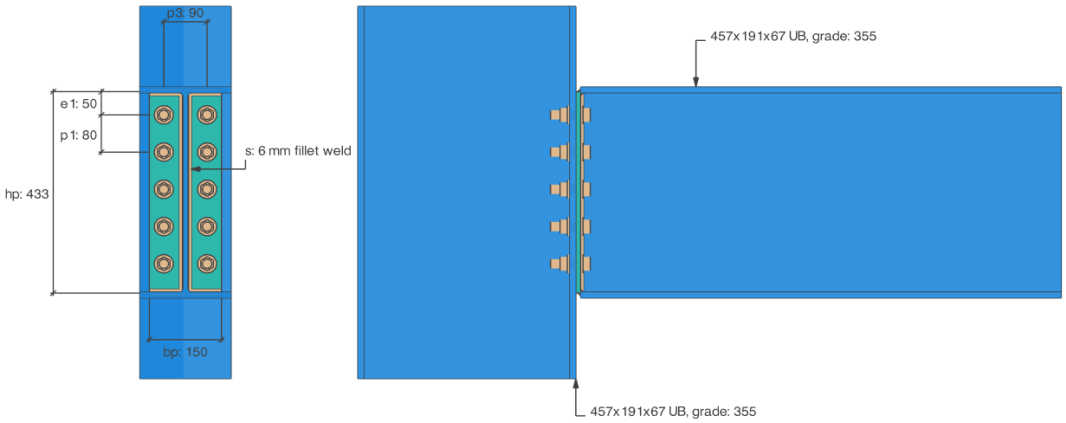
Computer and Design Services Ltd, Arrowsmith Court, 10 Station Approach, Broadstone, Dorset, BH18 8AX, Tel: +44 (0)1202 603031, Email: support@cads.co.uk

Beam-to-column end plate simple connection check

In accordance with EN 1993-1-8:2005 and SCI P358: Joints in simple construction.



Connection

Description	Value
Column connection location	Flange
Design shear force, V_{Ed}	100.00 kN

Supported beam

Description	Value
Section	457x191x67 UB
Overall depth, h_{b1}	453.4 mm
Width of flange, b_{b1}	189.9 mm
Thickness of flange, $t_{f,b1}$	12.7 mm
Thickness of web, $t_{w,b1}$	8.5 mm
Root radius, r_{b1}	10.2 mm
Grade of steel	S 355
Yield strength, f_{yb1}	355.0 N/mm²
Ultimate strength, f_{ub1}	470.0 N/mm²

Supporting column

Description	Value
Section	457x191x67 UB
Overall depth, h_{b2}	453.4 mm
Width of flange, b_{b2}	189.9 mm
Thickness of flange, $t_{f,b2}$	12.7 mm
Thickness of web, $t_{w,b2}$	8.5 mm
Root radius, r_{b2}	10.2 mm
Grade of steel	S 355
Yield strength, f_{yb2}	355.0 N/mm²
Ultimate strength, f_{ub2}	470.0 N/mm²

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End plate details

Description	Value
Plate type	Full depth end plate
Plate height, h_p	433.4 mm
Plate width, b_p	150.0 mm
Plate thickness, t_p	10.0 mm
End plate top projection, w_t	-10.0 mm
End plate bottom projection, w_b	-10.0 mm
Grade of steel	S 275
Yield strength, f_{yp}	275.0 N/mm²
Ultimate strength, f_{up}	410.0 N/mm²
Weld leg length, s	6.0 mm

Bolt details

Description	Value
Diameter of bolt, d	20.0 mm
Diameter of bolt hole, d_0	22.0 mm
Number of bolt rows, n_1	5
Vertical spacing of bolts, p_1	80.0 mm
Horizontal spacing of bolts, p_3	90.0 mm
Grade of bolt, Gr_{bo}	8.8
Ultimate strength, f_{ub}	800.0 N/mm²
Distance from top of end plate to first bolt row, e_{1t}	50.0 mm

