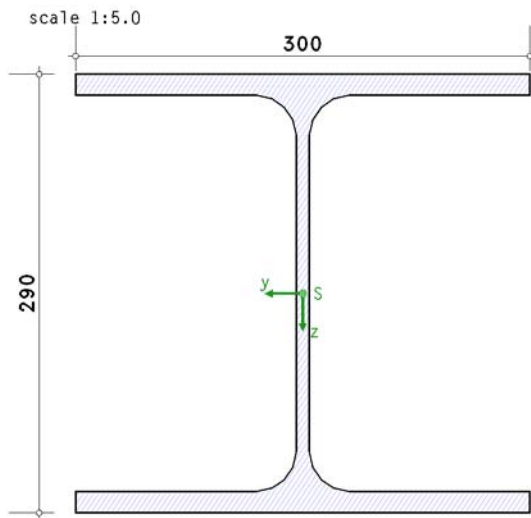


POS. 24: KINDMANN/KRÜGER 2.9.4

verification of cross-section EC 3-1-8 (12.10), NA: Deutschland

1. input report



steel

steel grade S235

material safety factor

resistance of cross-sections $\gamma_{M0} = 1.00$

geometry

section HE300A

resistance

plastic verification acc. to EC 3-1-1, 6.2

internal forces and moments referring to local axes of cross-section

σ -generating forces (N, M) work at centroid, τ -generating forces (V, T_t) work at shear center

Lk	N_{Ed} kN	$M_{y,Ed}$ kNm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNm	$V_{y,Ed}$ kN	
1	1000.00	220.00	100.00	0.00	0.00	a)
2	-1000.00	220.00	100.00	0.00	0.00	b)
3	370.00	220.00	300.00	0.00	0.00	c)
4	370.00	0.00	0.00	150.00	500.00	d)
5	370.00	230.00	200.00	70.00	500.00	e)

notes

buckling is not investigated.

2. Lk 1: a)

2.1. verification of cross-section

internal forces and moments: $N = 1000.00$ kN, $M_y = 220.00$ kNm, $V_z = 100.00$ kN

2.1.1. plastic verification

plastic verification for $N = 1000.00$ kN, $M_y = 220.00$ kNm, $V_z = 100.00$ kN

plate buckling: section class of the section $1 \leq 2$ **ok**

shear buckling: $h_p/t_p = 30.82 \leq 72 \cdot \epsilon / \eta = 60.00$ **ok**

plastic values: $N_{pl,Rd} = A \cdot f_y / \gamma_{M0} = 2644.40$ kN, $M_{pl,y,Rd} = W_{pl,y} \cdot f_y / \gamma_{M0} = 325.04$ kNm

$V_{pl,z,Rd} = A_{vz} \cdot f_y / (3^{1/2} \cdot \gamma_{M0}) = 505.78$ kN

shear force

reduction factors:

web: $0.5 \cdot V_{pl,z,Rd} = 252.89$ kN $> |V_{z,Ed}| = 100.00$ kN: $\rho_z = 0$ (no deduction)

$|V_{y,Ed}| = 0$: $\rho_y = 0$ (no deduction)

bending and axial force

deduction M_y : $N_{c,lim} = \min(0.25 \cdot N_{pl,Rd}, 0.5 \cdot A_w \cdot f_y / \gamma_{M0}) = 261.67$ kN, $A_w = h_w \cdot t_w = 2227.00$ cm²

$N_{Ed} > N_{c,lim}$: $f_{N,y} = (1-n)/(1-0.5 \cdot a) = 0.712 < 1$, $n = |N_{Ed}| / N_{pl,Rd} = 0.378$, $a = (A - A_f) / A = 0.254 \leq 0.5$

$$A_f = 2 \cdot b_f \cdot t_f = 84.00 \text{ cm}^2, \quad A = 112.53 \text{ cm}^2 \Rightarrow M_{pl,N,y,Rd} = M_{pl,y,Rd} \cdot f_{N,y} = 231.47 \text{ kNm}$$

bending

$$\text{verification: } I_{M_y,Ed}/M_{pl,N,y,Rd} = 0.950 < 1 \quad \text{ok}$$

3. Lk 2: b)

3.1. verification of cross-section

internal forces and moments: $N = -1000.00 \text{ kN}$, $M_y = 220.00 \text{ kNm}$, $V_z = 100.00 \text{ kN}$

