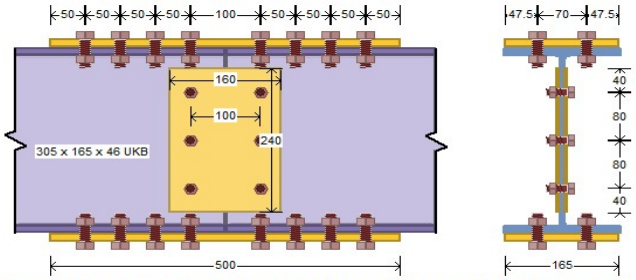
Flange plate splice calculations

Beam: Flange plates, medium UB

Span: 5.0 m. Section: 305 x 165 x 46 UKB S355



Flange plates: 500 x 165 x 15, M16 8.8 bolts (32). Web plates: 160 x 240 x 5, M12 8.8 bolts (6)

Splice 1: 2.0 m. from R1. B.M.: 127.5 kNm S.F.: 21.2 kN (factored)

Splice 2: 3.0 m. from R1. B.M.: 127.5 kNm S.F.: 21.2 kN (do.)

Design splices for a B.M. of 127.5 kNm and S.F. of 21.2 kN

Section dims: D = 306.6 B = 165.7 T = 11.8 t = 6.7 d = 265.2 r = 8.9

Use 500 x 165 x 15 mm S275 flange plates + 160 x 240 x 5 mm S275 web plates

Use 4 pairs of M16 8.8 bolts at 70 mm cross centres; inmost pairs of bolts 100 mm apart, 3 further sets of bolts at 50 mm pitch

Web plates resist shear: Use 3 pairs of M12 8.8 bolts at 100 mm (H) and 80 mm (V)

Basic detailing checks

Flange/Flange Plates: Using M16 bolts, washer diameter 30 mm

- Check flange bolt washer clears beam web: pitch (70 mm) >= 55 mm OK
- Flange plate bolt edge distance (47.5 mm) >= $1.2d_0$ (21.6 mm) OK
- Flange bolt edge distance (47.8 mm) >= $1.2d_0$ (21.6 mm) OK
- Flange plate bolt end distance (50 mm) >= $1.2d_0$ (21.6 mm) OK (n.b. bearing resistance may be reduced if <$3.0d_0$)
- Flange bolt end distance (50 mm) >= $1.2d_0$ (21.6 mm) OK (n.b. bearing resistance may be reduced if <$3.0d_0$)
- Flange bolt spacing (50 mm) >= $2.2d_0$ (39.6 mm) OK (n.b. bearing resistance may be reduced if <$3.75d_0$)
- Flange bolt spacing (70 mm) >= $2.4d_0$ (43.2 mm) OK

Web/Web Plates: Using M12 bolts, washer diameter 24 mm

- Check web plate clears beam roots: plate height, 240 mm < d, 265.2 mm OK
- Web plate bolt end distance H (30 mm) >= $1.2d_0$ (15.6 mm) OK
- Web plate bolt end distance V (40 mm) >= $1.2d_0$ (15.6 mm) OK
- Web plate bolt pitch (80 mm) >= $2.2d_0$ (28.6 mm) OK
- Web bolt end clearance (50 mm) >= $2.4d_0$ (31.2 mm) OK

All dimensional checks satisfied

Stiffness check

SCI AD243 recommends that flange plate I values should be not less than beam values

Beam/plate I_y: 9,900/12,808 cm^4; I_z: 896/1,123 cm^4

Basis of design

The applied moment at the splice position is assumed to be resisted by the compressive and tensile forces in the upper and lower flange plates. The shear force at the splice position is assumed to be carried by the web plates.

Check flange plate and beam flange resistance

Axial force in beam flanges = 127.5 x 1000/(306.6-11.8) = 432 kN

Beam flange area, gross = 1,955 mm^2, net = 1,530 mm^2; Flange plate area: gross = 2,475 mm^2, net = 1,935 mm^2

Beam: f_y = 355 N/mm^2; f_u = 470 N/mm^2; Flange plates: f_y = 275 N/mm^2; f_u = 410N/mm^2
Partial safety factors: γ_{Mo} = 1.0 [EC3-1-1 UK NA 2.15]; γ_{M2} = 1.25 [EC3-1-8 UK NA Table 1]

