PlanningApplications.com Summer House, Upper Court Road Woldingham SURREY CR3 7BF support@planningapplications.com 07922 148 701	Project BEAM 4 - & Plate - rear extension cavity wall over doors				Job no. 739	
	Calcs for Connor McKitrich				Start page no./Revision 1	
	Calcs by SB	Calcs date 31/05/2023	Checked by DB	Checked date 31/05/2023	Approved by SB	Approved date 31/05/2023

STEEL MASONRY SUPPORT

In accordance with EN1993-1-1:2005 incorporating Corrigenda February 2006 and April 2009 and the UK national annex

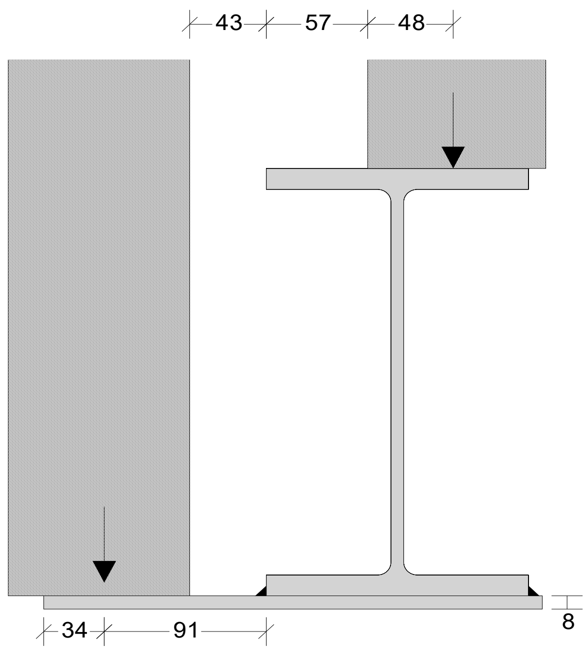
Tedds calculation version 1.0.03

Design summary

Overall design status PASS

Overall design utilisation 0.771

Description	Unit	Allowable	Applied	Utilisation	Result
Heel moment	kNm/m	2.933	0.150	0.051	PASS
Deflection	mm	1.8	0.1	0.029	PASS
Weld capacity	kN/m	945.2	240.6	0.255	PASS
Shear force (major axis)	kN	310.4	45.8	0.148	PASS
Bending (major-axis)	kNm	95.0	57.3	0.603	PASS
Bending (minor axis)	kNm	38.8	1.9	0.048	PASS
Warping	kNm	18.9	1.1	0.056	PASS
Bending and torsion				0.735	PASS
Plastic interaction				0.239	PASS
Torsion beam rotation	deg	2.00	1.39	0.695	PASS
Torsion beam deflection	mm	10.0	7.7	0.771	PASS



Partial factors - Section 6.1

Resistance of cross-sections γ_{M0} = **1**

Resist. of members to instability γ_{M1} = **1**

Resistance of joints γ_{M2} = **1.25**

Partial factor for permanent action γ_G = **1.35**

Partial factor for variable action γ_Q = **1.50**

Partial factor for permanent action (favourable) γ_{G_fav} = **1.00**

Partial factor for variable action (favourable) γ_{Q_fav} = **0.00**

Steel beam section details

Torsion beam section type — UB 254x146x43

Nominal yield strength — $f_y = f_{y,tb} = \mathbf{275}$ N/mm^2

Nominal ultimate tensile strength — $f_u = f_{u,tb} = \mathbf{410}$ N/mm^2

Masonry support section details

Section type — Plate 280x8(125)

