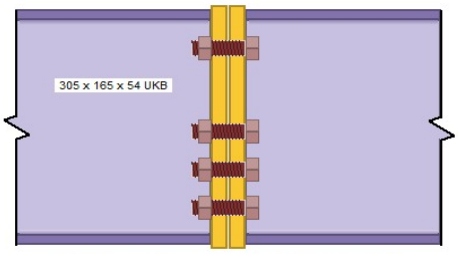
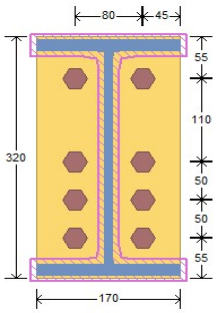
End plate splice calculations

Beam: End plates, medium UB

Span: 5.0 m. Section: 305 x 165 x 54 UKB S355



End plates: 170 x 320 x 20, M20 8.8 bolts (8)



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 = 310.4 B = 166.9 T = 13.7 t = 7.9 d = 265.2 r = 8.9

Use S275 end plates 170 x 320 x 20 mm, 4 pairs of M20 8.8 bolts

Bolts are at 80 mm cross centres; top of plate to top row of bolts: 55 mm; second row: 165 mm; rows 3- spaced at 50 mm

8.8 bolt strength: f_{yb} = 640 N/mm^2 f_{ub} = 800 N/mm^2 [EC3-1-8 Table 3.1]

Minimum fillet weld sizes: Top (compression) flange: nominal 8 mm (bearing fit assumed)
Bottom (tension) flange: 13.7/(2 x 0.7) = 9.8 mm, say 10 mm (full strength)
Web: 7.9/(2 x 0.7) = 5.6 mm, say 6 mm (full strength)

Basic detailing checks [EC3-18 Table 3.3]

Using M20 bolts, washer diameter 37 mm

Check plate height (320 mm) >= section depth (310 mm) OK
Check top bolt washer clears top flange weld: top of plate to top bolt (55 mm) >= 47 mm OK
Check bottom bolt washer clears bottom flange weld: top of plate to bottom bolt (265 mm) <= 271 mm OK
Check bolt washers clear web welds: bolt cross centres (80 mm) >= 57 mm OK
Check bolt cross centres (80 mm) >= 2.4d_0 (52.8 mm) OK
Check bolt vertical centres (50 mm) >= 2.2d_0 (48.4 mm) OK
Bolt edge distance (45 mm) >= 1.2d_0 (26.4 mm) OK
Top bolt end distance (55 mm) >= 1.2d_0 (26.4 mm) OK
Bottom bolt end distance (55 mm) >= 1.2d_0 (26.4 mm) OK

All dimensional checks satisfied

Basis of design

This calculation is derived from the SCI publication P207: Design of Moment Connections. The compression zone is taken as acting at the centre of the top flange. The top pair of bolts are assumed to act in shear only. The bending moment at the splice is resisted by the other bolt rows which may also be able to resist shear.

The tensile resistance of each bolt pair is the lowest of:

* The resistance of the bolt row acting alone
* Rows above bottom row: the resistance of this bolt row and the row(s) below it acting as a group less the combined resistance of the row(s) below it
* The tensile resistance of the beam web (row(s) above bottom row)

Beam: f_y = 355 N/mm^2; f_u = 470 N/mm^2; End plates: f_y = 265 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]

Bolt bearing resistance, $F_{b,Rd} = k_1.a_b.f_u.d.t_p/\gamma_{M2}$ = 2.50 x 0.833 x 410 x 20 x 20/(1.25 x 1000) = 273.3 kN

Bolt shear resistance, $F_v,R_d = a_v.f_{ub}.A_s/\gamma_{M2}$ = 0.6 x 800 x 245/(1.25 x 1000) = 94.1 kN [EC3-1-8 Table 3.4]

Bolt tension resistance, $F_{t,Ed} = \min[F_{t,Rd}, B_{p,Rd}]$ [EC3-1-8 Table 3.2 Category D]

Tension resistance, $F_{t,Rd} = k_2.f_{ub}.A_s/\gamma_{M2}$ = 0.9 x 800 x 245/(1000 x 1.25) = 141.1 kN <<< [EC3-1-8 Table 3.4]

Punching shear resistance, $B_{p,Rd} = 0.6.p.d_m.t_p.f_u/\gamma_{M2}$ = 0.6 x p x 32.3 x 20 x 410/(1000 x 1.25) = 400 kN [do.]

Shear resistance of bolts subject to tension, $F_{v,Ed} = F_{v,Rd}$ x (1.0 - ($F_{t,Ed}$/(1.4 x $F_{t,Rd}$))) [do.]

