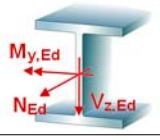
detailed problems acc. to Eurocode 3

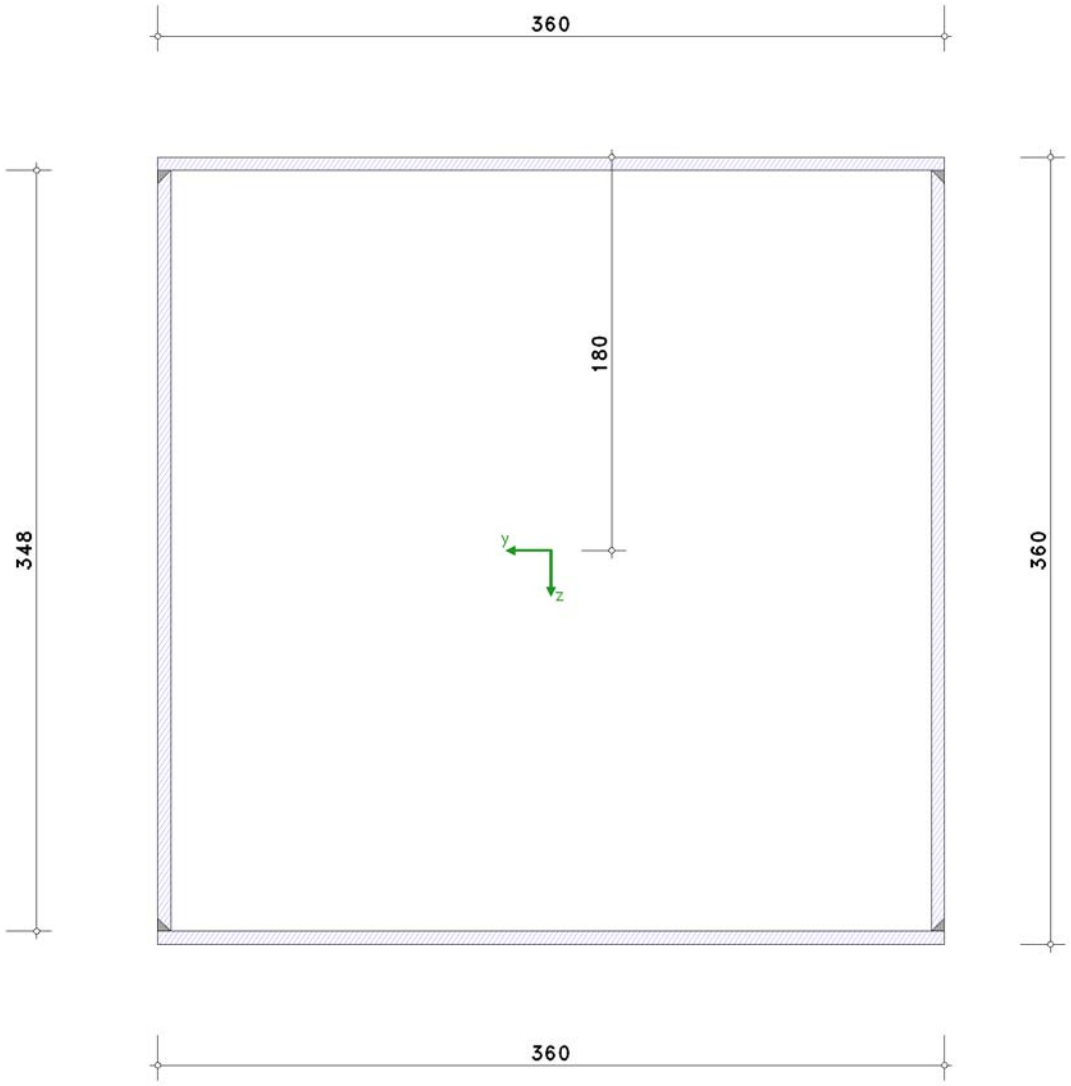
EC 3-1-5 (12.10), NA: Deutschland

steel grade
steel grade S 235
cross-section
beam: section parameters (box section):
h = 360.0 mm, t_w = 6.0 mm (2x), b_f = 360.0 mm, $b_ü$ = 0.0 mm, t_f = 6.0 mm
parameters
length of buckling field a = 800.0 cm
method of effective cross-sectional area
verification in beam field
calculation of buckling factors acc. to EC 3-1-5
effective cross-sectional properties: A_{eff} solely from compression, W_{eff} solely from bending
verification of stability acc. to EC 3-1-1, 6.3
loading
Lk 1: N_{Ed} = -690.0 kN M_{Ed} = 79.8 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.



