(1) UB 610×229×101

(a) Class? Web: $c_w/t_w = \dfrac{602.6 - (2)(14.8) - 2(12.7)}{10.5} = 58.2$ Class (1)

$< 72\varepsilon = (72)(0.81) = 58.5$

Flange: $c_f/t_f = \dfrac{227.6 - 2(12.7) - 10.5)}{(2)(14.8)} = 6.48$ class (1)

$< 9\varepsilon = 7.29$

$M_{pl} = f_y \cdot W_{pl} = (355)(2880)(10^3) = 1022$ kNm

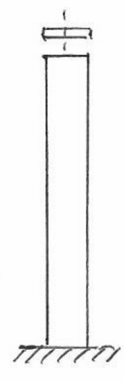
$M_{cr} = 265$ kNm

$\lambda_{LT} = \sqrt{\dfrac{M_{pl}}{M_{cr}}} = \sqrt{\dfrac{1022}{265}} = 1.96$ $\quad \dfrac{h}{b} > 2 \rightarrow$ curve (b) $\alpha = 0.34$

$\rightarrow \phi = 2.73 \rightarrow \chi = 0.216$

$M_{b,Rd} = \chi M_{pl}/\gamma_{M1} = (0.216)(1022) = 221$ kNm

(b)



$N_{Euler} = \dfrac{\pi^2}{L_e^2} EI_f$ $\quad I_f = \dfrac{t_f (b_f)^3}{12} = \dfrac{(14.8)(227.6)^3}{12}$

$= 1.45(10^7)$ mm^4

$L_e = 2L = 10$ m

$\sigma_{Euler} = \dfrac{N_{Euler}}{t_f \cdot b_f} = 85$ MPa

$\lambda = \sqrt{\dfrac{350}{85}} = 2.03$ curve (c) $\alpha = 0.49$

$\phi = 3.00 \rightarrow \chi = 0.19$

$\sigma_d = \chi \cdot f_y = 67$ MPa

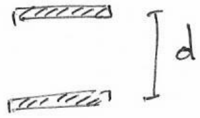
$M = \sigma_d \cdot W_{el,yy} = (67)(2515)(10^3) = 169$ kNm

This value is lower than the one found in (a) because this model ignores the stabilizing effect of the tension flange and the torsional resistance GJ of the cross-section. It also assumes a constant compressive force in the flange.

(c) $$M_{LT} = \frac{\pi}{L}\sqrt{EI_z GJ}\sqrt{1+\frac{\pi^2}{L^2}\frac{E\Gamma}{GJ}}$$ (data sheet)

if $GJ = 0 \Rightarrow M_{LT} = \frac{\pi^2}{L^2}\sqrt{EI_z E\Gamma}$

$\Gamma = \frac{I_z d^2}{4}$ (data sheet) $\Rightarrow M_{LT} = \frac{\pi^2 E}{L^2}\sqrt{\frac{I_z^2 d^2}{4}}$



$I_z = 2 I_{flange} \Rightarrow M_{LT} = \frac{\pi^2 E I_{flange}}{L^2} \cdot d$

Euler buckling load of the flange

2B (a) $A_s = (2000)(20) + 2(400)(30) = 64\,000 \text{ mm}^2$

$F_{s,max} = A_s \cdot f_y = 22\,720 \text{ kN}$

$b_{eff} = \min\left(\frac{L}{4}, 3300\right) = 3300 \text{ mm}$

$F_{c,max} = (0.85 f_{cd})(3300)(250)$

$= (0.85)\left(\frac{40}{1.5}\right)(3300)(250) = 18\,700 \text{ kN} < F_{s,max}$

→ N.A. in steel beam ; all of the slab is in compression

$N_{c,f} = F_{c,max}$

Choose ϕ 22 mm studs ; $f_u = 400$ MPa

$P_{Rd,1} = \frac{(0.8)(400)\pi(22)^2/4}{1.25} = 97.3 \text{ kN}$ ← critical

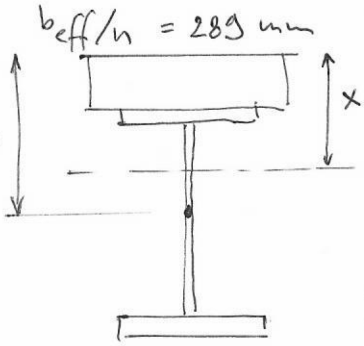
$P_{Rd,2} = \frac{(0.29)(22)^2\sqrt{(40)(35000)}}{1.25} = 132.9 \text{ kN}$