Steel grade - EN 10025-2:2004 — S275

Nominal thickness — $t_{nom,sb} = t_{plate} = \mathbf{8}$ mm

Nominal yield strength — $f_{y,sb} = \mathbf{275}$ N/mm^2

Nominal ultimate tensile strength — $f_{u,sb} = \mathbf{410}$ N/mm^2

Modulus of elasticity — $E_{sb} = \mathbf{210000}$ N/mm^2

Total length of plate — $l_{plate} = \mathbf{280}$ mm

Length of plate beyond outer edge of torsion beam — $l_h = \mathbf{125}$ mm

Supported materials detail

Density of masonry on torsion beam — $\rho_{m,tb} = \mathbf{20.0}$ kN/m^3

Width of masonry on torsion beam — $b_{m,tb} = \mathbf{100}$ mm

Height of masonry on torsion beam — $h_{m,tb} = \mathbf{600}$ mm

Eccentricity of torsion beam masonry — $e_{load,tb} = \mathbf{105}$ mm

Eccentricity of torsion beam material — $e_{tb} = \mathbf{57}$ mm

Add perm. force torsion beam (not masonry) — $G_{k,add,tb} = \mathbf{5.0}$ kN/m

Add var. force torsion beam (not masonry) — $Q_{k,add,tb} = \mathbf{5.0}$ kN/m

Density of masonry on support beam — $\rho_{m,sb} = \mathbf{20.0}$ kN/m^3

Width of masonry on support beam — $b_{m,sb} = \mathbf{102}$ mm

Height of masonry on support beam — $h_{m,sb} = \mathbf{600}$ mm

Eccentricity of support beam masonry — $e_{load,sb} = \mathbf{91}$ mm

Geometry

Cavity width — $b_{cavity} = \mathbf{100}$ mm

Supported width of masonry — $d_m = l_h + t_{shim} + e_{tb} - b_{cavity} = \mathbf{82}$ mm

Biaxial stress effects in the plate (SCI-P-110)

Maximum overall bending moment — $M_{y,Ed} = \mathbf{57.3}$ kNm

Dist to NA combined section (CoG torsion beam) — $z_{na,all} = (h_{tb} + t_{plate}) \times A_{pl} / (2 \times (A_{tb} + A_{pl})) = \mathbf{39}$ mm

Second moment of area of combined section — $I_{y,all} = (I_{ytb} + A_{tb} \times z_{na,all}^2) + A_{pl} \times (h_{tb} / 2 + t_{plate} / 2 - z_{na,all})^2 = \mathbf{9390}$ cm^4

Elastic section modulus of combined section — $Z_{y,all} = I_{y,all} / (h_{tb} / 2 + t_{plate} - z_{na,all}) = \mathbf{948.82}$ cm^3

Section modulus of plate — $Z_{y,plate} = 1m \times t_{plate}^2 / (6 \times 1m) = \mathbf{10.67}$ cm^3/m

Force of masonry on support plate — $F_1 = (b_{m,sb} \times h_{m,sb} \times \rho_{m,sb} + G_{k,add,sb}) \times \gamma_G + Q_{k,add,sb} \times \gamma_Q = \mathbf{1.7}$ kN/m

Bending at heel — $M_{y,Ed,plate} = F_1 \times e_{load,sb} = \mathbf{0.2}$ kNm/m

Moment capacity of plate — $M_{y,Rd,plate} = Z_{y,plate} \times f_{y,sb} / \gamma_{M0} = \mathbf{2.9}$ kNm/m

PASS - Moment capacity of plate exceeds applied moment

Longitudinal stress due to overall bending — $\sigma_1 = M_{y,Ed} / Z_{y,all} = \mathbf{60.4}$ N/mm^2

Constant relating to Von Mises curve — $c_{fp} = (4 \times f_{y,sb}^2 - 3 \times \sigma_1^2)^{0.5} = \mathbf{540.0}$ N/mm^2

Transverse bending stress ratio limit — $\alpha_{ts} = (c_{fp}^2 - \sigma_1^2) / (2 \times c_{fp} \times f_{y,sb}) = \mathbf{0.970}$

Transverse bending stress ratio — $\alpha_{ls} = M_{y,Ed,plate} / M_{y,Rd,plate} = \mathbf{0.051}$

PASS - Transverse bending stress ratio less than allowable limit

Deflection of plate

Unfactored force on support angle — $F_{1ser} = (b_{m,sb} \times h_{m,sb} \times \rho_{m,sb} + G_{k,add,sb}) + Q_{k,add,sb} = \mathbf{1.2}$ kN/m

