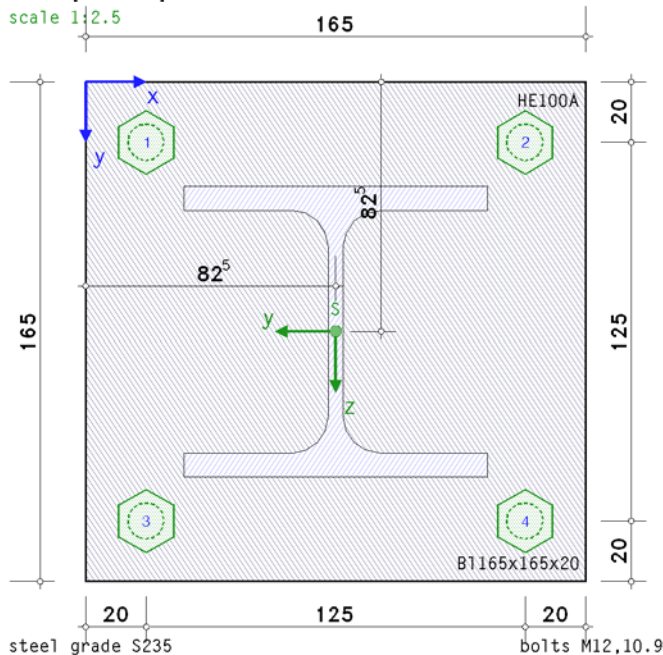


POS. 12: FIRE

bolted end plate connection EC 3-1-8 (12.10), NA: Deutschland

1. input report



steel grade

steel grade S235

bolts

bolt class 10.9, bolt size M12, normal wrench size

thread included in the shear plane

connection

end plate (rectangular): thickness $t_p = 20.0$ mm, width $b_p = 165.0$ mm, length $l_p = 165.0$ mm

beam: section HE100A

beam-end plate: surrounding fillet weld, weld thickness $a = 4.0$ mm

beam section centric on end plate (beam centroid in plate centre)

coordinates of the beam centroid on end plate $x_s = 82.5$ mm, $y_s = 82.5$ mm

bolts:

uniform arrangement of bolts, 2 vertical and 2 horizontal rows

edge distances top, below $e_o = e_u = 20.0$ mm, distances between bolts $p_y = 125.0$ mm

edge distances left, right $e_l = e_r = 20.0$ mm, distances between bolts $p_x = 125.0$ mm

verification in case of fire

temperature of beam section:

thermal action due to the standard curve, fire resistance time $t = 60.0$ min

shadow effect of the cross-section by wall/ceiling top

thermal insulation protection by plate cladding s. EC 3-1-2, appendix AA:

thermal conductivity $\lambda_p = 0.20$ W/(m·K), specific heat capacity $c_p = 1700$ J/(kg·K), maximum density $\rho_p = 945$ kg/m³

thickness of insulating material $d_p = 20.0$ mm

fire design at load level

temperature at the connection point:

simplified calculation based on temperature of the beam, reduction factor $f_{\theta} = 0.880$

calculation

verification:

calculation of internal forces and moments (FEM) and verifications of resistance

verification of end plate with the plastic method, verification of compression by contact

verification of beam section with the elastic method

verification of welds with the directional method

verification of bolts, check of distances

FEM-calculation (event of fire):

bolts are plastically calculated, spring constant of bolts $c_f = 2384.4$ kN/cm

plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd} = 56.3$ kN, $f_{t,f} = 0.950$, $F_{t,Rd} = 59.3$ kN

effective elongation at failure $\varepsilon_{t,f} = f_{t,e} \cdot \varepsilon_{ub} = 2.3\%$, $f_{t,e} = 0.250$, $\varepsilon_{ub} = 9.0\%$

without preloading ($F_{p,c} = 0$)

effective foundation modulus of end plate $c_b = 7403.4$ kN/cm³

number / dimension of finite elements each direction $n_x / \Delta x = 34 / 4.9$ mm, $n_y / \Delta y = 34 / 4.9$ mm

max. 50 iteration steps (tolerance limit 5%)

internal forces and moments referring to local axes of cross-section (event of fire, accidental design situation)

