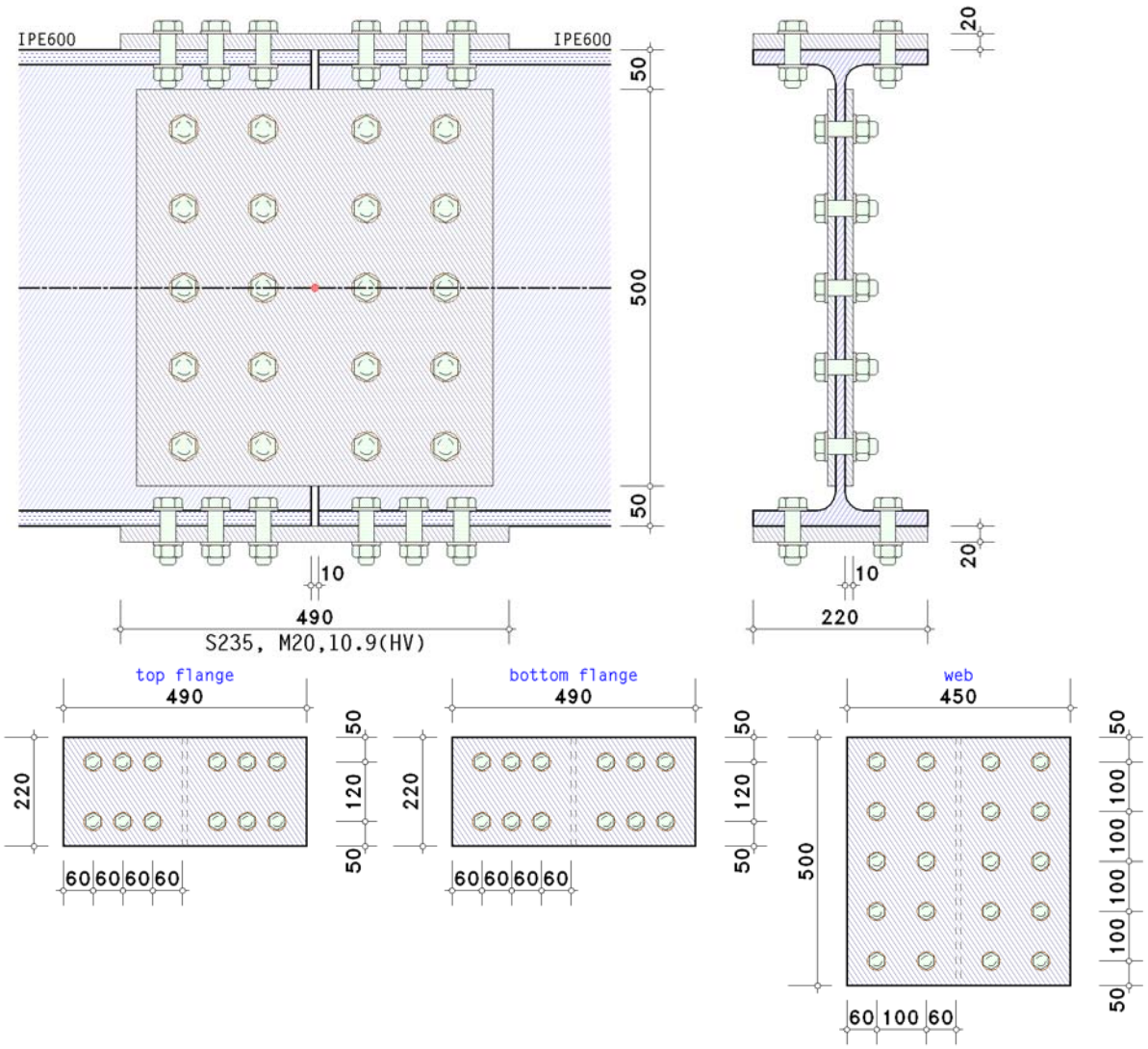
Rigid beam splice

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



steel grade

steel grade S235

bolts

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

beam

section IPE600

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 = 20.0 mm, width b = 220.0 mm, length l = 490.0 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, $e_{22} = 0.0$ mm

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

centre distance of bolt-rows towards tension $p_1 = 60.0$ mm

centric centre distance of bolt-rows towards tension $w_1 = 130.0$ mm

centric centre distance of bolt-rows across tension $w_2 = 120.0$ mm

plates at bottom flange:

external plate: thickness t = 20.0 mm, width b = 220.0 mm, length l = 490.0 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, $e_{22} = 0.0$ mm

centre distances of bolts to the tensional edge e_1 = 60.0 mm, e_{11} = 60.0 mm
centre distance of bolt-rows towards tension p_1 = 60.0 mm
centric centre distance of bolt-rows towards tension w_1 = 130.0 mm
centric centre distance of bolt-rows across tension w_2 = 120.0 mm
plates at web:
2 plates: thickness t = 10.0 mm, width b = 500.0 mm, length l = 450.0 mm
distance upper edge plate to the upper edge of beam (left) Δz_{Lw} = 50.0 mm (plates centric)
bolts in web:
2 x 5 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 = 60.0 mm, e_{11} = 60.0 mm
centre distance of bolt-rows towards tension p_1 = 100.0 mm
centre distance of bolt-rows across tension p_2 = 100.0 mm
centric centre distance of bolt-rows towards tension w_1 = 130.0 mm

