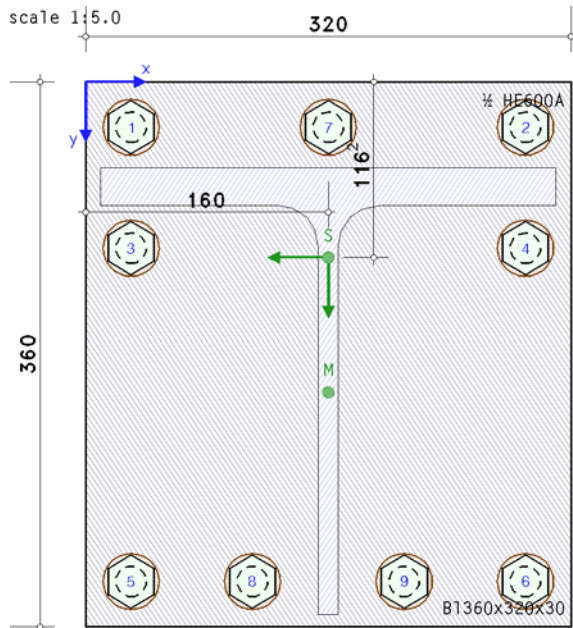# POS. 3: T

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

scale 1:5.0

steel grade
steel grade S355
bolts
bolts with big width across flats have to be preloaded with $F_{p,C}$ ‼
bolt class 10.9, bolt size M20
large width across flats (high strength bolt), controlled preloaded
preloading $F_{p,C}^* = 0.7 \cdot f_{yb} \cdot A_s = 154.3$ kN, thread included in the shear plane
connection
end-plate: thickness $t_p = 30.0$ mm, width $b_p = 320.0$ mm, length $l_p = 360.0$ mm
beam: section ½ HE600A
beam-end-plate: surrounding fillet weld, weld thickness a = 10.0 mm
coordinates of beam centroid on end-plate $x_s = 160.0$ mm, $y_s = 116.2$ mm
bolts:
coordinates of bolt axis:

$x_1 = 30.0$ mm, $y_1 = 30.0$ mm	$x_2 = 290.0$ mm, $y_2 = 30.0$ mm	$x_3 = 30.0$ mm, $y_3 = 110.0$ mm
$x_4 = 290.0$ mm, $y_4 = 110.0$ mm	$x_5 = 30.0$ mm, $y_5 = 330.0$ mm	$x_6 = 290.0$ mm, $y_6 = 330.0$ mm
$x_7 = 160.0$ mm, $y_7 = 30.0$ mm	$x_8 = 110.0$ mm, $y_8 = 330.0$ mm	$x_9 = 210.0$ mm, $y_9 = 330.0$ mm

calculation
verification:
calculation and verification of internal forces and moments (FEM)
verification of end-plate with the plastic method
verification of bolts, check of distances
FEM-calculation:
bolts are plasticly calculated, spring constant of bolts $c_f = 8021.1$ kN/cm
plastic limit force $F_{t,f} = f_{t,f} \cdot F_{t,Rd} = 167.6$ kN, $f_{t,f} = 0.950$, $F_{t,Rd} = 176.4$ kN, effective elongation at failure $\varepsilon_{t,f} = 4.5\%$
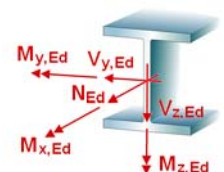preload force $F_{p,C} = 154.3$ kN
effective foundation modulus of end plate $c_b = 14000.0$ kN/cm³
number / dimension of finite elements each direction n_x / Δx = 24 / 13.3 mm, n_y / Δy = 27 / 13.3 mm
max. 50 iteration steps (tolerance limit 5‰)
internal forces and moments

Lk	N_{Ed} kN	$M_{y,Ed}$ kNm	$V_{z,Ed}$ kN	$M_{z,Ed}$ kNm	$V_{y,Ed}$ kN	$M_{x,Ed}$ kNm
1	-45.8	-178.3	125.7	-24.3	-9.7	10.3
2	3.6	17.7	0.4	89.9	39.1	-3.3
3	-15.6	-76.3	43.4	-49.9	-17.5	2.3
4	-15.0	-39.9	48.5	93.8	39.8	3.1
5	-8.0	-44.4	36.6	90.4	38.3	-3.6
6	-29.2	-89.6	74.0	-25.1	-8.5	10.9
7	-4.0	-14.2	7.2	-50.4	-16.7	2.6
8	-26.6	-102.0	84.7	94.3	38.9	2.7

