detailed problems acc. to Eurocode 3

EC 3-1-5 (12.10), NA: Deutschland

steel grade

steel grade S 355

cross-section

beam: parameter (I-section):

h = 1000.0 mm, t_w = 8.0 mm, b_f = 400.0 mm, t_f = 15.0 mm

parameters

length of buckling field a = 2000.0 cm

method of effective cross-sectional area

verification in beam field

calculation of buckling factors acc. to EC 3-1-5

effective cross-section values from resulting distribution of longitudinal stresses

no iteration to consider tension redistribution of failing cross-section parts

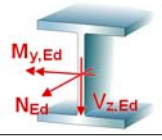
loading

Lk 1: N_{Ed} = -1000.0 kN M_{Ed} = 1500.0 kNm

partial safety factors for material

resistance of cross-sections γ_{M0} = 1.00

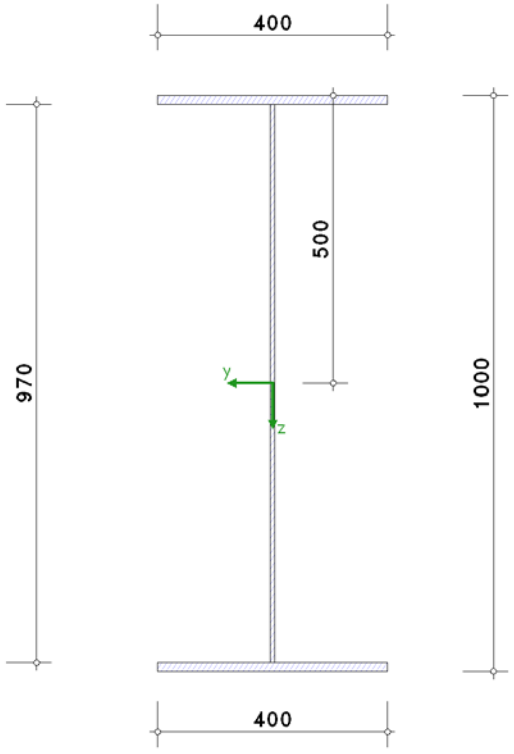
resistance of members in stability failure γ_{M1} = 1.10



verifications of buckling resistance

assumption: flange induced web buckling is excluded.

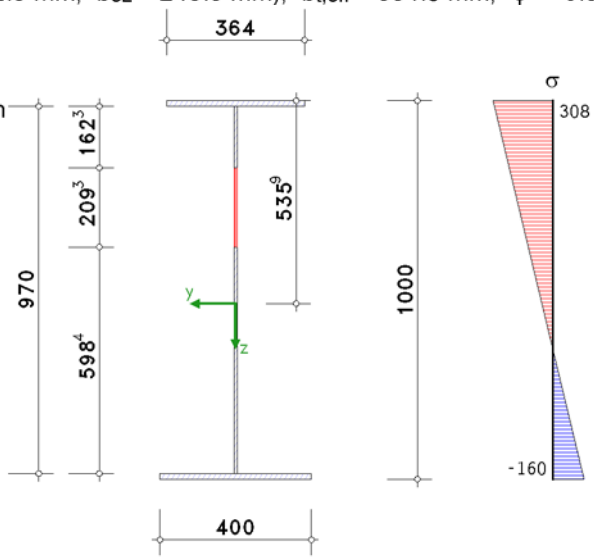
assumption: plate area is supported rigidly.



Lk 1:

method of effective cross-sectional area
EC 3-convention, compressive stresses positive
shear distortions are ignored.
cross-sectional properties: A = 197.60 cm², z_s = 500.0 mm, I_y = 351934.87 cm⁴, y_s = -0.0 mm, I_z = 16004.14 cm⁴
maximum/minimum stresses: σ_o = 263.7 N/mm², σ_u = -162.5 N/mm²
section class: 4 ⇒ verification of plate buckling required !!

plate buckling
effective cross-sectional area
flange top:
section class 4 for 11.20 < c/t = 13.07
critical buckling stress $\sigma_{cr,p} = k_\sigma \cdot \sigma_E$ = 479.5 N/mm², σ_E = 1111.6 N/mm², k_σ = 0.43
buckling slenderness ratio $\lambda_p = (f_y/\sigma_{cr,p})^{1/2}$ = 0.860
reduction factor $\rho = (\lambda_p - 0.188)/\lambda_p^2$ = 0.908 ≤ 1 for λ_p > 0.748, ψ = 1.000
effective width $b_{c,eff} = \rho \cdot b$ = 178.0 mm
flange bottom:
effective width $b_{t,eff}$ = b = 196.0 mm
web:
section class 4 for α = 0.634 and 81.83 < c/t = 121.25
critical buckling stress $\sigma_{cr,p} = k_\sigma \cdot \sigma_E$ = 189.7 N/mm², σ_E = 12.9 N/mm², k_σ = 14.69
buckling slenderness ratio $\lambda_p = (f_y/\sigma_{cr,p})^{1/2}$ = 1.368
reduction factor $\rho = (\lambda_p - 0.055 \cdot (3+\psi))/\lambda_p^2$ = 0.660 ≤ 1 for $\lambda_p > 0.5 + (0.085 - 0.055 \cdot \psi)^{1/2}$ = 0.842, ψ = -0.577
effective width $b_{c,eff} = (\rho \cdot b) / (1-\psi)$ = 405.9 mm (b_{e1} = 162.3 mm, b_{e2} = 243.5 mm), $b_{t,eff}$ = 354.8 mm, ψ = -0.577
limit loads refering to the reduced cross-section:
res. stresses σ_o = 308.0 N/mm², σ_u = -160.3 N/mm²
distance of centroid from top $z_{s,eff}$ = 535.9 mm
differential moment by Δz_s = 35.9 mm: ΔM_{Ed} = 35.94 kNm
cross-sectional area A_{eff} = 175.46 cm²
second moment of area $I_{y,eff}$ = 328014.41 cm⁴
section moduli of the pin $W_{y,eff,o}$ = 6207.18 cm³
$W_{y,eff,u}$ = 7184.54 cm³
load capacities $N_{Rd} = (f_y \cdot A_{eff}) / \gamma_{M0}$ = 6228.91 kN
$M_{Rd,o} = (f_y \cdot W_{eff,o}) / \gamma_{M0}$ = 2203.55 kNm
$M_{Rd,u} = (f_y \cdot W_{eff,u}) / \gamma_{M0}$ = 2550.51 kNm



verification
acting moment $M_{Ed}' = M_{Ed} - \Delta M_{Ed}$ = -1535.94 kNm
$|N_{Ed}|/N_{Rd} + |M_{Ed}'|/M_{Rd,o}$ = 0.161 + 0.697 = 0.858 < 1 ok.

total utilization: U = 0.858 < 1 ok.

Final Result

maximum utilization: max U = 0.858 < 1 ok.

verifications succeeded

Regulations

DIN EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;
Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010
DIN EN 1990/NA, Nationaler Anhang zur DIN EN 1990, Ausgabe Dezember 2010

DIN EN 1993-1-1, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau;
Deutsche Fassung EN 1993-1-1:2005 + AC:2009, Ausgabe Dezember 2010
DIN EN 1993-1-1/NA, Nationaler Anhang zur DIN EN 1993-1-1, Ausgabe Dezember 2010

DIN EN 1993-1-5, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-5: Plattenförmige Bauteile;
Deutsche Fassung EN 1993-1-5:2006 + AC:2009, Ausgabe Dezember 2010
DIN EN 1993-1-5/NA, Nationaler Anhang zur DIN EN 1993-1-5, Ausgabe Dezember 2010