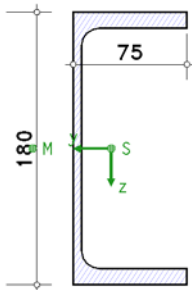


POS. 21: KINDMANN/KRÜGER 2.8.9

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

1. input report

scale 1:5.0



steel

steel grade S235

material safety factor

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

geometry

section UPE180

resistance

elastic verification, calculation as thin-walled cross-section

plastic verification with partial internal forces and moments

valid normal, shear-, equivalent stress: $\sigma_{x,Rd} = 235.0 \text{ N/mm}^2$, $\tau_{Rd} = 135.7 \text{ N/mm}^2$, $\sigma_{v,Rd} = 235.0 \text{ N/mm}^2$

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

warping forces (T_ω , B) work at shear center

Lk	$M_{y,Ed}$ kNcm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNcm	$T_{t,Ed}$ kNcm	$T_{\omega,Ed}$ kNcm	B_{Ed} kNcm ²	
1	674.00	13.21	56.00	-105.00	-20.00	-338.00	
2	674.00	0.00	0.00	0.00	0.00	0.00	My
3	0.00	0.00	56.00	0.00	0.00	0.00	Mz
4	0.00	0.00	0.00	0.00	0.00	-338.00	B
5	0.00	0.00	0.00	-105.00	0.00	0.00	T_t
6	0.00	13.21	0.00	0.00	0.00	0.00	V_z

notes

buckling is not investigated.

2. Lk 1

2.1. verification of cross-section

internal forces and moments: $M_y = 674.00 \text{ kNcm}$, $V_z = 13.21 \text{ kN}$, $M_z = 56.00 \text{ kNcm}$, $T_t = -105.00 \text{ kNcm}$, $T_\omega = -20.00 \text{ kNcm}$, $B =$

2.1.1. elastic verification

elastic verification for $M_y = 6.74 \text{ kNm}$, $V_z = 13.21 \text{ kN}$, $M_z = 0.56 \text{ kNm}$, $T_t = -1.05 \text{ kNm}$

$T_\omega = -0.20 \text{ kNm}$, $B = -0.03 \text{ kNm}^2$

elastic stresses: $\max |\sigma_x| = 67.15 \text{ N/mm}^2$, $\max \tau = 162.84 \text{ N/mm}^2$, $\max \sigma_v = 287.67 \text{ N/mm}^2$

$\max \sigma_x$ bei $y = 24.7 \text{ mm}$, $z = 90.0 \text{ mm}$:

$\sigma_x = 47.94 \text{ N/mm}^2$, $\tau = -72.86 \text{ N/mm}^2$, $\sigma_v = 135.00 \text{ N/mm}^2$

$\min \sigma_x$ bei $y = 24.7 \text{ mm}$, $z = -90.0 \text{ mm}$:

$\sigma_x = -67.15 \text{ N/mm}^2$, $\tau = -152.62 \text{ N/mm}^2$, $\sigma_v = 272.73 \text{ N/mm}^2$

$\max \tau$ bei $y = 15.7 \text{ mm}$, $z = -76.0 \text{ mm}$:

$\sigma_x = -56.65 \text{ N/mm}^2$, $\tau = 162.84 \text{ N/mm}^2$, $\sigma_v = 287.67 \text{ N/mm}^2$

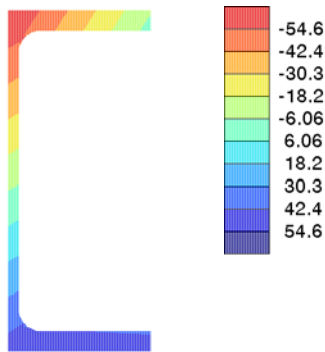
$\max \sigma_v$ bei $y = 15.7 \text{ mm}$, $z = -76.0 \text{ mm}$:

$\sigma_x = -56.65 \text{ N/mm}^2$, $\tau = 162.84 \text{ N/mm}^2$, $\sigma_v = 287.67 \text{ N/mm}^2$

