PlanningApplications.com
Summer House, Upper Court Road
Woldingham SURREY CR3 7BF
support@planningapplications.com 07922 148 701

Project				Job no.	
BEAM 3 - Centre Splice Connection 3				739	
Calcs for				Start page no./Revision	
Connor McKitrich				1	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
SB	30/05/2023	DB	30/05/2023	SB	30/05/2023

STEEL BEAM SPLICE DESIGN (EN1993)

In accordance with EN1993-1-1:2005 incorporating Corrigenda February 2006 and April 2009

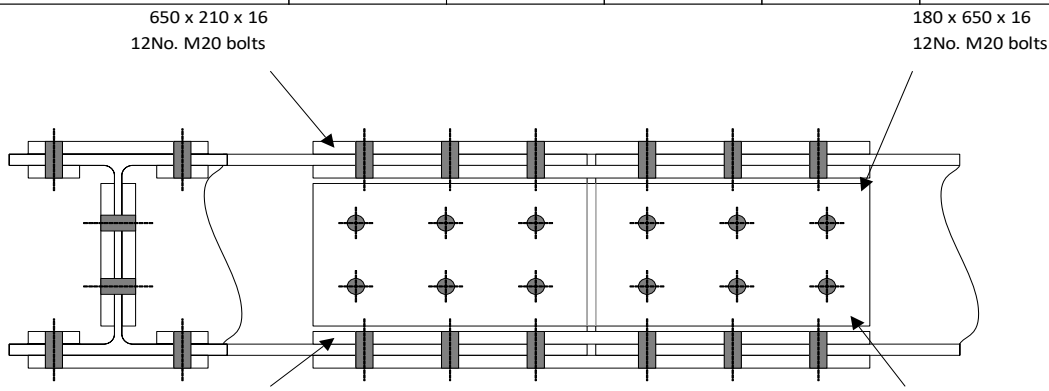
Tedds calculation version 1.0.00

Design summary

Overall design status PASS

Overall design utilisation 0.694

Description	Unit	Design	Resistance	Utilisation	Result
Flange bolt group	kN	104.9	188.2	0.558	PASS
Flange bolt slip resist. SLS	kN	86.5	124.7	0.694	PASS
Flange plate compression	kN	629.6	1452.0	0.434	PASS
Flange plate tension flange	kN	530.6	1298.9	0.409	PASS
Flange plate block tearing	kN	530.6	2536.3	0.209	PASS
Flange compression	kN	629.6	994.2	0.633	PASS
Flange tension	kN	530.6	994.2	0.534	PASS
Web bolt group	kN	88.2	128.2	0.688	PASS
Web bolt slip resist. SLS	kN	66.1	124.7	0.530	PASS
Web plate shear	kN	125.0	720.1	0.174	PASS
Web plate block tearing	kN	125.0	958.0	0.130	PASS
Web plate combined				0.692	PASS
Beam web net shear	kN	125.0	470.0	0.266	PASS



