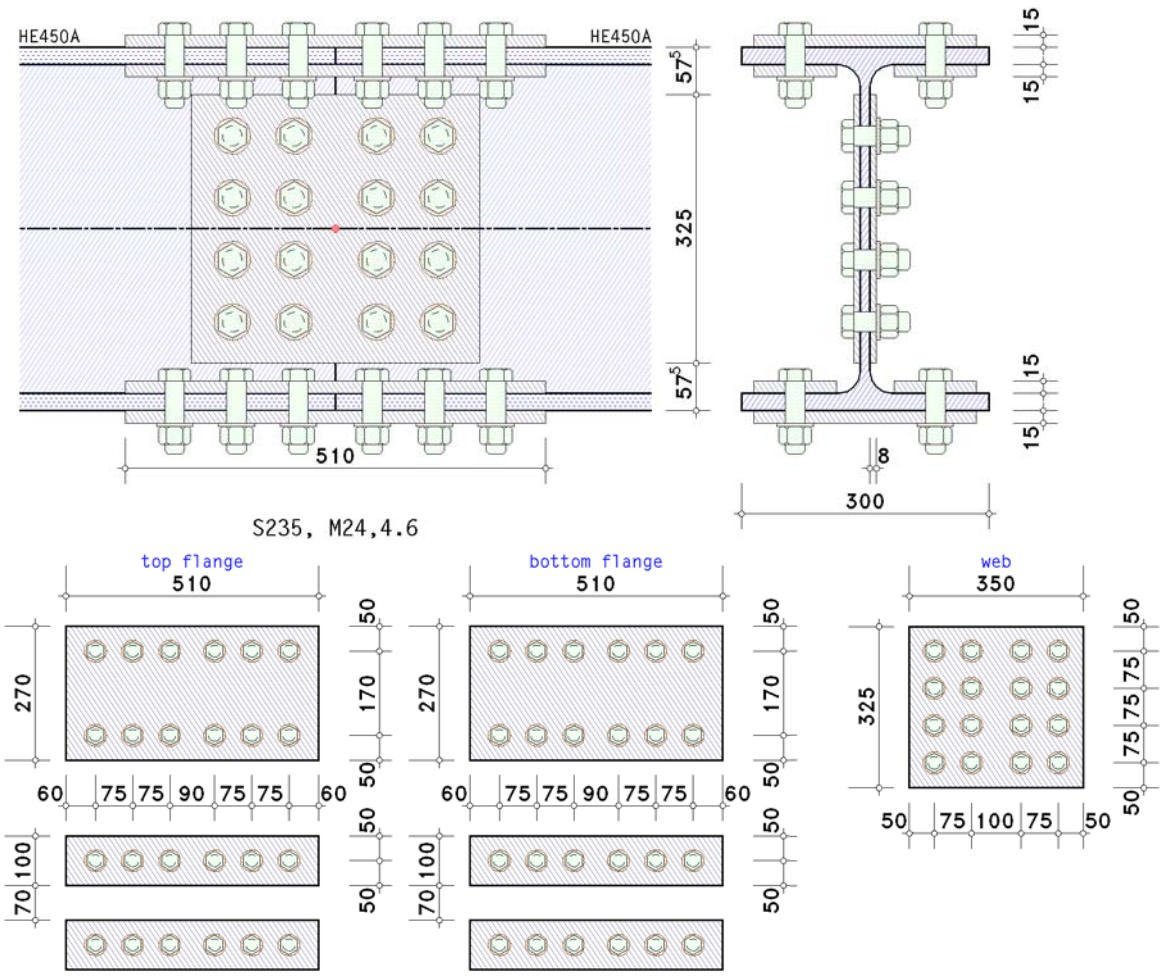
Rigid beam splice

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



steel grade

steel grade S235

bolts

bolt class 4.6, bolt size M24

beam

section HE450A

verification parameters

bolted plate joint:

misalignment of top edge of the beams Δz_{Tr} = 0.0 mm (centric beam)

plates at top flange:

external plate: thickness t = 15.0 mm, width b = 270.0 mm, length l = 510.0 mm

internal plate: thickness t = 15.0 mm, width b = 100.0 mm, length l = 510.0 mm

bolts in top flange:

3 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 = 50.0 mm, e_{22} = 50.0 mm

centre distances of bolts to the tensional edge e_1 = 60.0 mm, e_{11} = 45.0 mm

centre distance of bolt-rows towards tension p_1 = 75.0 mm

centric centre distance of bolt-rows towards tension w_1 = 90.0 mm

centric centre distance of bolt-rows across tension w_2 = 170.0 mm

plates at bottom flange:

external plate: thickness t = 15.0 mm, width b = 270.0 mm, length l = 510.0 mm

internal plate: thickness t = 15.0 mm, width b = 100.0 mm, length l = 510.0 mm

bolts in bottom flange:

3 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 = 50.0 mm, e_{22} = 50.0 mm

centre distances of bolts to the tensional edge e_1 = 60.0 mm, e_{11} = 45.0 mm

centre distance of bolt-rows towards tension p_1 = 75.0 mm

centric centre distance of bolt-rows towards tension w_1 = 90.0 mm

centric centre distance of bolt-rows across tension w_2 = 170.0 mm
plates at web:
2 plates: thickness t = 8.0 mm, width b = 325.0 mm, length l = 350.0 mm
distance upper edge plate to the upper edge of beam (left) Δz_{Lw} = 57.5 mm (plates centric)
bolts in web:
2 x 4 bolts
shear plane passes through the unthreaded portion of the bolt
centre distances of bolts across to tensile edge e_2 = 50.0 mm, e_{22} = 50.0 mm
centre distances of bolts to the tensional edge e_1 = 50.0 mm, e_{11} = 50.0 mm
centre distance of bolt-rows towards tension p_1 = 75.0 mm
centre distance of bolt-rows across tension p_2 = 75.0 mm
centric centre distance of bolt-rows towards tension w_1 = 100.0 mm

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

Lk 1: $N_{j,b,Ed}$ = 300.00 kN $M_{j,b,Ed}$ = 400.00 kNm $V_{j,b,Ed}$ = 120.00 kN

partial safety factors for material

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

Plate connection

notes
buckling is not investigated.

distance of bolt rows at top flange

edge dist.:	e_2 = 50.0 mm > 1.2·d_0 = 31.2 mm,	e_2 = 50.0 mm < 4·t_{min} + 40 mm = 100.0 mm
edge dist.:	e_2 = 50.0 mm > 1.2·d_0 = 31.2 mm,	e_2 = 50.0 mm < 4·t_{min} + 40 mm = 100.0 mm
pitch:	p_2 = 170.0 mm > 2.4·d_0 = 62.4 mm,	p_2 = 170.0 mm < min(14·t_{min}, 200 mm) = 200.0 mm
edge dist.:	e_1 = 60.0 mm > 1.2·d_0 = 31.2 mm,	e_1 = 60.0 mm < 4·t_1 + 40 mm = 100.0 mm
pitch:	p_1 = 75.0 mm > 2.2·d_0 = 57.2 mm,	p_1 = 75.0 mm < min(14·t_{min}, 200 mm) = 200.0 mm
edge dist.:	e_1 = 45.0 mm > 1.2·d_0 = 31.2 mm,	e_1 = 45.0 mm < 4·t_1 + 40 mm = 100.0 mm
pitch:	p_1 = 90.0 mm > 2.2·d_0 = 57.2 mm,	p_1 = 90.0 mm < min(14·t_{min}, 200 mm) = 200.0 mm