Tensile resistance: $N_{t,Rd}$ is the lesser of $N_{pl,Rd} = A.f_y/\gamma_{M0}$ [EC3-1-1 6.2.3 (2)] and $N_{u,Rd} = 0.9.A_{net}.f_u/\gamma_{M2}$ [6.2.3 (3)]
- Flange plate, $N_{pl,Rd}$ = 2,475 x 275/(1000 x 1.0) = 681 kN
- Flange plate, $N_{u,Rd}$ = 0.9 x 1,935 x 410/(1000 x 1.25) = 571 kN
- Beam flange, $N_{pl,Rd}$ = 1,955 x 275/(1000 x 1.0) = 538 kN
- Beam flange, $N_{u,Rd}$ = 0.9 x 1,530 x 470/(1000 x 1.25) = 518 kN <<< OK

Plate block shear resistance, $V_{eff,1,Rd} = f_u A_{nt}/\gamma_{M2} + (1/\sqrt{3})\, f_y A_{nv}/\gamma_{M0}$ [EC3-1-8 3.10.2 (2)]
A_{nt}, net tensile area = 90.5 x 15 = 1358 mm^2 A_{nv}, net shear area = 137 x 15 = 2055 mm^2
$V_{eff,1,Rd}$ = 410 x 1358/(1.25 x 1000) + (1/$\sqrt{3}$) x 275 x 2055/(1.0 x 1000) = 772 kN OK

Strut action moment: Flange area: 1,955 mm^2 Plate area: 2,475 mm^2 OK
Flange modulus, Z_y: 44.1cm^3 Plate modulus, Z_y: 55.5 cm^3 OK
Check for strut action moment not required

Local buckling: Flange plate bolt max spacing (100 mm) < 9e.t$_p$ (125 mm) - further check not required [EC3-1-8 Table 3.3 note 2]

Check flange plate bolts (M16 8.8)

Bolt resistance: Shear resistance per bolt, $F_v,R_d = a_v.f_{ub}.A_s/\gamma_{M2}$ [EC3-1-8 Table 3.4]
F_v,R_d = 0.6 x 800 x 157/(1.25 x 1000) = 60.3 kN
Bearing resistance per bolt, $F_{b,Rd} = k_1.a_b.f_u.d.t/\gamma_{M2}$ [EC3-1-8 Table 3.4]
$a_b = \min[e_1/3d_0; (p_1/3d_0) - 0.25; f_{ub}/f_{up}; 1.0]$
$k_1 = \min[2.8e_2/d_0 - 1.7; 1.4p_2/d_0 - 1.7; 2.5]$
$e_{1,\,plate}$ = 50; $e_{2,plate}$ = 47.5; $e_{1,flange}$ = 50; $e_{2,flange}$ = 47.8; d_0 = 18
$a_{b,flange,\,end}$ = 0.926; $a_{b,flange,\,oth}$ = 0.676; $a_{b,plate,\,end}$ = 0.926; $a_{b,plate,\,oth}$ = 0.676
- Plate end bolts: $F_{b,Rd}$ = 2.50 x 0.926 x 410 x 16 x 15/(1000 x 1.25) = 182.2 kN
- Plate other bolts: $F_{b,Rd}$ = 2.50 x 0.676 x 410 x 16 x 15/(1000 x 1.25) = 133.0 kN
- Flange end bolts: $F_{b,Rd}$ = 2.50 x 0.926 x 470 x 16 x 11.8/(1000 x 1.25) = 164.3 kN
- Flange other bolts: $F_{b,Rd}$ = 2.50 x 0.676 x 470 x 16 x 11.8/(1000 x 1.25) = 120.0 kN

Bolt group: Plate bearing: 2 x 182.2 + 6 x 133.0 = 763.5 kN OK
Flange bearing: 2 x 164.3 + 6 x 120.0 = 688.5 kN OK
Shear: $F_{v,Rd}$ = 2 x 4 x 60.3 = 482.3 kN OK

Bending summary: Flange bolt group shear resistance (482 kN) governs
Splice moment resistance = 482 x 306.6/1000 = 142.2 kNm OK

Check web plate and beam web resistance

Web plate shear resistance: Design SF = 21.2 kN
Web plate net area = 5 x (240 - (3 x 13) = 1,005 mm^2
Shear resistance (net area) = 2 x (1/$\sqrt{3}$).f_y.A_v/γ_{M0} = 2 x (1/$\sqrt{3}$) x 275 x 1,005/(1.0 x 1000) = 319 kN OK