$\frac{N_{c,f}}{P_{Rd,1}} = 192$ over 25 m → Rows of 2 @ 500 mm

28 (b) Live load = 6 kPa × 3.3 m = 19.8 kN/m

$V_{max} = (19.8)(25) = 495 \text{ kN}$

$n = 2n_0 = 2 \dfrac{200\,000}{35\,000} = 11.4$



Assume N.A. in beam

$A_S(1280 - x) = (289)(250)(x - 125)$

$\rightarrow x = 667.5$ mm

$$I = \frac{(20)(2000)^3}{12} + (20)(2000)(\overbrace{1280 - 667.5}^{612.5})^2$$

$$+ (30)(400)[1015 + 612.5]^2 + (30)(400)[1015 - 612.5]^2$$

$$+ \frac{(289)(250)^3}{12} + (289)(250)(667.5 - 125)^2$$

$$= 8.37(10^{10}) \text{ mm}^4$$

$$q = V\frac{A_c\bar{y}}{I} = V\frac{(289)(250)(667.5 - 125)}{8.37(10^{10})} = (4.68)(10^{-4})V = 232 \text{ N/mm}$$

$$\frac{232 \cdot \overset{\text{spacing}}{s}}{n \cdot A_{stud}} \leq 90 \text{ MPa} \rightarrow \frac{s}{n} \leq 147 \text{ mm}$$

studs in a row

if $n = 2 \rightarrow$ take $s = 250$ mm

3 (a) $\frac{a}{h} = \frac{3000}{2500} = 1.2$

$$K = 5.34 + \frac{4}{(a/h)^2} = 8.12$$

$$\sigma_{cr} = K \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{h}\right)^2 = 5.87 \text{ MPa}$$

$$\lambda = \sqrt{\frac{355/\sqrt{3}}{5.87}} = 5.91$$

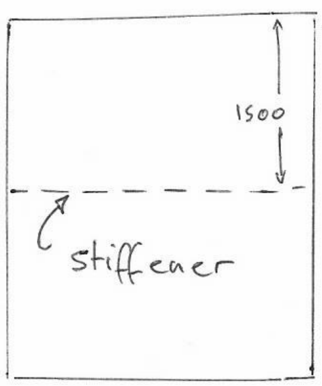
$$\chi = \frac{1.37}{0.7 + 5.91} = 0.21$$

$$V_{b,Rd} = \chi \frac{f_y}{\sqrt{3}} ht = 531 \text{ kN} \quad \underline{\text{Ok}}$$

(b) $\sigma_{cr} . h . t = 73.3$ kN

$$V_{service} = \frac{188}{1.5} = 125 \text{ kN} \quad \gg \quad 73.3 \text{ kN}$$

→ plate buckles and unbuckles during service



$$\frac{a}{h} = \frac{2500}{1500} = 1.7$$

$$K = 6.78$$

$$\sigma_{cr} = 13.6 \text{ MPa}$$

$$V_{cr} = \sigma_{cr} . t . 3000 = 204 \text{ kN}$$

$$> 125 \text{ kN} \quad \underline{\text{Ok}}$$

(4) $g_d = (12)(1.35) = 16.2 \text{ kN/m}$

$q_d = (20)(1.5) = 30 \text{ kN/m}$

$46.2 \text{ kN/m} \Rightarrow V_{Ed} = \frac{1}{2}(46.2)(5) = 116 \text{ kN}$

(a) Bolt shear

M20 $\rightarrow A_s = 245 \text{ mm}^2$ $\quad A = 314 \text{ mm}^2$

$F_{v,Rd} = 0.6 A_s f_{ub}/\gamma_{M2} = (0.6)(245)(400)/(1.1) = 53.5 \text{ kN}$