Distance from weld to load position $a_m = e_{load,sb} = \mathbf{91}$ mm

Length of load resultant to edge of plate $b_m = l_h - e_{load,sb} = \mathbf{34}$ mm

Dist from weld to load position as ratio of length $a_l = a_m / (a_m + b_m) = \mathbf{0.728}$

Effective second moment of area $I_{eff\_def} = t_{plate}^3 / 12 = \mathbf{42667}$ mm^4/m

Deflection at end of plate $\delta = (a_l^2 \times (3 - a_l) / 6) \times (F_{1ser} \times (a_m + b_m)^3) / (E_{sb} \times I_{eff\_def}) = \mathbf{0.05}$ mm

Deflection limit $\delta_{lim} = \min((1 + d_m / b_{cavity}) \times 1mm, 2mm) = \mathbf{1.82}$ mm

PASS - Deflection is within specified criteria

Weld details - assume a full length weld and that the plate acts as a propped cantilever with the prop at the weld position and the fixed end at the centre of the torsion beam

Shear force at weld position $F_A = F_1 \times \max((1 + (3 \times e_{load,sb}) / (2 \times b_{tb} / 2)), 1.4) = \mathbf{4.7}$ kN/m

Maximum possible force in plate $F_p = (l_h + \min(b_{tb}, l_{plate} - l_h)) \times t_{plate} \times f_{y,sb} = \mathbf{599.1}$ kN

Longitudinal shear between beam and plate $F_l = 2 \times F_p / L = \mathbf{239.6}$ kN/m

Horizontal shear between beam and plate $F_h = F_1 \times e_{load,sb} / (s_{weld} / 2 + t_{plate} / 2) = \mathbf{21.5}$ kN/m

Resultant weld force $F_{w,Ed} = (F_A^2 + F_l^2 + F_h^2)^{0.5} = \mathbf{240.6}$ kN/m

Leg length of weld $s_{weld} = \mathbf{6.00}$ mm

Throat thickness of weld $a_{weld} = 1 / \sqrt{(2)} \times s_{weld} = \mathbf{4.24}$ mm

Length of weld per metre run $l_{weld} = \mathbf{1000}$ mm/m

Ultimate tensile strength used for weld $f_{u,weld} = \min(f_{u,sb}, f_{u,tb}) = \mathbf{410.0}$ N/mm^2

Correlation factor (table 4.1) $\beta_w = \mathbf{0.85}$

Design shear strength $f_{vw,d} = f_{u,weld} / (\sqrt{(3)} \times \beta_w \times \gamma_{M2}) = \mathbf{222.8}$ N/mm^2

Design resistance of weld $F_{w,Rd} = f_{vw,d} \times a_{weld} = \mathbf{945.2}$ kN/m

PASS - weld capacity exceeds applied force

Eccentricities

Distance to shear centre of torsion beam $e_{0,tb} = \mathbf{0}$ mm

Eccentricity of support beam masonry $e_{m,sb} = e_{load,sb} + b_{tb} / 2 = \mathbf{165}$ mm

Eccentricity of torsion beam masonry $e_{m,tb} = b_{tb} / 2 - e_{load,tb} = \mathbf{-31}$ mm

Eccentricity of support beam $e_{b,sb} = c_{zsb} + b_{tb} / 2 = \mathbf{59}$ mm

Eccentricity of torsion beam $e_{b,tb} = \mathbf{0}$ mm

Torsional loading ULS (unfavourable)

Loading of support beam masonry $w_{sb} = (h_{m,sb} \times b_{m,sb} \times \rho_{m,sb}) \times \gamma_G = \mathbf{1.65}$ kN/m

Loading of torsion beam masonry $w_{tb} = (h_{m,tb} \times b_{m,tb} \times \rho_{m,tb} + G_{k,add,tb}) \times \gamma_G + Q_{k,add,tb} \times \gamma_Q = \mathbf{15.87}$ kN/m