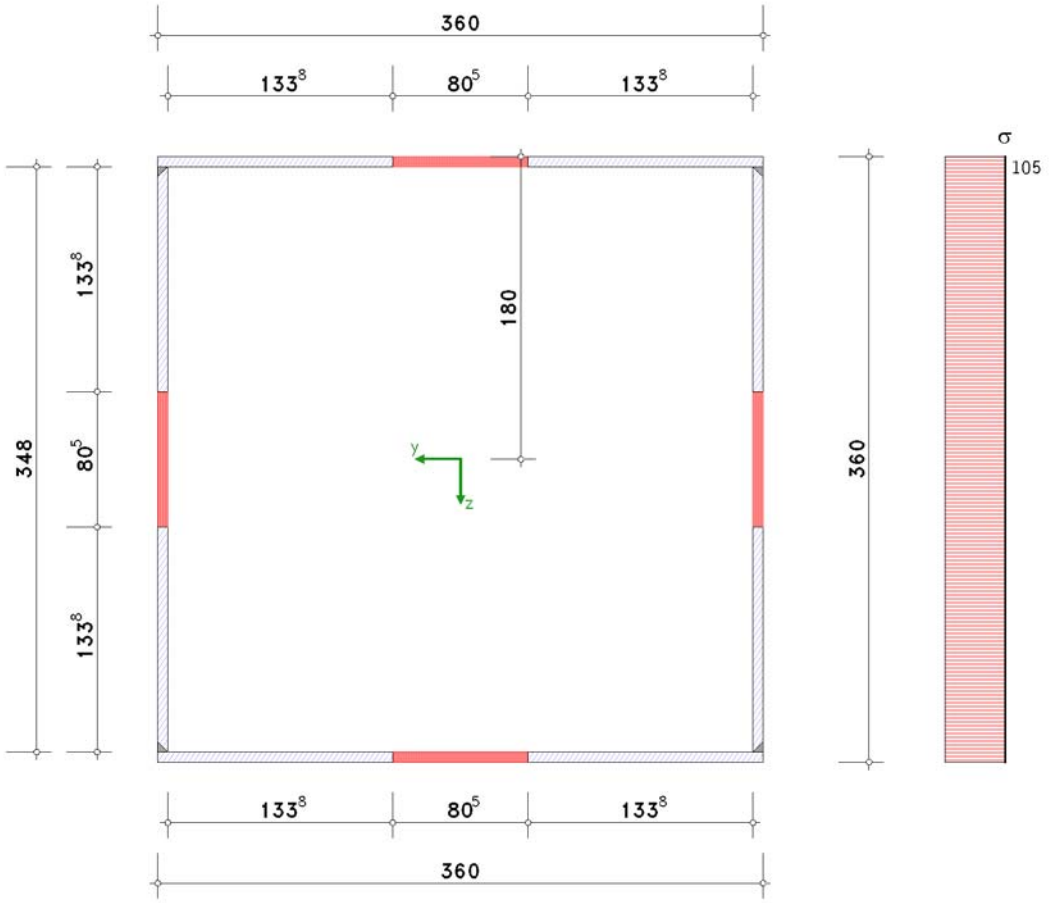
Lk 1:

method of effective cross-sectional area
EC 3-convention, compressive stresses positive
shear distortions are ignored.
cross-sectional properties: A = 84.96 cm², z_s = 180.0 mm, I_y = 17749.84 cm⁴, y_s = 0.0 mm, I_z = 17749.84 cm⁴
maximum/minimum stresses: σ_o = 162.1 N/mm², σ_u = 0.3 N/mm²
section class: 4 ⇒ verification of plate buckling required !!