Plate block shear resistance, $V_{eff,2,Rd} = 0.5.f_u.A_{nt}/\gamma_{M2} + (1/\sqrt{3})\, f_y.A_{nv}/\gamma_{M0}$ [EC3-1-8 3.10.2 (3)]
A_{nt}, net tensile area = 2 x 23.5 x 5 = 235 mm^2 A_{nv}, net shear area = 2 x 167.5 x 5 = 1675.0 mm^2
$V_{eff,2,Rd}$ = 0.5 x 410 x 235/(1.25 x 1000) + (1/$\sqrt{3}$) x 275 x 1675/(1.0 x 1000) = 304 kN OK

Check web plate bolts (M12 8.8)

Bolt shear resistance: (bolts in double shear) Shear resistance per bolt, $F_v,R_d = 0.85 \times a_v.f_{ub}.A_s/\gamma_{M2}$ [EC3-1-8 Table 3.4; M12 0.85 factor 3.6 (5)]
F_v,R_d = 2 x 0.85 x 0.6 x 800 x 84.3/(1.25 x 1000) = 55.0 kN
Shear resistance of bolt group, $V_{Rd,1} = n.F_v,R_d/\sqrt{(1 + (Bn)^2)}$ [NCCI SN017a 3])
$B = 6z(n.(n+1).p_1) = 6 \times 50/(3 \times 4 \times 80) = 0.313$
$V_{Rd,1}$ = 3 x 55.0/$\sqrt{(1 + (0.313 \times 3)^2)}$ = 120.4 kN OK

Web plate bearing resistance, $V_{Rd,2} = n/\sqrt{((1/F_{b,Rd,ver})^2 + (B.n/F_{b,Rd,hor})^2)}$ [NCCI SN017a 4]

$F_{b,Rd,ver} = k_1.a_b.f_{u.p}.d.t_p/g_{M2}$
$a_b = min[e_1/3d_0; (p_1/3d_0) - 0.25; f_{ub}/f_{up}; 1.0] = 1.00$ ($d_0 = 13$; $e_1 = 40$; $e_2 = 30$; $p_1 = 80$)
$k_1 = min[2.8e_2/d_0 - 1.7; 2.5] = 2.50$
$F_{b,Rd,ver} = 2.50 \times 1.00 \times 410 \times 12 \times 5/(1000 \times 1.25) = 49.2$ kN

$F_{b,Rd,hor} = k_1.a_b.f_{u.p}.d.t_p/g_{M2}$
$a_b = min[e_2/3d_0; f_{ub}/f_{up}; 1.0] = 0.769$
$k_1 = min[2.8e_1/d_0 - 1.7; (1.4.p_1/d_0) -1.7; 2.5] = 2.50$
$F_{b,Rd,hor} = 2.50 \times 0.769 \times 410 \times 12 \times 5/(1000 \times 1.25) = 49.2$ kN
$V_{Rd,2} = 2 \times 3/\sqrt{((1/49.2)^2 + (0.313 \times 3/37.8)^2)} = 187.3$ kN - Shear governs

Beam web bearing resistance, $V_{Rd,8} = n/\sqrt{((1/F_{b,Rd,ver})^2 + (B.n/F_{b,Rd,hor})^2)}$ [NCCI SN017a 10]

$F_{b,Rd,ver} = k_1.a_b.f_{u.p}.d.t_p/g_{M2}$
$a_b = min[e_1/3d_0; (p_1/3d_0) - 0.25; f_{ub}/f_{up}; 1.0] = 1.00$ ($e_1 = 73.3$; $e_2 = 50$; $p_1 = 80$)
$k_1 = min[2.8e_2/d_0 - 1.7; 2.5] = 2.50$
$F_{b,Rd,ver} = 2.50 \times 1.00 \times 410 \times 12 \times 5/(1000 \times 1.25) = 65.9$ kN

$F_{b,Rd,hor} = k_1.a_b.f_{u.p}.d.t_p/g_{M2}$
$a_b = min[e_1/3d_0; (p_1/3d_0) - 0.25; f_{ub}/f_{up}; 1.0] = 1.00$
$k_1 = min[2.8e_2/d_0 - 1.7; 2.5] = 2.50$
$F_{b,Rd,ver} = 2.50 \times 1.00 \times 470 \times 12 \times 6.7/(1000 \times 1.25) = 65.9$ kN
$V_{Rd,8} = 3/\sqrt{((1/65.9)^2 + (0.313 \times 3/75.6)^2)} = 153.1$ kN - Shear governs

Splice shear resistance = 120.4 kN OK

Splice design OK