Cover plate Splice

Design forces

Design moment (ULS) M_{Ed} = **150.0** kNm

Design moment (SLS) $M_{Ed,ser}$ = **125.0** kNm

Design shear force (ULS) V_{Ed} = **125.0** kN

Design shear force (SLS) $V_{Ed,ser}$ = **90.0** kN

Design axial force (ULS) N_{Ed} = **125.0** kN

Design axial force (SLS) $N_{Ed,ser}$ = **90.0** kN

Partial factors

Resistance of cross section γ_{M0} = **1.00**

Resistance of members to instability γ_{M1} = **1.00**

Cross sections in tension to fracture γ_{M2} = **1.10**

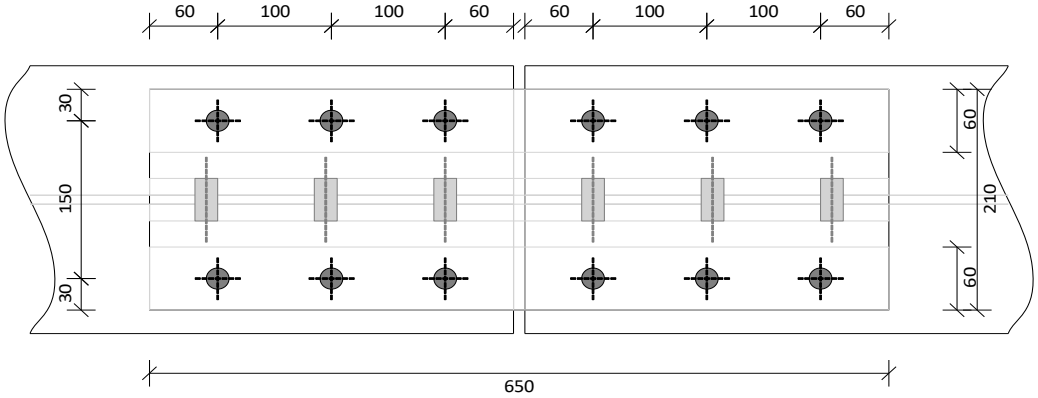
Resistance of bolts $\gamma_{M2,b}$ = **1.25**

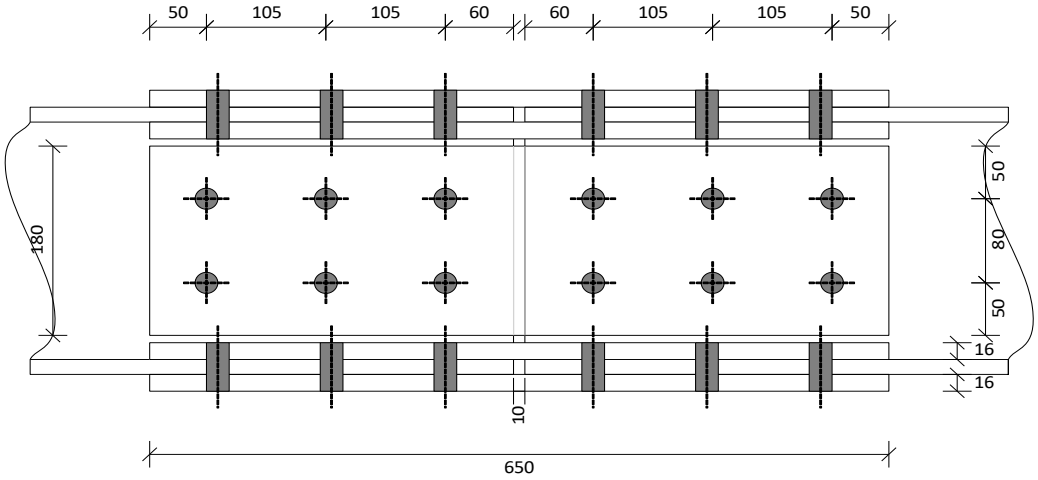
Slip resistance γ_{M3} = **1.25**

Slip resistance, servicability	$\gamma_{M3,ser}$ = **1.10**
Structural integrity	$\gamma_{M,u}$ = **1.10**

Beam details

Section name	UC 254x254x73
Steel grade	S275
Yield strength	$f_{y,bm}$ = **275** N/mm^2
Ultimate strength	$f_{u,bm}$ = **410** N/mm^2
Section height	h = **254.1** mm
Section width	b = **254.6** mm
Flange thickness	t_f = **14.2** mm
Web thickness	t_w = **8.6** mm
Gap between beams	g_v = **10.0** mm





Flange bolt details

Number of bolt rows	$n_{1,fp}$ = **3**
Bolt size	**M20**
Bolt grade	**8.8**
Yield strength	$f_{yb,fp}$ = **640** N/mm^2
Ultimate strength	$f_{ub,fp}$ = **800** N/mm^2
End distance in plate	$e_{1,fp}$ = **60** mm

End distance in beam	$e_{1,cf}$ = **60** mm
Edge distance in plate	$e_{2,fp}$ = **30** mm
Bolt pitch	$p_{1,fp}$ = **100** mm
Bolt gauge	$p_{2,fp}$ = **150** mm

