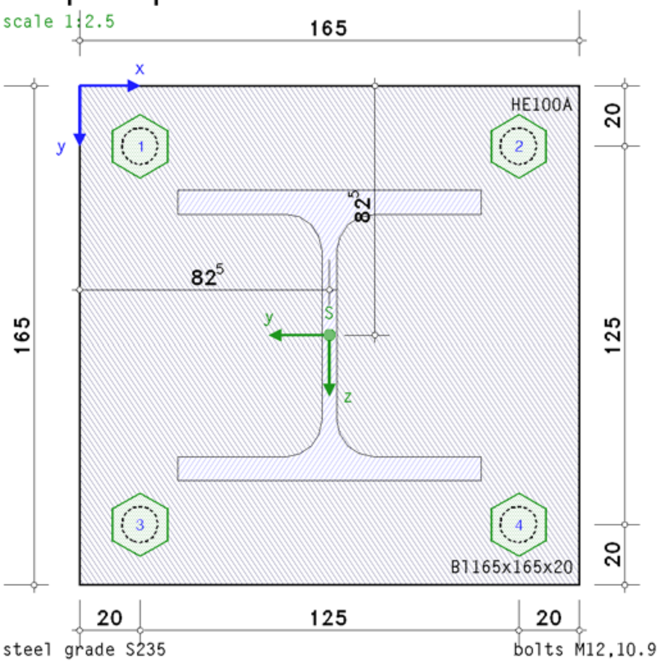
POS. 12: FIRE PROOF DOUBLE-T

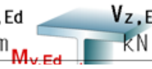
bolted end-plate connection EC 3-1-8 (12.10), NA: Deutschland 4H-EC3FS version: 2/2025-1b

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 section by wall/ceiling top
thermal insulation protection by plate cladding s. EC 3-1-2, appendix AA:
thermal conductivity λ_p = 0.20 W/(m·K), specific heat capacity c_p = 1700 J/(kg·K), maximum density ρ_p = 945 kg/m³
thickness of insulating material d_p = 20.0 mm
fire design at load level
temperature at the connection point:
vereinfachte calculation due to der temperature of the beam, reduction factor f_Θ = 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 plasticly 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 $\varepsilon_{t,f} = f_{t,\varepsilon} \cdot \varepsilon_{ub}$ = 2.3%, $f_{t,\varepsilon}$ = 0.250, ε_{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 refering to local axes of cross-section (event of fire, außergewöhnliche Bemessungssituation)

Lk	N_{Ed} kN	$M_{y,Ed}$ kNm	$V_{z,Ed}$ kN	
1	-0.36	-5.86	3.57	Import Lk 1
2	-0.17	-5.80	3.55	Import Lk 2
3	0.09	-5.79	3.55	Import Lk 3
4	0.17	-5.86	3.57	Import Lk 4
5	0.09	-5.93	3.58	Import Lk 5
6	-0.17	-5.92	3.58	Import Lk 6

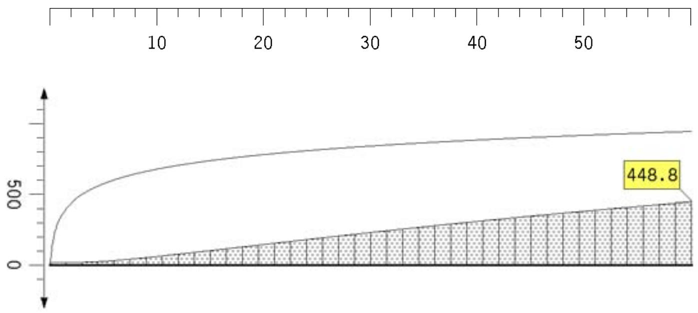


partial safety factors for material
resistance of components in the event of fire $\gamma_{M,fi}$ = 1.00

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

FEM: the bolt distance from the free edge of the plate edge is too small (min e = 20.0 mm < 24.0 mm).
the accuracy of the results cannot be guaranteed !!

temperature at the connection point
cross-section temperature:
section factor of the protected component A_p/V = 292.0 / 2123.6 ·10³ = 137.5 1/m
temperature development:



temperature in °C
fire time in min
max T_a = 448.8°C
max t = 60 min

cross-section temperature acc. to t = 60.0 min: T_a = 448.8 °C
connectiontemperatur Θ = 0.880·448.8°C = 394.9 °C

utilizations
in utilization of bolts due to tension $U_{t,s}$ ist minimum plastic utilization of the connection U_{pl} and plastic utilization of tensile forces of bolts $U_{pl,s}$ is included.

