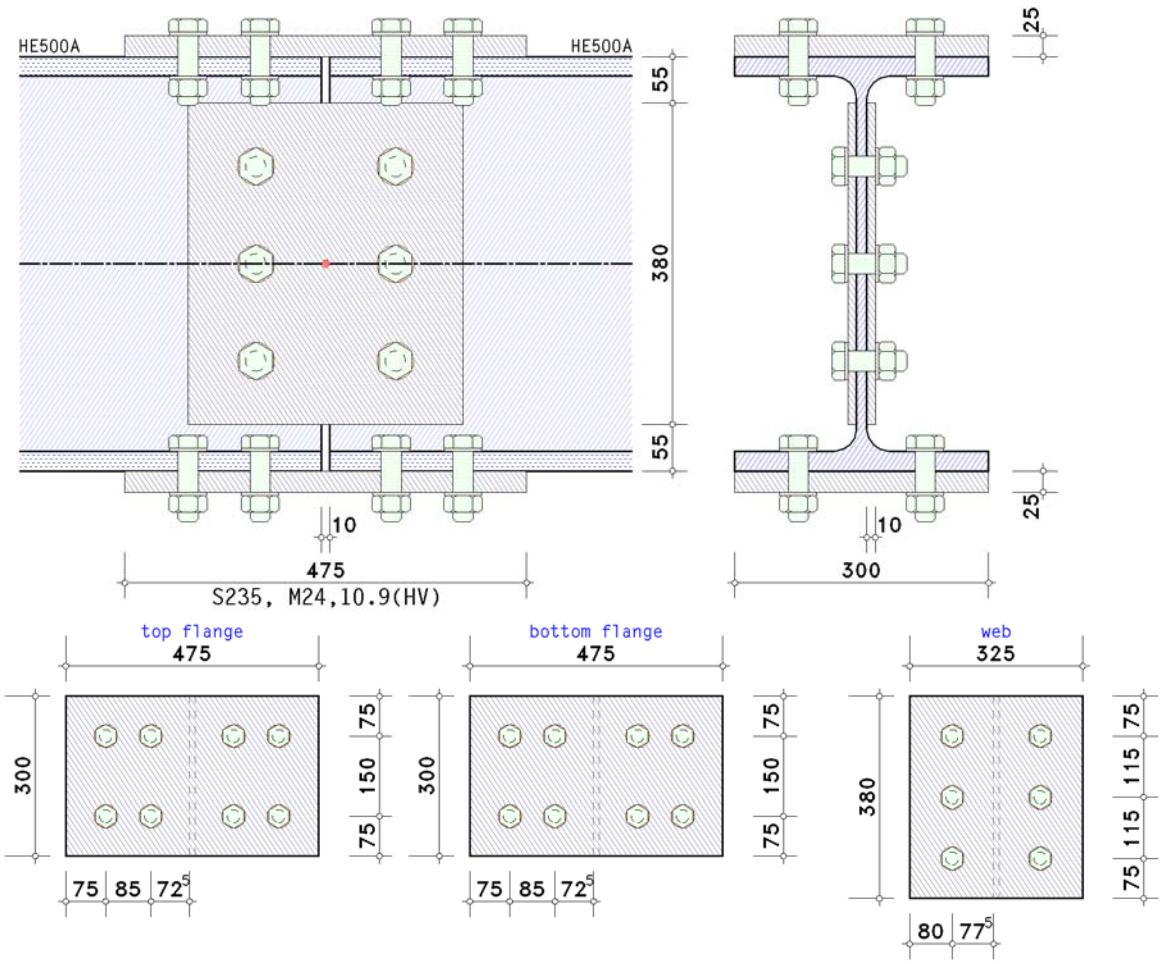
# Rigid beam splice

EC 3-1-8 (12.10), NA: Deutschland




**steel grade**

steel grade S235

**bolts**

bolt class 10.9, bolt size M24

large width across flats (high strength bolt), controlled preloaded, preloading $F_{p,C}^* = 0.7 \cdot f_{yb} \cdot A_s = 222.4$ kN

**beam**

section HE500A

**verification parameters**

bolted plate joint:

gap between the beams $\Delta s = 10.0$ mm

misalignment of top edge of the beams $\Delta z_{Tr} = 0.0$ mm (centric beam)

plates at top flange:

external plate: thickness t = 25.0 mm, width b = 300.0 mm, length l = 475.0 mm

bolts in top flange:

2 x 1 bolts each half of flange

shear plane passes through the unthreaded portion of the bolt

centre distances of bolts across to tensile edge $e_2 = 75.0$ mm, $e_{22} = 0.0$ mm

centre distances of bolts to the tensional edge $e_1 = 75.0$ mm, $e_{11} = 72.5$ mm

centre distance of bolt-rows towards tension $p_1 = 85.0$ mm

centric centre distance of bolt-rows towards tension $w_1 = 155.0$ mm

centric centre distance of bolt-rows across tension $w_2 = 150.0$ mm

plates at bottom flange:

external plate: thickness t = 25.0 mm, width b = 300.0 mm, length l = 475.0 mm

bolts in bottom flange:

2 x 1 bolts each half of flange

shear plane passes through the unthreaded portion of the bolt

centre distances of bolts across to tensile edge $e_2 = 75.0$ mm, $e_{22} = 0.0$ mm

centre distances of bolts to the tensional edge $e_1 = 75.0$ mm, $e_{11} = 72.5$ mm

centre distance of bolt-rows towards tension $p_1 = 85.0$ mm

centric centre distance of bolt-rows towards tension $w_1 = 155.0$ mm

centric centre distance of bolt-rows across tension $w_2 = 150.0$ mm

plates at web:
2 plates: thickness t = 10.0 mm, width b = 380.0 mm, length l = 325.0 mm
distance upper edge plate to the upper edge of beam (left) $\Delta z_{Lw}$ = 55.0 mm (plates centric)
bolts in web:
1 x 3 bolts
thread included in the shear plane
centre distances of bolts across to tensile edge $e_2$ = 75.0 mm, $e_{22}$ = 75.0 mm
centre distances of bolts to the tensional edge $e_1$ = 80.0 mm, $e_{11}$ = 77.5 mm
centre distance of bolt-rows across tension $p_2$ = 115.0 mm
centric centre distance of bolt-rows towards tension $w_1$ = 165.0 mm

**internal forces and moments in the intersection point of system axes (sign convention of statics)**

Lk 1: $N_{j,b,Ed}$ = 120.00 kN $M_{j,b,Ed}$ = 250.00 kNm $V_{j,b,Ed}$ = 90.00 kN

**partial safety factors for material**

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

## Plate connection

notes
high strength bolts have to be controlled prestressed, bolt category D (tension), A (shear).
however, connection is verified due to EC 3-1-8 regardless of preloading.
no verification for cross-sections.
buckling is not investigated.

distance of bolt rows at top flange

| | | |
|---|---|---|
| edge dist.: | $e_2$ = 75.0 mm > 1.2·$d_0$ = 31.2 mm, | $e_2$ = 75.0 mm < 4·$t_{min}$ + 40 mm = 132.0 mm |
| pitch: | $p_2$ = 150.0 mm > 2.4·$d_0$ = 62.4 mm, | $p_2$ = 150.0 mm < min(14·$t_{min}$, 200 mm) = 200.0 mm |
| edge dist.: | $e_1$ = 75.0 mm > 1.2·$d_0$ = 31.2 mm, | $e_1$ = 75.0 mm < 4·$t_1$ + 40 mm = 140.0 mm |
| pitch: | $p_1$ = 85.0 mm > 2.2·$d_0$ = 57.2 mm, | $p_1$ = 85.0 mm < min(14·$t_{min}$, 200 mm) = 200.0 mm |
| edge dist.: | $e_1$ = 72.5 mm > 1.2·$d_0$ = 31.2 mm, | $e_1$ = 72.5 mm < 4·$t_1$ + 40 mm = 140.0 mm |
| pitch: | $p_1$ = 155.0 mm > 2.2·$d_0$ = 57.2 mm, | $p_1$ = 155.0 mm < min(14·$t_{min}$, 200 mm) = 200.0 mm |

distance of bolt rows at web

| | | |
|---|---|---|
| edge dist.: | $e_2$ = 75.0 mm > 1.2·$d_0$ = 31.2 mm, | $e_2$ = 75.0 mm < 4·$t_{min}$ + 40 mm = 80.0 mm |
| pitch: | $p_2$ = 115.0 mm > 2.4·$d_0$ = 62.4 mm, | $p_2$ = 115.0 mm < min(14·$t_{min}$, 200 mm) = 140.0 mm |
| edge dist.: | $e_2$ = 75.0 mm > 1.2·$d_0$ = 31.2 mm, | $e_2$ = 75.0 mm < 4·$t_{min}$ + 40 mm = 80.0 mm |
| edge dist.: | $e_1$ = 80.0 mm > 1.2·$d_0$ = 31.2 mm, | $e_1$ = 80.0 mm ≤ 4·$t_1$ + 40 mm = 80.0 mm |
| edge dist.: | $e_1$ = 77.5 mm > 1.2·$d_0$ = 31.2 mm, | $e_1$ = 77.5 mm < 4·$t_1$ + 40 mm = 80.0 mm |
| pitch: | $p_1$ = 165.0 mm > 2.2·$d_0$ = 57.2 mm, | $p_1$ = 165.0 mm > min(14·$t_{min}$, 200 mm) = 140.0 mm !! |