Flange plate details

Internal plate width	$b_{fp,int} = 2 \times e_{2,fp}$ = **60** mm
External plate width	$b_{fp,ext} = 2 \times e_{2,fp} + p_{2,fp}$ = **210** mm
Plate length	$l_{fp} = g_v + 2 \times (n_{1,fp} - 1) \times p_{1,fp} + 2 \times (e_{1,cf} + e_{1,fp})$ = **650** mm
Plate thickness	t_{fp} = **16** mm
Plate grade	**S275**
Yield strength	$f_{y,fp}$ = **275** N/mm^2
Ultimate strength	$f_{u,fp}$ = **410** N/mm^2

Web bolt details

Number of bolt columns	$n_{1,wp}$ = **3**
Number of bolt rows	$n_{2,wp}$ = **2**
Bolt size	**M20**
Bolt grade	**8.8**
Yield strength	$f_{yb,wp}$ = **640** N/mm^2
Ultimate strength	$f_{ub,wp}$ = **800** N/mm^2
End distance in plate	$e_{1,wp}$ = **50** mm
End distance in beam	$e_{1,cw}$ = **60** mm
Edge distance in plate	$e_{2,wp}$ = **50** mm
Bolt gauge	$p_{1,wp}$ = **105** mm
Bolt pitch	$p_{2,wp}$ = **80** mm

Web plate details

Number of web plates	N_{wp} = **2**
Plate width	$b_{wp} = g_v + 2 \times (n_{1,wp} - 1) \times p_{1,wp} + 2 \times (e_{1,cw} + e_{1,wp})$ = **650** mm
Plate height	$h_{wp} = (n_{2,wp} - 1) \times p_{2,wp} + 2 \times e_{2,wp}$ = **180** mm
Plate thickness	t_{wp} = **16** mm
Plate grade	**S275**
Yield strength	$f_{y,wp}$ = **275** N/mm^2
Ultimate strength	$f_{u,wp}$ = **410** N/mm^2

Continuity - EN1993-1-8 cl.6.2.7.1(13)

Design bending resistance moment - eq 6.13	$M_{c,y,Rd} = W_{pl,y} \times f_{y,bm} / \gamma_{M0}$ = **272.8** kNm
Min design bending resist. momnt for continuity	$M_{Ed,cont} = 0.25 \times M_{c,y,Rd}$ = **68.2** kNm
	$M_{Ed,cont} / M_{Ed}$ = **0.455**
	M_{Ed} is greater or equal to 0.25 × $M_{c,y,Rd}$ so continuity is satisfied

Internal forces - ULS

Second moment of area	$I_{y,web} = (h - 2 \times t_f)^3 \times t_w / 12$ = **824** cm^4
Area of web	$A_w = (h - 2 \times t_f) \times t_w$ = **1941** mm^2
Force in each flange due to moment	$F_{f,M} = (1 - (I_{y,web} / I_y)) \times M_{Ed} / (h - t_f)$ = **580.1** kN
Force in each flange due to axial force	$F_{f,N} = (1 - A_w / A) \times N_{Ed} / 2$ = **49.5** kN
Total force in tension flange	$F_{tf} = F_{f,M} - F_{f,N}$ = **530.6** kN
Total force in compression flange	$F_{cf} = F_{f,M} + F_{f,N}$ = **629.6** kN

Flange bolt forces - ULS

Force in compression flange bolts	$F_{cf,v} = F_{cf} / (2 \times n_{1,fp})$ = **104.9** kN
Force in tension flange bolts	$F_{tf,v} = F_{tf} / (2 \times n_{1,fp})$ = **88.4** kN
Maximum design force on flange bolts	$F_{f,v,Ed} = \max(F_{cf,v}, F_{tf,v})$ = **104.9** kN

Flange bolt resistance (Table 3.4)