$\times 3 < 116 \text{ kN}$ Ok

Bearing

$\alpha_d = \min\left(\frac{50}{66}, \frac{100}{66} - \frac{1}{4}\right) = 0.76$

$k_1 = \min\left((2.8)\frac{50}{22} - 1.7, 2.5\right) = 2.5$

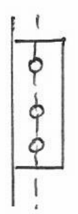
$\left\{ \begin{array}{l} \text{UB}: t_w = 6.4 \text{ mm} \\ \text{flag plate}: \underbrace{t = 5 \text{ mm}}_{\text{critical}} \end{array} \right.$

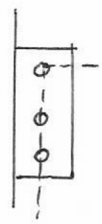
$\alpha_b = \min\left(\alpha_d, \frac{400}{450}, 1\right) = 0.76$

$F_{b,Rd} = k_1 \alpha_b f_u d t/\gamma_{M2} = 84.6 \text{ kN}$

$\times 3 < 116 \text{ kN}$ Ok

Fracture





$F_{f,1} = \frac{f_y}{\sqrt{3}}(300 - 3(22))(5)/(1.1)$

$= 218 \text{ kN}$ Ok

$F_{f,2} = \left[0.5 \frac{f_u(50 - 11)}{1.1} + \frac{f_y}{\sqrt{3}} \frac{(250 - 55)}{1.0}\right](5)$

$= 243 \text{ kN}$ Ok

(b) Weld $\quad V_{Ed} = 116 \text{ kN} \quad M_{Ed} = (116)(0.05) = 5.8 \text{ kNm}$

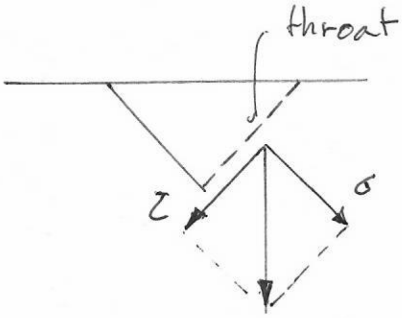
$\tau_v = \frac{V_{Ed}}{2 t_t \cdot L_{eff}}$

$= 92.4 \text{ MPa}$

$t_t = \frac{3}{\sqrt{2}} = 2.12 \text{ mm}$ (throat)

$L_{eff} = 300 - (2)(2.12) = 296 \text{ mm}$

M_{Ed}



2 fillet welds

$$(2)\left(\frac{\sqrt{2}}{2}\tau\right)(2)(t_t)\frac{L_{eff}^{\overbrace{\,2\,}^{W}}}{6} = M_d$$

$$\Rightarrow \tau = \sigma = \frac{6M_d}{2\sqrt{2}\; t_t\, L_{eff}^2} = 66.2 \text{ MPa}$$

$$\sqrt{\sigma^2 + 3(\tau^2 + \tau_v^2)} \overset{?}{\leq} \frac{490}{(0.9)(1.1)}$$

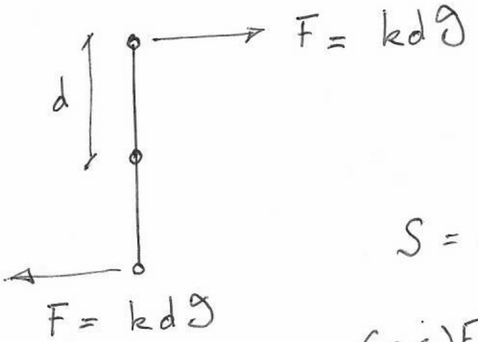
$$208 \text{ MPa} < 490 \text{ MPa} \quad \underline{\text{ok}}$$

and

$$\sigma \overset{?}{\leq} (0.9)\frac{490}{1.1}$$

$$66 \text{ MPa} < 400 \text{ MPa} \quad \underline{\text{ok}}$$

(c)



$$M = \underbrace{2kd^2}_{S}\theta$$

$$S = 2kd^2 = (2)(60)(100)^2 = 1200 \text{ kNm/rad}$$

$$(0.5)\frac{EI}{L} = (0.5)\frac{(200\,000)(12510)(10^4)}{(5000)} = 2500 \text{ kNm/rad}$$

Yes

$$\frac{1}{k} = \frac{1}{108} + \frac{1}{135}$$

$$\Rightarrow k = 60 \text{ kN/mm}$$