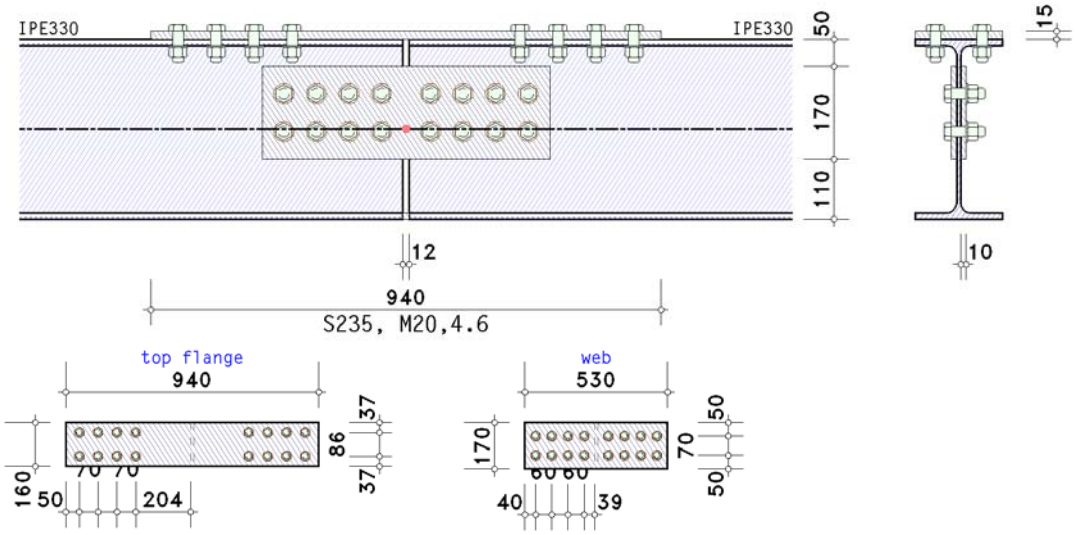
Rigid beam splice

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



steel grade

steel grade S235

bolts

bolt class 4.6, bolt size M20

beam

section IPE330

verification parameters

bolted plate joint:

gap between the beams Δs = 12.0 mm

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

transfer of compressive force by contact

plates at top flange:

external plate: thickness t = 15.0 mm, width b = 160.0 mm, length l = 940.0 mm

bolts in top flange:

4 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 = 37.0 mm, e_{22} = 0.0 mm

centre distances of bolts to the tensional edge e_1 = 50.0 mm, e_{11} = 204.0 mm

centre distance of bolt-rows towards tension p_1 = 70.0 mm

centric centre distance of bolt-rows towards tension w_1 = 420.0 mm

centric centre distance of bolt-rows across tension w_2 = 86.0 mm

plates at web:

2 plates: thickness t = 10.0 mm, width b = 170.0 mm, length l = 530.0 mm

distance upper edge plate to the upper edge of beam (left) Δz_{Lw} = 50.0 mm

bolts in web:

4 x 2 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 = 40.0 mm, e_{11} = 39.0 mm

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

centre distance of bolt-rows across tension p_2 = 70.0 mm

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

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

Lk 1: $M_{j,b,Ed}$ = -120.00 kNm $V_{j,b,Ed}$ = 100.00 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
no verification for cross-sections.
buckling is not investigated.

distance of bolt rows at top flange

edge dist.:	$e_2 = 37.0$ mm $> 1.2 \cdot d_0 = 26.4$ mm,	$e_2 = 37.0$ mm $< 4 \cdot t_{min} + 40$ mm $= 86.0$ mm
pitch:	$p_2 = 86.0$ mm $> 2.4 \cdot d_0 = 52.8$ mm,	$p_2 = 86.0$ mm $< \min(14 \cdot t_{min}, 200$ mm$) = 161.0$ mm
edge dist.:	$e_1 = 50.0$ mm $> 1.2 \cdot d_0 = 26.4$ mm,	$e_1 = 50.0$ mm $< 4 \cdot t_1 + 40$ mm $= 100.0$ mm
pitch:	$p_1 = 70.0$ mm $> 2.2 \cdot d_0 = 48.4$ mm,	$p_1 = 70.0$ mm $< \min(14 \cdot t_{min}, 200$ mm$) = 161.0$ mm
edge dist.:	$e_1 = 204.0$ mm $> 1.2 \cdot d_0 = 26.4$ mm,	$e_1 = 204.0$ mm $> 4 \cdot t_1 + 40$ mm $= 100.0$ mm !!
pitch:	$p_1 = 420.0$ mm $> 2.2 \cdot d_0 = 48.4$ mm,	$p_1 = 420.0$ mm $> \min(14 \cdot t_{min}, 200$ mm$) = 161.0$ mm !!