plate buckling
effective cross-sectional area for N_{Ed} = 690.0 kN, M_{Ed} = 0
web:
section class 4 for 42.00 < c/t = 58.00
critical buckling stress $\sigma_{cr,p} = k_\sigma \cdot \sigma_E$ = 225.7 N/mm², σ_E = 56.4 N/mm², k_σ = 4.00
buckling slenderness ratio $\lambda_p = (f_y/\sigma_{cr,p})^{1/2}$ = 1.020
reduction factor $\rho = (\lambda_p - 0.055\cdot(3+\psi))/\lambda_p^2$ = 0.769 ≤ 1 for $\lambda_p > 0.5 + (0.085-0.055\cdot\psi)^{1/2}$ = 0.673, ψ = 1.000
effective width $b_{c,eff} = \rho \cdot b$ = 267.5 mm (b_{e1} = 133.8 mm, b_{e2} = 133.8 mm)
flange induced web buckling:
h_w/t_w = 58.00 < $(k\cdot E)/(f_y\cdot(A_w/A_{fc})^{1/2})$ = 683.39 ok. with k = 0.55, A_w = 20.88 cm², A_{fc} = 10.80 cm²
flange top:
section class 4 for 42.00 < c/t = 58.00
critical buckling stress $\sigma_{cr,p} = k_\sigma \cdot \sigma_E$ = 225.7 N/mm², σ_E = 56.4 N/mm², k_σ = 4.00
buckling slenderness ratio $\lambda_p = (f_y/\sigma_{cr,p})^{1/2}$ = 1.020
reduction factor $\rho = (\lambda_p - 0.055\cdot(3+\psi))/\lambda_p^2$ = 0.769 ≤ 1 for $\lambda_p > 0.5 + (0.085-0.055\cdot\psi)^{1/2}$ = 0.673, ψ = 1.000
effective width $b_{c,eff} = \rho \cdot b$ = 267.5 mm (b_{e1} = 133.8 mm, b_{e2} = 133.8 mm)
flange bottom:
section class 4 for 42.00 < c/t = 58.00
critical buckling stress $\sigma_{cr,p} = k_\sigma \cdot \sigma_E$ = 225.7 N/mm², σ_E = 56.4 N/mm², k_σ = 4.00

buckling slenderness ratio $\lambda_p = (f_y/\sigma_{cr,p})^{1/2} = 1.020$
reduction factor $\rho = (\lambda_p - 0.055\cdot(3+\psi))/\lambda_p^2 = 0.769 \le 1$ for $\lambda_p > 0.5 + (0.085-0.055\cdot\psi)^{1/2} = 0.673$, $\psi = 1.000$
effective width $b_{c,eff} = \rho\cdot b = 267.5$ mm ($b_{e1} = 133.8$ mm, $b_{e2} = 133.8$ mm)

limit loads refering to the reduced cross-section:
distance of centroid from top $z_{s,eff} = 180.0$ mm
cross-sectional area $A_{eff} = 65.64$ cm²
load capacities $N_{Rd} = (f_y\cdot A_{eff}) / \gamma_{M1} = 1402.35$ kN



