk}$ Allowable bending stress $f_{mk}$ [N/mm <sup>2</sup> ]	Raumlast $\gamma_k$ Material density $\gamma_k$ [kN/m <sup>3</sup> ]	Widerstandsbeiwert $\gamma_m$ Material safety factor $\gamma_m$
S235	210'000	235	235	235	80.0	1.05
S355		355	355	355		
S500		500	500	500		

Beton Concrete	Elastizitätsmodul E Modulus of elasticity E [N/mm <sup>2</sup> ]	Zugfestigkeit $f_{tk}$ (unbewehrt) Allowable tensile stress $f_{tk}$ (unreinforced) [N/mm <sup>2</sup> ]	Druckfestigkeit $f_{tk}$ Allowable compressive stress $f_{tk}$ [N/mm <sup>2</sup> ]	Raumlast $\gamma_k$ Material density $\gamma_k$ [kN/m <sup>3</sup> ]	Widerstandsbeiwert $\gamma_m$ Material safety factor $\gamma_m$
C 12/15	28'000	1.1	12	25	1.5
C 20/25	30'000	1.5	20		
C 35/45	34'000	2.2	35		
C 55/65	37'000	2.9	55		

### Materialkennwerte / Material properties

E = Elastizitätsmodul / Modulus of elasticity  
f = Materialfestigkeit / Resistance of materials  
 $\gamma_m$  = Widerstandsbeiwert / Material safety factor  
 $\gamma_k$  = Raumlast / Material density

# Tragwerksentwurf I+II

## Formeln und Tabellen

### Tragfähigkeitsformeln / Formulas of load-bearing capacity:




Bemessungswert der Zugfestigkeit Design value allowable tensile stress	$f_{td} = f_{tk} / \gamma_M$	[N/mm <sup>2</sup> ]
Bemessungswert der Druckfestigkeit Design value allowable compressive stress	$f_{cd} = f_{ck} / \gamma_M$	[N/mm <sup>2</sup> ]
Bemessungswert der Biegefestigkeit Design value allowable bending strength	$f_{md} = f_{mk} / \gamma_M$	[N/mm <sup>2</sup> ]
Spannung / Stress	$\sigma = N_d / A$	[N/mm <sup>2</sup> ]
Bemessungswert der Kraft Design value of force	$F_d = F_k \cdot \gamma$	[kN]
Verformung / Deformation	$\Delta \ell = N_k / A \cdot \ell / E$	[mm]
Moment / Bending moment (nur bei vertikaler Lastenwirkung / only for vertical loading cases)	$M_i = F_i \cdot \ell = F_{ih} \cdot y_i = H \cdot y_i$	[kNm]

### Bemessungsformeln / Dimensioning Formulas

Belastungsart / Nature of force:	Bemessen / Dimension:	Tragsicherheitsnachweis / Proof:
<b>Zug / Tension:</b>	$A_{req} = \frac{N_d}{f_{td}}$ [mm <sup>2</sup> ]	$N_d \leq N_{allow} = f_{td} \cdot A_{ef}$ [N] <sup>(1)</sup> $f_{t,ef} = \frac{N_d}{A_{ef}} \leq f_{td}$ [N/mm <sup>2</sup> ] <sup>(2)</sup>
<b>Druck / Compression:</b> - Materialversagen / Material failure:	$A_{req} = \frac{N_d}{f_{cd}}$ [mm <sup>2</sup> ]	$N_d \leq N_{allow} = f_{cd} \cdot A_{ef}$ [N] <sup>(1)</sup> $f_{c,ef} = \frac{N_d}{A_{ef}} \leq f_{cd}$ [N/mm <sup>2</sup> ] <sup>(2)</sup>
<b>Biegung / Bending:</b>	$W_{req} = \frac{M_d}{f_{md}}$ [mm <sup>3</sup> ]	$f_{m,ef} = \frac{M_d}{W_{ef}} \leq f_{md}$ [N/mm <sup>2</sup> ]

### Querschnittswerte / Section properties:

<sup>(1)</sup> Normalkraftnachweis / Axial force proof  
<sup>(2)</sup> Spannungsnachweis / Stress proof

Rechteck/ Rectangular		$A = b \cdot h$ [mm <sup>2</sup> ]	$I_y = \frac{b \cdot h^3}{12}$ [mm <sup>4</sup> ] $I_z = \frac{h \cdot b^3}{12}$ [mm <sup>4</sup> ]	$W_y = \frac{b \cdot h^2}{6}$ [mm <sup>3</sup> ] $W_z = \frac{h \cdot b^2}{6}$ [mm <sup>3</sup> ]
Kreis/ Circle		$A = r^2 \cdot \pi$ [mm <sup>2</sup> ]	$I = \frac{\pi \cdot r^4}{4}$ [mm <sup>4</sup> ]	$W = \frac{\pi \cdot r^3}{4}$ [mm <sup>3</sup> ]
Kreisring/ Circular ring		$A = (R^2 - r^2) \cdot \pi$ [mm <sup>2</sup> ]	$I = \frac{\pi \cdot (R^4 - r^4)}{4}$ [mm <sup>4</sup> ]	$W = \frac{\pi \cdot (R^4 - r^4)}{4R}$ [mm <sup>3</sup> ]

### Trigonometrie / Trigonometry:

$\gamma = 90^\circ$

$\sin \beta = b/c$	$\cos \beta = a/c$	$\tan \beta = b/a$
$\sin \alpha = a/c$	$\cos \alpha = b/c$	$\tan \alpha = a/b$