Self weight of support beam $w_{sw,sb} = A_{pl} \times \rho_{SEC3} \times g_{acc} \times \gamma_G = \mathbf{0.23}$ kN/m

Self weight of torsion beam $w_{sw,tb} = A_{tb} \times \rho_{SEC3} \times g_{acc} \times \gamma_G = \mathbf{0.57}$ kN/m

Torsional loading ULS (favourable)

Loading of support beam masonry $w_{sb\_fav} = (h_{m,sb} \times b_{m,sb} \times \rho_{m,sb}) \times \gamma_{G\_fav} = \mathbf{1.22}$ kN/m

Loading of torsion beam masonry $w_{tb\_fav} = (h_{m,tb} \times b_{m,tb} \times \rho_{m,tb} + G_{k,add,tb}) \times \gamma_{G\_fav} + Q_{k,add,tb} \times \gamma_{Q\_fav} = \mathbf{6.20}$ kN/m

Self weight of support beam $w_{sw,sb\_fav} = A_{pl} \times \rho_{SEC3} \times g_{acc} \times \gamma_{G\_fav} = \mathbf{0.17}$ kN/m

Self weight of torsion beam $w_{sw,tb\_fav} = A_{tb} \times \rho_{SEC3} \times g_{acc} \times \gamma_{G\_fav} = \mathbf{0.42}$ kN/m

Torsional loading SLS (unfavourable)

Loading of support beam masonry $w_{sb,ser} = h_{m,sb} \times b_{m,sb} \times \rho_{m,sb} = \mathbf{1.22}$ kN/m

Loading of torsion beam masonry $w_{tb,ser} = h_{m,tb} \times b_{m,tb} \times \rho_{m,tb} + G_{k,add,tb} + Q_{k,add,tb} = \mathbf{11.20}$ kN/m

Self weight of support beam $w_{sw,sb,ser} = A_{pl} \times \rho_{SEC3} \times g_{acc} = \mathbf{0.17}$ kN/m

Self weight of torsion beam $w_{sw,tb,ser} = A_{tb} \times \rho_{SEC3} \times g_{acc} = \mathbf{0.42}$ kN/m

Torsional effects

Applied torque (ULS +ve ecc. unfav, -ve ecc. fav) $T_{d,w,fav1} = abs(w_{sb} \times e_{m,sb} + w_{tb\_fav} \times e_{m,tb} + w_{sw,sb} \times e_{b,sb} + w_{sw,tb} \times e_{b,tb})$ = **0.09** kNm/m

Applied torque (ULS +ve ecc. fav, -ve ecc. unfav) $T_{d,w,fav2} = abs(w_{sb\_fav} \times e_{m,sb} + w_{tb} \times e_{m,tb} + w_{sw,sb\_fav} \times e_{b,sb} + w_{sw,tb\_fav} \times e_{b,tb})$ = **0.29** kNm/m

Applied torque (ULS all unfavourable) $T_{d,w} = abs(w_{sb} \times e_{m,sb} + w_{tb} \times e_{m,tb} + w_{sw,sb} \times e_{b,sb} + w_{sw,tb} \times e_{b,tb})$ = **0.21** kNm/m

Total torque (ULS) $T_d = max(T_{d,w}, T_{d,w,fav1}, T_{d,w,fav2}) \times L$ = **1.43** kNm

Applied torque (SLS) $T_{d,w,ser} = abs(w_{sb,ser} \times e_{m,sb} + w_{tb,ser} \times e_{m,tb} + w_{sw,sb,ser} \times e_{b,sb} + w_{sw,tb,ser} \times e_{b,tb})$ = **0.14** kNm/m

Total torque (SLS) $T_{d,ser} = T_{d,w,ser} \times L$ = **0.70** kNm

STEEL BEAM TORSION DESIGN (EN1993)

In accordance with EN1993-1-1:2005 incorporating Corrigenda February 2006 and April 2009 and the UK national annex