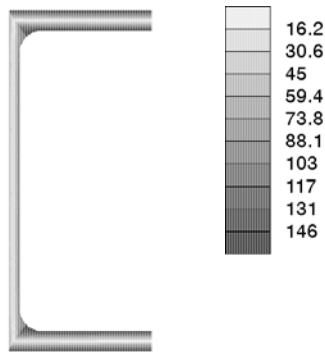
valid equivalent stress: $\sigma_{v,Rd} = 235.0 \text{ N/mm}^2$

verification: $\sigma_v = 287.67 \text{ N/mm}^2 > \sigma_{v,Rd} = 235.00 \text{ N/mm}^2 \Rightarrow U_\sigma = 1.224 > 1$ **fault !!**

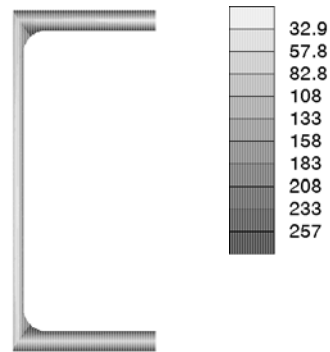
normal stresses σ_x [N/mm²]
min $\sigma_x = -68.2$, max $\sigma_x = 49.0$



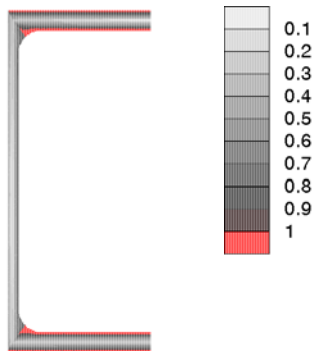
shear stresses τ [N/mm²]
max $\tau = 161.9$



equivalent stresses σ_v [N/mm²]
max $\sigma_v = 285.6$



utilization U_σ
max $U_\sigma = 1.215$



stresses, utilizations

y mm	z mm	σ_x N/mm ²	τ N/mm ²	σ_v N/mm ²	U_σ
0.0	0.0	-68.21	152.18	272.26	1.159 > 1
-9.0	14.0	-53.92	161.90	285.56	1.215 > 1
0.0	180.0	48.97	152.18	268.09	1.141 > 1

y,z: node coordinates; σ_x, τ, σ_v : stresses; U_σ : stress utilization

2.1.2. plastic verification

plastic verification for $M_y = 6.74$ kNm, $V_z = 13.21$ kN, $M_z = 0.56$ kNm, $T_t = -1.05$ kNm

$T_\omega = -0.20$ kNm, $B = -0.03$ kNm²

valid normal/shear stress: $\sigma_{x,Rd} = 235.0$ N/mm², $\tau_{Rd} = 135.7$ N/mm²

top flange: shear force $V_O = 1.16$ kN, torsion $T_{pO} = -0.46$ kNm, shear stress $\tau_O = 118.51$ N/mm² $\Rightarrow U_{\tau,O} = 0.873$
flange bending $M_{\sigma,O} = -0.71$ kNm, bending stress $\sigma_O = 25.97$ N/mm² $\Rightarrow U_{\sigma,O} = 0.227$
resistance forces $N_{max,O} = 24.51$ kN, $N_{min,O} = -52.58$ kN

bottom flange: shear force $V_U = -1.16$ kN, torsion $T_{pU} = -0.46$ kNm, shear stress $\tau_U = 118.51$ N/mm² $\Rightarrow U_{\tau,U} = 0.873$
flange bending $M_{\sigma,U} = 1.27$ kNm, bending stress $\sigma_U = 46.38$ N/mm² $\Rightarrow U_{\sigma,U} = 0.405$
resistance forces $N_{max,U} = 62.13$ kN, $N_{min,U} = -11.23$ kN

web: shear force $V_S = 13.21$ kN, torsion $T_{pS} = -0.14$ kNm, shear stress $\tau_S = 62.39$ N/mm² $\Rightarrow U_{\tau,S} = 0.460$
resistance forces $N_{max,S} = 182.49$ kN, $N_{min,S} = -182.49$ kN

main bending: moment $M_y = 6.74$ kNm, resistance moments $M_{y,max} = 16.96$ kNm, $M_{y,min} = -10.24$ kNm $\Rightarrow U_{M_y} = 0.249$

total (possibly due to load increase): max $U = 0.896 < 1$ **ok**

3. Lk 2: M_y

3.1. verification of cross-section

internal forces and moments: $M_y = 674.00$ kNcm

3.1.1. elastic verification

elastic verification for $M_y = 6.74$ kNm

elastic stresses: max $|\sigma_x| = 44.93$ N/mm², max $\tau = 0.00$ N/mm², max $\sigma_v = 44.93$ N/mm²

max σ_x bei $y = 24.7$ mm, $z = 90.0$ mm: $\sigma_x = 44.93$ N/mm², $\tau = 0.00$ N/mm², $\sigma_v = 44.93$ N/mm²

