## Brace 4. Torsional Beam Bracing

$F_y := 260 \cdot MPa$ $\nu := 0.3$ $E := 200000 \cdot MPa$ $\phi := 0.75$ $\phi_b := 0.9$

$L := 24 \cdot m$ length of girders

$M_f := 140 \cdot m \cdot ton$ factored moment (maximum)

$n_{sb} := 4$ number of (span) braces (transversal to girders)

$s_b := 2.4 \cdot m$ separation between girders and length of torsional braces segments

### Unsymmetrical girder

$b_{f\_top} := 15 \cdot cm$ $t_{f\_top} := 2 \cdot cm$ $h := 125 \cdot cm$ $t_w := 1.2 \cdot cm$

$b_{f\_bottom} := 40 \cdot cm$ $t_{f\_bottom} := 2.5 \cdot cm$

$C_{bb} := 1$ Cb for the braces

$b_2 := b_{f\_bottom}$ $t_2 := t_{f\_bottom}$ $b_1 := b_{f\_top}$ $t_1 := t_{f\_top}$

$A := (h - t_1 - t_2) \cdot t_w + b_1 \cdot t_1 + b_2 \cdot t_2$ Area of this Section $A = 274.6\,cm^2$

$$b(y) := \begin{cases} b_2 & \text{if } y \le t_2 \\ \text{otherwise} & \\ \quad \begin{cases} t_w & \text{if AND2}(y > t_2, y \le h - t_1) \\ b_1 & \text{otherwise} \end{cases} & \end{cases}$$

$$y_g := \frac{\int_{0 \cdot cm}^{h} y \cdot b(y)\, dy}{A}$$ $y_g = 43.44\,cm$ from bottom $c := h - y_g$ $c = 81.56\,cm$ $t := y_g$

$$I_x := \int_{-y_g}^{h - y_g} y^2 \cdot b(y + y_g)\, dy$$ $I_x = 586101.38\,cm^4$

$$I_y := \frac{t_1 \cdot b_1^{\,3} + (h - t_1 - t_2) \cdot t_w^{\,3} + t_2 \cdot b_2^{\,3}}{12}$$

$$I_{yc} := \frac{t_1 \cdot b_1^{\,3}}{12} \qquad I_{yt} := \frac{t_2 \cdot b_2^{\,3}}{12}$$

$$I_{y\_eff} := I_{yc} + \frac{t}{c} \cdot I_{yt}$$

$$M_{br\_req} := \frac{0.04 \cdot L \cdot M_f^{\,2}}{n_{sb} \cdot E \cdot I_{y\_eff} \cdot C_{bb}^{\,2}}$$

$$S_{x\_req} := \frac{M_{br\_req}}{\phi_b \cdot F_y} \qquad S_{x\_req} = 126.15\,cm^3$$

$$k_{stiff} := \frac{2 \cdot 6 + (n_{sb} - 1) \cdot 12}{n_{sb} + 1} \qquad k_{stiff} = 9.6$$

$$\beta_{T\_req} := \frac{2.4 \cdot L \cdot M_f^{\,2}}{\phi \cdot n_{sb} \cdot E \cdot I_{y\_eff} \cdot C_{bb}^{\,2}}$$

$$I_{br\_req} := \frac{\beta_{T\_req} \cdot s_b}{k_{stiff} \cdot E} \qquad I_{br\_req} = 295.18\,cm^4$$

$H_{tot} := h$ $T_w := t_w$ to preserve dimension while below reusing notation for braces

## Braces

$b_f := 10 \cdot cm$ $t_f := 1.5 \cdot cm$ $h := 25 \cdot cm$ $t_w := 1 \cdot cm$

$B := b_f$ $C := b_f - t_w$ $D := h - 2 \cdot t_f$ $H := h$

$$A := \left(h - t_f\right)\cdot t_w + 2\cdot\left(b_f - \frac{t_w}{2}\right)\cdot t_f$$ Area of this Section

$$x_g := \frac{2\cdot B^2\cdot t_f + D\cdot {t_w}^2}{2\cdot B\cdot H - 2\cdot D\cdot C}$$ from external face of web

$$I_y := \frac{h\cdot {t_w}^3 + 2t_f\cdot\left(b_f - t_w\right)^3}{12} + h\cdot t_w\cdot\left(x_g - \frac{t_w}{2}\right)^2 + 2\cdot t_f\cdot\left(b_f - t_w\right)\cdot\left[\frac{\left(b_f - t_w\right)}{2} + t_w - x_g\right]^2$$

$$I_x := \frac{1}{12}\cdot\left(B\cdot H^3 - C\cdot D^3\right)$$

$$S_x := \frac{I_x}{\frac{h}{2}}$$

$\frac{I_x}{I_{br\_req}} = 17.06$ $\frac{S_x}{S_{x\_req}} = 3.19$ must be bigger than 1 for OK

$$\beta_b := \frac{k_{stiff}\cdot E\cdot I_x}{s_b}$$

$$\beta_{sec} := \frac{1}{\frac{1}{\beta_{T\_req}} - \frac{1}{\beta_b}}$$

$$\beta_c := 2\cdot\beta_{sec}$$

## Web Stiffener at brace location

$h_i := 50 \cdot cm$ height of bottom of brace from axis of bottom flange $t_s := 1 \cdot cm$ $b_s := 30 \cdot cm$ unwarranted guess stiffener dimensions

Given tw of girder is surmised per fig 23 in Yura, Fundamentals of Beam bracing

$$\beta_c = \frac{3.3 \cdot E}{h_i} \cdot \left( \frac{H_{tot}}{h_i} \right)^2 \cdot \left( \frac{1.5 \cdot h_i \cdot T_w^{\,3}}{12} + \frac{t_s \cdot b_s^{\,3}}{12} \right)$$

$b_s := \text{Find}(b_s)$ $b_s = 8.44\,cm$ required (horizontal) width of stiffener stiffener extends the full height