Tedds calculation version 1.0.05

Partial factors - Section 6.1

Resistance of cross-sections γ_{M0} = **1**

Resistance of members to instability γ_{M1} = **1**

Section details

Section type UB 254x146x43 (BS4-1)

Steel grade - EN 10025-2:2004 S275

Nominal thickness of element $t_{nom} = max(t_f, t_w)$ = **12.7** mm

Nominal yield strength f_y = **275** N/mm^2

Nominal ultimate tensile strength f_u = **410** N/mm^2

Modulus of elasticity E = **210000** N/mm^2

Shear centre

Distance between flange shear centres $h_s = h - t_f$ = **246.9** mm

Shear centre (above bottom flange centroid) $e_{s,bf} = h_s / 2$ = **123.5** mm

Analysis results

Design bending moment - major axis $M_{y,Ed}$ = **57.3** kNm

Design shear force - major axis $V_{y,Ed}$ = **45.8** kN

Classification

Internal compression parts subject to bending - Table 5.2 (sheet 1 of 3)

Width of section c = d = **219** mm

$c / t_w = 30.4 = 32.9 \times \varepsilon <= 72 \times \varepsilon$ Class 1

Outstand flanges - Table 5.2 (sheet 2 of 3)

Width of section $c = (b - t_w - 2 \times r) / 2$ = **62.5** mm

$c / t_f = 4.9 = 5.3 \times \varepsilon <= 9 \times \varepsilon$ Class 1

Section is class 1

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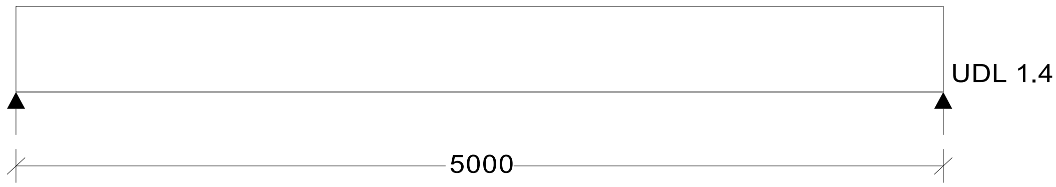
Torsional loads



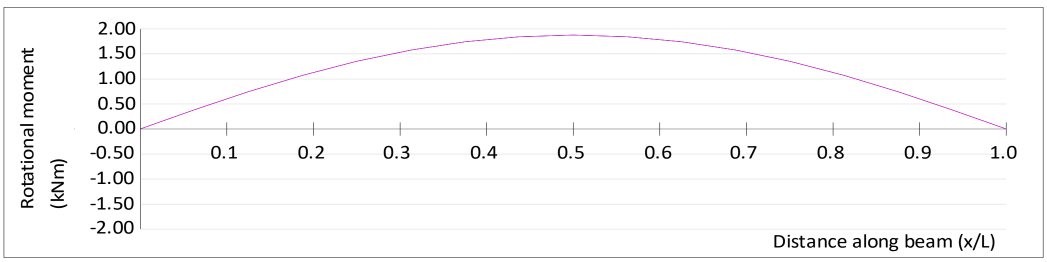
Torsional loading

Load No.	Load type	Load (kNm)	Distance along beam (mm)
1	UDL	1.4	-

Rotation ϕ (SCI P385 Appendix C Case 4)

$\phi = T_d \times a^2 / (G_{SEC3} \times I_t \times L) \times ((x \times L - x^2) / (2 \times a^2) + \cosh(x / a) - \tanh(L / (2 \times a)) \times \sinh(x / a) - 1)$