distance of bolt rows at web

edge dist.:	e_2 = 50.0 mm > 1.2·d_0 = 31.2 mm,	e_2 = 50.0 mm < 4·t_{min} + 40 mm = 72.0 mm
pitch:	p_2 = 75.0 mm > 2.4·d_0 = 62.4 mm,	p_2 = 75.0 mm < min(14·t_{min}, 200 mm) = 112.0 mm
edge dist.:	e_2 = 50.0 mm > 1.2·d_0 = 31.2 mm,	e_2 = 50.0 mm < 4·t_{min} + 40 mm = 72.0 mm
edge dist.:	e_1 = 50.0 mm > 1.2·d_0 = 31.2 mm,	e_1 = 50.0 mm < 4·t_1 + 40 mm = 72.0 mm
pitch:	p_1 = 75.0 mm > 2.2·d_0 = 57.2 mm,	p_1 = 75.0 mm < min(14·t_{min}, 200 mm) = 112.0 mm
edge dist.:	e_1 = 50.0 mm > 1.2·d_0 = 31.2 mm,	e_1 = 50.0 mm < 4·t_1 + 40 mm = 72.0 mm
pitch:	p_1 = 100.0 mm > 2.2·d_0 = 57.2 mm,	p_1 = 100.0 mm < min(14·t_{min}, 200 mm) = 112.0 mm

distance of bolt rows at bottom flange

edge dist.:	e_2 = 50.0 mm > 1.2·d_0 = 31.2 mm,	e_2 = 50.0 mm < 4·t_{min} + 40 mm = 100.0 mm
edge dist.:	e_2 = 50.0 mm > 1.2·d_0 = 31.2 mm,	e_2 = 50.0 mm < 4·t_{min} + 40 mm = 100.0 mm
pitch:	p_2 = 170.0 mm > 2.4·d_0 = 62.4 mm,	p_2 = 170.0 mm < min(14·t_{min}, 200 mm) = 200.0 mm
edge dist.:	e_1 = 60.0 mm > 1.2·d_0 = 31.2 mm,	e_1 = 60.0 mm < 4·t_1 + 40 mm = 100.0 mm
pitch:	p_1 = 75.0 mm > 2.2·d_0 = 57.2 mm,	p_1 = 75.0 mm < min(14·t_{min}, 200 mm) = 200.0 mm
edge dist.:	e_1 = 45.0 mm > 1.2·d_0 = 31.2 mm,	e_1 = 45.0 mm < 4·t_1 + 40 mm = 100.0 mm
pitch:	p_1 = 90.0 mm > 2.2·d_0 = 57.2 mm,	p_1 = 90.0 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} = 300.00 kN, $M_{y,Ed}$ = 400.00 kNm
stresses in points of cross-section:

pt. 1:	y = 0.0 mm	z = 48.0 mm	σ_x = -89.60 N/mm²
pt. 2:	y = 0.0 mm	z = 392.0 mm	σ_x = 148.71 N/mm²
pt. 3:	y = 150.0 mm	z = 10.5 mm	σ_x = -115.58 N/mm²
pt. 4:	y = -150.0 mm	z = 10.5 mm	σ_x = -115.58 N/mm²
pt. 5:	y = 150.0 mm	z = 429.5 mm	σ_x = 174.68 N/mm²
pt. 6:	y = -150.0 mm	z = 429.5 mm	σ_x = 174.68 N/mm²

load distribution (section) at gross section
top flange: N_{fo} = -749.95 kN
web: N_w = 79.94 kN, $M_{y,w}$ = 39.37 kNm, $V_{z,w}$ = 120.00 kN
bottom flange: N_{fu} = 970.01 kN