Flange plate bearing strength	$f_{u,fp} \times 2 \times t_{fp}$ = **13120** kN/m
Beam flange bearing strength	$f_{u,bm} \times t_f$ = **5822** kN/m
Critical section for bearing	Beam flange
Bolt shear area	$A_{s,fp}$ = **245.0** mm^2
Shear area factor	$\alpha_{v,fp}$ = **0.6**
Length of joint	$L_j = (n_{1,fp} - 1) \times p_{1,fp}$ = **200** mm
Reduction factor due to length of joint	$\beta_{LF,fp}$ = **1.000**
Shear resistance of single bolt	$F_{v,fp,Rd} = \alpha_{v,fp} \times f_{ub,fp} \times A_{s,fp} / \gamma_{M2,b}$ = **94.1** kN
Bolt bearing factors	$k_{1,f} = \min(1.4 \times p_{2,fp} / d_{0,fp} - 1.7, 2.5)$ = **2.50**
	$\alpha_{b,f} = \min(e_{1,cf} / (3 \times d_{0,fp}), p_{1,fp} / (3 \times d_{0,fp}) - 1/4, f_{ub,fp} / f_{u,bm}, 1.0)$ = **0.91**
Bearing resistance of bolt	$F_{b,f,Rd} = k_{1,f} \times \alpha_{b,f} \times f_{u,bm} \times d_{b,fp} \times t_f / \gamma_{M2,b}$ = **211.7** kN
Design resistance of bolt	$F_{f,Rd} = \min(2 \times F_{v,fp,Rd}, F_{b,f,Rd})$ = **188.2** kN
	$F_{f,v,Ed} / F_{f,Rd}$ = **0.558**
	PASS - Bolt resistance exceeds applied force on bolt

Internal forces - SLS

Force in each flange due to moment	$F_{f,M,ser} = (1 - (I_{y,web} / I_y)) \times M_{Ed,ser} / (h - t_f)$ = **483.4** kN
Force in each flange due to axial force	$F_{f,N,ser} = (1 - A_w / A) \times N_{Ed,ser} / 2$ = **35.6** kN
Total force in tension flange	$F_{tf,ser} = F_{f,M,ser} - F_{f,N,ser}$ = **447.8** kN
Total force in compression flange	$F_{cf,ser} = F_{f,M,ser} + F_{f,N,ser}$ = **519.0** kN

Flange bolt forces - SLS

Force in compression flange bolts	$F_{cf,v,ser} = F_{cf,ser} / (2 \times n_{1,fp})$ = **86.5** kN
Force in tension flange bolts	$F_{tf,v,ser} = F_{tf,ser} / (2 \times n_{1,fp})$ = **74.6** kN
Maximum design force on flange bolts	$F_{f,v,Ed,ser} = \max(F_{cf,v,ser}, F_{tf,v,ser})$ = **86.5** kN

Flange bolt resistance SLS

Pre-loading force	$F_{p,C,fp,ser} = 0.7 \times f_{ub,fp} \times A_{s,fp}$ = **137.2** kN
Bolt type factor	k_s = **1.00**
Slip factor	μ = **0.50**
Slip resistance of single bolt	$F_{s,fp,Rd,ser} = k_s \times 2 \times \mu \times F_{p,C,fp,ser} / \gamma_{M3,ser}$ = **124.7** kN
	$F_{f,v,Ed,ser} / F_{s,fp,Rd,ser}$ = **0.694**
	PASS - Bolt resistance exceeds applied force on bolt

Flange cover plates - resistance of plates in compression

Gross area of plate to 1 flange	$A_{fp} = b_{fp,ext} \times t_{fp} + 2 \times b_{fp,int} \times t_{fp}$ = **5280** mm^2
Pitch between the bolts rows of the splice	$p_{1,j} = \max(2 \times e_{1,cf} + g_v, p_{1,fp})$ = **130** mm
Critical buckling length	$L_{cr} = 0.6 \times p_{1,j}$ = **78** mm
Steel strength factor (cl.6.3.1.3)	$\varepsilon = \sqrt{(235 \text{N/mm}^2 / f_{y,fp})}$ = **0.92**
Radius of gyration of plate	$i_{z,fp} = t_{fp} / \sqrt{(12)}$ = **4.6** mm
Non-dimensional slenderness factor (cl.6.3.1.3)	$\lambda_1 = 93.9 \times \varepsilon$ = **86.80**
	$\bar{\lambda} = L_{cr} / i_{z,fp} \times 1 / \lambda_1$ = **0.19**
Buckling curve - solid section (Table 6.2)	c