Additional minor moment due to rotation, $M_{z,add,Ed} = M_{y,Ed} \times \phi$

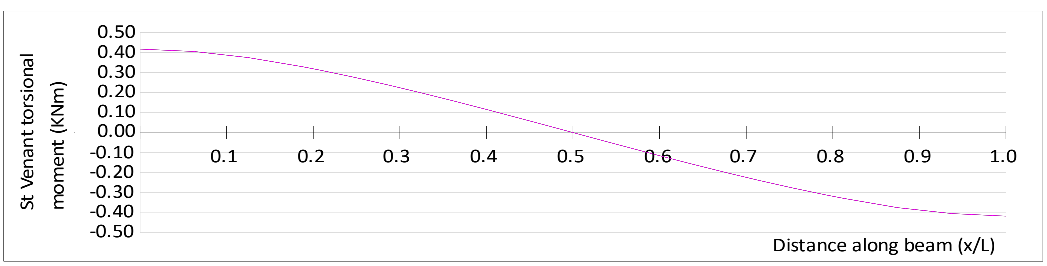


Additional minor design moment due to rotation $M_{z,add,Ed}$ = **1.88** kNm

St Venant ϕ' (SCI P385 Appendix C Case 4)

$\phi' = T_d \times a / (G_{SEC3} \times I_t \times L) \times (L / (2 \times a) - x / a + \sinh(x / a) - \tanh(L / (2 \times a)) \times \cosh(x / a))$

Design value of the internal St Venant torsion moment $T_{t,Ed} = G_{SEC3} \times I_t \times \phi'$

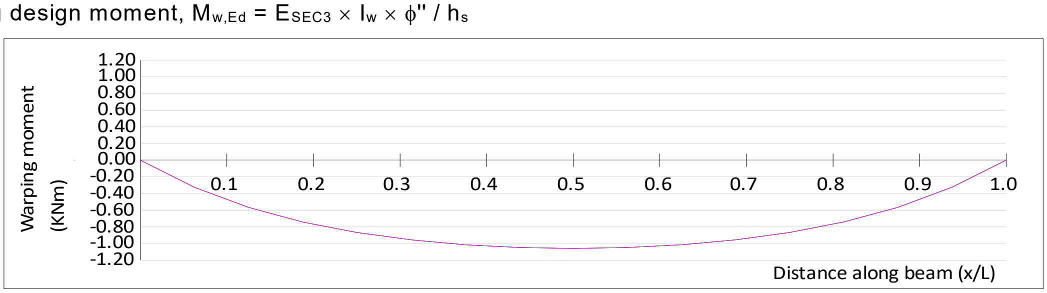


St Venant torsion design moment $T_{t,Ed}$ = **0.42** kNm

Warping ϕ'' (SCI P385 Appendix C Case 4)

$\phi'' = T_d / (G_{SEC3} \times I_t \times L) \times (-1 + \cosh(x / a) - \tanh(L / (2 \times a)) \times \sinh(x / a))$

Warping design moment, $M_{w,Ed} = E_{SEC3} \times I_w \times \phi'' / h_s$

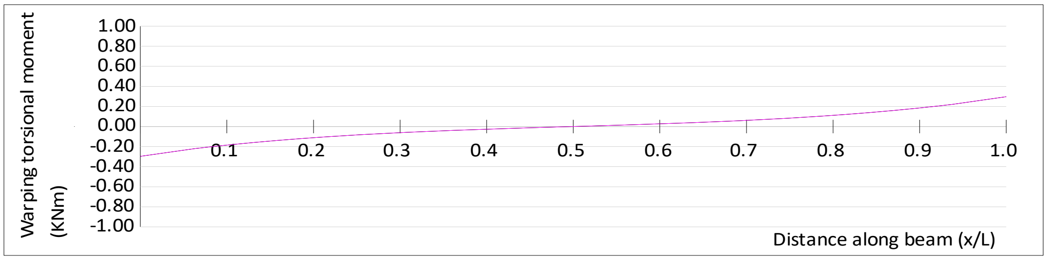


Warping design moment $M_{w,Ed}$ = **1.06** kNm

Warping torsional ϕ''' (SCI P385 Appendix C Case 4)

$\phi''' = T_d / (G_{SEC3} \times I_t \times L \times a) \times (\sinh(x / a) - \tanh[L / (2 \times a)] \times \cosh(x / a))$