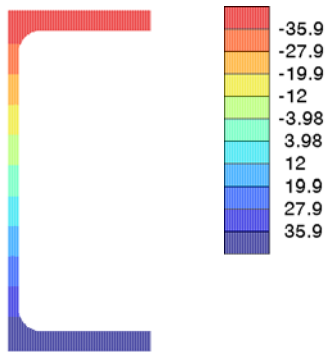
min σ_x bei $y = -50.3$ mm, $z = -90.0$ mm: $\sigma_x = -44.93$ N/mm², $\tau = 0.00$ N/mm², $\sigma_v = 44.93$ N/mm²

max σ_v bei $y = -50.3$ mm, $z = -90.0$ mm: $\sigma_x = -44.93$ N/mm², $\tau = 0.00$ N/mm², $\sigma_v = 44.93$ N/mm²

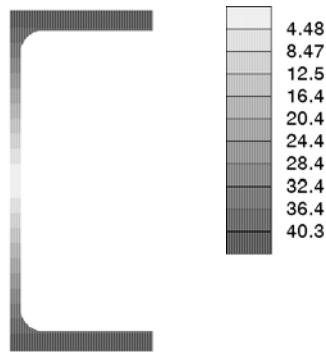
valid equivalent stress: $\sigma_{v,Rd} = 235.0$ N/mm²

verification: $\sigma_v = 44.93$ N/mm² $< \sigma_{v,Rd} = 235.00$ N/mm² $\Rightarrow U_\sigma = 0.191 < 1$ **ok**

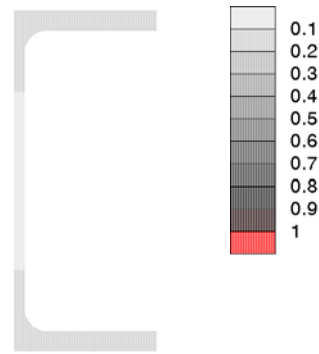
normal stresses σ_x [N/mm²]
min $\sigma_x = -44.8$, max $\sigma_x = 44.8$



equivalent stresses σ_v [N/mm²]
max $\sigma_v = 44.8$



utilization U_σ
max $U_\sigma = 0.191$



stresses, utilizations

y mm	z mm	σ_x N/mm ²	σ_v N/mm ²	U_σ
-75.0	0.0	-44.82	44.82	0.191
0.0	0.0	-44.82	44.82	0.191
0.0	180.0	44.82	44.82	0.191

y,z: node coordinates; σ_x, σ_v : stresses; U_σ : stress utilization

3.1.2. plastic verification

plastic verification for $M_y = 6.74$ kNm

valid normal/shear stress: $\sigma_{x,Rd} = 235.0$ N/mm², $\tau_{Rd} = 135.7$ N/mm²

top flange: flange bending $M_{\sigma,O} = -1.19$ kNm, bending stress $\sigma_O = 43.44$ N/mm² $\Rightarrow U_{\sigma,O} = 0.185$

resistance forces $N_{max,O} = 56.30$ kN, $N_{min,O} = -103.15$ kN

bottom flange: flange bending $M_{\sigma,U} = 1.19$ kNm, bending stress $\sigma_U = 43.44$ N/mm² $\Rightarrow U_{\sigma,U} = 0.185$

resistance forces $N_{max,U} = 103.15$ kN, $N_{min,U} = -56.30$ kN

web: resistance forces $N_{max,S} = 205.51$ kN, $N_{min,S} = -205.51$ kN

main bending: moment $M_y = 6.74$ kNm, resistance moments $M_{y,max} = 25.65$ kNm, $M_{y,min} = -17.71$ kNm $\Rightarrow U_{My} = 0.128$

total (possibly due to load increase): max $U = 0.185 < 1$ **ok**

4. Lk 3: M_z

4.1. verification of cross-section

internal forces and moments: $M_z = 56.00$ kNcm

4.1.1. elastic verification

elastic verification for $M_z = 0.56$ kNm

elastic stresses: max $|\sigma_x| = 19.56$ N/mm², max $\tau = 0.00$ N/mm², max $\sigma_v = 19.56$ N/mm²

max σ_x bei $y = -50.3$ mm, $z = -84.8$ mm: $\sigma_x = 19.56$ N/mm², $\tau = 0.00$ N/mm², $\sigma_v = 19.56$ N/mm²