3.1.1. plastic verification

plastic verification for $N = -1000.00 \text{ kN}$, $M_y = 220.00 \text{ kNm}$, $V_z = 100.00 \text{ kN}$

plate buckling: section class of the section $1 \leq 2$ ok

shear buckling: $h_p/t_p = 30.82 \leq 72 \cdot \varepsilon/\eta = 60.00$ ok

plastic values: $N_{pl,Rd} = A \cdot f_y/\gamma_{M0} = 2644.40 \text{ kN}$, $M_{pl,y,Rd} = W_{pl,y} \cdot f_y/\gamma_{M0} = 325.04 \text{ kNm}$

$$V_{pl,z,Rd} = A_{vz} \cdot f_y/(3^{1/2} \cdot \gamma_{M0}) = 505.78 \text{ kN}$$

shear force

reduction factors:

web: $0.5 \cdot V_{pl,z,Rd} = 252.89 \text{ kN} > |V_{z,Ed}| = 100.00 \text{ kN}$: $\rho_z = 0$ (no deduction)

$|V_{y,Ed}| = 0$: $\rho_y = 0$ (no deduction)

bending and axial force

deduction M_y : $N_{c,lim} = \min(0.25 \cdot N_{pl,Rd}, 0.5 \cdot A_w \cdot f_y/\gamma_{M0}) = 261.67 \text{ kN}$, $A_w = h_w \cdot t_w = 2227.00 \text{ cm}^2$

$$N_{Ed} > N_{c,lim}: f_{N,y} = (1-n)/(1-0.5 \cdot a) = 0.712 < 1, \quad n = |N_{Ed}|/N_{pl,Rd} = 0.378, \quad a = (A - A_f)/A = 0.254 \leq 0.5$$

$$A_f = 2 \cdot b_f \cdot t_f = 84.00 \text{ cm}^2, \quad A = 112.53 \text{ cm}^2 \Rightarrow M_{pl,N,y,Rd} = M_{pl,y,Rd} \cdot f_{N,y} = 231.47 \text{ kNm}$$

bending

$$\text{verification: } I_{M_y,Ed}/M_{pl,N,y,Rd} = 0.950 < 1 \quad \text{ok}$$

4. Lk 3: c)

4.1. verification of cross-section

internal forces and moments: $N = 370.00 \text{ kN}$, $M_y = 220.00 \text{ kNm}$, $V_z = 300.00 \text{ kN}$

4.1.1. plastic verification

plastic verification for $N = 370.00 \text{ kN}$, $M_y = 220.00 \text{ kNm}$, $V_z = 300.00 \text{ kN}$

plate buckling: section class of the section $1 \leq 2$ ok

shear buckling: $h_p/t_p = 30.82 \leq 72 \cdot \varepsilon/\eta = 60.00$ ok

plastic values: $N_{pl,Rd} = A \cdot f_y/\gamma_{M0} = 2644.40 \text{ kN}$, $M_{pl,y,Rd} = W_{pl,y} \cdot f_y/\gamma_{M0} = 325.04 \text{ kNm}$

$$V_{pl,z,Rd} = A_{vz} \cdot f_y/(3^{1/2} \cdot \gamma_{M0}) = 505.78 \text{ kN}$$

shear force

reduction factors:

web: $0.5 \cdot V_{pl,z,Rd} = 252.89 \text{ kN} < |V_{z,Ed}| = 300.00 \text{ kN}$: $\rho_z = (2 \cdot |V_{z,Ed}|/V_{pl,z,Rd} - 1)^2 = 0.035$

