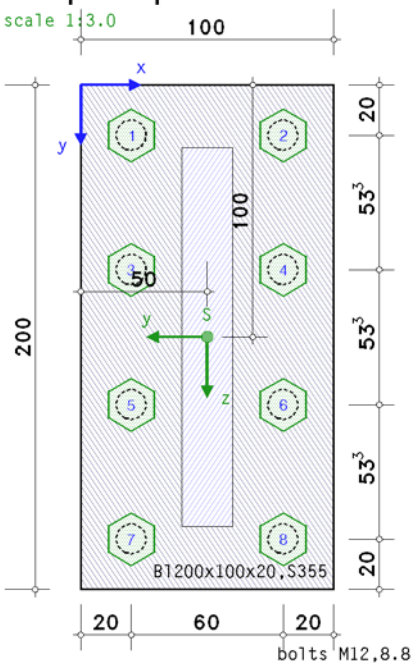
# POS. 8: FLAT STEEL

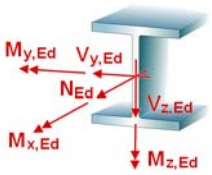
bolted end-plate connection EC 3-1-8 (12.10), NA: Deutschland 4H-EC3FS version: 2/2025-1b

## 1. input report




**bolts**
bolt class 8.8, bolt size M12, normal wrench size
thread included in the shear plane
**connection**
end-plate (rectangular): thickness $t_p$ = 20.0 mm, width $b_p$ = 100.0 mm, length $l_p$ = 200.0 mm, steel grade S355
beam: section parameters (flat steel):
h = 150.0 mm, t = 20.0 mm, steel grade S235
beam-end-plate: surrounding butt weld (full penetrated)
beam section centric on end-plate (beam centroid in plate centre)
coordinates of the beam centroid on end-plate $x_s$ = 50.0 mm, $y_s$ = 100.0 mm
bolts:
uniform arrangement of bolts, 2 vertical and 4 horizontal rows
edge distances top, below $e_o = e_u$ = 20.0 mm, distances between bolts $p_y$ = 53.3 mm
edge distances left, right $e_l = e_r$ = 20.0 mm, distances between bolts $p_x$ = 60.0 mm
**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 bolts, check of distances
FEM-calculation:
bolts are plasticly calculated, spring constant of bolts $c_f$ = 3381.7 kN/cm
plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd}$ = 46.1 kN, $f_{t,f}$ = 0.950, $F_{t,Rd} = (k_2 \cdot f_{ub} \cdot A_s) / \gamma_{M2}$ = 48.56 kN, $k_2$ = 0.90
effective elongation at failure $\varepsilon_{t,f} = f_{t,\varepsilon} \cdot \varepsilon_{ub}$ = 3.0%, $f_{t,\varepsilon}$ = 0.250, $\varepsilon_{ub}$ = 12.0%
without preloading ($F_{p,C}$ = 0)
effective foundation modulus of end plate $c_b$ = 10500.0 kN/cm³
number / dimension of finite elements each direction $n_x$ / $\Delta x$ = 20 / 5.0 mm, $n_y$ / $\Delta y$ = 40 / 5.0 mm
max. 50 iteration steps (tolerance limit 5‰)
**internal forces and moments** refering to local axes of cross-section

| Lk | $N_{Ed}$ kN | $M_{y,Ed}$ kNcm | $V_{z,Ed}$ kN | $M_{z,Ed}$ kNcm | $V_{y,Ed}$ kN | $M_{x,Ed}$ kNcm |
|---|---|---|---|---|---|---|
| 1 | -12.34 | -93.52 | 0.92 | 70.92 | 0.16 | -0.12 |
| 2 | 7.05 | -2244.87 | 25.86 | -347.75 | -0.78 | 129.03 |
| 3 | 1.10 | -28.71 | 0.54 | -152.64 | -0.34 | -7.61 |
| 4 | -1.02 | -2283.76 | 26.09 | -213.61 | -0.48 | 133.53 |
| 5 | -1.72 | -2283.89 | 26.08 | -183.13 | -0.41 | 16.86 |
| 6 | 1.60 | -28.62 | 0.54 | -173.98 | -0.39 | 74.06 |
| 7 | -1.84 | -2281.83 | 26.07 | -178.23 | -0.40 | 12.35 |
| 8 | 1.68 | -30.06 | 0.55 | -177.41 | -0.40 | 77.22 |
| 9 | 6.45 | -2267.74 | 26.00 | -258.61 | -0.58 | 131.97 |




**partial safety factors for material**
resistance of cross-sections $\gamma_{M0}$ = 1.00

resistance of bolts, welds, plates in bearing $\gamma_{M2}$ = 1.25

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 !!