Imperfection factor (Table 6.1)	α = **0.49**
Buckling reduction factor (cl.6.3.1.2)	$\Phi = 0.5 \times (1 + \alpha \times (\bar{\lambda} - 0.2) + \bar{\lambda}^2)$ = **0.52**
	$\chi_{fp} = 1.0$ = **1.00**
Design compressive resistance (eqn. 6.47)	$N_{b,fp,Rd} = \chi_{fp} \times A_{fp} \times f_{y,fp} / \gamma_{M1}$ = **1452** kN
Utilisation	$F_{cf} / N_{b,fp,Rd}$ = **0.434**

PASS - Flange cover plate compressive resistance greater than design compressive force

Flange cover plates - resistance of plates in tension

Net area of plate to 1 flange	$A_{fp,net} = A_{fp} - 4 \times t_{fp} \times d_{0,fp}$ = **3872** mm^2
Tension resistance of gross area (eqn.6.6)	$N_{pl,fp,Rd} = A_{fp} \times f_{y,fp} / \gamma_{M0}$ = **1452** kN
Tension resistance of net area (eqn.6.6)	$N_{u,fp,Rd} = 0.9 \times A_{fp,net} \times f_{u,fp} / \gamma_{M2}$ = **1298.88** kN
Design tension resistance	$N_{t,fp,Rd} = \min(N_{pl,fp,Rd}, N_{u,fp,Rd})$ = **1298.88** kN
Utilisation	$F_{tf} / N_{t,fp,Rd}$ = **0.409**

PASS - Flange cover plate tensile resistance greater than design tensile force

Flange cover plates - block tearing

Net area of plate to subject to shear	$A_{fp,nv} = 4 \times t_{fp} \times (e_{1,fp} + (n_{1,fp} - 1) \times p_{1,fp} - (n_{1,fp} - 0.5) \times d_{0,fp})$ = **13120** mm^2
Net area of plate to subject to tension	$A_{fp,nt} = t_{fp} \times (2 \times e_{2,fp} - d_{0,fp}) + t_{fp} \times (b_{fp,int} - d_{0,fp})$ = **1216** mm^2
Block tearing resistance (EN1993-1-8 eqn.3.9)	$N_{bt,Rd} = f_{u,fp} \times A_{fp,nt} / \gamma_{M2} + f_{y,fp} \times A_{fp,nv} / (\sqrt{(3)} \times \gamma_{M0})$ = **2536.32** kN
Utilisation	$F_{tf} / N_{bt,Rd}$ = **0.209**

PASS - Flange cover plate block tearing resistance greater than design tensile force

Beam flange - resistance in compression

Gross area of flange	$A_f = b \times t_f$ = **3615.3** mm^2
Assume χ is 1.0 due to presence of beam web	χ = **1.00**
Design compressive resistance (eqn. 6.47)	$N_{b,Rd} = \chi \times A_f \times f_{y,bm} / \gamma_{M1}$ = **994.21** kN
Utilisation	$F_{cf} / N_{b,Rd}$ = **0.633**

PASS - Beam flange compressive resistance greater than design compressive force

Beam flange - resistance in tension

Net area of flange	$A_{f,net} = A_f - 2 \times t_f \times d_{0,fp}$ = **2990.5** mm^2
Tension resistance of gross area (eqn.6.6)	$N_{pl,Rd} = A_f \times f_{y,bm} / \gamma_{M0}$ = **994.21** kN
Tension resistance of net area (eqn.6.6)	$N_{u,Rd} = 0.9 \times A_{f,net} \times f_{u,bm} / \gamma_{M2}$ = **1003.18** kN
Design tension resistance	$N_{t,Rd} = \min(N_{pl,Rd}, N_{u,Rd})$ = **994.21** kN
Utilisation	$F_{tf} / N_{t,Rd}$ = **0.534**

PASS - Beam flange tensile resistance greater than design tensile force

Internal forces - ULS

Moment in the web (at the CL of the splice)	$M_w = M_{Ed} \times I_{y,web} / I_y$ = **10.8** kNm
Force in web due to axial force	$F_{w,N} = N_{Ed} \times A_w / A$ = **26.1** kN
Force in web due to vertical shear	$F_{w,V} = V_{Ed}$ = **125.0** kN

