

B.203.1

Maximum of load combinations

S 355

$$E = 210000 \text{ N/mm}^2$$

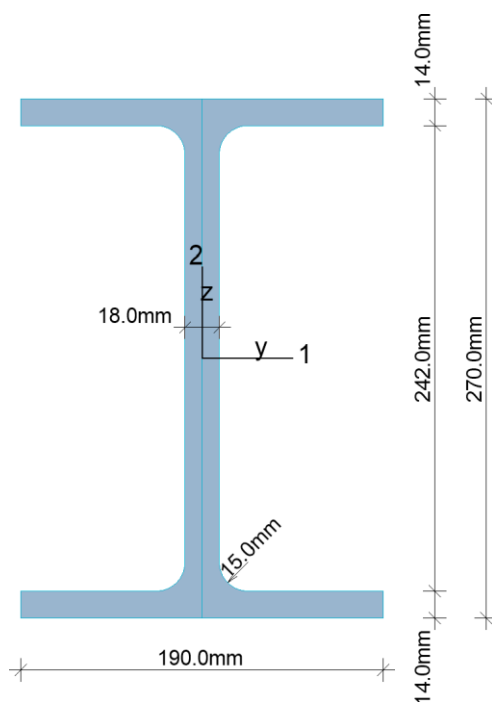
$$G = 80769 \text{ N/mm}^2$$

$$\gamma_{M0,ult} = 1.00 \quad \gamma_{M0,acc/seis} = 1.00$$

$$\gamma_{M1,ult} = 1.00 \quad \gamma_{M1,acc/seis} = 1.00$$

$$\gamma_{M2,ult} = 1.25 \quad \gamma_{M2,acc/seis} = 1.00$$

2xUPE 270 2xUPE 270



$$P = 1238 \text{ mm} \quad f_y = 355 \text{ N/mm}^2$$

$$A = 9869 \text{ mm}^2 \quad \varepsilon = 0.81$$

$$I_y = 1.112e+08 \text{ mm}^4 \quad \lambda_1 = 76.40$$

$$I_z = 1.615e+07 \text{ mm}^4$$

$$I_1 = 1.112e+08 \text{ mm}^4$$

$$I_2 = 1.615e+07 \text{ mm}^4$$

$$W_{pl,1} = 9.672e+05 \text{ mm}^3$$

$$W_{pl,2} = 2.747e+05 \text{ mm}^3$$

$$W_{el,min,1} = 8.236e+05 \text{ mm}^3$$

$$W_{el,min,2} = 1.700e+05 \text{ mm}^3$$

$$i_1 = 106 \text{ mm}$$

$$i_2 = 40 \text{ mm}$$

$$I_t = 9.644e+05 \text{ mm}^4$$

$$I_w = 2.556e+11 \text{ mm}^6$$

Shear resistance, 1-1 - Part 1-1: 6.2.6, 6.2.8

LC: '6.10 a Y+ wind down ', $x = 0 \text{ mm}$

Class_N = 1, Class_{M1} = 1, Class_{M2} = 1

$$V_{1,pl,Rd} = \frac{A_{1,v} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{5513 \cdot 355}{\sqrt{3} \cdot 1.00} = 1129.97 \text{ kN} \quad (6.18)$$

$$V_{1,pl,T,Rd} = \sqrt{1 - \frac{\tau_{t,Ed}}{1.25 (f_y / \sqrt{3}) / \gamma_{M0}}} \cdot V_{1,pl,Rd} = \sqrt{1 - \frac{0.00}{1.25 (355 / \sqrt{3}) / 1.00}} \cdot 1129.97 = 1129.97 \text{ kN} \quad (6.26)$$

$$\frac{V_{1,Ed}}{V_{1,pl,T,Rd}} = \frac{0.00}{1129.97} = 0.00 \leq 1.00 \quad (6.25) - \text{OK}$$

Shear resistance, 2-2 - Part 1-1: 6.2.6, 6.2.8

LC: '6.10 a Y+ wind down ', $x = 0 \text{ mm}$

Class_N = 1, Class_{M1} = 1, Class_{M2} = 1

$$V_{2,pl,Rd} = \frac{A_{2,v} \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}} = \frac{5227 \cdot 355}{\sqrt{3} \cdot 1.00} = 1071.36 \text{ kN} \quad (6.18)$$

$$V_{2,pl,T,Rd} = \sqrt{1 - \frac{\tau_{t,Ed}}{1.25 (f_y / \sqrt{3}) / \gamma_{M0}}} \cdot V_{2,pl,Rd} = \sqrt{1 - \frac{0.00}{1.25 (355 / \sqrt{3}) / 1.00}} \cdot 1071.36 = 1071.36 \text{ kN} \quad (6.26)$$