Lk	N_{Ed}	$M_{y,Ed}$	$V_{z,Ed}$	$M_{z,Ed}$	$V_{y,Ed}$	$M_{x,Ed}$
	kN	kNm	kN	kNm	kN	kNm
9	-41.2	-159.2	121.6	59.9	23.8	6.8
10	-45.5	-173.4	125.2	-24.9	-8.7	10.6
11	3.4	14.3	0.7	90.3	38.4	-3.5

partial safety factors for material
resistance of cross-sections $\gamma_{M0} = 1.00$
resistance of bolts, welds, plates in bearing $\gamma_{M2} = 1.25$

Calculation

parts of fillet weld outside of end plate !

utilizations

Lk	U_p	U_σ	U_b	U_{wt}	$U_{t,s}$	$U_{vt,s}$	$U_{b,s}$	U
--	-	-	-	-	-	-	-	-
1	0.586	0.377	0.586	0.130	0.950	0.904	0.121	0.950*
2	0.417	0.190	0.417	0.064	0.931	0.692	0.022	0.931
3	0.255	0.206	0.255	0.067	0.936	0.704	0.032	0.936
4	0.513	0.374	0.513	0.128	0.950	0.769	0.062	0.950*
5	0.493	0.371	0.493	0.126	0.950	0.709	0.035	0.950*
6	0.245	0.120	0.245	0.056	0.902	0.787	0.070	0.902
7	0.224	0.089	0.224	0.053	0.887	0.657	0.014	0.887
8	fault	0.560	0.885	1.226	---	---	---	---
9	0.918	0.514	0.918	0.781	0.950	0.907	0.122	0.950*
10	0.563	0.364	0.563	0.121	0.950	0.905	0.121	0.950*
11	0.423	0.200	0.423	0.066	0.934	0.693	0.022	0.934

U_p: utilization of end-plate; U_σ: utilization of end-plate due to stress; U_p: utilization of end-plate due to compression by contact
$U_{wt,s}$: utilization of bolts due to elongation; $U_{t,s}$: utilization of bolts due to tension; $U_{vt,s}$: utilization of bolts due to shear in tension
$U_{b,s}$: utilization of bolts due to bearing resistance; U: total utilization
*) maximum utilization

Final Result

design resistance not ensured !!

verification could not be executed, see Lk 8 !!

Regulations

DIN EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;
  Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010
DIN EN 1990/NA, Nationaler Anhang zur DIN EN 1990, Ausgabe Dezember 2010

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

DIN 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
DIN EN 1993-1-8/NA, Nationaler Anhang zur DIN EN 1993-1-8, Ausgabe Dezember 2010

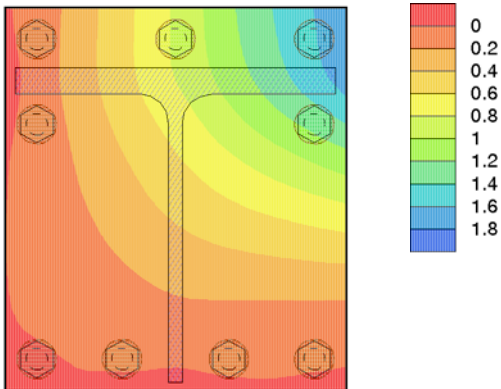## Detailed edition of Lk 8 (decisive)

end-plate

design values: N = -26.59 kN, M_y = -102.02 kNm, M_z = 94.34 kNm

FEM: weak bolts, utilization due to elongation exceeded !!

deformations u_z [mm], lifting off positive
min u_z = -0.08 mm, max u_z = 1.77 mm

deformation of end-plate

Kno	x	y	u_z
	mm	mm	mm
673	320.0	0.0	1.771

x,y: node coordinates; u_z: deformations (lifting off positive)

tension force of bolts

	x	y	w_t	F_t	ε_{wt}	U_{wt}	
	mm	mm	mm	kN	%		
1	30.0	30.0	0.087	166.88	0.524	0.116	
2	290.0	30.0	1.584	167.58	5.515	1.226	> 1
3	30.0	110.0	0.077	166.76	0.490	0.109	
4	290.0	110.0	1.261	167.58	4.438	0.986	
5	30.0	330.0	-0.004	154.47	0.234	0.052	
6	290.0	330.0	0.017	162.32	0.289	0.064	
7	160.0	30.0	0.829	167.58	2.998	0.666	
8	110.0	330.0	0.013	161.80	0.276	0.061	
9	210.0	330.0	0.028	165.16	0.326	0.072	

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

utilization of bolts due to elongation [bolt 2] U_{max} = 1.226 > 1 **not ok. !!**