AY 2023/2024

CV4102- Advanced steel design

1 $\beta = \frac{b_1+b_2}{2b_0}$

$= \frac{160+160}{2(200)}$

$= 0.8$

$\gamma = \frac{d_0}{2t_0}$

$= \frac{200}{2(12.5)}$

$= 8$

From table 7.8

$\frac{b_1}{b_0} = \frac{b_2}{b_0} = \frac{160}{200} = 0.8 > 0.35$ and $> 0.1 + 0.01\frac{b_0}{t_0} = 0.26$

For compression brace :

$\frac{b_1}{t_1} = \frac{h_1}{t_0} = \frac{160}{10} = 16 < 35$

For tension brace :

$\frac{b_2}{t_2} = \frac{h_2}{t_2} = \frac{160}{16} = 16 < 35$ $< 33\varepsilon = 30.492$ ($\therefore$ class 1)

$\frac{h_0}{b_0} = \frac{h_1}{b_1} = \frac{h_2}{b_2} = 1 > 0.5$ and < 2

$\frac{b_0}{t_0} = \frac{h_0}{t_0} = \frac{200}{12.5} = 16 < 35$ $< 33\varepsilon = 30.492$ (class 1)

$\frac{g}{b_0} = \frac{45}{200} = 0.225 > 0.5(1-\beta) = 0.1$ and $< 1.5(1-\beta) = 0.3$

$g = 45 > t_1 + t_2 = 20$

From table 7.9

$0.6 < \frac{b_1+b_2}{2b_1} = 0.8 < 1.3$ and $\frac{b_0}{t_0} = \frac{200}{12.5} = 16 > 15$ $\therefore$ table 7.10 can be used

From table 7.10

$N_{1,rd} = \frac{8.9\gamma^{0.5} k_n f_{y0} t_0^2}{\sin\theta}\left(\frac{b_1+b_2}{2b_0}\right) / \gamma_{M1}$

$k_n = 1.3 - \frac{0.4n}{\beta}$

$= 1.3 - \frac{0.4(0.6)}{0.8} = 1$

$N_{1,rd} = \frac{8.9 \times 8^{0.5} \times 1 \times 355 \times 12.5^2}{\sin 45}\left(\frac{160+160}{2(200)}\right) / 1$

$= 1579.75 kN$

$\simeq 1580 kN$

$N_{2,rd} = 1580 kN$

$A_1 f_{y1} = A_2 f_{y2} = (160^2 - 140^2)(355)$

$= 2130 kN > N_{1,rd}$

$\therefore$ chord face failure

1c $\frac{g}{b_0} > 1.5(1-\beta)$

$\frac{g}{200} > 1.5(1-0.8)$

$g > 200(1.5(1-0.8))$

$g > 60 m$

1b $\sigma_{Ed} = 0.9 f_{y0}$

$n = 0.9$

$k = 1.3 - \frac{0.4n}{\beta}$

$= 1.3 - \frac{0.4(0.9)}{0.8}$

$= 0.85$

$N_{1,rd} = \frac{8.9 \gamma^{0.5} k_n f_{y0} t_0^2}{\sin 45} \left(\frac{b_1 + b_2}{2b_0} \right) / \gamma_{M1}$

$= \frac{8.9 \times 8^{0.5} \times 0.85 \times 355 \times 12.5^2}{\sin 45} \left[\frac{160 + 160}{200} \right] / 1$

$= 1342.79 \text{ kN}$

$\simeq 1340 \text{ kN}$

By increasing the magnitude n value increases, k_n decreases and since $N_{1,rd}$ is proportional to k_n, $N_{1,rd}$ decreases

By changing the direction, the chord will be under tension, $k_n = 1$ $\therefore$ $N_{1,rd} = 1580 \text{ kN}$

2a Throat length $= 7 \times \cos 45$

$= 4.9497$

weld area $= [127 + (127-9) + 2(152-14)] \times 4.9497$

$= 2578.8 \text{ mm}^2$

Maximum vertical shear $f_s = \frac{P}{A}$

$= \frac{200 \times 10^3}{2578.8} = 77.555 \text{ N/mm}^2$

Second Moment

$$I_{yy} = 2 \times \frac{(152-14)^3 (4.9497)}{12} + \left[\frac{127(4.9497)^3}{12} + 127(4.9497) \times \left[\frac{152-14+4.9497}{2}\right]^2\right] + 2\left[\frac{\frac{127-9}{2}(4.9497)^3}{12} + \frac{127-9}{2}(4.9497)\left(\frac{152-14+4.9497}{2}\right)^2\right]$$