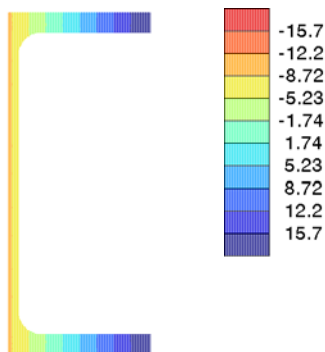
min σ_x bei $y = 24.7$ mm, $z = -90.0$ mm: $\sigma_x = -9.61$ N/mm², $\tau = 0.00$ N/mm², $\sigma_v = 9.61$ N/mm²

max σ_v bei $y = -50.3$ mm, $z = -84.8$ mm: $\sigma_x = 19.56$ N/mm², $\tau = 0.00$ N/mm², $\sigma_v = 19.56$ N/mm²

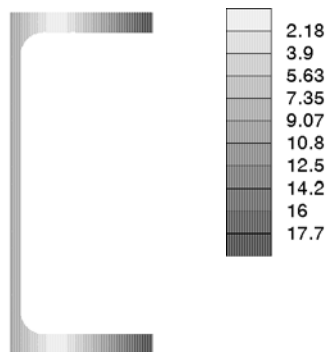
valid equivalent stress: $\sigma_{v,Rd} = 235.0$ N/mm²

verification: $\sigma_v = 19.56$ N/mm² $< \sigma_{v,Rd} = 235.00$ N/mm² $\Rightarrow U_\sigma = 0.083 < 1$ **ok**

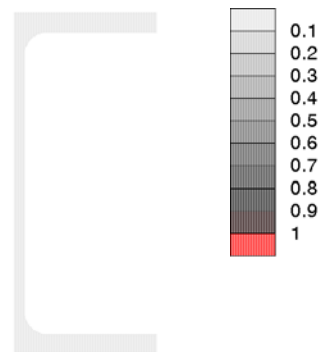
normal stresses σ_x [N/mm²]
min $\sigma_x = -9.6$, max $\sigma_x = 19.6$



equivalent stresses σ_v [N/mm²]
max $\sigma_v = 19.6$



utilization U_σ
max $U_\sigma = 0.083$



stresses, utilizations

y mm	z mm	σ_x N/mm ²	σ_v N/mm ²	U_σ
-75.0	0.0	19.61	19.61	0.083
-75.0	5.3	19.61	19.61	0.083
-75.0	10.5	19.61	19.61	0.083
0.0	0.0	-9.62	9.62	0.041

4.1.2. plastic verification

plastic verification for $M_z = 0.56 \text{ kNm}$

valid normal/shear stress: $\sigma_{x,Rd} = 235.0 \text{ N/mm}^2$, $\tau_{Rd} = 135.7 \text{ N/mm}^2$

top flange: flange bending $M_{\sigma,O} = 0.28 \text{ kNm}$, bending stress $\sigma_O = 10.20 \text{ N/mm}^2 \Rightarrow U_{\sigma,O} = 0.043$

resistance forces $N_{\max,O} = 86.23 \text{ kN}$, $N_{\min,O} = -75.28 \text{ kN}$

bottom flange: flange bending $M_{\sigma,U} = 0.28 \text{ kNm}$, bending stress $\sigma_U = 10.20 \text{ N/mm}^2 \Rightarrow U_{\sigma,U} = 0.043$

resistance forces $N_{\max,U} = 86.23 \text{ kN}$, $N_{\min,U} = -75.28 \text{ kN}$

web: resistance forces $N_{\max,S} = 205.51 \text{ kN}$, $N_{\min,S} = -205.51 \text{ kN}$

total (possibly due to load increase): $\max U = 0.047 < 1$ **ok**

5. Lk 4: B

5.1. verification of cross-section

internal forces and moments: $B = -338.00 \text{ kNm}^2$

5.1.1. elastic verification

elastic verification for $B = -0.03 \text{ kNm}^2$

elastic stresses: $\max |\sigma_x| = 17.78 \text{ N/mm}^2$, $\max \tau = 0.00 \text{ N/mm}^2$, $\max \sigma_y = 17.78 \text{ N/mm}^2$