Lc	N _{Ed} kN	M _{y,Ed} kNm	V _{z,Ed} kN		Lc	N _{Ed} kN	M _{y,Ed} kNm	V _{z,Ed} kN	
1	-0.36	-5.86	3.57	import Lc 1	4	0.17	-5.86	3.57	import Lc 4
2	-0.17	-5.80	3.55	import Lc 2	5	0.09	-5.93	3.58	import Lc 5
3	0.09	-5.79	3.55	import Lc 3	6	-0.17	-5.92	3.58	import Lc 6

partial safety factors for material

resistance of components in the event of fire $\gamma_{M,fi} = 1.00$

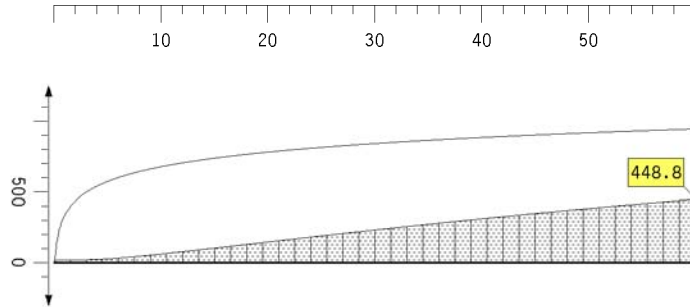
local stresses especially of the beam and of welds are not considered !

temperature at the connection point

cross-section temperature:

section factor of the protected component $A_p/V = 292.0 / 2123.6 \cdot 10^3 = 137.5 \text{ 1/m}$

temperature development:



temperature in °C

fire time in min

max $T_a = 448.8^\circ\text{C}$

max $t = 60 \text{ min}$

cross-section temperature acc. to $t = 60.0 \text{ min}$: $T_a = 448.8^\circ\text{C}$

connection temperature $\Theta = 0.880 \cdot 448.8^\circ\text{C} = 394.9^\circ\text{C}$

utilizations

Lc	U_p	U_σ	U_b	U_{pl}	$U_{pl,s}$	$U_{wt,s}$	$U_{t,s}$	$U_{vt,s}$	$U_{b,s}$	U_q	$U_{c/t}$	U_w	U
1	0.325	0.325	0.093	0.330	0.412	0.108	0.113	0.297	0.013	0.344	0.213	0.322	0.412
2	0.322	0.322	0.092	0.328	0.408	0.107	0.112	0.294	0.013	0.341	0.212	0.318	0.408
3	0.322	0.322	0.092	0.329	0.409	0.107	0.112	0.295	0.013	0.340	0.212	0.318	0.409
4	0.326	0.326	0.093	0.333	0.414	0.109	0.113	0.298	0.013	0.344	0.213	0.322	0.414
5	0.330	0.330	0.094	0.337	0.419	0.110	0.115	0.302	0.013	0.349	0.214	0.326	0.419*
6	0.329	0.329	0.094	0.335	0.417	0.110	0.114	0.300	0.013	0.348	0.214	0.325	0.417

U_p : utilization of end plate; U_σ : utilization of end plate due to stress; U_b : utilization of end plate due to compression by contact

U_{pl} : min. plastic utilization of the connection; $U_{pl,s}$: plastic utilization of tensile forces of bolts; $U_{wt,s}$: utilization of bolts due to elongation

$U_{t,s}$: utilization of bolts due to tension; $U_{vt,s}$: utilization of bolts due to shear; $U_{b,s}$: utilization of bolts due to bearing resistance

U_q : stress utilization of the beam; $U_{c/t}$: c/t-utilization of the beam; U_w : utilization of welds

U : total utilization

*) maximum utilization

2. final result

maximum utilization of end plate due to 6 Lc: max U_p with corresponding values

node	x mm	y mm	u_z mm	b_z N/mm ²	m_{xx} kNm/m	m_{yy} kNm/m	m_{xy} kNm/m	q_x kN/m	q_y kN/m	U_p
622	82.5	126.2	0.000	4.87	1.73	5.56	-0.00	-0.05	690.76	0.330

x,y: node coordinates; u_z : deformations (lifting off positive); b_z : compression by contact (compression positive); m_{xx}, m_{yy}, m_{xy} : moments
 q_x, q_y : shear forces; q_x, q_y : shear forces; U_p : utilization of end plate

maximum utilization of bolts due to 6 Lc: max U_s with corresponding values

	x mm	y mm	F_t kN	U_{wt}	U_{vt}	U_b	U_s
1	20.0	20.0	23.58	0.110	0.301	0.008	0.301
2	145.0	20.0	23.62	0.110	0.302	0.008	0.302
3	20.0	145.0	0.00	---	0.028	0.013	0.115
4	145.0	145.0	0.00	---	0.028	0.013	0.115

x,y: bolt coordinates; F_t : bolt force; U_{wt} : utilization due to elongation; U_{vt} : utilization due to shear