Project Details

$$\frac{V_{2,Ed}}{V_{2,pl,T,Rd}} = \frac{469.65}{1071.36} = 0.44 \leq 1.00 \quad (6.25) - \text{OK}$$

Torsional resistance - Part 1-1: 6.2.7

LC: '6.10 a Y+ wind down ', $x = 0$ mm

Class_N = 1, Class_{M1} = 1, Class_{M2} = 1

$\tau_{\max, \text{unit}} = 27.69 \frac{\text{N/mm}^2}{\text{kNm}}$ is calculated by FEM analysis.

$$T_{Rd} = \frac{f_y}{\sqrt{3} \cdot \tau_{\max, \text{unit}} \cdot Y_{M0}} = \frac{355}{\sqrt{3} \cdot 27.69 \cdot 1.00} = 7.40 \text{ kNm}$$

$$\frac{T_{Ed}}{T_{Rd}} = \frac{0.00}{7.40} = 0.00 \leq 1.00 \quad (6.23) - \text{OK}$$

Shear stress - Part 1-1: 6.2.6

Not relevant

Normal stress - Part 1-1: 6.2.1

Not relevant

Pure normal resistance - Part 1-1: 6.2.3, 6.2.4

Not relevant

Normal capacity - Part 1-1: 6.2

LC: '6.10 a Y+ wind down ', $x = 1500$ mm

Class_N = 1, Class_{M1} = 1, Class_{M2} = 1

$$V_{1,Ed} = 0.00 \text{ kN} \leq 0.5 \cdot V_{1,pl,T,Rd} = 0.5 \cdot 1129.97 = 564.98 \text{ kN} \rightarrow \rho_1 = 0.00$$

$$V_{2,Ed} = 10.65 \text{ kN} \leq 0.5 \cdot V_{2,pl,T,Rd} = 0.5 \cdot 1071.36 = 535.68 \text{ kN} \rightarrow \rho_2 = 0.00$$

$$\frac{N_{Ed}}{N_{Rd}} + \frac{M_{1,Ed}}{M_{1,Rd}} + \frac{M_{2,Ed}}{M_{2,Rd}} = \frac{0.00}{3503.55} + \frac{335.38}{343.37} + \frac{0.00}{97.51} = 0.98 \leq 1.00 \quad (6.2) - \text{OK}$$

Flexural buckling, 1-1 - Part 1-1: 6.3.1

LC: '6.10 a Y+ wind down ', $x = 0$ mm

Class_N = 1, Class_{M1} = 1, Class_{M2} = 1

$$\bar{\lambda}_1 = \frac{L_{cr,1}}{i_1 \cdot \lambda_1} = \frac{3000}{106 \cdot 76.40} = 0.37 \quad (6.50)$$

$$\alpha_1 = 0.21 \quad (\text{Buckling curve: a})$$

$$\varphi_1 = 0.5 \left[1 + \alpha_1 \cdot (\bar{\lambda}_1 - 0.2) + \bar{\lambda}_1^2 \right] = 0.5 \left[1 + 0.21 \cdot (0.37 - 0.2) + 0.37^2 \right] = 0.59$$

$$\chi_1 = \min \left(\frac{1}{\varphi_1 + \sqrt{\varphi_1^2 - \bar{\lambda}_1^2}}, 1.0 \right) = \min \left(\frac{1}{0.59 + \sqrt{0.59^2 - 0.37^2}}, 1.0 \right) = 0.96 \quad (6.49)$$

$$N_{b,Rd,1} = \frac{\chi_1 \cdot A \cdot f_y}{Y_{M1}} = \frac{0.96 \cdot 9869 \cdot 355}{1.00} = 3365.25 \text{ kN} \quad (6.47)$$

$$\frac{N_{Ed}}{N_{b,Rd,1}} = \frac{0.00}{3365.25} = 0.00 \leq 1.00 \quad (6.46) - \text{OK}$$

