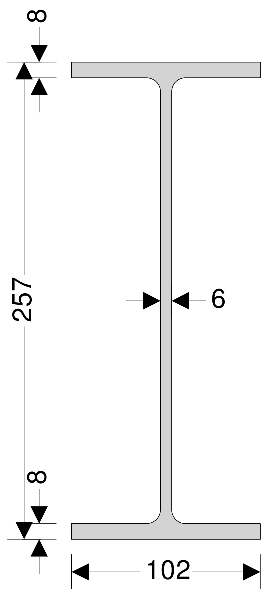
STEEL BEAM TORSION DESIGN

In accordance with BS5950-1:2000 incorporating Corrigendum No.1

Tedds calculation version 2.0.01



Section details

Section type UKB 254x102x25

Steel grade S275

Design stength $p_{yw} = p_y =$ **275** N/mm^2

Constant $\varepsilon = \sqrt{(275\ N/mm^2 / p_y)} =$ **1.000**

Calculated torsional properties

Shear area of web $A_{vy} = t \times D =$ **15.4** cm^2

Plastic modulus of web $S_{vx} = t \times D^2 / 4 =$ **99.2** cm^3

Torsion bending constant $a = \sqrt{(E \times H / (G \times J))} =$ **966** mm

Normalised warping function $W_{n0} = (D - T) \times B / 4 =$ **63.4** cm^2

Statical moment in the flange $Q_f = (S_x - t \times D^2 / 4) / 4 =$ **52** cm^3

Statical moment at mid-depth of section $Q_w = S_x / 2 =$ **153** cm^3

Warping statical moment $S_{w1} = (D - T) \times B^2 \times T / 16 =$ **136** cm^4

Geometry - Beam unrestrained against lateral-torsional buckling between supports.

Effective span L = **4000** mm

Length of segment for LT buckling $L_{LT} =$ **4000** mm

Compression flanges laterally restrained

Compression flange partially restrained against rotation on plan

Effective length for LT buckling $L_{E\_LT} = L_{LT} \times 0.85 =$ **3400** mm

Loading - Torsional loading comprises only full-length uniformly distributed load(s)

Internal forces & moments on member under factored loading for uls design

Applied shear force $F_{vy} =$ **6.0** kN

Maximum bending moment $M_{LT} = M_x =$ **11.90** kNm

Applied torque $T_q =$ **0.46** kNm

Minor axis bending moment M_y = 0 kNm

Compression force F_c = 0 kN

Equivalent uniform moment factors

EUM factor (Cl. 4.3.6.6 and T18) m_{LT} = **1.000**

Torsional deflection parameters

Beam is torsion fixed and warping free at each end. (as defined in SCI-P-057 section 2.1.6) - Appendix B case 4

Dist along the beam for first derivative of twist z_1 = 0 mm

Dist along the beam for second derivative of twist z_2 = L / 2 = **2000** mm

First derivative of angle of twist $\phi'_1 = T_q / (G \times J) \times a / L \times [L^2 / (2 \times a) \times (1 / L - 2 \times z_1 / L^2) + \sinh(z_1 / a) - \tanh(L / (2 \times a)) \times \cosh(z_1 / a)] \times 1$ rads = **2.42×10^-2** rads/m

Third derivative of angle of twist $\phi'''_1 = T_q / (G \times J \times a^2) \times a/L \times [\sinh(z_1 / a) - \tanh(L / (2 \times a)) \times \cosh(z_1 / a)] \times 1$ rads = **-2.28×10^-2** rads/m³

Angle of twist $\phi_2 = T_q \times a / (G \times J) \times a / L \times [L^2 / (2 \times a^2) \times (z_2 / L - z_2^2 / L^2) + \cosh(z_2 / a) - \tanh(L / (2 \times a)) \times \sinh(z_2 / a) - 1] \times 1$ rads = **0.030** rads

Second derivative of angle of twist $\phi''_2 = T_q / (G \times J \times a) \times a / L \times [\cosh(z_2 / a) - \tanh(L / (2 \times a)) \times \sinh(z_2 / a) - 1] \times 1$ rads = **-1.71×10^-2** rads/m²

Design parameters

Total angle of twist $\phi = \text{abs}(\phi_2)$ = **0.030** rads

First derivative of ϕ $\phi' = \text{abs}(\phi'_1)$ = **2.42×10^-2** rads/m

Second derivative of ϕ $\phi'' = \text{abs}(\phi''_2)$ = **1.71×10^-2** rads/m²

Third derivative of ϕ $\phi''' = \text{abs}(\phi'''_1)$ = **2.28×10^-2** rads/m³

Section classification

b / T = **6.1**

d / t = **37.5**

$r_{1s} = \min(1.0, \max(-1.0, F_c / (d \times t \times p_{yw})))$ = **0.000**

$r_{2s} = F_c / (A_g \times p_{yw})$ = **0.000**

Section classification is plastic

Shear capacity (parallel to y-axis)

Design shear force F_{vy} = **6.0** kN

Design shear resistance (Cl. 4.2.3) $P_{vy} = 0.6 \times p_y \times A_{vy}$ = **254.6** kN

Pass - Shear

Moment capacity (x-axis)

Design bending moment M_x = **11.9** kNm

Moment capacity $M_{cxu} = p_y \times S_x$ = **84.0** kNm

Moment capacity low shear (Cl. 4.2.5.1) $M_{cx} = \min(p_y \times S_x, 1.2 \times p_y \times Z_x)$ = **84.0** kNm