top flange
internal forces and moments at flange: N = N_{fo} = -749.95 kN
load parts: external plate f_a = 57.4%, internal plate f_i = 21.3%
beam
compression
maximum normal stress: σ_x = 115.58 N/mm² (s.o.)
verification: σ_x = 115.58 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.492 < 1 ok.
external plate
compression
compression resistance $F_{c,Rd} = (A \cdot f_y) / \gamma_{M0}$ = 951.75 kN
verification: F_{Ed} = 749.95 kN < $F_{c,Rd}/f_a$ = 1656.75 kN ⇒ U = 0.453 < 1 ok.
internal plates
compression
compression resistance $F_{c,Rd} = (A \cdot f_y) / \gamma_{M0}$ = 352.50 kN
verification: F_{Ed} = 749.95 kN < $F_{c,Rd}/f_i$ = 1656.75 kN ⇒ U = 0.453 < 1 ok.
bolts
cross-section of points
maximum stress max $T_i = T_1$ = 124.99 kN bei 6 bolts
shear
shear resistance $F_{v,Rd}$ = 173.7 kN
verification: $F_{Ed} = T_1$ = 124.99 kN < $F_{v,Rd}$ = 173.72 kN ⇒ U = 0.720 < 1 ok.
bearing resistance
flange: bearing resistance $F_{b,Rd}$ = 258.2 kN
external plate: bearing resistance $F_{b,Rd}$ = 184.4 kN
internal plates: bearing resistance $F_{b,Rd}$ = 184.4 kN
minimum bearing resistance: min $F_{b,Rd}$ = 209.35 kN
verification: $F_{Ed} = T_3$ = 124.99 kN < $F_{b,Rd}$ = 209.35 kN ⇒ U = 0.597 < 1 ok.

bottom flange
internal forces and moments at flange: N = N_{fo} = 970.01 kN
load parts: external plate f_a = 57.4%, internal plate f_i = 21.3%
beam
tension
$A_{net} \cdot 0.9 \cdot f_u/\gamma_{M2}$ = 1349.91 kN < $A \cdot f_y/\gamma_{M0}$ = 1480.50 kN ⇒ considering deduction of holes
maximum normal stress: σ_x = 174.68 N/mm² (s.o.)
verification: σ_x = 174.68 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.743 < 1 ok.
external plate
tension
tension resistance $F_{t,Rd} = \min(N_{pl,Rd}, N_{u,Rd})$ = 847.58 kN
verification: F_{Ed} = 970.01 kN < $F_{t,Rd}/f_a$ = 1475.42 kN ⇒ U = 0.657 < 1 ok.
internal plates
tension
tension resistance $F_{t,Rd} = \min(N_{pl,Rd}, N_{u,Rd})$ = 287.71 kN
verification: F_{Ed} = 970.01 kN < $F_{t,Rd}/f_i$ = 1352.25 kN ⇒ U = 0.717 < 1 ok.
bolts
cross-section of points
maximum stress max $T_i = T_6$ = 161.67 kN bei 6 bolts
shear
shear resistance $F_{v,Rd}$ = 173.7 kN
verification: $F_{Ed} = T_1$ = 161.67 kN < $F_{v,Rd}$ = 173.72 kN ⇒ U = 0.931 < 1 ok.
bearing resistance
flange: bearing resistance $F_{b,Rd}$ = 258.2 kN
external plate: bearing resistance $F_{b,Rd}$ = 184.4 kN
internal plates: bearing resistance $F_{b,Rd}$ = 184.4 kN
minimum bearing resistance: min $F_{b,Rd}$ = 209.35 kN
verification: $F_{Ed} = T_3$ = 161.67 kN < $F_{b,Rd}$ = 209.35 kN ⇒ U = 0.772 < 1 ok.

