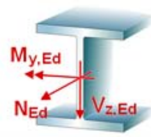
POS. 18: WAGENKNECHT BD.2, BSP.11.10.6

detailed problems acc. to Eurocode 3

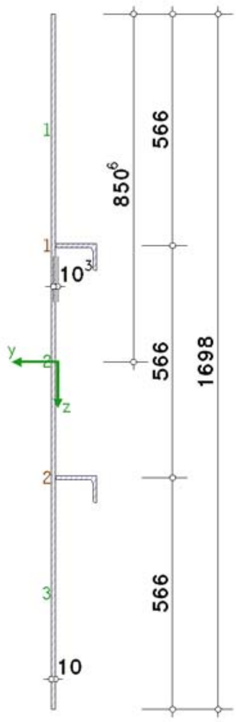
EC 3-1-5 (12.10), NA: Deutschland

steel grade
steel grade S 235
cross-section
buckling field: thickness t = 10.0 mm, width b = 1698.0 mm
longitudinal stiffeners: number n_{st} = 2
section L100X65X9
distance of the first stiffener to the top edge of plate $d_{st,0}$ = 566.0 mm
constant distance of stiffeners d_{st} = 566.0 mm
transverse stiffeners to limit the buckling field:
section parameters (T-section):
h = 260.0 mm, t_w = 10.0 mm, b_f = 100.0 mm, t_f = 10.0 mm
parameters
length of buckling field a = 345.0 cm
method of reduced stresses
verification in beam field
calculation of buckling factors with 4H-tool
loading
internal forces and moments refering to the stiffened cross-section:
Lk 1: N_{Ed} = -2182.0 kN V_{Ed} = 687.0 kN
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: local buckling of stiffeners is excluded.
assumption: transverse stiffeners serve as rigid support of the plated panel.



method of reduced stresses

EC 3-convention, compressive stresses positive

shear distortions are ignored.

cross-sectional properties: $A = 198.20$ cm², $z_s = 850.6$ mm, $I_y = 430845.31$ cm⁴, $y_s = 10.3$ mm, $I_z = 1546.56$ cm⁴

maximum/minimum stresses: $\sigma_o = 110.1$ N/mm², $\sigma_u = 110.1$ N/mm², $\tau = 40.5$ N/mm²

buckling factors (4H-tool)

web: $\alpha_{cr} = 1.948$, $\alpha_{cr,1} = 2.024$, $\alpha_{cr,2} = 2.024$, $\alpha_{cr,3} = 2.024$

reduced stresses

single buckling field 1:

$\sigma_{Ed} = 110.1$ N/mm², $\tau_{Ed} = 40.5$ N/mm²

non-dimensional slenderness ratio $\lambda_p = \lambda_c = \lambda_w = (\alpha_{ult}/\alpha_{cr})^{1/2} = 0.943$, $\alpha_{ult} = 1.801$, $\alpha_{cr} = 2.024$ (4H-tool)

reduction factor $\rho = (\lambda_p\text{-}0.055\cdot(3+\psi))/\lambda_p^2 = 0.813 \le 1$ for $\lambda_p > 0.5 + (0.085\text{-}0.055\cdot\psi)^{1/2} = 0.673$, $\psi = 1.000$

reduction factor $\chi_w = 0.83/\lambda_w = 0.880$ for $0.83/\eta = 0.692 \le \lambda_w < 1.08$

ultimate buckling stresses $\sigma_{Rd} = \rho\cdot f_y/\gamma_{M1} = 173.7$ N/mm², $\tau_{Rd} = \chi_w\cdot f_y/(3^{1/2}\cdot\gamma_{M1}) = 108.5$ N/mm²

verification: $((\sigma_{Ed}/\sigma_{Rd})^2 + (\tau_{Ed}/\tau_{Rd})^2)^{1/2} = 0.735 < 1$ ok.

single buckling field 2:

$\sigma_{Ed} = 110.1$ N/mm², $\tau_{Ed} = 40.5$ N/mm²

non-dimensional slenderness ratio $\lambda_p = \lambda_c = \lambda_w = (\alpha_{ult}/\alpha_{cr})^{1/2} = 0.943$, $\alpha_{ult} = 1.801$, $\alpha_{cr} = 2.024$ (4H-tool)

reduction factor $\rho = (\lambda_p\text{-}0.055\cdot(3+\psi))/\lambda_p^2 = 0.813 \le 1$ for $\lambda_p > 0.5 + (0.085\text{-}0.055\cdot\psi)^{1/2} = 0.673$, $\psi = 1.000$

reduction factor $\chi_w = 0.83/\lambda_w = 0.880$ for $0.83/\eta = 0.692 \le \lambda_w < 1.08$

ultimate buckling stresses $\sigma_{Rd} = \rho\cdot f_y/\gamma_{M1} = 173.7$ N/mm², $\tau_{Rd} = \chi_w\cdot f_y/(3^{1/2}\cdot\gamma_{M1}) = 108.5$ N/mm²

verification: $((\sigma_{Ed}/\sigma_{Rd})^2 + (\tau_{Ed}/\tau_{Rd})^2)^{1/2} = 0.735 < 1$ ok.