**maximum values for spacings and edge distances only in order to avoid local buckling and to prevent corrosion.**

distance of bolt rows at bottom flange

| | | |
|---|---|---|
| edge dist.: | $e_2$ = 75.0 mm > 1.2·$d_0$ = 31.2 mm, | $e_2$ = 75.0 mm < 4·$t_{min}$ + 40 mm = 132.0 mm |
| pitch: | $p_2$ = 150.0 mm > 2.4·$d_0$ = 62.4 mm, | $p_2$ = 150.0 mm < min(14·$t_{min}$, 200 mm) = 200.0 mm |
| edge dist.: | $e_1$ = 75.0 mm > 1.2·$d_0$ = 31.2 mm, | $e_1$ = 75.0 mm < 4·$t_1$ + 40 mm = 140.0 mm |
| pitch: | $p_1$ = 85.0 mm > 2.2·$d_0$ = 57.2 mm, | $p_1$ = 85.0 mm < min(14·$t_{min}$, 200 mm) = 200.0 mm |
| edge dist.: | $e_1$ = 72.5 mm > 1.2·$d_0$ = 31.2 mm, | $e_1$ = 72.5 mm < 4·$t_1$ + 40 mm = 140.0 mm |
| pitch: | $p_1$ = 155.0 mm > 2.2·$d_0$ = 57.2 mm, | $p_1$ = 155.0 mm < min(14·$t_{min}$, 200 mm) = 200.0 mm |

### Lk 1

load distribution to the plates considering the section stiffness
considering only the right beam !!

**elastic stresses at net section**

$N_{Ed}$ = 120.00 kN, $M_{y,Ed}$ = 250.00 kNm
stresses in points of cross-section:

| | | | |
|---|---|---|---|
| pt. 1: | y = 0.0 mm | z = 50.0 mm | $\sigma_x$ = -49.76 N/mm² |
| pt. 2: | y = 0.0 mm | z = 440.0 mm | $\sigma_x$ = 73.39 N/mm² |
| pt. 3: | y = 150.0 mm | z = 11.5 mm | $\sigma_x$ = -61.91 N/mm² |
| pt. 4: | y = -150.0 mm | z = 11.5 mm | $\sigma_x$ = -61.91 N/mm² |
| pt. 5: | y = 150.0 mm | z = 478.5 mm | $\sigma_x$ = 85.54 N/mm² |
| pt. 6: | y = -150.0 mm | z = 478.5 mm | $\sigma_x$ = 85.54 N/mm² |

**load distribution (section) at gross section**

top flange: $N_{fo}$ = -435.91 kN
web: $N_w$ = 33.43 kN, $M_{y,w}$ = 26.03 kNm, $V_{z,w}$ = 90.00 kN
bottom flange: $N_{fu}$ = 522.49 kN

top flange
internal forces and moments at flange: N = $N_{fo}$ = -435.91 kN
**beam**
compression
maximum normal stress: $\sigma_x$ = 61.91 N/mm² (s.o.)
verification: $\sigma_x$ = 61.91 N/mm² < $\sigma_{Rd}$ = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.263 < 1 ok.
**plate**
compression
compression resistance $F_{c,Rd} = (A \cdot f_y) / \gamma_{M0}$ = 1762.50 kN
verification: $F_{Ed}$ = 435.91 kN < $F_{c,Rd}/f_a$ = 1762.50 kN ⇒ U = 0.247 < 1 ok.
**bolts**
cross-section of points
maximum stress max $T_i = T_1$ = 108.98 kN bei 4 bolts
shear
shear resistance $F_{v,Rd}$ = 217.1 kN
verification: $F_{Ed} = T_1$ = 108.98 kN < $F_{v,Rd}$ = 217.15 kN ⇒ U = 0.502 < 1 ok.
bearing resistance
flange: bearing resistance $F_{b,Rd}$ = 333.7 kN
external plate: bearing resistance $F_{b,Rd}$ = 362.8 kN
minimum bearing resistance: min $F_{b,Rd}$ = 333.75 kN
verification: $F_{Ed} = T_2$ = 108.98 kN < $F_{b,Rd}$ = 333.75 kN ⇒ U = 0.327 < 1 ok.