web
internal forces and moments at web: N = N_w = 79.94 kN, M = $M_{y,w}$ = 39.37 kNm, V = $V_{z,w}$ = 120.00 kN
load parts: per plate f_a = 50%
beam
bending and shear
$A_{net} \cdot 0.9 \cdot f_u/\gamma_{M2}$ = 715.39 kN < $A \cdot f_y/\gamma_{M0}$ = 929.66 kN ⇒ considering deduction of holes
maximum normal, shear stress: σ_x = 148.71 N/mm² (s.o.), $\tau = V/A_{vz}$ = 18.24 N/mm²
verification: σ_x = 148.71 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.633 < 1 ok.
τ = 18.24 N/mm² < τ_{Rd} = 135.68 N/mm² ⇒ U_τ = 0.134 < 1 ok.
σ_v = 152.02 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ U = 0.647 < 1 ok.
plate

bending and shear
$A_{net} \cdot 0.9 \cdot f_u/\gamma_{M2} = 458.27$ kN $<$ $A \cdot f_y/\gamma_{M0} = 611.00$ kN $\Rightarrow$ considering deduction of holes
stresses in points of cross-section:
pt. 1: y = 0.0 mm z = 0.0 mm σ_x = -165.67 N/mm²
pt. 2: y = 0.0 mm z = 325.0 mm σ_x = 210.88 N/mm²
maximum normal, shear stress: σ_x = 210.88 N/mm², $\tau = 1.5 \cdot V/A$ = 34.62 N/mm²
verification: σ_x = 210.88 N/mm² $<$ σ_{Rd} = 235.00 N/mm² $\Rightarrow$ $U_{\sigma x}$ = 0.897 $<$ 1 ok.
τ = 34.62 N/mm² $<$ τ_{Rd} = 135.68 N/mm² $\Rightarrow$ U_τ = 0.255 $<$ 1 ok.
σ_v = 219.24 N/mm² $<$ σ_{Rd} = 235.00 N/mm² $\Rightarrow$ U = 0.933 $<$ 1 ok.

bolts
cross-section of points
maximum stress max $T_i = T_4$ = 102.43 kN bei 8 bolts
shear
shear resistance $F_{v,Rd}$ = 173.7 kN
verification: $F_{Ed} = T_1$ = 102.43 kN $<$ $F_{v,Rd}$ = 173.72 kN $\Rightarrow$ U = 0.590 $<$ 1 ok.
bearing resistance
web: bearing resistance $F_{b,Rd}$ = 132.3 kN
plate: bearing resistance $F_{b,Rd}$ = 92.0 kN
minimum bearing resistance: min $F_{b,Rd}$ = 132.26 kN
verification: $F_{Ed} = T_1$ = 102.43 kN $<$ $F_{b,Rd}$ = 132.26 kN $\Rightarrow$ U = 0.774 $<$ 1 ok.

resistance of cross-section

plastic cross-sectional check for N = 300.00 kN, M_y = 400.00 kNm, V_z = 120.00 kN
valid normal/shear stress: zul σ_{Rd} = 23.50 kN/cm², zul τ_{Rd} = 13.57 kN/cm²
top flange: resistance forces $N_{max,O}$ = 1480.50 kN, $N_{min,O}$ = -1480.50 kN
bottom flange: resistance forces $N_{max,U}$ = 1480.50 kN, $N_{min,U}$ = -1480.50 kN
web: shear force V_S = 120.00 kN, shear stress τ_S = 2.49 kN/cm² $\Rightarrow$ $U_{\tau,S}$ = 0.184
resistance forces $N_{max,S}$ = 1113.11 kN, $N_{min,S}$ = -1113.11 kN
main bending: axial force N = 300.00 kN, resistance forces N_{max} = 4074.11 kN, N_{min} = -4074.11 kN $\Rightarrow$ U_N = 0.074
moment M_y = 400.00 kNm, resistance moments $M_{y,max}$ = 728.46 kNm, $M_{y,min}$ = -728.46 kNm $\Rightarrow$ U_{My} = 0.549
total (possibly due to load increase): max U = 0.569 $<$ 1 ok.
utilizations: resistance U_σ = 0.569 $<$ 1 ok., c/t-ratio $U_{c/t}$ = 0.283 $<$ 1 ok.

maximum utilization

maximum utilization: max U_{right} = 0.933 $<$ 1 ok.
web - plates

Final Result

maximum utilization: max U = 0.933 $<$ 1 ok.

verification succeeded

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