single buckling field 3:

$\sigma_{Ed} = 110.1$ N/mm², $\tau_{Ed} = 40.5$ N/mm²

non-dimensional slenderness ratio $\lambda_p = \lambda_c = \lambda_w = (\alpha_{ult}/\alpha_{cr})^{1/2} = 0.943$, $\alpha_{ult} = 1.801$, $\alpha_{cr} = 2.024$ (4H-tool)

reduction factor $\rho = (\lambda_p\text{-}0.055\cdot(3+\psi))/\lambda_p^2 = 0.813 \le 1$ for $\lambda_p > 0.5 + (0.085\text{-}0.055\cdot\psi)^{1/2} = 0.673$, $\psi = 1.000$

reduction factor $\chi_w = 0.83/\lambda_w = 0.880$ for $0.83/\eta = 0.692 \le \lambda_w < 1.08$

ultimate buckling stresses $\sigma_{Rd} = \rho\cdot f_y/\gamma_{M1} = 173.7$ N/mm², $\tau_{Rd} = \chi_w\cdot f_y/(3^{1/2}\cdot\gamma_{M1}) = 108.5$ N/mm²

verification: $((\sigma_{Ed}/\sigma_{Rd})^2 + (\tau_{Ed}/\tau_{Rd})^2)^{1/2} = 0.735 < 1$ ok.

overall buckling field:

$\sigma_{Ed} = 110.1$ N/mm², $\tau_{Ed} = 40.5$ N/mm²

non-dimensional slenderness ratio $\lambda_p = \lambda_c = \lambda_w = (\alpha_{ult}/\alpha_{cr})^{1/2} = 0.961$, $\alpha_{ult} = 1.801$, $\alpha_{cr} = 1.948$ (4H-tool)

reduction factor $\rho = (\lambda_p\text{-}0.055\cdot(3+\psi))/\lambda_p^2 = 0.802 \le 1$ for $\lambda_p > 0.5 + (0.085\text{-}0.055\cdot\psi)^{1/2} = 0.673$, $\psi = 1.000$

critical buckling stress $\sigma_{cr,p} = \alpha_{cr}\cdot\sigma_{Ed}' = 214.5$ N/mm², $\sigma_{Ed}' = 110.1$ N/mm²

critical buckling stress $\sigma_{cr,c} = \sigma_{cr,c,sl}\cdot\sigma_1/\sigma_{sl} = 177.8$ N/mm², $\sigma_1/\sigma_{sl} = 1.000$, $\sigma_{cr,c,sl} = 177.8$ N/mm²

reduction factor $\chi_c = 0.514 \le 1$ for $\lambda_c > 0.2$

final reduction factor $\rho = (\rho\text{-}\chi_c)\cdot\xi\cdot(2\text{-}\xi) + \chi_c = 0.621$ with $\xi = 0.206$

reduction factor $\chi_w = 0.83/\lambda_w = 0.863$ for $0.83/\eta = 0.692 \le \lambda_w < 1.08$

ultimate buckling stresses $\sigma_{Rd} = \rho\cdot f_y/\gamma_{M1} = 132.6$ N/mm², $\tau_{Rd} = \chi_w\cdot f_y/(3^{1/2}\cdot\gamma_{M1}) = 106.5$ N/mm²

verification: $((\sigma_{Ed}/\sigma_{Rd})^2 + (\tau_{Ed}/\tau_{Rd})^2)^{1/2} = 0.913 < 1$ ok.

longitudinal stiffeners: torsional buckling of stiffener $I_{T,st}/I_{p,st} = 0.47\% < 5.3\cdot f_y/E = 0.59\%$ ok.

transverse stiffeners:

rigid support of buckling field:

assumption: transverse stiffeners without axial force.

$I_{st} = 2510.06$ cm⁴ $> \sigma_m/E \cdot (b/\pi)^4 \cdot (1+w_0\cdot 300\cdot u/b) = 10.60$ cm⁴ ok.

torsional buckling:

$I_{T,st}/I_{p,st} = 0.10\% < 5.3\cdot f_y/E = 0.59\%$ ok.

minimum moment of inertia to ensure a rigid support:

$I_{sl} = 7105.27$ cm⁴ $> 0.75\cdot h_w\cdot t^3 = 127.35$ cm⁴ ok. for $a/h_w = 2.03 \ge 2^{1/2}$

total utilization: $U = 0.913 < 1$ ok.

Final Result

maximum utilization: max $U = 0.913 < 1$ 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