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

distance of bolt rows at web

edge dist.:	$e_2 = 50.0$ mm $> 1.2 \cdot d_0 = 26.4$ mm,	$e_2 = 50.0$ mm $< 4 \cdot t_{min} + 40$ mm $= 70.0$ mm
pitch:	$p_2 = 70.0$ mm $> 2.4 \cdot d_0 = 52.8$ mm,	$p_2 = 70.0$ mm $< \min(14 \cdot t_{min}, 200$ mm$) = 105.0$ mm
edge dist.:	$e_2 = 50.0$ mm $> 1.2 \cdot d_0 = 26.4$ mm,	$e_2 = 50.0$ mm $< 4 \cdot t_{min} + 40$ mm $= 70.0$ mm
edge dist.:	$e_1 = 40.0$ mm $> 1.2 \cdot d_0 = 26.4$ mm,	$e_1 = 40.0$ mm $< 4 \cdot t_1 + 40$ mm $= 80.0$ mm
pitch:	$p_1 = 60.0$ mm $> 2.2 \cdot d_0 = 48.4$ mm,	$p_1 = 60.0$ mm $< \min(14 \cdot t_{min}, 200$ mm$) = 105.0$ mm
edge dist.:	$e_1 = 39.0$ mm $> 1.2 \cdot d_0 = 26.4$ mm,	$e_1 = 39.0$ mm $< 4 \cdot t_1 + 40$ mm $= 80.0$ mm
pitch:	$p_1 = 90.0$ mm $> 2.2 \cdot d_0 = 48.4$ mm,	$p_1 = 90.0$ mm $< \min(14 \cdot t_{min}, 200$ mm$) = 105.0$ mm

Lk 1

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

elastic stresses at net section
$N_{Ed} = -0.00$ kN, $M_{y,Ed} = -120.00$ kNm
stresses in points of cross-section:

pt. 1:	$y = 0.0$ mm	$z = 29.5$ mm	$\sigma_x = 177.97$ N/mm²
pt. 2:	$y = 0.0$ mm	$z = 300.5$ mm	$\sigma_x = -138.96$ N/mm²
pt. 3:	$y = 80.0$ mm	$z = 5.7$ mm	$\sigma_x = 205.75$ N/mm²
pt. 4:	$y = -80.0$ mm	$z = 5.7$ mm	$\sigma_x = 205.75$ N/mm²
pt. 5:	$y = 80.0$ mm	$z = 324.3$ mm	$\sigma_x = -166.74$ N/mm²
pt. 6:	$y = -80.0$ mm	$z = 324.3$ mm	$\sigma_x = -166.74$ N/mm²

load distribution (plates) at gross section
top flange: $N_{fo} = 359.28$ kN
web: $N_w = -20.13$ kN, $M_{y,w} = 4.01$ kNm, $V_{z,w} = 100.00$ kN
bottom flange: $N_{fu} = -319.02$ kN