Flexural buckling, 2-2 - Part 1-1: 6.3.1

LC: '6.10 a Y+ wind down ', $x = 0$ mm

Class_N = 1, Class_{M1} = 1, Class_{M2} = 1

$$\bar{\lambda}_2 = \frac{L_{cr,2}}{i_2 \cdot \lambda_1} = \frac{3000}{40 \cdot 76.40} = 0.97 \quad (6.50)$$

$$\alpha_2 = 0.34 \quad (\text{Buckling curve: b})$$

$$\varphi_2 = 0.5 \left[1 + \alpha_2 \cdot (\bar{\lambda}_2 - 0.2) + \bar{\lambda}_2^2 \right] = 0.5 \left[1 + 0.34 \cdot (0.97 - 0.2) + 0.97^2 \right] = 1.10$$

$$\chi_2 = \min \left(\frac{1}{\varphi_2 + \sqrt{\varphi_2^2 - \bar{\lambda}_2^2}}, 1.0 \right) = \min \left(\frac{1}{1.10 + \sqrt{1.10^2 - 0.97^2}}, 1.0 \right) = 0.62 \quad (6.49)$$

$$N_{b,Rd,2} = \frac{\chi_2 \cdot A \cdot f_y}{\gamma_{M1}} = \frac{0.62 \cdot 9869 \cdot 355}{1.00} = 2157.35 \text{ kN} \quad (6.47)$$

$$\frac{N_{Ed}}{N_{b,Rd,2}} = \frac{0.00}{2157.35} = 0.00 \leq 1.00 \quad (6.46) - \text{OK}$$

Torsional-flexural buckling - Part 1-1: 6.3.1

LC: '6.10 a Y+ wind down ', $x = 0 \text{ mm}$

$$\text{Class}_N = 1, \text{Class}_{M1} = 1, \text{Class}_{M2} = 1$$

$$i_0 = \sqrt{i_1^2 + i_2^2 + y_0^2 + z_0^2} = \sqrt{106^2 + 40^2 + 0^2 + 0^2} = 114 \text{ mm}$$

$$N_{cr,1} = \frac{\pi^2 \cdot E \cdot I_1}{L_{cr,1}^2} = \frac{\pi^2 \cdot 210000 \cdot 111183438}{3000^2} = 25604.52 \text{ kN}$$

$$N_{cr,2} = \frac{\pi^2 \cdot E \cdot I_2}{L_{cr,2}^2} = \frac{\pi^2 \cdot 210000 \cdot 16152933}{3000^2} = 3719.87 \text{ kN}$$

$$N_{cr,T} = \frac{1}{i_0^2} \left(G \cdot I_t + \frac{\pi^2 \cdot E \cdot I_w}{L_t^2} \right) = \frac{1}{114^2} \left(80769 \cdot 9.644e + 05 + \frac{\pi^2 \cdot 210000 \cdot 2.556e + 11}{3000^2} \right) = 10599.93 \text{ kN}$$

$$\begin{aligned} i_0^2 (N - N_{cr,1}) (N - N_{cr,2}) (N - N_{cr,T}) - N^2 y_0^2 (N - N_{cr,2}) - N^2 z_0^2 (N - N_{cr,1}) \\ = 114^2 (N - 25604.52) (N - 3719.87) (N - 10599.93) - N^2 0^2 (N - 3719.87) \\ - N^2 0^2 (N - 25604.52) = 0 \end{aligned}$$

Smallest root of the above equation related to the torsional-flexural buckling:

$$N_{cr,TF} = 10599.93 \text{ kN}$$

$$N_{cr} = \min(N_{cr,T}, N_{cr,TF}) = \min(10599.93, 10599.93) = 10599.93 \text{ kN}$$

$$\bar{\lambda}_T = \sqrt{\frac{A \cdot f_y}{N_{cr}}} = \sqrt{\frac{9869 \cdot 355}{10599.93}} = 0.57 \quad (6.53)$$

$$\alpha_T = 0.34 \quad (\text{Buckling curve: b})$$

$$\varphi_T = 0.5 \left[1 + \alpha_T \cdot (\bar{\lambda}_T - 0.2) + \bar{\lambda}_T^2 \right] = 0.5 \left[1 + 0.34 \cdot (0.57 - 0.2) + 0.57^2 \right] = 0.73$$

$$\chi_T = \min \left(\frac{1}{\varphi_T + \sqrt{\varphi_T^2 - \bar{\lambda}_T^2}}, 1.0 \right) = \min \left(\frac{1}{0.73 + \sqrt{0.73^2 - 0.57^2}}, 1.0 \right) = 0.85 \quad (6.49)$$

$$N_{b,Rd,T} = \frac{\chi_T \cdot A \cdot f_y}{\gamma_{M1}} = \frac{0.85 \cdot 9869 \cdot 355}{1.00} = 2976.09 \text{ kN} \quad (6.47)$$

$$\frac{N_{Ed}}{N_{b,Rd,T}} = \frac{0.00}{2976.09} = 0.00 \leq 1.00 - \text{OK}$$