Warping torsional design moment, $T_{w,Ed} = E_{SEC3} \times I_w \times \phi'''$



Warping torsional design moment $T_{w,Ed}$ = **0.30** kNm

Check shear - Section 6.2.6

Height of web $h_w = h - 2 \times t_f$ = **234.2** mm

η = **1.000**

$h_w / t_w = 32.5 = 35.2 \times \varepsilon / \eta < 72 \times \varepsilon / \eta$

Shear buckling resistance can be ignored

Design shear force $V_{y,Ed}$ = **45.81** kN

Shear area - cl 6.2.6(3) $A_v = \max(A - 2 \times b \times t_f + (t_w + 2 \times r) \times t_f, \eta \times h_w \times t_w)$ = **2020** mm^2

Design shear resistance - cl 6.2.6(2) $V_{pl,y,Rd} = A_v \times (f_y / \sqrt{(3)}) / \gamma_{M0}$ = **320.8** kN

Shear stress due to St Venant torsion $\tau_{t,Ed} = T_{t,Ed} \times t_w / I_t$ = **12.57** N/mm^2

Reduced shear resistance due to torsion - eq 6.26 $V_{c,y,Rd} = V_{pl,T,y,Rd} = \sqrt{(1 - \tau_{t,Ed} / (1.25 \times (f_y / \sqrt{(3)}) / \gamma_{M0}))} \times V_{pl,y,Rd}$ = **310.4** kN

$V_{y,Ed} / V_{pl,T,y,Rd}$ = **0.148**

PASS - Design shear resistance exceeds design shear force

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **57.3** kNm

Design bending resistance moment - eq 6.13 $M_{c,y,Rd} = M_{pl,y,Rd} = W_{pl.y} \times f_y / \gamma_{M0}$ = **155.7** kNm

$M_{y,Ed} / M_{pl,y,Rd}$ = **0.368**

PASS - Design bending resistance moment exceeds design bending moment

Slenderness ratio for lateral torsional buckling

Loading factor C_1 C_1 = **1.127**

Loading factor C_2 C_2 = **0.454**

Loading factor C_3 C_3 = **0.52**

Poissons ratio ν = **0.3**

Shear modulus $G = E / [2 \times (1 + \nu)]$ = **80769** N/mm^2

Unrestrained effective length L = **5000** mm

Distance from shear centre to level of load $z_g = (h_{tb} / 2 \times w_{tb} - h_{tb} / 2 \times w_{sb}) / (w_{tb} + w_{sb})$ = **105.3** mm

Elastic critical buckling moment $M_{cr} = C_1 \times \pi^2 \times E \times I_z / (k_{z,cr} \times L^2) \times (\sqrt{((k_{z,cr} / k_{w,cr})^2 \times I_w / I_z + L^2 \times G \times I_t / (\pi^2 \times E \times I_z) + (C_2 \times z_g)^2)} - (C_2 \times z_g))$ = **113.9** kNm

Slenderness ratio for lateral torsional buckling $\bar{\lambda}_{LT} = \sqrt{(W_{pl.y} \times f_y / M_{cr})}$ = **1.169**

Limiting slenderness ratio $\bar{\lambda}_{LT,0}$ = **0.4**

Lateral torsional buckling cannot be ignored

Check buckling resistance - Section 6.3.2.1

Buckling curve - Table 6.5 — b

Imperfection factor - Table 6.3 — α_{LT} = **0.34**

Correction factor for rolled sections — β = **0.75**

LTB reduction determination factor — $\Phi_{LT} = 0.5 \times (1 + \alpha_{LT} \times (\bar{\lambda}_{LT} - \bar{\lambda}_{LT,0}) + \beta \times \bar{\lambda}_{LT}^2)$ = **1.144**

LTB reduction factor - eq 6.57 — $\chi_{LT} = \min(1 / (\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \beta \times \bar{\lambda}_{LT}^2)}), 1, 1 / \bar{\lambda}_{LT}^2)$ = **0.597**

Modification factor — $f = \min(1 - 0.5 \times (1 - k_c) \times [1 - 2 \times (\bar{\lambda}_{LT} - 0.8)^2], 1)$ = **0.979**