bottom flange
internal forces and moments at flange: N = $N_{fo}$ = 522.49 kN
**beam**
tension
$A_{net} \cdot 0.9 \cdot f_u/\gamma_{M2}$ = 1478.48 kN < $A \cdot f_y/\gamma_{M0}$ = 1621.50 kN ⇒ considering deduction of holes
maximum normal stress: $\sigma_x$ = 85.54 N/mm² (s.o.)
verification: $\sigma_x$ = 85.54 N/mm² < $\sigma_{Rd}$ = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.364 < 1 ok.
**plate**
tension
tension resistance $F_{t,Rd} = \min(N_{pl,Rd}, N_{u,Rd})$ = 1607.04 kN
verification: $F_{Ed}$ = 522.49 kN < $F_{t,Rd}/f_a$ = 1607.04 kN ⇒ U = 0.325 < 1 ok.
**bolts**
cross-section of points
maximum stress max $T_i = T_4$ = 130.62 kN bei 4 bolts
shear
shear resistance $F_{v,Rd}$ = 217.1 kN
verification: $F_{Ed} = T_1$ = 130.62 kN < $F_{v,Rd}$ = 217.15 kN ⇒ U = 0.602 < 1 ok.
bearing resistance
flange: bearing resistance $F_{b,Rd}$ = 333.7 kN
external plate: bearing resistance $F_{b,Rd}$ = 362.8 kN
minimum bearing resistance: min $F_{b,Rd}$ = 333.75 kN
verification: $F_{Ed} = T_2$ = 130.62 kN < $F_{b,Rd}$ = 333.75 kN ⇒ U = 0.391 < 1 ok.

web
internal forces and moments at web: N = $N_w$ = 33.43 kN, M = $M_{y,w}$ = 26.03 kNm, V = $V_{z,w}$ = 90.00 kN
load parts: per plate $f_a$ = 50%
**beam**
bending and shear
$A_{net} \cdot 0.9 \cdot f_u/\gamma_{M2}$ = 970.44 kN < $A \cdot f_y/\gamma_{M0}$ = 1099.80 kN ⇒ considering deduction of holes
maximum normal, shear stress: $\sigma_x$ = 73.39 N/mm² (s.o.), $\tau = V/A_{vz}$ = 12.05 N/mm²
verification: $\sigma_x$ = 73.39 N/mm² < $\sigma_{Rd}$ = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.312 < 1 ok.
$\tau$ = 12.05 N/mm² < $\tau_{Rd}$ = 135.68 N/mm² ⇒ $U_\tau$ = 0.089 < 1 ok.
$\sigma_v$ = 76.29 N/mm² < $\sigma_{Rd}$ = 235.00 N/mm² ⇒ U = 0.325 < 1 ok.
**plate**
bending and shear
$A_{net} \cdot 0.9 \cdot f_u/\gamma_{M2}$ = 782.78 kN < $A \cdot f_y/\gamma_{M0}$ = 893.00 kN ⇒ considering deduction of holes
stresses in points of cross-section:
pt. 1: y = 0.0 mm z = 0.0 mm $\sigma_x$ = -58.20 N/mm²
pt. 2: y = 0.0 mm z = 380.0 mm $\sigma_x$ = 69.27 N/mm²
maximum normal, shear stress: $\sigma_x$ = 69.27 N/mm², $\tau = 1.5 \cdot V/A$ = 17.76 N/mm²
verification: $\sigma_x$ = 69.27 N/mm² < $\sigma_{Rd}$ = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.295 < 1 ok.
$\tau$ = 17.76 N/mm² < $\tau_{Rd}$ = 135.68 N/mm² ⇒ $U_\tau$ = 0.131 < 1 ok.
$\sigma_v$ = 75.79 N/mm² < $\sigma_{Rd}$ = 235.00 N/mm² ⇒ U = 0.323 < 1 ok.
**bolts**
cross-section of points
maximum stress max $T_i = T_3$ = 159.46 kN bei 3 bolts
shear
shear resistance $F_{v,Rd}$ = 282.4 kN
verification: $F_{Ed} = T_1$ = 159.46 kN < $F_{v,Rd}$ = 282.40 kN ⇒ U = 0.565 < 1 ok.
bearing resistance

web: bearing resistance $F_{b,Rd}$ = 207.4 kN
plate: bearing resistance $F_{b,Rd}$ = 172.8 kN
minimum bearing resistance: min $F_{b,Rd}$ = 207.36 kN
verification: $F_{Ed} = T_1$ = 159.46 kN < $F_{b,Rd}$ = 207.36 kN ⇒ U = 0.769 < 1 ok.

## maximum utilization

maximum utilization: max $U_{right}$ = 0.769 < 1 ok.
web - bolts (bearing resistance)

## Final Result

**maximum utilization:** max U = 0.769 < 1 ok.

**verification succeeded**

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## 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