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

Lk 1: $M_{j,b,Ed}$ = 500.00 kNm $V_{j,b,Ed}$ = 200.00 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
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 = 50.0 mm > 1.2·d_0 = 26.4 mm,	e_2 = 50.0 mm < 4·t_{min} + 40 mm = 116.0 mm
pitch:	p_2 = 120.0 mm > 2.4·d_0 = 52.8 mm,	p_2 = 120.0 mm < min(14·t_{min}, 200 mm) = 200.0 mm
edge dist.:	e_1 = 60.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 60.0 mm < 4·t_1 + 40 mm = 120.0 mm
pitch:	p_1 = 60.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 60.0 mm < min(14·t_{min}, 200 mm) = 200.0 mm
edge dist.:	e_1 = 60.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 60.0 mm < 4·t_1 + 40 mm = 120.0 mm
pitch:	p_1 = 130.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 130.0 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 = 26.4 mm,	e_2 = 50.0 mm < 4·t_{min} + 40 mm = 80.0 mm
pitch:	p_2 = 100.0 mm > 2.4·d_0 = 52.8 mm,	p_2 = 100.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm
edge dist.:	e_2 = 50.0 mm > 1.2·d_0 = 26.4 mm,	e_2 = 50.0 mm < 4·t_{min} + 40 mm = 80.0 mm
edge dist.:	e_1 = 60.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 60.0 mm < 4·t_1 + 40 mm = 80.0 mm
pitch:	p_1 = 100.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 100.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm
edge dist.:	e_1 = 60.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 60.0 mm < 4·t_1 + 40 mm = 80.0 mm
pitch:	p_1 = 130.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 130.0 mm < min(14·t_{min}, 200 mm) = 140.0 mm

distance of bolt rows at bottom flange

edge dist.:	e_2 = 50.0 mm > 1.2·d_0 = 26.4 mm,	e_2 = 50.0 mm < 4·t_{min} + 40 mm = 116.0 mm
pitch:	p_2 = 120.0 mm > 2.4·d_0 = 52.8 mm,	p_2 = 120.0 mm < min(14·t_{min}, 200 mm) = 200.0 mm
edge dist.:	e_1 = 60.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 60.0 mm < 4·t_1 + 40 mm = 120.0 mm
pitch:	p_1 = 60.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 60.0 mm < min(14·t_{min}, 200 mm) = 200.0 mm
edge dist.:	e_1 = 60.0 mm > 1.2·d_0 = 26.4 mm,	e_1 = 60.0 mm < 4·t_1 + 40 mm = 120.0 mm
pitch:	p_1 = 130.0 mm > 2.2·d_0 = 48.4 mm,	p_1 = 130.0 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} = -0.00 kN, $M_{y,Ed}$ = 500.00 kNm
stresses in points of cross-section:

pt. 1:	y = 0.0 mm	z = 43.0 mm	σ_x = -145.79 N/mm²
pt. 2:	y = 0.0 mm	z = 557.0 mm	σ_x = 167.84 N/mm²
pt. 3:	y = 110.0 mm	z = 9.5 mm	σ_x = -166.23 N/mm²
pt. 4:	y = -110.0 mm	z = 9.5 mm	σ_x = -166.23 N/mm²
pt. 5:	y = 110.0 mm	z = 590.5 mm	σ_x = 188.28 N/mm²
pt. 6:	y = -110.0 mm	z = 590.5 mm	σ_x = 188.28 N/mm²

load distribution (section) at gross section
top flange: N_{fo} = -687.39 kN
web: $M_{y,w}$ = 100.48 kNm, $V_{z,w}$ = 200.00 kN
bottom flange: N_{fu} = 687.39 kN

top flange
internal forces and moments at flange: N = N_{fo} = -687.39 kN
beam
compression
maximum normal stress: σ_x = 166.23 N/mm² (s.o.)
verification: σ_x = 166.23 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.707 < 1 ok.
plate
compression
compression resistance $F_{c,Rd} = (A \cdot f_y) / \gamma_{M0}$ = 1034.00 kN
verification: F_{Ed} = 687.39 kN < $F_{c,Rd}/f_a$ = 1034.00 kN ⇒ U = 0.665 < 1 ok.
bolts
cross-section of points
maximum stress max $T_i = T_6$ = 114.57 kN bei 6 bolts
shear
shear resistance $F_{v,Rd}$ = 150.8 kN
verification: $F_{Ed} = T_1$ = 114.57 kN < $F_{v,Rd}$ = 150.80 kN ⇒ U = 0.760 < 1 ok.
bearing resistance
flange: bearing resistance $F_{b,Rd}$ = 180.3 kN
external plate: bearing resistance $F_{b,Rd}$ = 189.8 kN
minimum bearing resistance: min $F_{b,Rd}$ = 180.33 kN
verification: $F_{Ed} = T_3$ = 114.57 kN < $F_{b,Rd}$ = 180.33 kN ⇒ U = 0.635 < 1 ok.