Modified LTB reduction factor - eq 6.58 — $\chi_{LT,mod} = \min(\chi_{LT} / f, 1, 1 / \bar{\lambda}_{LT}^2)$ = **0.610**

Design buckling resistance moment - eq 6.55 — $M_{b,Rd} = \chi_{LT,mod} \times W_{pl.y} \times f_y / \gamma_{M1}$ = **95** kNm

$M_{y,Ed} / M_{b,y,Rd}$ = **0.603**

PASS - Design buckling resistance exceeds design buckling moment

Check bending moment - Section 6.2.5

Design bending moment — $M_{z,Ed,total} = M_{z,Ed} + M_{z,add,Ed}$ = **1.9** kNm

Design bending resistance moment - eq 6.13 — $M_{c,z,Rd} = M_{pl,z,Rd} = W_{pl.z} \times f_y / \gamma_{M0}$ = **38.8** kNm

$M_{z,Ed,total} / M_{pl,z,Rd}$ = **0.048**

PASS - Design bending resistance moment exceeds design bending moment

Check warping moment

Warping moment in flange — $M_{w,Ed}$ = **1.06** kNm

Plastic modulus of flange — $W_{pl.f} = t_f \times b^2 / 4$ = **68.89** cm^3

Design warping resistance of flange — $M_{w,Rd} = W_{pl.f} \times f_y / \gamma_{M0}$ = **18.94** kNm

$M_{w,Ed} / M_{w,Rd}$ = **0.056**

PASS - Bending resistance in one flange exceeds the design warping moment

Combined bending and torsion (EN1993-6 Annex A)

Equiv. uniform moment factor (parabolic curve) — C_{mz} = **0.95**

Characteristic moment resistance - y axis — $M_{y,Rk} = W_{pl.y} \times f_y$ = **155.7** kNm

Characteristic moment resistance - z axis — $M_{z,Rk} = W_{pl.z} \times f_y$ = **38.8** kNm

Characteristic warping resistance — $M_{w,Rk} = W_{pl.f} \times f_y$ = **18.9** kNm

Interaction factors — $k_w = 0.7 - 0.2 \times M_{w,Ed} / (M_{w,Rk} / \gamma_{M1})$ = **0.69**

$k_{zw} = 1 - M_{z,Ed,total} / (M_{z,Rk} / \gamma_{M1})$ = **0.95**

$k_\alpha = 1 / (1 - M_{y,Ed} / M_{cr})$ = **2.01**

Interaction formula eqn A.1 — $M_{y,Ed} / (\chi_{LT} \times M_{y,Rk} / \gamma_{M1}) + C_{mz} \times M_{z,Ed,total} / (M_{z,Rk} / \gamma_{M1}) + k_w \times k_{zw} \times k_\alpha \times M_{w,Ed} / (M_{w,Rk} / \gamma_{M1})$ = **0.735**

PASS - Combined bending and torsion check satisfied

Plastic verification - Exp.6.41

$(M_{y,Ed} / M_{pl,y,Rd})^2 + M_{z,Ed,total} / M_{pl,z,Rd} + M_{w,Ed} / M_{w,Rd}$ = **0.239**

PASS - Plastic interaction criterion is less than 1.0

Serviceability limit checks

Rotation limit — $\phi_{ser,lim}$ = **2.00** deg

Rotation of torsion beam — $\phi_{ser} = M_{z,add,Ed} \times 180 / (M_{y,Ed} \times \gamma_G \times \pi)$ = **1.39** deg

PASS - Rotation limit exceeds rotation in torsion beam

Vertical deflection limit — $\delta_{v,lim}$ = **10.0** mm

SLS loading on beam — $f_{d,ser} = w_{sb,ser} + w_{tb,ser} + w_{sw,sb,ser} + w_{sw,tb,ser}$ = **13.02** kN/m

Vertical deflection of torsion beam — $\delta_v = 5 \times f_{d,ser} \times L^4 / (384 \times E_{sb} \times I_{ytb})$ = **7.7** mm

PASS - Vertical deflection limit exceeds vertical deflection in torsion beam