Pass - Moment capacity exceeds design bending moment

Lateral torsional buckling

Effective length for lateral torsional buckling L_{E_LT} = **3400** mm

Slenderness ratio $\lambda = L_{E\_LT} / r_y$ = **158**

Buckling parameter u = **0.866**

Flange ratio η = 0.5

Torsional index x = **31.5**

Slenderness factor $v = 1 / (1 + 0.05 \times (\lambda / x)^2)^{0.25}$ = **0.82**

Ratio - cl 4.3.6.9 β_w = 1.0 = **1.000**

Equivalent slenderness – cl 4.3.6.7 $\lambda_{LT} = u \times v \times \lambda \times \sqrt{(\beta_w)}$ = **111**

Limiting slendernes – Annex B2.2 $\lambda_{L0} = 0.4 \times \sqrt{(\pi^2 \times E_{S5950} / p_y)}$ = **34**

Euler stress $p_E = \pi^2 \times E_{S5950} / \lambda_{LT}^2$ = **163** N/mm²

Perry factor $\eta_{LT} = \max(7.0 \times (\lambda_{LT} - \lambda_{L0}) / 1000, 0)$ = **0.540**

$\phi_{LT} = (p_y + (\eta_{LT} + 1) \times p_E) / 2$ = **262880916.767**

Bending strength $p_b = p_E \times p_y / (\phi_{LT} + \sqrt{(\phi_{LT}^2 - p_E \times p_y)})$ = **107** N/mm²

Buckling resistance moment $M_b = p_b \times S_x$ = **32.7** kNm

Max moment governing buckling resistance M_{LT} = **11.9** kNm

Equiv uniform moment factor for LTB m_{LT} = **1.00**

M_b / m_{LT} = **32.7** kNm

Pass - lat. tors. buckling

Buckling under combined bending & torsion -SCI-P-057 section 2.3

For simplicity, a conservative check is applied using the maximum stresses due to each of the separate load effects, even though these do not necessarily all occur at the same section along the member.

Span factor L / a = **4.14**

Angle of twist ϕ = **0.030** rads

Second derivative of ϕ ϕ'' = **17.1×10⁻³** rads/m²

Induced minor axis moment $M_{yt} = M_x \times \phi / 1$ rad = **0.35** kNm

Normal stress at flange tip due to M_{yt} $\sigma_{byt} = M_{yt} / Z_y$ = **12** N/mm²

Normal stress at flange tip due to warping $\sigma_w = E_{S5950} \times W_{n0} \times \phi'' / 1$ rad = **22** N/mm²

Interaction index $i_b = M_x \times m_{LT} / M_b + (\sigma_{byt} + \sigma_w) / p_y \times (1 + 0.5 \times M_x \times m_{LT} / M_b)$ = **0.51**

Pass - Combined bending and torsion check satisfied

Local capacity under combined bending & torsion

For simplicity, a conservative check is applied using the maximum stresses due to each of the separate load effects, even though these do not necessarily all occur at the same section along the member.

Max. direct stress due to M_x $\sigma_{bx} = M_x / Z_x$ = **45** N/mm²

Combined stress - eqn 2.22 $\sigma_{bx} + \sigma_{byt} + \sigma_w$ = **79** N/mm²

Design strength p_y = **275** N/mm²

Pass - Local capacity

Combined shear stresses - SCI-P-057 section 2.3

For simplicity, a conservative check is applied using the maximum shear stresses due to each of the separate load effects, even though these do not necessarily all occur at the same section along the member.

Max shear stresses due to bending in web $\tau_{bw} = F_{vy} \times Q_w / (I_x \times t)$ = **4** N/mm²

Max shear stresses due to bending in flange $\tau_{bf} = F_{vy} \times Q_f / (I_x \times T)$ = **1** N/mm²

Max shear stresses due to torsion in web $\tau_{tw} = \text{abs}(G \times t \times \phi' / 1\text{rad})$ = **11** N/mm²

Max shear stresses due to torsion in flange $\tau_{tf} = \text{abs}(G \times T \times \phi' / 1\text{ rad})$ = **16** N/mm²

Max shear stresses due to warping in flange $\tau_{wf} = \text{abs}(-E_{S5950} \times S_{w1} \times \phi''' / 1\text{ rad} / T)$ = **1** N/mm²

Amp shear stress torsion & warping in web $\tau_{vtw} = \tau_{tw} \times (1 + 0.5 \times M_x \times m_{LT} / M_b)$ = **14** N/mm²

Amp shear stress torsion & warping in flange $\tau_{vtf} = (\tau_{tf} + \tau_{wf}) \times (1 + 0.5 \times M_x \times m_{LT} / M_b)$ = **20** N/mm²

Combined shear stresses due to bending, torsion & warping:

Combined shear stresses in web $\tau_w = \tau_{bw} + \tau_{vtw}$ = **18** N/mm²

Combined shear stresses in flange $\tau_f = \tau_{bf} + \tau_{vtf}$ = **21** N/mm²

Shear strength $p_v = 0.6 \times p_y$ = **165** N/mm²

Pass - Combined shear stresses

Twist check

Total applied torque (unfactored) T_{qu} = **0.46** kNm

Maximum twist under sls loading $\phi_{sls} = \phi \times T_{qu} / T_q$ = **1.69** deg

Twist limit ϕ_{lim} = **2.00** deg

Pass - Twist