Lk	U_p	U_σ	U_b	$U_{pl,s}$	$U_{pl,t,s}$	$U_{wt,s}$	$U_{t,s}$	$U_{vt,s}$	$U_{b,s}$	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
$U_{pl,s}$: minimum plastic utilization of the connection; $U_{pl,t,s}$: 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_{ct}: 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 Lk: max U_p with corresponding values

node	x mm	y mm	u_z mm	b_z N/mm²	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 Lk: 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 [Lk 5]	max U_p = 0.330 < 1 ok
maximum utilization of bolts due to elongation [Lk 5]	max $U_{wt,s}$ = 0.110 < 1 ok
maximum utilization of bolts [Lk 5]	max U_s = 0.419 < 1 ok
maximum utilization of the beam [Lk 5]	max (U_q,U_{ct}) = 0.349 < 1 ok
maximum utilization of welds [Lk 5]	max U_w = 0.326 < 1 ok
maximum utilization [Lk 5]	**max U = 0.419 < 1** ok

verification succeeded

3. 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 Dezember 2018

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 Dezember 2010

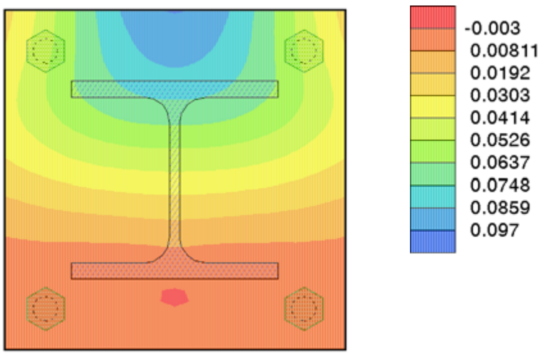
EN 1993-1-2, Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 1-2: Allgemeine Regeln -
Tragwerksbemessung für den Brandfall; Deutsche Fassung EN 1993-1-2, Ausgabe Dezember 2010
EN 1993-1-2/NA, Nationaler Anhang zur EN 1993-1-2, Ausgabe Dezember 2010

4. Lk 5 (decisive)

4.1. end-plate

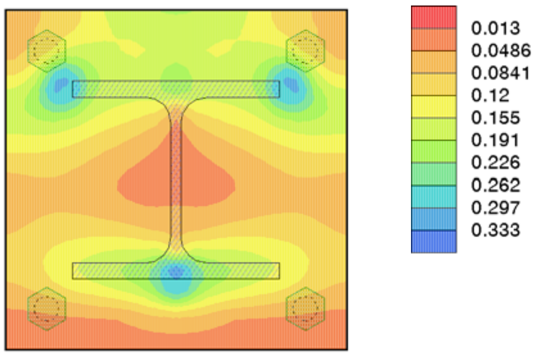
design values: $N = 0.09$ kN, $M_y = -5.93$ kNm, $M_z = 0.01$ kNm

deformations u_z [mm]
min u_z = -0.0032 mm, max u_z = 0.0976 mm



deformations lifting off positive

utilization of end-plate U_p
min U_p = 0.013, max U_p = 0.330



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 bolts $U_{pl,s,min} = 0.337 < 1$ ok
plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.419 < 1$ ok

4.2. bolts

design values: min F_t = 0.00 kN, max F_t = 23.62 kN, V_z = 3.58 kN, V_y = 0.00 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 max U_s the minimum plastic utilization of bolts min $U_{pl,s}$ = 0.337
and plastic utilization of tensile forces of bolts $U_{pl,t,s}$ = 0.419 is included.

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

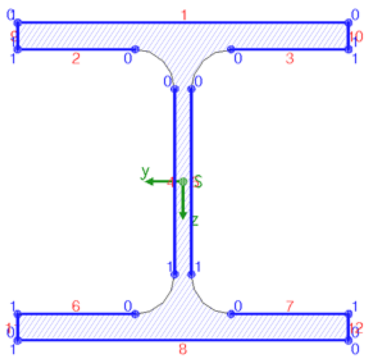
4.3. beam

elastic verification for N = 0.09 kN, M_y = -5.93 kNm, V_z = 3.58 kN
verification: σ_v = 81.91 N/mm² < $\sigma_{v,Rd}$ = 235.00 N/mm² ⇒ U_σ = 0.349 < 1 ok
c/t-verification: utilization $U_{c/t}$ = 0.214 < 1 ok

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

4.4. welds

design values: N = 0.09 kN, M_y = -5.93 kNm, V_z = 3.58 kN, M_z = 0.01 kNm,
V_y = 0.00 kN
weld 4: weld thickness a = 4.0 mm > $a_{max} = 0.7 \cdot t_{min}$ = 3.5 mm (welding technology, s. DIN 18800) !!



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

Max: $\sigma_{1,w,Ed}$ = 129.28 N/mm² < $f_{1w,d}$ = 397.04 N/mm²,
$\sigma_{2,w,Ed}$ = 64.64 N/mm² < $f_{2w,d}$ = 285.87 N/mm² ⇒ U_w = 0.326 < 1 ok

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

4.5. total

utilization Lk 5 U_{max} = 0.419 < 1 ok