Lateral torsional buckling, top flange - Part 1-1: 6.3.2.2

LC: '6.10 a Y+ wind down ', $x = 1500 \text{ mm}$

$$\text{Class}_N = 1, \text{Class}_{M1} = 1, \text{Class}_{M2} = 1$$

$$N_{cr,LT} = \frac{\pi^2 \cdot E \cdot I_z}{(k_z \cdot L_{cr})^2} = \frac{\pi^2 \cdot 2.100e + 05 \cdot 1.615e + 07}{(1.00 \cdot 750)^2} = 59517.94 \text{ kN}$$

Loaded on top edge.

$$Z = (C_2 \cdot z_g - C_3 \cdot z_j) = (0.45 \cdot 135 - 0.52 \cdot 0) = 60.75 \text{ mm}$$

$$\begin{aligned}
 M_{cr} &= C_1 \cdot N_{cr,LT} \cdot \left(\left[\left(\frac{k_z}{k_w} \right)^2 \cdot \frac{I_w}{I_z} + \frac{G \cdot I_t}{N_{cr,LT}} + Z^2 \right]^{0.5} - Z \right) \\
 &= 1.13 \cdot 5.952e + 07 \cdot \left(\left[\left(\frac{1.00}{1.00} \right)^2 \cdot \frac{2.556e + 11}{1.615e + 07} + \frac{8.077e + 04 \cdot 9.644e + 05}{5.952e + 07} + 60.75^2 \right]^{0.5} - 60.75 \right) \\
 &= 5619.70 \text{ kNm}
 \end{aligned}$$

$$\bar{\lambda}_{LT} = \sqrt{\frac{W_y \cdot f_y}{M_{cr}}} = \sqrt{\frac{967230 \cdot 355}{5.620e + 09}} = 0.25$$

$$\alpha_{LT} = 0.21 \quad (\text{Buckling curve: a})$$

$$\varphi_{LT} = 0.5 \left[1 + \alpha_{LT} \cdot (\bar{\lambda}_{LT} - 0.2) + \bar{\lambda}_{LT}^2 \right] = 0.5 \left[1 + 0.21 \cdot (0.25 - 0.2) + 0.25^2 \right] = 0.54$$

$$\chi_{LT} = \min \left(\frac{1}{\varphi_{LT} + \sqrt{\varphi_{LT}^2 - \bar{\lambda}_{LT}^2}}, 1.0 \right) = \min \left(\frac{1}{0.54 + \sqrt{0.54^2 - 0.25^2}}, 1.0 \right) = 0.99 \quad (6.56)$$

$$M_{y,b,Rd} = \frac{\chi_{LT} \cdot W_y \cdot f_y}{\gamma_{M1}} = \frac{0.99 \cdot 967230 \cdot 355}{1.00} = 339.78 \text{ kNm} \quad (6.55)$$

$$\frac{M_{1,Ed}}{M_{y,b,Rd}} = \frac{335.38}{339.78} = 0.99 \leq 1.00 \quad (6.54) - \text{OK}$$

Lateral torsional buckling, bottom flange - Part 1-1: 6.3.2.2

LC: '6.11', $x = 3000 \text{ mm}$

$$\text{Class}_N = 1, \text{Class}_{M1} = 1, \text{Class}_{M2} = 1$$

$$N_{cr,LT} = \frac{\pi^2 \cdot E \cdot I_z}{(k_z \cdot L_{cr})^2} = \frac{\pi^2 \cdot 2.100e + 05 \cdot 1.615e + 07}{(1.00 \cdot 3000)^2} = 3719.87 \text{ kN}$$

Loaded on top edge.

$$Z = (C_2 \cdot z_g - C_3 \cdot z_j) = (0.45 \cdot 135 - 0.52 \cdot 0) = 60.75 \text{ mm}$$

$$\begin{aligned}
 M_{cr} &= C_1 \cdot N_{cr,LT} \cdot \left(\left[\left(\frac{k_z}{k_w} \right)^2 \cdot \frac{I_w}{I_z} + \frac{G \cdot I_t}{N_{cr,LT}} + Z^2 \right]^{0.5} - Z \right) \\
 &= 1.13 \cdot 3.720e + 06 \cdot \left(\left[\left(\frac{1.00}{1.00} \right)^2 \cdot \frac{2.556e + 11}{1.615e + 07} + \frac{8.077e + 04 \cdot 9.644e + 05}{3.720e + 06} + 60.75^2 \right]^{0.5} - 60.75 \right) \\
 &= 590.12 \text{ kNm}
 \end{aligned}$$