$\max \sigma_x$ bei $y = -50.3 \text{ mm}$, $z = -84.8 \text{ mm}$: $\sigma_x = 17.78 \text{ N/mm}^2$, $\tau = 0.00 \text{ N/mm}^2$, $\sigma_y = 17.78 \text{ N/mm}^2$

$\min \sigma_x$ bei $y = -50.3 \text{ mm}$, $z = 84.8 \text{ mm}$: $\sigma_x = -17.78 \text{ N/mm}^2$, $\tau = 0.00 \text{ N/mm}^2$, $\sigma_y = 17.78 \text{ N/mm}^2$

$\max \sigma_y$ bei $y = -50.3 \text{ mm}$, $z = 84.8 \text{ mm}$: $\sigma_x = -17.78 \text{ N/mm}^2$, $\tau = 0.00 \text{ N/mm}^2$, $\sigma_y = 17.78 \text{ N/mm}^2$

valid equivalent stress: $\sigma_{v,Rd} = 235.0 \text{ N/mm}^2$

verification: $\sigma_v = 17.78 \text{ N/mm}^2 < \sigma_{v,Rd} = 235.00 \text{ N/mm}^2 \Rightarrow U_\sigma = 0.076 < 1$ **ok**

normal stresses $\sigma_x \text{ [N/mm}^2]$

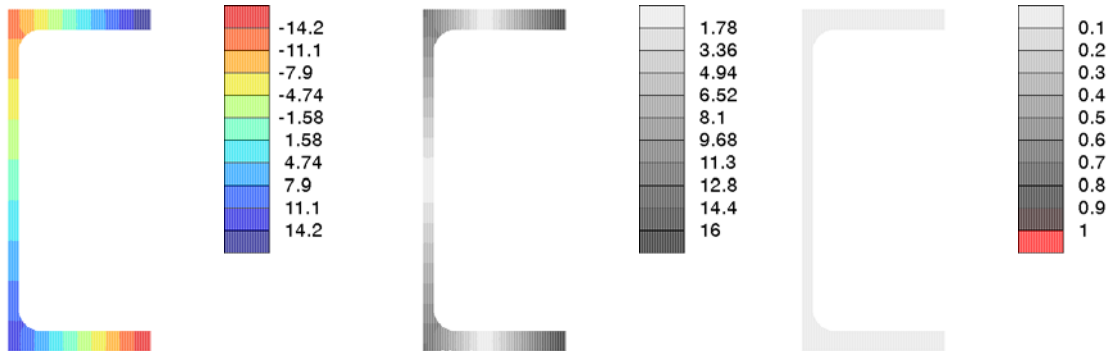
$\min \sigma_x = -17.8$, $\max \sigma_x = 17.8$

equivalent stresses $\sigma_v \text{ [N/mm}^2]$

$\max \sigma_v = 17.8$

utilization U_σ

$\max U_\sigma = 0.076$



stresses, utilizations

y mm	z mm	σ_x N/mm ²	σ_v N/mm ²	U_σ
-75.0	0.0	17.78	17.78	0.076
-75.0	5.3	17.78	17.78	0.076
-75.0	10.5	17.78	17.78	0.076
-75.0	180.0	-17.78	17.78	0.076

y,z: node coordinates; σ_x, σ_y : stresses; U_σ : stress utilization

5.1.2. plastic verification

plastic verification for $B = -0.03 \text{ kNm}^2$

valid normal/shear stress: $\sigma_{x,Rd} = 235.0 \text{ N/mm}^2$, $\tau_{Rd} = 135.7 \text{ N/mm}^2$

top flange: flange bending $M_{\sigma,O} = 0.20 \text{ kNm}$, bending stress $\sigma_O = 7.27 \text{ N/mm}^2 \Rightarrow U_{\sigma,O} = 0.031$

resistance forces $N_{\max,O} = 84.68 \text{ kN}$, $N_{\min,O} = -76.88 \text{ kN}$