### 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 | $U_p$ | $U_\sigma$ | $U_b$ | $U_{pl,s}$ | $U_{pl,t,s}$ | $U_{wt,s}$ | $U_{t,s}$ | $U_{vt,s}$ | $U_{b,s}$ | U |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.060 | 0.060 | 0.025 | 0.005 | 0.063 | 0.009 | 0.012 | 0.055 | --- | 0.063 |
| 2 | 0.740 | 0.740 | 0.461 | 0.661 | 0.904 | 0.564 | 0.161 | 0.717 | 0.119 | 0.904* |
| 3 | 0.133 | 0.133 | 0.022 | 0.090 | 0.134 | 0.021 | 0.029 | 0.125 | 0.002 | 0.134 |
| 4 | 0.696 | 0.696 | 0.449 | 0.649 | 0.828 | 0.408 | 0.161 | 0.713 | 0.108 | 0.828 |
| 5 | 0.686 | 0.686 | 0.443 | 0.647 | 0.812 | 0.372 | 0.161 | 0.691 | 0.063 | 0.812 |
| 6 | 0.151 | 0.151 | 0.025 | 0.104 | 0.154 | 0.023 | 0.033 | 0.164 | 0.016 | 0.164 |
| 7 | 0.685 | 0.685 | 0.441 | 0.646 | 0.808 | 0.365 | 0.161 | 0.691 | 0.061 | 0.808 |
| 8 | 0.154 | 0.154 | 0.025 | 0.106 | 0.157 | 0.024 | 0.034 | 0.167 | 0.016 | 0.167 |
| 9 | 0.714 | 0.714 | 0.456 | 0.666 | 0.865 | 0.481 | 0.161 | 0.715 | 0.113 | 0.865 |

$U_p$: utilization of end-plate; $U_\sigma$: 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: total utilization
*) maximum utilization

## 2. final result

### maximum utilization of end-plate due to 9 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 | $U_p$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 376 | 45.0 | 30.0 | 0.279 | 0.00 | -27.24 | -17.78 | -0.30 | 1142.28 | 479.99 | 0.740 |

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 9 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 | 46.13 | 0.564 | 0.717 | 0.010 | 0.717 |
| 2 | 80.0 | 20.0 | 46.11 | 0.213 | 0.711 | 0.009 | 0.711 |
| 3 | 20.0 | 73.3 | 46.13 | 0.338 | 0.706 | 0.006 | 0.706 |
| 4 | 80.0 | 73.3 | 34.68 | 0.090 | 0.621 | 0.029 | 0.621 |
| 5 | 20.0 | 126.7 | 38.54 | 0.097 | 0.655 | 0.013 | 0.655 |
| 6 | 80.0 | 126.7 | 4.48 | 0.011 | 0.235 | 0.023 | 0.235 |
| 7 | 20.0 | 180.0 | 0.21 | --- | 0.447 | 0.119 | 0.447 |
| 8 | 80.0 | 180.0 | 0.20 | --- | 0.202 | 0.053 | 0.202 |

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 2] | max $U_p$ = 0.740 < 1 ok |
| maximum utilization of bolts due to elongation [Lk 2] | max $U_{wt,s}$ = 0.564 < 1 ok |
| maximum utilization of bolts [Lk 2] | max $U_s$ = 0.904 < 1 ok |
| **maximum utilization [Lk 2]** | **max U = 0.904 < 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

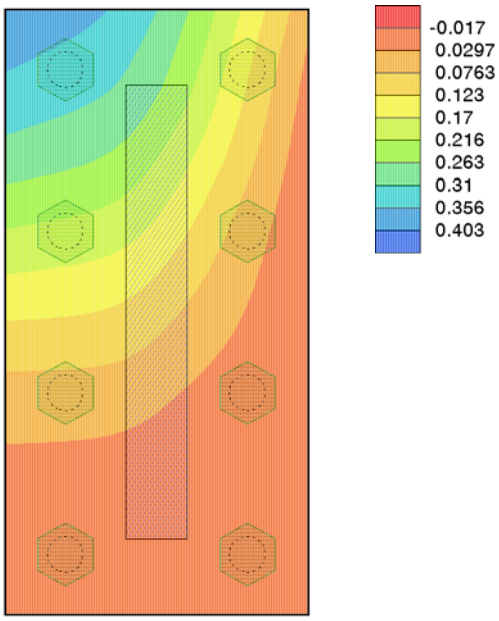
EN 1993-1-8, Eurocode 3: Bemessung und Konstruktion von Stahlbauten -
Teil 1-8: Bemessung von Anschlüssen;
Deutsche Fassung EN 1993-1-8:2005 + AC:2009, Ausgabe Dezember 2010
EN 1993-1-8/NA, Nationaler Anhang zur EN 1993-1-8, Ausgabe Dezember 2010