$$\bar{\lambda}_{LT} = \sqrt{\frac{W_y \cdot f_y}{M_{cr}}} = \sqrt{\frac{967230 \cdot 355}{5.901e + 08}} = 0.76$$

$$\alpha_{LT} = 0.21 \quad (\text{Buckling curve: a})$$

$$\varphi_{LT} = 0.5 \left[1 + \alpha_{LT} \cdot (\bar{\lambda}_{LT} - 0.2) + \bar{\lambda}_{LT}^2 \right] = 0.5 \left[1 + 0.21 \cdot (0.76 - 0.2) + 0.76^2 \right] = 0.85$$

$$\chi_{LT} = \min \left(\frac{1}{\varphi_{LT} + \sqrt{\varphi_{LT}^2 - \bar{\lambda}_{LT}^2}}, 1.0 \right) = \min \left(\frac{1}{0.85 + \sqrt{0.85^2 - 0.76^2}}, 1.0 \right) = 0.82 \quad (6.56)$$

$$M_{y,b,Rd} = \frac{\chi_{LT} \cdot W_y \cdot f_y}{\gamma_{M1}} = \frac{0.82 \cdot 967230 \cdot 355}{1.00} = 280.28 \text{ kNm} \quad (6.55)$$

$$\frac{M_{1,Ed}}{M_{y,b,Rd}} = \frac{0.00}{280.28} = 0.00 \leq 1.00 \quad (6.54) - \text{OK}$$

Interaction between normal force and bending 1. - Part 1-1: 6.3.3

LC: '6.10 a Y+ wind down', $x = 1500 \text{ mm}$

$$\text{Class}_N = 1, \text{Class}_{M1} = 1, \text{Class}_{M2} = 1$$

k_{ij} factors are calculated according to Method 1

$$C_{my} = 1.00 \quad C_{yy} = 1.00$$

$$C_{mz} = 1.00 \quad C_{yz} = 0.96$$

$$C_{mLT} = 1.00 \quad C_{zy} = 1.00$$

$$C_{zz} = 0.82$$

$$M_{2,Rk} = f_y \cdot W_{pl,2} = 355 \cdot 274684 = 97.51 \text{ kNm}$$

$$\frac{N_{Ed}^{comp}}{N_{b,Rd,1}} + k_{11} \cdot \frac{M_{1,Ed}}{M_{y,b,Rd}} + k_{12} \cdot \frac{M_{2,Ed}}{\frac{M_{2,Rk}}{\gamma_{M1}}} = \frac{0.00}{3365.25} + 1.00 \cdot \frac{335.38}{339.78} + 0.70 \cdot \frac{0.00}{\frac{97.51}{1.00}} = 0.99 \leq 1.00 \quad (6.61) - \text{OK}$$

Interaction between normal force and bending 2. - Part 1-1: 6.3.3

LC: '6.10 a Y+ wind down ', $x = 1500 \text{ mm}$

Class_N = 1, Class_{M1} = 1, Class_{M2} = 1

k_{ij} factors are calculated according to Method 1

$$C_{my} = 1.00 \quad C_{yy} = 1.00$$

$$C_{mz} = 1.00 \quad C_{yz} = 0.96$$

$$C_{mLT} = 1.00 \quad C_{zy} = 1.00$$

$$C_{zz} = 0.82$$

$$M_{2,Rk} = f_y \cdot W_{pl,2} = 355 \cdot 274684 = 97.51 \text{ kNm}$$

$$\frac{N_{Ed}^{comp}}{N_{b,Rd,2}} + k_{21} \cdot \frac{M_{1,Ed}}{M_{y,b,Rd}} + k_{22} \cdot \frac{M_{2,Ed}}{\frac{M_{2,Rk}}{\gamma_{M1}}} = \frac{0.00}{2157.35} + 0.53 \cdot \frac{335.38}{339.78} + 1.21 \cdot \frac{0.00}{\frac{97.51}{1.00}} = 0.52 \leq 1.00 \quad (6.62) - \text{OK}$$

Interaction between normal force and bending, 2nd order - Part 1-1: 6.3.3

Not relevant

Shear buckling - Part 1-5: 5

$$\frac{h_w}{t} = \frac{242}{18} = 13.4 \leq \frac{72}{\eta} \cdot \varepsilon = \frac{72}{1.20} \cdot 0.81 = 48.8 \rightarrow \text{Not relevant}$$

Summary