top flange
internal forces and moments at flange: $N = N_{fo} = 359.28$ kN
beam
tension
$A_{net} \cdot 0.9 \cdot f_u / \gamma_{M2} = 345.77$ kN $<$ $A \cdot f_y / \gamma_{M0} = 432.40$ kN $\Rightarrow$ considering deduction of holes
maximum normal stress: $\sigma_x = 205.75$ N/mm² (s.o.)
verification: $\sigma_x = 205.75$ N/mm² $<$ $\sigma_{Rd} = 235.00$ N/mm² $\Rightarrow$ $U_{\sigma x} = 0.876 < 1$ ok.
plate
tension
tension resistance $F_{t,Rd} = \min(N_{pl,Rd}, N_{u,Rd}) = 451.01$ kN
verification: $F_{Ed} = 359.28$ kN $<$ $F_{t,Rd}/f_a = 451.01$ kN $\Rightarrow$ $U = 0.797 < 1$ ok.
bolts
cross-section of points
maximum stress max $T_i = T_1 = 44.91$ kN bei 8 bolts
shear
shear resistance $F_{v,Rd} = 60.3$ kN
verification: $F_{Ed} = T_1 = 44.91$ kN $<$ $F_{v,Rd} = 60.32$ kN $\Rightarrow$ $U = 0.745 < 1$ ok.
bearing resistance
flange: bearing resistance $F_{b,Rd} = 134.2$ kN
external plate: bearing resistance $F_{b,Rd} = 175.1$ kN
minimum bearing resistance: min $F_{b,Rd} = 134.24$ kN
verification: $F_{Ed} = T_1 = 44.91$ kN $<$ $F_{b,Rd} = 134.24$ kN $\Rightarrow$ $U = 0.335 < 1$ ok.

bottom flange
internal forces and moments at flange: N = N_{fo} = -319.02 kN
transfer of compressive force by contact
beam
compression
maximum normal stress: σ_x = 166.74 N/mm² (s.o.)
verification: σ_x = 166.74 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.710 < 1 ok.

web
internal forces and moments at web: N = N_w = -20.13 kN, M = $M_{y,w}$ = 4.01 kNm, V = $V_{z,w}$ = 100.00 kN
load parts: per plate f_a = 50%
beam
bending and shear
$A_{net} \cdot 0.9 \cdot f_u/\gamma_{M2}$ = 441.29 kN < $A \cdot f_y/\gamma_{M0}$ = 477.64 kN ⇒ considering deduction of holes
maximum normal, shear stress: σ_x = 177.97 N/mm² (s.o.), $\tau = V/A_{vz}$ = 32.46 N/mm²
verification: σ_x = 177.97 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.757 < 1 ok.
τ = 32.46 N/mm² < τ_{Rd} = 135.68 N/mm² ⇒ U_τ = 0.239 < 1 ok.
σ_v = 186.64 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ U = 0.794 < 1 ok.
plate
bending and shear
$A_{net} \cdot 0.9 \cdot f_u/\gamma_{M2}$ = 326.59 kN < $A \cdot f_y/\gamma_{M0}$ = 399.50 kN ⇒ considering deduction of holes
stresses in points of cross-section:
pt. 1: y = 0.0 mm z = 0.0 mm σ_x = -56.15 N/mm²
pt. 2: y = 0.0 mm z = 170.0 mm σ_x = 40.17 N/mm²
maximum normal, shear stress: σ_x = 56.15 N/mm², $\tau = 1.5 \cdot V/A$ = 44.12 N/mm²
verification: σ_x = 56.15 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ $U_{\sigma x}$ = 0.239 < 1 ok.
τ = 44.12 N/mm² < τ_{Rd} = 135.68 N/mm² ⇒ U_τ = 0.325 < 1 ok.
σ_v = 94.82 N/mm² < σ_{Rd} = 235.00 N/mm² ⇒ U = 0.404 < 1 ok.
bolts
cross-section of points
maximum stress max T_i = T_1 = 48.25 kN bei 8 bolts
shear
shear resistance $F_{v,Rd}$ = 120.6 kN
verification: F_{Ed} = T_1 = 48.25 kN < $F_{v,Rd}$ = 120.64 kN ⇒ U = 0.400 < 1 ok.
bearing resistance
web: bearing resistance $F_{b,Rd}$ = 71.2 kN
plate: bearing resistance $F_{b,Rd}$ = 94.9 kN
minimum bearing resistance: min $F_{b,Rd}$ = 71.18 kN
verification: F_{Ed} = T_1 = 48.25 kN < $F_{b,Rd}$ = 71.18 kN ⇒ U = 0.678 < 1 ok.

maximum utilization

maximum utilization: max U_{right} = 0.876 < 1 ok.
top flange - stresses

Final Result

maximum utilization: max U = 0.876 < 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