Web bolt forces - ULS

Web bolt group inertia	$I_{b,wp}$ = **53700** mm^2
Extreme horiz. bolt position from group centroid	$x_{max} = (p_{1,wp} \times (n_{1,wp} - 1)) / 2$ = **105.0** mm
Extreme vert. bolt position from group centroid	$z_{max} = (p_{2,wp} \times (n_{2,wp} - 1)) / 2$ = **40.0** mm
Number of bolts in bolt group	$n_{wp} = n_{1,wp} \times n_{2,wp}$ = **6**
Add. moment due to eccentricity of bolt group	$M_{add} = V_{Ed} \times (g_v / 2 + e_{1,cw} + (p_{1,wp} \times (n_{1,wp} - 1)) / 2)$ = **21.3** kNm
Horizontal component of force on extreme bolt	$F_{x,M} = (M_w + M_{add}) \times z_{max} / I_{b,wp}$ = **23.9** kN
Vertical component of force on extreme bolt	$F_{z,M} = (M_w + M_{add}) \times x_{max} / I_{b,wp}$ = **62.7** kN

Resultant force on extreme bolt	$F_{w,v,Ed} = ((F_{z,M} + F_{w,V} / n_{wp})^2 + (F_{x,M} + F_{w,N} / n_{wp})^2)^{0.5}$ = **88.2** kN
Web bolt resistance (Table 3.4)	
Web plate bearing strength	$f_{u,wp} \times N_{wp} \times t_{wp}$ = **13120** kN/m
Beam web bearing strength	$f_{u,bm} \times t_w$ = **3526** kN/m
Critical section for bearing	Beam web
Bolt shear area	$A_{s,wp}$ = **245.0** mm^2
Shear area factor	$\alpha_{v,wp}$ = **0.6**
Shear resistance of single bolt	$F_{v,wp,Rd} = N_{wp} \times \alpha_{v,wp} \times f_{ub,wp} \times A_{s,wp} / \gamma_{M2,b}$ = **188.2** kN
Bolt bearing factors	$k_{1,w} = \min(1.4 \times p_{2,wp} / d_{0,wp} - 1.7, 2.5)$ = **2.50**
	$\alpha_{b,w} = \min(e_{1,cw} / (3 \times d_{0,wp}), p_{1,wp} / (3 \times d_{0,wp}) - 1/4, f_{ub,wp} / f_{u,bm}, 1.0)$ = **0.91**
Bearing resistance of bolt	$F_{b,w,Rd} = k_{1,w} \times \alpha_{b,w} \times f_{u,bm} \times d_{b,wp} \times t_w / \gamma_{M2,b}$ = **128.2** kN
Design resistance of bolt	$F_{w,Rd} = \min(F_{v,wp,Rd}, F_{b,w,Rd})$ = **128.2** kN
	$F_{w,v,Ed} / F_{w,Rd}$ = **0.688**
	PASS - Bolt resistance exceeds applied force on bolt
Internal forces - SLS	
Moment in the web (at the CL of the splice)	$M_{w,ser} = M_{Ed,ser} \times I_{y,web} / I_y$ = **9.0** kNm
Force in web due to axial force	$F_{w,N,ser} = N_{Ed,ser} \times A_w / A$ = **18.8** kN
Force in web due to vertical shear	$F_{w,V,ser} = V_{Ed,ser}$ = **90.0** kN
Web bolt forces - SLS	
Add. moment due to eccentricity of bolt group	$M_{add,ser} = V_{Ed,ser} \times (g_v / 2 + e_{1,cw} + (p_{1,wp} \times (n_{1,wp} - 1)) / 2)$ = **15.3** kNm
Horizontal component of force on extreme bolt	$F_{x,M,ser} = (M_{w,ser} + M_{add,ser}) \times z_{max} / I_{b,wp}$ = **18.1** kN
Vertical component of force on extreme bolt	$F_{z,M,ser} = (M_{w,ser} + M_{add,ser}) \times x_{max} / I_{b,wp}$ = **47.6** kN
Resultant force on extreme bolt	$F_{w,v,Ed,ser} = ((F_{z,M,ser} + F_{w,V,ser} / n_{wp})^2 + (F_{x,M,ser} + F_{w,N,ser} / n_{wp})^2)^{0.5}$ = **66.1** kN
Web bolt resistance SLS	
Pre-loading force	$F_{p,C,wp,ser} = 0.7 \times f_{ub,wp} \times A_{s,wp}$ = **137.2** kN
Slip resistance of single bolt	$F_{s,wp,Rd,ser} = k_s \times N_{wp} \times \mu \times F_{p,C,wp,ser} / \gamma_{M3,ser}$ = **124.7** kN
	$F_{w,v,Ed,ser} / F_{s,wp,Rd,ser}$ = **0.530**
	PASS - Bolt resistance exceeds applied force on bolt
Resistance of web cover plate in shear	
Resist. of gross shear area of web plate (Eqn.6.18)	$V_{wp,g,Rd} = 2 \times h_{wp} \times t_{wp} \times f_{y,wp} / (1.27 \times \sqrt{(3)} \times \gamma_{M0})$ = **720.10** kN
Net area of web plate	$A_{v,wp,net} = (h_{wp} - n_{2,wp} \times d_{0,wp}) \times t_{wp}$ = **2176** mm^2
Resist. of net shear area of web plate (Eqn.6.18)	$V_{wp,net,Rd} = 2 \times A_{v,wp,net} \times f_{u,wp} / (\sqrt{(3)} \times \gamma_{M2})$ = **936.53** kN
Plastic resistance of web cover plate	$V_{pl,wp,Rd} = \min(V_{wp,g,Rd}, V_{wp,net,Rd})$ = **720.10** kN
	$V_{Ed} / V_{pl,wp,Rd}$ = **0.174**
	PASS - Shear resistance of web plate exceeds applied shear
Block tearing of web cover plate	
Area subject to tension	$A_{nt} = t_{wp} \times (e_{1,wp} - d_{0,wp} / 2)$ = **624** mm^2
Area subject to shear	$A_{nv} = t_{wp} \times (h_{wp} - e_{2,wp} - (n_{2,wp} - 0.5) \times d_{0,wp})$ = **1552** mm^2
Block tearing resistance	$V_{b,Rd} = 2 \times (f_{u,wp} \times A_{nt} / \gamma_{M2} + f_{y,wp} \times A_{nv} / (\sqrt{(3)} \times \gamma_{M0}))$ = **957.99** kN
	$V_{Ed} / V_{b,Rd}$ = **0.130**
	PASS - Block tearing resistance of web plate exceeds applied shear
Resistance of beam web shear accounting for holes	
Height of web	$h_w = h - 2 \times t_f$ = **225.7** mm