bottom flange
internal forces and moments at flange: N = N_{fo} = 687.39 kN
beam
tension
$A_{net} \cdot 0.9 \cdot f_u/\gamma_{M2}$ = 866.76 kN < $A \cdot f_y/\gamma_{M0}$ = 982.30 kN ⇒ considering deduction of holes
maximum normal stress: σ_x = 188.28 N/mm² (s.o.)
verification: σ_x = 188.28 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.801 < 1 ok.
plate
tension
tension resistance $F_{t,Rd} = \min(N_{pl,Rd}, N_{u,Rd})$ = 912.38 kN
verification: F_{Ed} = 687.39 kN < $F_{t,Rd}/f_a$ = 912.38 kN ⇒ U = 0.753 < 1 ok.
bolts
cross-section of points
maximum stress max $T_i = T_6$ = 114.57 kN bei 6 bolts
shear
shear resistance $F_{v,Rd}$ = 150.8 kN
verification: $F_{Ed} = T_1$ = 114.57 kN < $F_{v,Rd}$ = 150.80 kN ⇒ U = 0.760 < 1 ok.
bearing resistance
flange: bearing resistance $F_{b,Rd}$ = 180.3 kN
external plate: bearing resistance $F_{b,Rd}$ = 189.8 kN
minimum bearing resistance: min $F_{b,Rd}$ = 180.33 kN
verification: $F_{Ed} = T_3$ = 114.57 kN < $F_{b,Rd}$ = 180.33 kN ⇒ U = 0.635 < 1 ok.

web
internal forces and moments at web: M = $M_{y,w}$ = 100.48 kNm, V = $V_{z,w}$ = 200.00 kN
load parts: per plate f_a = 50%
beam
bending and shear
$A_{net} \cdot 0.9 \cdot f_u/\gamma_{M2}$ = 1256.60 kN < $A \cdot f_y/\gamma_{M0}$ = 1449.48 kN ⇒ considering deduction of holes
maximum normal, shear stress: σ_x = 167.84 N/mm² (s.o.), $\tau = V/A_{vz}$ = 23.87 N/mm²
verification: σ_x = 167.84 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.714 < 1 ok.
τ = 23.87 N/mm² < τ_{Rd} = 135.68 N/mm² ⇒ U_τ = 0.176 < 1 ok.
σ_v = 172.86 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ U = 0.736 < 1 ok.
plate
bending and shear
$A_{net} \cdot 0.9 \cdot f_u/\gamma_{M2}$ = 1010.88 kN < $A \cdot f_y/\gamma_{M0}$ = 1175.00 kN ⇒ considering deduction of holes
stresses in points of cross-section:
pt. 1: y = 0.0 mm z = 0.0 mm σ_x = -152.95 N/mm²
pt. 2: y = 0.0 mm z = 500.0 mm σ_x = 152.95 N/mm²
maximum normal, shear stress: σ_x = 152.95 N/mm², $\tau = 1.5 \cdot V/A$ = 30.00 N/mm²
verification: σ_x = 152.95 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.651 < 1 ok.
τ = 30.00 N/mm² < τ_{Rd} = 135.68 N/mm² ⇒ U_τ = 0.221 < 1 ok.
σ_v = 161.53 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ U = 0.687 < 1 ok.
bolts
cross-section of points
maximum stress max $T_i = T_5$ = 119.58 kN bei 10 bolts

shear
shear resistance $F_{v,Rd}$ = 301.6 kN
verification: $F_{Ed} = T_1$ = 119.58 kN < $F_{v,Rd}$ = 301.59 kN ⇒ U = 0.396 < 1 ok.
bearing resistance
web: bearing resistance $F_{b,Rd}$ = 172.8 kN
plate: bearing resistance $F_{b,Rd}$ = 144.0 kN
minimum bearing resistance: min $F_{b,Rd}$ = 172.80 kN
verification: $F_{Ed} = T_1$ = 119.58 kN < $F_{b,Rd}$ = 172.80 kN ⇒ U = 0.692 < 1 ok.

maximum utilization

maximum utilization: max U_{right} = 0.801 < 1 ok.
bottom flange - stresses

Final Result

maximum utilization: max U = 0.801 < 1 ok.

verification succeeded