Detailing dimensions

Description	Value
Distance from bottom of end plate to last bolt row, e_{1b}	63.4 mm
Distance from edge of the end plate to the bolt row, e_2	30.0 mm
Distance from top beam flange to first bolt row, e_{3t}	41.3 mm
Distance from bottom beam flange to last bolt row, e_{3b}	60.7 mm
Distance from beam web to bolt column, e_4	40.8 mm
Horizontal distance from bolt to the edge of column flange , e_{6l}	50.0 mm
Horizontal distance from bolt to the edge of column flange , e_{6r}	50.0 mm
Spanner/wrench clearance, c	32.0 mm

Partial safety factors

Description	Value
PSF for resistance of cross-section, γ_{M0}	1.00
PSF for resistance of weld, $\gamma_{M2,w}$	1.25
PSF for resistance of bolts, $\gamma_{M2,b}$	1.25
PSF for resistance of cross section to fracture, $\gamma_{M2,f}$	1.10

Detailing and geometry requirements

(Check 1 of section 4.7: SCI P358 and EC3: warnings and errors)

ℹ The connection passes all SCI detailing recommendations given in SCI P358.

ℹ The connection passes fixing dimension requirements based on spanner clearance c.

Weld shear resistance check

(Check 2 of section 4.7: SCI P358).

It is assumed that the weld metal strength grade matches or over matches the plate and section materials in accordance with BS EN 1011-1.

Effective length of the weld	$l_{eff} = 2 \cdot (h_{b1} - 2 \cdot t_{f,b1}) = 2 \cdot (453.4 - 2 \cdot 12.7) = 856.0$ mm
Effective throat thickness	$a = 0.707 \cdot s = 0.707 \cdot 6.0 = 4.2$ mm
Nominal ultimate tensile strength of weaker part	$f_u = \min(f_{ub1}, f_{up}) = \min(470.0, 410.0) = 410.0$ N/mm²
Correlation factor (Table 4.1 of EN 1993-1-8:2005)	$\beta_w = 0.85$
Full strength weld throat thickness	$a_{min} = 0.8 \cdot \frac{f_y}{\sqrt{2}} \cdot \beta_w \cdot \gamma_{M2,w} \cdot t_{w,b1}/f_u = 0.8 \cdot \frac{275.0}{\sqrt{2}} \cdot 0.85 \cdot 1.25 \cdot 8.5/410.0 = 3.4$ mm

ℹ The effective throat thickness (a) exceeds (amin). Therefore full strength fillet welds are provided ensuring that the weld is not the weakest part of the connection.

Shear strength of the weld is as given by (cl 4.5.3.3 (3) EN 1993-1-8:2005)

Shear strength of the weld	$F_{v,wd} = \frac{f_u}{\sqrt{3}}/(\beta_w \cdot \gamma_{M2,w}) = \frac{410.0}{\sqrt{3}}/(0.85 \cdot 1.25) = 222.8$ N/mm²
Shear resistance of the weld	$F_{w,Rd} = F_{v,wd} \cdot 10^{-3} \cdot a \cdot l_{eff} = 222.8 \cdot 10^{-3} \cdot 4.2 \cdot 856.0 = 808.98$ kN

Weld shear resistance check

$$\frac{V_{Ed}}{F_{w,Rd}} = \frac{100.00}{808.98} = 0.124 <= 1.00$$

✓ The check has passed.

Supported beam shear resistance

(Check 4 of section 4.7: SCI P358)

Gross area of the beam web	$A_g = 8550.0$ mm²
Shear area of the beam web	$A_v = A_g - 2 \cdot b_{b1} \cdot t_{f,b1} + (t_{w,b1} + 2 \cdot r_{b1}) \cdot t_{f,b1}$ $= 8550.0 - 2 \cdot 189.9 \cdot 12.7 + (8.5 + 2 \cdot 10.2) \cdot 12.7 = 4093.6$ mm²
Partial factor for resistance of cross section	$\gamma_{m0} = 1.0$
Supported beam shear resistance	$V_{c,Rd} = \frac{f_{yb1} \cdot 10^{-3} \cdot A_v}{\sqrt{3} \cdot \gamma_{m0}} = \frac{355.0 \cdot 10^{-3} \cdot 4093.6}{\sqrt{3} \cdot 1.0} = 839.02$ kN

Supported beam shear resistance check

$$\frac{V_{Ed}}{V_{c,Rd}} = \frac{100.00}{839.02} = 0.119 <= 1.00$$

✓ The check has passed.