	η = **1.000**
Shear area - cl 6.2.6(3)	$A_v = \max(A - 2 \times b \times t_f + (t_w + 2 \times r) \times t_f, \eta \times h_w \times t_w)$ = **2562** mm^2
Net shear area	$A_{v,net} = A_v - (n_{2,wp} \times d_{0,wp} \times t_w)$ = **2184** mm^2
Design shear net resistance - cl 6.2.6(2)	$V_{nw,Rd} = A_{v,net} \times f_{u,bm} / (\sqrt{(3)} \times \gamma_{M2})$ = **470.0** kN
	$V_{Ed} / V_{nw,Rd}$ = **0.266**
	PASS - Net shear resistance of beam web exceeds applied shear force

Resistance of web cover plate to combined bending, shear and axial

Elastic modulus of web cover plate	$W_{wp} = t_{wp} \times h_{wp}^2 / 6$ = **86400** mm^3
Bending resistance of web cover plate	$M_{c,wp,Rd} = 2 \times W_{wp} \times f_{y,wp} / \gamma_{M0}$ = **47.5** kNm
Axial resistance of web cover plate	$N_{wp,Rd} = 2 \times t_{wp} \times h_{wp} \times f_{y,wp}$ = **1584.0** kN
Appied moment	$M_{wp,Ed} = M_w + M_{add}$ = **32.1** kNm
Applied axial force	$N_{wp,Ed} = F_{w,N}$ = **26.1** kN
Interaction formula	$N_{wp,Ed} / N_{wp,Rd} + M_{wp,Ed} / M_{c,wp,Rd}$ = **0.692**
	PASS - Combined bending, shear and axial check satisfied