U_b : utilization due to bearing resistance; U_s : utilization of bolts

maximum utilization of end plate [Lc 5]

maximum utilization of bolts due to elongation [Lc 5]

maximum utilization of bolts [Lc 5]

maximum utilization of the beam [Lc 5]

maximum utilization of welds [Lc 5]

maximum utilization [Lc 5]

max $U_p = 0.330 < 1$ ok

max $U_{wt,s} = 0.110 < 1$ ok

max $U_s = 0.419 < 1$ ok

max $(U_q, U_{ct}) = 0.349 < 1$ ok

max $U_w = 0.326 < 1$ ok

max $U = 0.419 < 1$ ok

verification succeeded

3. Lc 5 (decisive)

3.1. end plate

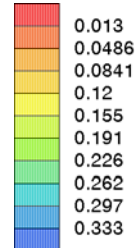
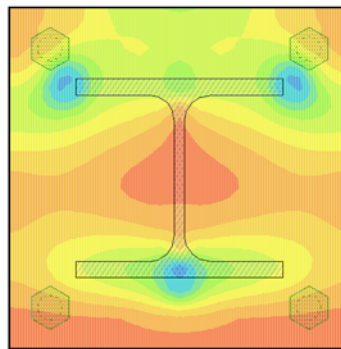
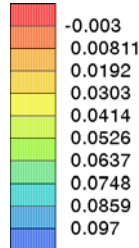
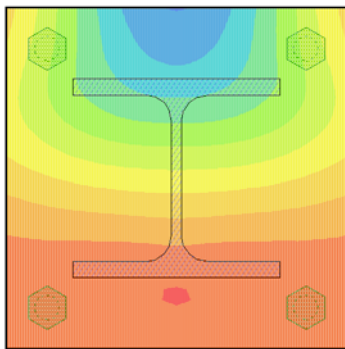
design values: $N = 0.09 \text{ kN}$, $M_y = -5.93 \text{ kNm}$, $M_z = 0.01 \text{ kNm}$

deformations u_z [mm]

min $u_z = -0.0032 \text{ mm}$, max $u_z = 0.0976 \text{ mm}$

utilization of end plate U_p

min $U_p = 0.013$, max $U_p = 0.330$



deformations lifting off positive

utilization of end plate

node	x mm	y mm	u_z mm	U_p
561	77.6	0.0	0.097	0.194
622	82.5	126.2	0.000	0.330

x,y: node coordinates; u_z : deformations (lifting off positive); U_p : utilization of end plate

utilization of bolts

	x mm	y mm	w_t mm	F_t kN	ϵ_{wt} %	U_{wt}
1	20.0	20.0	0.049	23.58	0.247	0.110
2	145.0	20.0	0.050	23.62	0.248	0.110
3	20.0	145.0	-0.001	0.00	0.000	---
4	145.0	145.0	-0.001	0.00	0.000	---

x,y: bolt coordinates; w_t : deformation (tension positive); F_t : bolt force; ϵ_{wt} : elongation
 U_{wt} : utilization due to elongation

utilization of end plate [node 622] $U_{max} = 0.330 < 1$ ok

utilization of bolts due to elongation [bolt 2] $U_{s,max} = 0.110 < 1$ ok

minimum plastic utilization of the connection $U_{pl,min} = 0.337 < 1$ ok

plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.419 < 1$ ok

3.2. bolts

design values: min $F_t = 0.00 \text{ kN}$, max $F_t = 23.62 \text{ kN}$, $V_z = 3.58 \text{ kN}$, $V_y = 0.00 \text{ kN}$

verification of bolts

U_{tp} utilization due to punching shear failure, U_{vt} utilization due to shear in tension, U_b utilization due to bearing resistance, U utilization of bolts

bolt 1	$U_{tp,1} = 0.114$	$U_{vt,1} = 0.301$	$U_{b,1} = 0.008$	$U_1 = 0.301$
bolt 2	$U_{tp,2} = 0.115$	$U_{vt,2} = 0.302$	$U_{b,2} = 0.008$	$U_2 = 0.302$
bolt 3	$U_{tp,3} = 0.000$	$U_{vt,3} = 0.028$	$U_{b,3} = 0.013$	$U_3 = 0.028$
bolt 4	$U_{tp,4} = 0.000$	$U_{vt,4} = 0.028$	$U_{b,4} = 0.013$	$U_4 = 0.028$
total:	$U_{tp} = 0.115$	$U_{vt} = 0.302$	$U_b = 0.013$	$U = 0.302 < 1$ ok

in utilization of bolts U_{max} ist minimum plastic utilization of the connection $U_{pl,min} = 0.337$ and plastic utilization of tensile forces of bolts $U_{pl,s} = 0.419$ is included.