bottom flange: flange bending $M_{\sigma,U} = -0.20 \text{ kNm}$, bending stress $\sigma_U = 7.27 \text{ N/mm}^2 \Rightarrow U_{\sigma,U} = 0.031$

resistance forces $N_{\max,U} = 76.88 \text{ kN}$, $N_{\min,U} = -84.68 \text{ kN}$

web: resistance forces $N_{\max,S} = 205.51 \text{ kN}$, $N_{\min,S} = -205.51 \text{ kN}$

total (possibly due to load increase): $\max U = 0.041 < 1$ **ok**

6. Lk 5: Tt

6.1. verification of cross-section

internal forces and moments: $T_t = -105.00 \text{ kNm}$

6.1.1. elastic verification

elastic verification for $T_t = -1.05$ kNm

elastic stresses: max $|\sigma_x| = 0.00$ N/mm², max $\tau = 157.73$ N/mm², max $\sigma_v = 273.19$ N/mm²

max σ_v bei $y = -36.4$ mm, $z = -79.5$ mm: $\sigma_x = 0.00$ N/mm², $\tau = 157.73$ N/mm², $\sigma_v = 273.19$ N/mm²

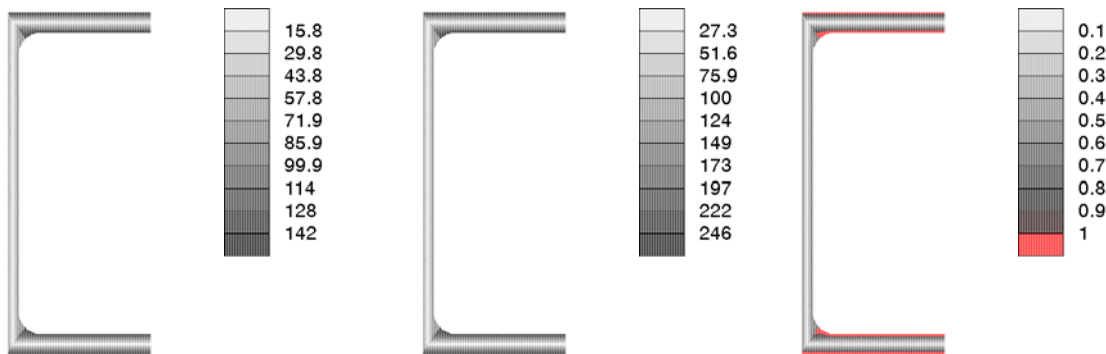
valid equivalent stress: $\sigma_{v,Rd} = 235.0$ N/mm²

verification: $\sigma_v = 273.19$ N/mm² > $\sigma_{v,Rd} = 235.00$ N/mm² $\Rightarrow U_\sigma = 1.163 > 1$ **fault !!**

shear stresses τ [N/mm²]
max $\tau = 157.7$

equivalent stresses σ_v [N/mm²]
max $\sigma_v = 273.2$

utilization U_σ
max $U_\sigma = 1.163$



stresses, utilizations

y mm	z mm	τ N/mm ²	σ_v N/mm ²	U_σ
-75.0	0.0	157.73	273.19	1.163 > 1
-75.0	10.5	157.73	273.19	1.163 > 1
0.0	0.0	157.73	273.19	1.163 > 1

y,z: node coordinates; τ, σ_v : stresses; U_σ : stress utilization

6.1.2. plastic verification

plastic verification for $T_t = -1.05$ kNm

valid normal/shear stress: $\sigma_{x,Rd} = 235.0$ N/mm², $\tau_{Rd} = 135.7$ N/mm²

top flange: torsion $T_{pO} = -0.46$ kNm, shear stress $\tau_O = 118.49$ N/mm² $\Rightarrow U_{\tau,O} = 0.873$

resistance forces $N_{max,O} = 39.37$ kN, $N_{min,O} = -39.37$ kN

bottom flange: torsion $T_{pU} = -0.46$ kNm, shear stress $\tau_U = 118.49$ N/mm² $\Rightarrow U_{\tau,U} = 0.873$

resistance forces $N_{max,U} = 39.37$ kN, $N_{min,U} = -39.37$ kN

web: torsion $T_{pS} = -0.14$ kNm, shear stress $\tau_S = 58.74$ N/mm² $\Rightarrow U_{\tau,S} = 0.433$