$|V_{y,Ed}| = 0$: $\rho_y = 0$ (no deduction)

axial force and shear force/torsion

web: $\Delta A_w = \rho_z \cdot A_w = 0.99 \text{ cm}^2$, $A_w = 28.53 \text{ cm}^2$

$$\Rightarrow N_{pl,V,Rd} = A_{red} \cdot f_y/\gamma_{M0} = 2621.14 \text{ kN}, \quad A_{red} = A - \Delta A_w = 111.54 \text{ cm}^2$$

bending and shear force/torsion

web: $W_{V,y} = W_{pl,y} - \rho_z \cdot W_{pl,w} = 1375.39 \text{ cm}^3$, $W_{pl,w} = W_{pl,y} - W_{pl,y,f} = 223.96 \text{ cm}^3$, $W_{pl,y,f} = 2 \cdot b_f \cdot t_f \cdot z_f = 1159.20 \text{ cm}^3$

$$\Rightarrow M_{pl,V,y,Rd} = W_{V,y} \cdot f_y/\gamma_{M0} = 323.22 \text{ kNm}$$

bending and axial force

deduction M_y : $N_{c,lim} = \min(0.25 \cdot N_{pl,V,Rd}, 0.5 \cdot A_w \cdot f_y/\gamma_{M0}) = 252.59 \text{ kN}$, $A_w = h_w \cdot t_w \cdot (1 - \rho_z) = 2149.71 \text{ cm}^2$

$$N_{Ed} > N_{c,lim}: f_{N,y} = (1-n)/(1-0.5 \cdot a) = 0.980 < 1, \quad n = |N_{Ed}|/N_{pl,V,Rd} = 0.141, \quad a = (A_{red} - A_f)/A_{red} = 0.247 \leq 0.5$$

$$A_f = 2 \cdot b_f \cdot t_f = 84.00 \text{ cm}^2, \quad A_{red} = 111.54 \text{ cm}^2 \Rightarrow M_{pl,V,N,y,Rd} = M_{pl,y,Rd} \cdot f_{N,y} = 316.68 \text{ kNm}$$

bending

$$\text{verification: } I_{M_y,Ed}/M_{pl,V,N,y,Rd} = 0.695 < 1 \quad \text{ok}$$

5. Lk 4: d)

5.1. verification of cross-section

internal forces and moments: $N = 370.00 \text{ kN}$, $M_z = 150.00 \text{ kNm}$, $V_y = 500.00 \text{ kN}$

5.1.1. plastic verification

plastic verification for $N = 370.00 \text{ kN}$, $M_z = 150.00 \text{ kNm}$, $V_y = 500.00 \text{ kN}$

plate buckling: section class of the section $1 \leq 2$ **ok**

shear buckling: $h_p/t_p = 30.82 \leq 72 \cdot \varepsilon/\eta = 60.00$ **ok**

plastic values: $N_{pl,Rd} = A \cdot f_y/\gamma_{M0} = 2644.40 \text{ kN}$, $M_{pl,z,Rd} = W_{pl,z} \cdot f_y/\gamma_{M0} = 150.60 \text{ kNm}$

$V_{pl,y,Rd} = A_{vy} \cdot f_y/(3^{1/2} \cdot \gamma_{M0}) = 1020.97 \text{ kN}$

shear force

reduction factors:

$|V_{z,Ed}| = 0$: $\rho_z = 0$ (no deduction)

flanges: $0.5 \cdot V_{pl,y,Rd} = 510.49 \text{ kN} > |V_{y,Ed}| = 500.00 \text{ kN}$: $\rho_y = 0$ (no deduction)

bending and axial force

deduction M_z : $N_{c,lim} = A_w \cdot f_y/\gamma_{M0} = 523.35 \text{ kN}$, $A_w = h_w \cdot t_w = 2227.00 \text{ cm}^2$