utilization of bolts $U_{max} = 0.419 < 1$ ok

3.3. beam

elastic verification for $N = 0.09 \text{ kN}$, $M_y = -5.93 \text{ kNm}$, $V_z = 3.58 \text{ kN}$

verification: $\sigma_v = 81.91 \text{ N/mm}^2 < \sigma_{v,Rd} = 235.00 \text{ N/mm}^2 \Rightarrow U_\sigma = 0.349 < 1$ ok

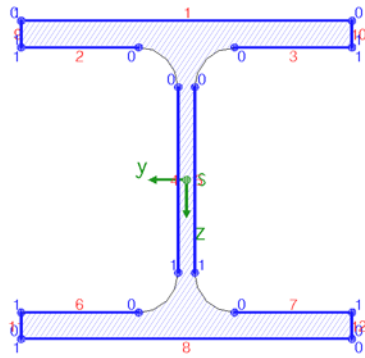
c/t-verification: utilization $U_{c/t} = 0.214 < 1$ ok

utilization of the beam $\max(U_\sigma, U_{c/t}) = 0.349 < 1$ ok

3.4. welds

design values: $N = 0.09 \text{ kN}$, $M_y = -5.93 \text{ kNm}$, $V_z = 3.58 \text{ kN}$, $M_z = 0.01 \text{ kNm}$,
 $V_y = 0.00 \text{ kN}$

weld 4: weld thickness $a = 4.0 \text{ mm} > a_{\max} = 0.7 \cdot t_{\min} = 3.5 \text{ mm}$ (welding technology, s. DIN 18800) !!



weld 1:	$a_w = 4.0 \text{ mm}$	$l_w = 100.0 \text{ mm}$
weld 2:	$a_w = 4.0 \text{ mm}$	$l_w = 35.5 \text{ mm}$
weld 3:	see weld 2	
weld 4:	$a_w = 4.0 \text{ mm}$	$l_w = 56.0 \text{ mm}$
weld 5:	see weld 4	
weld 6:	$a_w = 4.0 \text{ mm}$	$l_w = 35.5 \text{ mm}$
weld 7:	see weld 6	
weld 8:	$a_w = 4.0 \text{ mm}$	$l_w = 100.0 \text{ mm}$
weld 9:	$a_w = 4.0 \text{ mm}$	$l_w = 8.0 \text{ mm}$
weld 10:	see weld 9	
weld 11:	$a_w = 4.0 \text{ mm}$	$l_w = 8.0 \text{ mm}$
weld 12:	see weld 11	

Max: $\sigma_{1,w,Ed} = 129.28 \text{ N/mm}^2 < f_{1w,d} = 397.04 \text{ N/mm}^2$,
 $\sigma_{2,w,Ed} = 64.64 \text{ N/mm}^2 < f_{2w,d} = 285.87 \text{ N/mm}^2 \Rightarrow U_w = 0.326 < 1 \text{ ok}$

utilization of welds $U_{\max} = 0.326 < 1 \text{ ok}$

3.5. total

utilization Lc 5 $U_{\max} = 0.419 < 1 \text{ ok}$

4. Regulations

EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;

Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010

EN 1990/NA, Nationaler Anhang zur EN 1990, Ausgabe Dezember 2010

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

EN 1993-1-1/A1, Ergänzungen zur EN 1993-1-1, Ausgabe Juli 2014

EN 1993-1-1/NA, Nationaler Anhang zur EN 1993-1-1, Ausgabe Oktober 2022

EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -

Teil 1-8: Bemessung von Anschlüssen;

Deutsche Fassung EN 1993-1-8:2005 + AC:2009, Ausgabe Dezember 2010

EN 1993-1-8/NA, Nationaler Anhang zur EN 1993-1-8, Ausgabe November 2020

prEN 1993-1-14, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -

Teil 1-14: Bemessung mithilfe von Finite-Element-Berechnung;

Deutsche und englische Fassung prEN 1993-1-14:2023, Ausgabe September 2023

EN 1993-1-2, Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 1-2: Allgemeine Regeln -

Tragwerksbemessung für den Brandfall; Deutsche Fassung EN 1993-1-2, Ausgabe Dezember 2010

EN 1993-1-2/NA, Nationaler Anhang zur EN 1993-1-2, Ausgabe Dezember 2010