$= 8.3656 \times 10^6 \text{ mm}^4$

Elastic section modulus

$W_{el} = \frac{I_{yy}}{y} = \frac{8.3656 \times 10^6}{\frac{152-14}{2} + 4.9497}$

$= 1.1313 \times 10^5 \text{ mm}^3$

Maximum bending stress

$f_b = \frac{M}{W_{el}}$

$= \frac{200 \times 10^3 \times 120}{1.1313 \times 10^5}$

$= 212.15$

$f_r = \sqrt{f_s^2 + f_b^2}$

$= \sqrt{77.555^2 + 212.15^2}$

$= 225.88 \text{ N/mm}^2$

$f_{vw,d} = \frac{f_u / \sqrt{3}}{\beta_w \times \gamma_{M2}} = \frac{430/\sqrt{3}}{0.85 \times 1.25}$

$= 233.65 \text{ N/mm}^2 > 225.88 \text{ N/mm}^2 \quad \therefore$ okay

2b $a = 6 \times \cos 45$

$= 4.2426$

Area $= 2(180 + 2(160)) \times 4.2426$

$= 4242.6$

$f_s = \frac{200 \times 10^3}{4242.6}$

$= 47.140$

$$I_{yy} = 2\left(\frac{4.2426(2(160))^3}{12}\right) + 2\left(\frac{180(4.2426)^3}{12} + 180(4.2426)\left[\frac{2(160)+4.2426}{2}\right]^2\right)$$

$= 6.3316 \times 10^7$

$W_{el} = \frac{6.3316 \times 10^7}{160 + 4.2426}$

$= 3.8550 \times 10^5$

$f_b = \frac{M}{W_{el}}$

$= \frac{200 \times 10^3 \times 120}{3.8550 \times 10^5}$

$= 62.256$

$f_r = \sqrt{f_s^2 + f_b^2}$

$= \sqrt{47.140^2 + 62.256^2}$

$= 78.090$

$f_{vw,d} = \frac{f_u / \sqrt{3}}{\beta_w \times \gamma_{M2}}$

$= \frac{430/\sqrt{3}}{0.85 \times 1.25} = 233.65 \text{ N/mm}^2 > 78.090 \text{ N/mm}^2$

2c 6mm fillet weld will fail first.

3a $\frac{a}{h_w} = \frac{3000}{2000}$

$= 1.5 > 1$

$k_\tau = 5.34 + 4.00 \left(\frac{h_w}{a}\right)^2$

$= 7.1178$

$\bar{\lambda}_w = \frac{h_w}{37.4 t_w \varepsilon \sqrt{k_\tau}}$

$= \frac{2000}{37.4 \times 15 \times \sqrt{\frac{355}{275}} \times \sqrt{7.1178}}$

$= 1.1762 > 1.08$

$\chi_w = \frac{0.83}{\bar{\lambda}_w} = \frac{0.83}{1.1762}$

$= 0.70572$

$V_{bw,rd} = \frac{\chi_w f_{yw} h_w t_w}{\sqrt{3}\,\gamma_{M1}}$

$= \frac{0.70572 \times 355 \times 2000 \times 15}{\sqrt{3} \times 1}$

$= 4339.30\text{ kN}$

$c = a\left(0.25 + \frac{1.6 b_f t_f^2 f_{yf}}{t_w h_w^2 f_{yw}}\right)$

$= 3000\left(0.25 + \frac{1.6 \times 600 \times 30^2}{15 \times 2000^2}\right)$

$= 793.2$

$V_{bf,rd} = \frac{b_f t_f^2 f_{yf}}{c\,\gamma_{M1}}\left(1 - \left(\frac{M_{Ed}}{M_{f,rd}}\right)^2\right)$

$= \frac{600 \times 15^2 \times 355}{793.2 \times 1}\left(1 - 0.75^2\right)$

$= 26.434$

$V_{b,rd} = V_{bw,rd} + V_{bf,rd}$

$= 4339.30 + 26.434$

$= 4365.74\text{ kN} < \frac{\eta f_{yw} h_w t_w}{\sqrt{3} \times \gamma_{M1}} = \frac{1 \times 355 \times 2000 \times 15}{\sqrt{3} \times 1} = 6148.78\text{ kN}$ ∴ okay