resistance forces $N_{max,S} = 185.25$ kN, $N_{min,S} = -185.25$ kN

total (possibly due to load increase): max $U = 0.876 < 1$ **ok**

7. Lk 6: Vz

7.1. verification of cross-section

internal forces and moments: $V_z = 13.21$ kN

7.1.1. elastic verification

elastic verification for $V_z = 13.21$ kN

elastic stresses: max $|\sigma_x| = 0.00$ N/mm², max $\tau = 15.37$ N/mm², max $\sigma_v = 26.63$ N/mm²

max τ bei $y = 22.0$ mm, $z = 0.0$ mm: $\sigma_x = 0.00$ N/mm², $\tau = 15.37$ N/mm², $\sigma_v = 26.63$ N/mm²

max σ_v bei $y = 22.0$ mm, $z = 0.0$ mm: $\sigma_x = 0.00$ N/mm², $\tau = 15.37$ N/mm², $\sigma_v = 26.63$ N/mm²

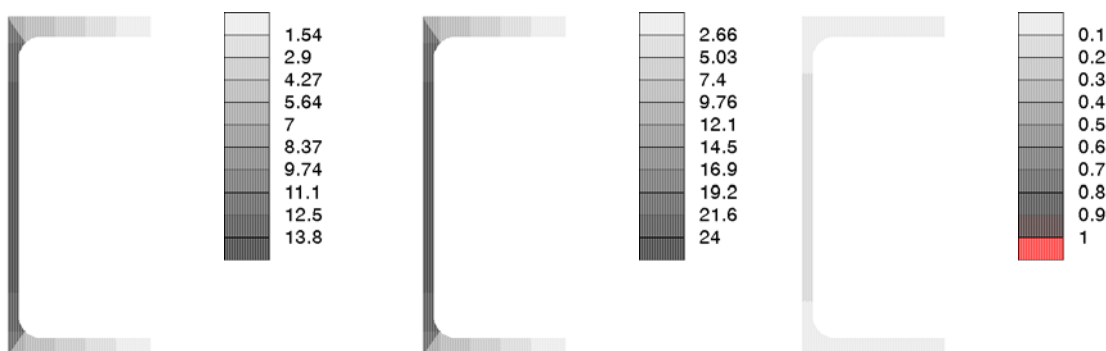
valid equivalent stress: $\sigma_{v,Rd} = 235.0$ N/mm²

verification: $\sigma_v = 26.63$ N/mm² < $\sigma_{v,Rd} = 235.00$ N/mm² $\Rightarrow U_\sigma = 0.113 < 1$ **ok**

shear stresses τ [N/mm²]
max $\tau = 15.4$

equivalent stresses σ_v [N/mm²]
max $\sigma_v = 26.6$

utilization U_σ
max $U_\sigma = 0.113$



stresses, utilizations

y mm	z mm	τ N/mm ²	σ_v N/mm ²	U_σ
0.0	90.0	15.37	26.63	0.113
-5.5	90.0	15.37	26.63	0.113
-2.8	90.0	15.37	26.63	0.113

y,z: node coordinates; τ, σ_v : stresses; U_σ : stress utilization

7.1.2. plastic verification

plastic verification for $V_z = 13.21$ kN

valid normal/shear stress: $\sigma_{x,Rd} = 235.0$ N/mm², $\tau_{Rd} = 135.7$ N/mm²

top flange: shear force $V_O = 2.34$ kN, shear stress $\tau_O = 2.97$ N/mm² $\Rightarrow U_{\tau,O} = 0.022$

resistance forces $N_{max,O} = 80.79$ kN, $N_{min,O} = -80.79$ kN

bottom flange: shear force $V_U = -2.34$ kN, shear stress $\tau_O = 2.97$ N/mm² $\Rightarrow U_{\tau,U} = 0.022$

resistance forces $N_{max,U} = 80.79$ kN, $N_{min,U} = -80.79$ kN

web: shear force $V_S = 13.21$ kN, shear stress $\tau_S = 15.11$ N/mm² $\Rightarrow U_{\tau,S} = 0.111$

resistance forces $N_{max,S} = 204.23$ kN, $N_{min,S} = -204.23$ kN

total (possibly due to load increase): max $U = 0.111 < 1$ **ok**

8. final result

maximum utilization [Lk 1]: resistance max $U = 1.224 > 1$ **fault !!**

resistance not ensured !!