$N_{Ed} \leq N_{c,lim}$ or $n \leq a$: $f_{N,z} = 1 \Rightarrow M_{pl,z,Rd} = M_{pl,z,Rd} \cdot f_{N,z} = 150.60 \text{ kNm}$

bending

verification: $|M_{z,Ed}|/M_{pl,z,Rd} = 0.996 < 1$ **ok**

6. Lk 5: e)

6.1. verification of cross-section

internal forces and moments: $N = 370.00 \text{ kN}$, $M_y = 230.00 \text{ kNm}$, $V_z = 200.00 \text{ kN}$, $M_z = 70.00 \text{ kNm}$, $V_y = 500.00 \text{ kN}$

6.1.1. plastic verification

plastic verification for $N = 370.00 \text{ kN}$, $M_y = 230.00 \text{ kNm}$, $V_z = 200.00 \text{ kN}$, $M_z = 70.00 \text{ kNm}$

$V_y = 500.00 \text{ kN}$

plate buckling: section class of the section $1 \leq 2$ **ok**

shear buckling: $h_p/t_p = 30.82 \leq 72 \cdot \varepsilon/\eta = 60.00$ **ok**

plastic values: $N_{pl,Rd} = A \cdot f_y/\gamma_{M0} = 2644.40 \text{ kN}$, $M_{pl,y,Rd} = W_{pl,y} \cdot f_y/\gamma_{M0} = 325.04 \text{ kNm}$

$V_{pl,z,Rd} = A_{vz} \cdot f_y/(3^{1/2} \cdot \gamma_{M0}) = 505.78 \text{ kN}$, $M_{pl,z,Rd} = W_{pl,z} \cdot f_y/\gamma_{M0} = 150.60 \text{ kNm}$, $V_{pl,y,Rd} = A_{vy} \cdot f_y/(3^{1/2} \cdot \gamma_{M0}) = 1020.97 \text{ kN}$

shear force

reduction factors:

web: $0.5 \cdot V_{pl,z,Rd} = 252.89 \text{ kN} > |V_{z,Ed}| = 200.00 \text{ kN}$: $\rho_z = 0$ (no deduction)

flanges: $0.5 \cdot V_{pl,y,Rd} = 510.49 \text{ kN} > |V_{y,Ed}| = 500.00 \text{ kN}$: $\rho_y = 0$ (no deduction)

bending and axial force

deduction M_y : $N_{c,lim} = \min(0.25 \cdot N_{pl,Rd}, 0.5 \cdot A_w \cdot f_y/\gamma_{M0}) = 261.67 \text{ kN}$, $A_w = h_w \cdot t_w = 2227.00 \text{ cm}^2$

$N_{Ed} > N_{c,lim}$: $f_{N,y} = (1-n)/(1-0.5 \cdot a) = 0.985 < 1$, $n = |N_{Ed}|/N_{pl,Rd} = 0.140$, $a = (A - A_f)/A = 0.254 \leq 0.5$

$A_f = 2 \cdot b_f \cdot t_f = 84.00 \text{ cm}^2$, $A = 112.53 \text{ cm}^2 \Rightarrow M_{pl,N,y,Rd} = M_{pl,y,Rd} \cdot f_{N,y} = 320.15 \text{ kNm}$

deduction M_z : $N_{c,lim} = A_w \cdot f_y/\gamma_{M0} = 523.35 \text{ kN}$, $A_w = h_w \cdot t_w = 2227.00 \text{ cm}^2$

$N_{Ed} \leq N_{c,lim}$ or $n \leq a$: $f_{N,z} = 1 \Rightarrow M_{pl,z,Rd} = M_{pl,z,Rd} \cdot f_{N,z} = 150.60 \text{ kNm}$

bending

verification: $(|M_{y,Ed}|/M_{pl,N,y,Rd})^\alpha + (|M_{z,Ed}|/M_{pl,z,Rd})^\beta = 0.516 + 0.465 = 0.981 < 1$ **ok**

with $\alpha = 2.00$, $\beta = 1.00 = 5 \cdot n \geq 1$

utilization: $U = 0.981^{1/2} = 0.990$

7. final result

maximum utilization [Lk 4]: resistance max $U = 0.996 < 1$ **ok**

verification succeeded