Bolt resistance

(Check 8 of section 4.7: SCI P358)

ℹ Shear resistance of one bolt is as given by (Table 3.4 of EN1993-1-8)

Partial factor for resistance of bolts	$\gamma_{m2} = \gamma_{M2,b} = 1.25$
Shear area of bolt	$A_s = 245.0\ mm^2$
Coefficient for bolt shear resistance based on its grade	$\alpha_v = 0.6$
Shear resistance of one bolt	$F_{v,Rd} = \frac{\alpha_v \cdot f_{ub} \cdot 10^{-3} \cdot A_s}{\gamma_{m2}} = \frac{0.6 \cdot 800.0 \cdot 10^{-3} \cdot 245.0}{1.25} = 94.08\ kN$

Bolt bearing resistance (plate)

Coefficients	$\alpha_{bp1} = \frac{p_1}{3 \cdot d_0} - 0.25 = \frac{80.0}{3 \cdot 22.0} - 0.25 = 0.962$
	$\alpha_{bp2} = \frac{f_{ub}}{f_{up}} = \frac{800.0}{410.0} = 1.951$
	$\alpha_{bp} = \min(\alpha_{bp1},\alpha_{bp2},1) = \min(0.962,1.951,1) = 0.962$
Coefficient	$k_{11} = \frac{2.8 \cdot e_2}{d_0} - 1.7 = \frac{2.8 \cdot 30.0}{22.0} - 1.7 = 2.118$
Coefficient	$k_1 = \min(k_{11},2.5) = \min(2.118,2.5) = 2.118$
Bearing resistance (for bearing on end plate)	$F_{b,Rd,p} = \frac{k_1 \cdot \alpha_{bp} \cdot f_{up} \cdot 10^{-3} \cdot d \cdot t_p}{\gamma_{m2}} = \frac{2.118 \cdot 0.962 \cdot 410.0 \cdot 10^{-3} \cdot 20.0 \cdot 10.0}{1.25} = 133.69\ kN$

Bolt bearing resistance (column flange)

Coefficient	$\alpha_{b2,1} = \frac{p_1}{3 \cdot d_0} - 0.25 = \frac{80.0}{3 \cdot 22.0} - 0.25 = 0.962$
Coefficient	$\alpha_{b2,2} = \frac{f_{ub}}{f_{up}} = \frac{800.0}{410.0} = 1.951$
Coefficient	$\alpha_{b2} = \min(\alpha_{b2,1},\alpha_{b2,2},1) = \min(0.962,1.951,1) = 0.962$
	$k_{21} = \frac{2.8 \cdot e2b}{d_0} - 1.7 = \frac{2.8 \cdot 50.0}{22.0} - 1.7 = 4.657$
Coefficient	$k_{22} = \frac{1.4 \cdot p_3}{d_0} - 1.7 = \frac{1.4 \cdot 90.0}{22.0} - 1.7 = 4.027$
Coefficient	$k_2 = \min(k_{21},k_{22},2.5) = \min(4.657,4.027,2.5) = 2.500$
Bearing resistance (bearing on column flange)	$F_{b,Rd,2} = \frac{k_2 \cdot \alpha_{b2} \cdot f_{ub2} \cdot 10^{-3} \cdot d \cdot t_{f,b2}}{\gamma_{m2}} = \frac{2.500 \cdot 0.962 \cdot 470.0 \cdot 10^{-3} \cdot 20.0 \cdot 12.7}{1.25} = 229.72\ kN$