# 4. Lk 2 (decisive)

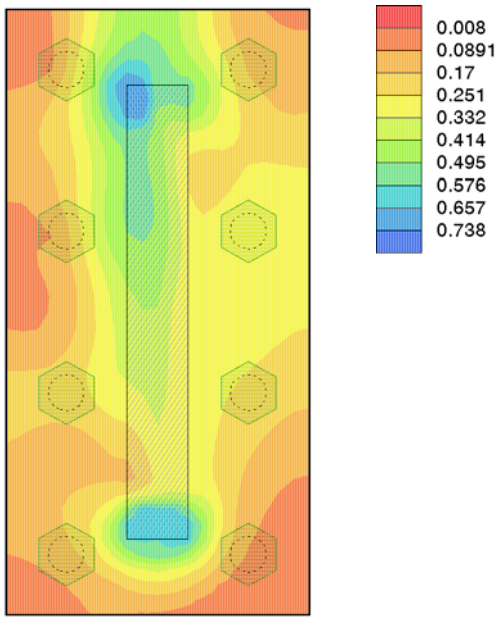
## 4.1. end-plate

design values: N = 7.05 kN, $M_y$ = -22.45 kNm, $M_z$ = -3.48 kNm

**deformations $u_z$** [mm]
min $u_z$ = -0.0170 mm, max $u_z$ = 0.3989 mm




**utilization of end-plate $U_p$**
min $U_p$ = 0.008, max $U_p$ = 0.740




deformations lifting off positive

**utilization of end-plate**

| node | x | y | $u_z$ | $U_p$ |
|---|---|---|---|---|
| | mm | mm | mm | |
| 1 | 0.0 | 0.0 | 0.399 | 0.012 |
| 376 | 45.0 | 30.0 | 0.279 | 0.740 |

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

**utilization of bolts**

| | x | y | wt | $F_t$ | $\varepsilon_{wt}$ | $U_{wt}$ |
|---|---|---|---|---|---|---|
| | mm | mm | mm | kN | % | |
| 1 | 20.0 | 20.0 | 0.338 | 46.13 | 1.692 | 0.564 |
| 2 | 80.0 | 20.0 | 0.128 | 46.11 | 0.638 | 0.213 |
| 3 | 20.0 | 73.3 | 0.203 | 46.13 | 1.013 | 0.338 |
| 4 | 80.0 | 73.3 | 0.054 | 34.68 | 0.270 | 0.090 |
| 5 | 20.0 | 126.7 | 0.058 | 38.54 | 0.292 | 0.097 |
| 6 | 80.0 | 126.7 | 0.008 | 5.19 | 0.038 | 0.013 |
| 7 | 20.0 | 180.0 | -0.001 | 0.21 | 0.000 | --- |
| 8 | 80.0 | 180.0 | -0.002 | 0.20 | 0.000 | --- |

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

**utilization of end-plate [node 376]** $U_{max} = 0.740 < 1$ ok
**utilization of bolts due to elongation [bolt 1]** $U_{s,max} = 0.564 < 1$ ok
**minimum plastic utilization of bolts** $U_{pl,s,min} = 0.661 < 1$ ok
**plastic utilization of tensile forces of bolts** $U_{pl,t,s} = 0.904 < 1$ ok

## 4.2. bolts

design values: min $F_t$ = 0.20 kN, max $F_t$ = 46.13 kN, $V_z$ = 25.86 kN, $V_y$ = -0.78 kN,
$M_x$ = 1.29 kNm

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 | $U_{tp,1} = 0.161$ | $U_{vt,1} = 0.717$ | $U_{b,1} = 0.010$ | $U_1 = 0.717$ |
| bolt 2 | $U_{tp,2} = 0.161$ | $U_{vt,2} = 0.711$ | $U_{b,2} = 0.009$ | $U_2 = 0.711$ |
| bolt 3 | $U_{tp,3} = 0.161$ | $U_{vt,3} = 0.706$ | $U_{b,3} = 0.006$ | $U_3 = 0.706$ |
| bolt 4 | $U_{tp,4} = 0.121$ | $U_{vt,4} = 0.621$ | $U_{b,4} = 0.029$ | $U_4 = 0.621$ |
| bolt 5 | $U_{tp,5} = 0.134$ | $U_{vt,5} = 0.655$ | $U_{b,5} = 0.013$ | $U_5 = 0.655$ |
| bolt 6 | $U_{tp,6} = 0.018$ | $U_{vt,6} = 0.215$ | $U_{b,6} = 0.029$ | $U_6 = 0.215$ |
| bolt 7 | $U_{tp,7} = 0.001$ | $U_{vt,7} = 0.447$ | $U_{b,7} = 0.119$ | $U_7 = 0.447$ |
| bolt 8 | $U_{tp,8} = 0.001$ | $U_{vt,8} = 0.202$ | $U_{b,8} = 0.053$ | $U_8 = 0.202$ |

total: $U_{tp} = 0.161$ $U_{vt} = 0.717$ $U_b = 0.119$ $U = 0.717 < 1$ ok

in utilization of bolts max $U_s$ the minimum plastic utilization of bolts min $U_{pl,s} = 0.661$ and plastic utilization of tensile forces of bolts $U_{pl,t,s} = 0.904$ is included.

**utilization of bolts** $U_{max} = 0.904 < 1$ ok

### 4.3. total

utilization Lk 2 $U_{max} = 0.904 < 1$ ok