3b Contribution of web $= \frac{4339.30}{4365.74} \times 100\%$

$= 99.395\%$

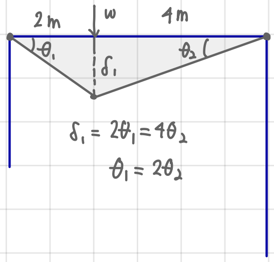
$\approx 99.4\%$

Contribution of flange $= \frac{26.434}{4365.74} \times 100\%$

$= 0.60548\%$

$\approx 0.605\%$

4 Beam mechanism



$\delta_1 = 2\theta_1 = 4\theta_2$

$\theta_1 = 2\theta_2$

internal virtual work

$Mp\,\theta_1 + Mp\theta_2 + 2Mp(\theta_1+\theta_2)$

$Mp(2\theta_2) + Mp\theta_2 + 2Mp(2\theta_2+\theta_2) = 9Mp\theta_2$

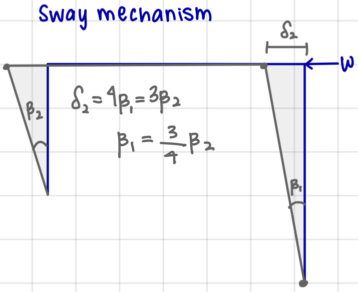
External virtual work

$w\delta_1 = 4\theta_2 w$

$9Mp\cancel{\theta_2} = 4\cancel{\theta_2}w$

$w = \frac{9Mp}{4}$

Sway mechanism



$\delta_2 = 4\beta_1 = 3\beta_2$

$\beta_1 = \frac{3}{4}\beta_2$

internal virtual work

$Mp\beta_2 + Mp\beta_1 + Mp\beta_1 = \frac{4}{3}Mp\beta_1 + Mp\beta_1 + Mp\beta_1$

$= \frac{10}{3}Mp\beta_1$

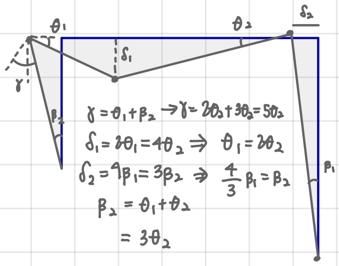
External virtual work

$w\delta_2 = 4w\beta_1$

$\frac{10}{3}Mp\cancel{\beta_1} = 4w\cancel{\beta_1}$

$w = \frac{5}{6}Mp$

Combined Mechanism



$\gamma = \theta_1 + \beta_2 \rightarrow \gamma = 2\theta_2 + 3\theta_2 = 5\theta_2$

$\delta_1 = 2\theta_1 = 4\theta_2 \Rightarrow \theta_1 = 2\theta_2$

$\delta_2 = 4\beta_1 = 3\beta_2 \Rightarrow \frac{4}{3}\beta_1 = \beta_2$

$\beta_2 = \theta_1 + \theta_2$

$= 3\theta_2$

internal virtual work

$Mp5\theta_2 + 2Mp3\theta_2 + Mp\left(\frac{3}{4}\times 3\theta_2\right) + Mp\left(\frac{3}{4}\times 3\theta_2\right) = \frac{31}{2}Mp\theta_2$

External virtual work

$w\delta_1 + w\delta_2 = 4\theta_2 w + 4w(3\theta_2)$

$= 16\theta_2 w$

$\frac{31}{2}Mp\cancel{\theta_2} = 16\cancel{\theta_2}w$

$\frac{31}{32}Mp = w$

$\therefore$ The failure load is $w = \frac{5}{6}Mp = 16.67\,kN$

4b

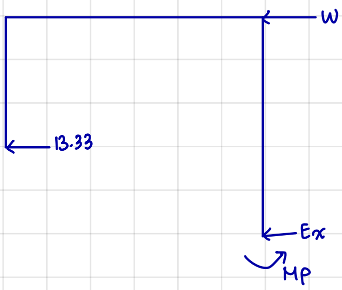
Taking Moment about B

$+\circlearrowleft \Sigma M_B = 0$

$Mp + Mp - Ax(3) = 0$

$\frac{2Mp}{3} = Ax$

$Ax = 13.33\,kN$



$\xrightarrow{+} \Sigma F_x = 0$

$13.33 - 16.67 - Ex = 0$

$Ex = -3.33\,kN$

$= 3.33\,kN\,(\rightarrow)$