Bolt bearing resistance

Bearing resistance of one bolt	$F_{b,Rd} = \min(F_{b,Rd,p}, F_{b,Rd,2}) = \min(133.69, 229.72) = 133.689$ kN

Since $F_{b,Rd} > 0.8 \cdot F_{v,Rd}$

Resistance of bolt group	$F_{Rd} = 1.6 \cdot n_1 \cdot F_{v,Rd} = 1.6 \cdot 5 \cdot 94.08 = 752.64$ kN

Resistance of bolt group check

$\frac{V_{Ed}}{F_{Rd}} = \frac{100.00}{752.64} = 0.133 <= 1.00$

✓ The check has passed.

Supporting column local shear resistance

(Check 10 of section 4.7: SCI P358)

Distance	$e_t = 5 \cdot d = 5 \cdot 20.0 = 100.0$ mm
Distance	$e_b = \min\left(5 \cdot d, \frac{p_3}{2}\right) = \min\left(5 \cdot 20.0, \frac{90.0}{2}\right) = 45.0$ mm
Shear area of supporting column	$A_v = t_{f,b2} \cdot (e_t + (n_1 - 1) \cdot p_1 + e_b) = 12.7 \cdot (100.0 + (5 - 1) \cdot 80.0 + 45.0) = 5905.5$ mm²
Partial factor for resistance of cross section	$\gamma_{m0} = 1.0$
Local shear resistance of supporting column	$V_{Rd1} = \frac{A_v \cdot f_{yb2} \cdot 10^{-3}}{\sqrt{3} \cdot \gamma_{m0}} = \frac{5905.5 \cdot 355.0 \cdot 10^{-3}}{\sqrt{3} \cdot 1.0} = 1210.39$ kN
Net shear area - supporting column	$A_{v,net} = A_v - n_1 \cdot d_0 \cdot t_{f,b2} = 5905.5 - 5 \cdot 22.0 \cdot 12.7 = 4508.5$ mm²
Partial factor for the ultimate tension resistance of cross section	$\gamma_{m2} = 1.1$
Local shear resistance of supporting column net section	$V_{Rd2} = \frac{A_{v,net} \cdot f_{ub2} \cdot 10^{-3}}{\sqrt{3} \cdot \gamma_{m2}} = \frac{4508.5 \cdot 470.0 \cdot 10^{-3}}{\sqrt{3} \cdot 1.1} = 1112.18$ kN
Local shear resistance of supporting column	$V_{Rd,s} = \min(V_{Rd1}, V_{Rd2}) = \min(1210.39, 1112.18) = 1112.18$
Supporting column shear resistance	$V_{Rd,min} = 2 \cdot V_{Rd,s} = 2 \cdot 1112.18 = 2224.37$ kN

Shear resistance check

$\frac{V_{Ed}}{V_{Rd,min}} = \frac{100.00}{2224.37} = 0.045 <= 1.00$

✓ The check has passed.

Critical component check

Connection resistance	$cc = \min(V_{c,Rd}, F_{Rd}, V_{Rd,min}) = \min(839.02, 752.64, 2224.37) = 752.64$ kN

ℹ Critical component - Resistance of bolt group

Critical component resistance check

$\frac{V_{Ed}}{cc} = \frac{100.00}{752.64} = 0.133 <= 1.00$

✓ The check has passed.

Result summary

Check	Value	Limit	Utilisation	Result
Weld shear resistance check	100.000 kN	808.982 kN	0.124	✓ Pass
Supported beam shear resistance check	100.000 kN	839.015 kN	0.119	✓ Pass
Resistance of bolt group check	100.000 kN	752.640 kN	0.133	✓ Pass
Shear resistance check	100.000 kN	2224.368 kN	0.045	✓ Pass
Critical component resistance check	100.000 kN	752.640 kN	0.133	✓ Pass

Appendix 1: Explanation of geometry variables used in calculations