effective section modulus for $M_{Ed} = -79.8$ kNm, $N_{Ed} = 0$

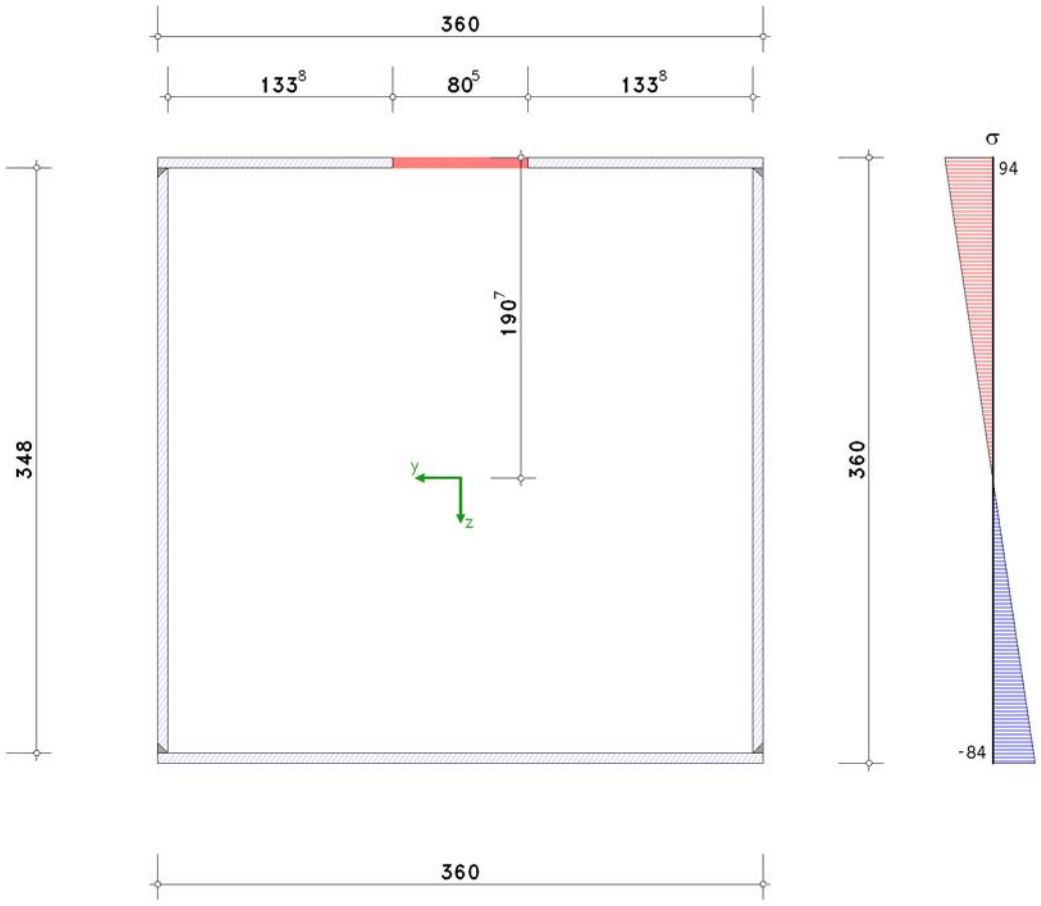
web:
section class 1 for $\alpha = 0.500$ and $c/t = 58.00 < 72.00$
effective width $b_{c,eff} = (\rho\cdot b) / (1-\psi) = 174.0$ mm ($b_{e1} = 69.6$ mm, $b_{e2} = 104.4$ mm), $b_{t,eff} = 174.0$ mm, $\psi = -1.000$

flange induced web buckling:
$h_w/t_w = 58.00 < (k\cdot E)/(f_y\cdot(A_w/A_{fc})^{1/2}) = 372.76$ **ok.** with $k = 0.30$, $A_w = 20.88$ cm², $A_{fc} = 10.80$ cm²

flange top:
section class 4 for $42.00 < c/t = 58.00$
critical buckling stress $\sigma_{cr,p} = k_\sigma\cdot\sigma_E = 225.7$ N/mm², $\sigma_E = 56.4$ N/mm², $k_\sigma = 4.00$
buckling slenderness ratio $\lambda_p = (f_y/\sigma_{cr,p})^{1/2} = 1.020$
reduction factor $\rho = (\lambda_p - 0.055\cdot(3+\psi))/\lambda_p^2 = 0.769 \le 1$ for $\lambda_p > 0.5 + (0.085-0.055\cdot\psi)^{1/2} = 0.673$, $\psi = 1.000$
effective width $b_{c,eff} = \rho\cdot b = 267.5$ mm ($b_{e1} = 133.8$ mm, $b_{e2} = 133.8$ mm)

flange bottom:
stresses at edge of plate $\sigma_o = -79.6$ N/mm² ≤ 0, $\sigma_u = -79.6$ N/mm² ≤ 0 ⇒ no buckling !!

limit loads refering to the reduced cross-section:
distance of centroid from top $z_{s,eff} = 190.7$ mm
second moment of area $I_{y,eff} = 16145.45$ cm⁴
section modulus $W_{y,eff} = 860.32$ cm³
load capacities $M_{Rd} = (f_y\cdot W_{eff}) / \gamma_{M1} = 183.80$ kNm



verification (M-N-interaction)
$|N_{Ed}|/N_{Rd} + |M_{Ed}|/M_{Rd,u} = 0.492 + 0.434 = 0.926 < 1$ **ok.**

total utilization: $U = 0.926 < 1$ **ok.**

Final Result

maximum utilization: max $U = 0.926 < 1$ **ok.**
assumptions: succeeded **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