Max tensile length of web per bolt row, L_t = (80/2) x tan 60 = 69.3 mm above and below each row
N.B. the length below may not extend into the length above from the row below

Web tensile resistance per mm = $A.f_y/\gamma_{M0}$ = 1.0 x 7.9 x 355/(1.0 x 1000) = 2.80 kN/mm

L_{eff} factors: m, bolt centre to 20% into web weld = 31.3 mm (6mm welds assumed) [EC3-18 Fig 6.8]
[EC3-1-8 Table 6.6] n, effective edge distance = min {edge distance, 1.25m} = 39.1 mm [Table 6.2]
a = 6.28 (2p) [EC3-18 Fig 6.11, SCI P207 Appendix III]

T-stub eff. lengths [EC3-1-8 Tab.6.4]	Bolt row considered individually				Bolt row considered as part of a group			
	Circular pattern, $l_{eff,cp}$		Non-circular pattern, $l_{eff,nc}$		Circular pattern, $l_{eff,cp}$		Non-circular pattern, $l_{eff,nc}$	
Bottom row	2pm	196mm	am	196mm	pm + p	148mm	0.5p + am - (2m + 0.625e)	131mm
Inter rows	2pm	196mm	4m + 1.25e	181mm	2p	100mm	p	50mm
Other end row	2pm	196mm	4m + 1.25e	181mm	pm + p	148mm	2m + 0.625e +0.5p	116mm
Mode 1	$l_{eff,1} = \min\{l_{eff,nc}, l_{eff,cp}\}$				$l_{eff,1} = \min\{l_{eff,nc}, l_{eff,cp}\}$			
Mode 2	$l_{eff,2} = l_{eff,nc}$				$l_{eff,2} = l_{eff,nc}$			

$M_{pl,1} = 0.25L_{eff,1} \times t^2 \times f_y/\gamma_{M0}$ $M_{pl,2} = 0.25L_{eff,2} \times t^2 \times f_y/\gamma_{M0}$ [EC3-1-8 Table 6.2]

Row resistance

Mode 1 (end plate yields at bolt positions and either side of web): $F_{T,1,Rd} = 4M_{pl,1,Rd}/m$ [EC3-1-8 Table 6.2]
Mode 2 (end plate yields either side of web; bolts fail in tension): $F_{T,2,Rd} = (2M_{pl,2,Rd} + n(SF_{t,Rd}))/(m + n)$ [do.]
Mode 3 (bolt tensile failure): $F_{T,3,Rd} = SF_{t,Rd}$ [do.]

Bolt rows are numbered from the bottom: Bottom pair = 1; Top pair (ignored when calculating moment resistance) = 4

Row	$L_{eff,1}$	$L_{eff,2}$	$M_{pl,1}$	$M_{pl,2}$	Mode 1	Mode 2	Mode 3	$L_{t,web}$	$P_{t,web}$	$P_{t,group}$ kN	$F_{T,Rd}$ kN
1	196	196	5,203	5,203	666.0	304.8	282.2				282.2
2	181	181	4,803	4,803	614.8	293.4	282.2	139	388.6		217.1
[1+2]	*246*	*246*	*6,528*	*6,528*	*835.6*	*499.3*	*564.5*				
[1+2]-1					553.4	217.1	282.2				
3	181	181	4,803	4,803	614.8	293.4	282.2	139	388.6		194.5
[1..3]	*296*	*296*	*7,853*	*7,853*	*1,005.2*	*693.8*	*846.7*				
[1..3]-1-2					505.9	194.5	347.4				
[2+3]	*231*	*231*	*6,128*	*6,128*	*784.4*	*487.9*	*564.5*	*189*		*528.8*	
[2+3]-2					567.3	270.9	347.4		311.8		

Check moment and shear resistance of splice

Calculate maximum moment resistance and resulting shear resistance
Shear resistance will be greater if splice is subject to a lower moment

Compressive resistance of top flange = $A.f_y/\gamma_{mo}$ = 166.9 x 13.7 x 355/(1.0 x 1000) = 812 kN
Compression zone centre is assumed to be centre of top flange, 11.7 mm from top of end plate

Bolt line	Bolt LA mm	$F_{T,Rd}$ kN	Row RM kNm	Bolt F_v/P_v	F_v kN
1	253	282.2	71.51	0.29	53.8
2	203	217.1	44.14	0.45	84.8
3	153	*170.8	26.20	0.57	106.8
4	43	0.0	0.00	1.00	188.2
Totals		670.1 kN	141.84 kNm		433.5 kN

** tension reduced to be within elastic limit*

Section ultimate moment resistance = 300 kNm; Splice resistance = 141.8 kNm (47.2%)

Splice 1: Design moment: 127.5 kNm Design shear force: 21.2 kN

No further checking necessary

Splice 2: Design moment: 127.5 kNm Design shear force: 21.2 kN

No further checking necessary

EuroBeam website: http://www.eurobeam.co.uk/eurobeam.htm