

1. W310x143, $r_x = 138 \text{ mm}$, $A = 18200 \text{ mm}^2$

a) λ_m ? Column B: $R_L = 350 \text{ kN} (\text{Dead})$, $550 \text{ kN} (\text{Live})$
 $F_L = 600 \text{ kN} (\text{dead})$, $1000 \text{ kN} (\text{live})$

For lower column

$$G_e = 10 \text{ (pinned)}$$

$$G_u = \frac{348}{L_c}, f_{c3} = 34.8 E 6 \text{ mm}^4$$

$$\frac{348}{L_g}, I_{410 \times 60} = 21.6 E 6 \text{ mm}^4$$

$$I_{410 \times 74} = 275 E 6 \text{ mm}^4$$

$$I_{410 \times 54} = 186 E 6$$

$$I_{410 \times 67} = 245 E 6$$

$$\therefore G_u = \frac{348/4200 + \frac{348}{3600}}{\frac{216}{9300} + \frac{275}{11000}} = 3.722567289$$

$$K \approx 0.93; \quad (\text{Amer } 6) \quad 1-219$$

For upper column

$$G_e = \frac{348/3600 + \frac{348}{3600}}{\frac{216}{9300} + \frac{275}{11000}} = 3.722567289$$

$$G_u = \frac{348/3600}{\frac{186}{9300} + \frac{245}{11000}} = 2.1553$$

$$K \approx 0.87 \quad (1-219)$$

b) Check bottom

$$\frac{M_{xx} L_{xx}}{r_x} = \frac{0.935 \cdot 4200}{138} = 28.3049 < 200, \text{ OK} \quad \leftarrow \text{govern's}$$

Check top

$$\frac{0.87 \cdot 3600}{138} = 22.696 < 200, \text{ OK}$$

Section classification

$$\frac{b}{h} = \frac{323 - 2(22.9)}{14} = 19.8 \leq \frac{19.00}{\sqrt{345}} = 102.3, \therefore \text{not class 4}$$

$$\frac{b_e t}{t} = \frac{309/2}{22.9} = 6.746 \leq \frac{200}{\sqrt{345}} = 107.676, \therefore \text{not class 4}$$

$$\lambda = \sqrt{\frac{345}{\pi^2 \cdot 2E5}} / 28.3049 = 0.374202$$

$$C_r = 0.9 \cdot 345 \cdot 18200 \cdot (1 + 0.374202^{2.134})^{-1/1.34} \\ = 5366.24 \text{ kN}$$

$$1.25(350+600) + 1.5(550+1000) = 3512.5 \text{ kN}$$

$$C_r > 3512.5, \therefore \text{OK}$$

② $L = 6\text{m}$, $w = 410 \times 54$, spring = 1.6m, of 15kN DL, 25kN LL

$$\text{Landing} = 15 \cdot 1.25 + 25 \cdot 1.5 = 56.25 \text{ kN}$$

$$\text{From } \underline{\text{D}} \text{ in } 5-135, M_x = R_1 x - P(x-a), R_1 = \frac{P}{l}(1-a+b), b = l-a-1.6 \\ = \frac{P}{l}(2l-2a-1.6)$$

$$\therefore M_x = \frac{P}{l}[2l-2a-1.6]x + Px - Pa$$

$$= (Px + Pa)x, \text{ when } M_x \text{ is maximized, } \frac{dM}{dx} = 0$$

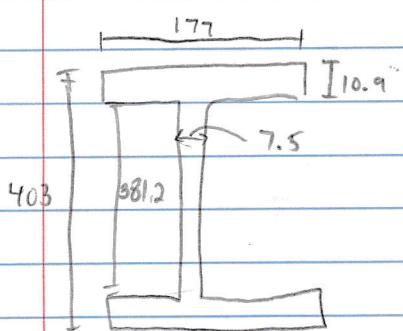
$$\frac{dM}{dx} = P + \frac{2Pa}{l} - \frac{1.6P}{l} = 0, a = ? \quad P = 56.25, l = 6\text{m}$$

$$56.25 \cdot 2.2 = 123.75 \quad b = 6 - 2.2 - 1.6 = 2.2$$

$$= 3.65$$

Since $a < b$, for symmetric loading b is satisfied, $M_{max} = Pa$

$$M = 56.25 \cdot 2.2 = 123.75 \text{ kNm}$$



$$\frac{b}{t} = \frac{177/2}{10.9} = 8.11927 < \frac{200}{\sqrt{345}} = 10.76, \therefore \text{Not class 4}$$

$$< \frac{170}{\sqrt{345}} = 9.152 \therefore \text{Not class 3}$$

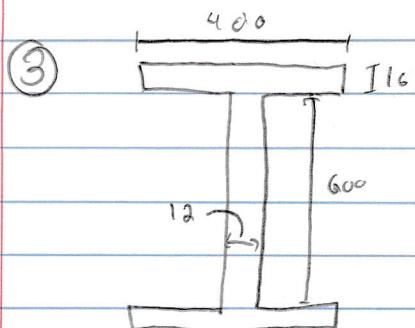
$$\frac{h}{t} = \frac{403 - 2(10.9)}{7.5} = 50.827 < \frac{1900}{\sqrt{345}} = 102.22, \therefore \text{not class 4}$$

$$< \frac{1700}{\sqrt{345}}, \therefore \text{not class 3}$$

$$Z = \frac{381.2}{2} \cdot \frac{381.2}{4} \cdot 7.5 \cdot 2 + 177 \cdot 10.9 \cdot 7 \cdot \left(\frac{381.2}{2} + \frac{10.9}{2} \right)$$

$$= 1028941.23 \text{ mm}^3$$

$$M_f = 0.9 \cdot 1028941.23 \cdot 345 = 319.49 \text{ kNm} > 123.75, \therefore \text{OK}$$



$$J = 2 \cdot \frac{1}{3} \cdot 400 \cdot 16^3 + \frac{1}{3} \cdot 600 \cdot 12^3 \\ = 1437866667 \text{ mm}^4$$

$$(I_y = 600 \int_{-6}^6 y^2 dy + 2 \cdot 16 \cdot \int_{-200}^{200} y^2 dy) \\ = \frac{600}{3} [6^3 - (-6)^3] + 2 \cdot 16 \cdot \left[\frac{200^3}{3} - \left(-200^3 \right) \right] = 170753066.7$$

Section class fraction

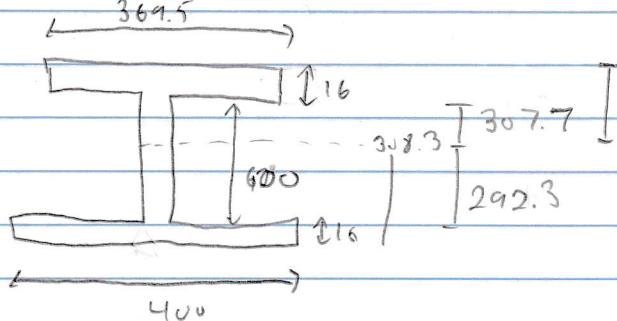
$$(r = I_y / \left(\frac{600 - 16}{2} \right)^2)$$

$$\frac{b_{ef}}{16} = \frac{400/12}{16} = 12.5 \neq \frac{200}{\sqrt{300}} = 11.547, \therefore \text{class 4}$$

$$\frac{h}{w} = \frac{600}{12} \leq \frac{1000}{\sqrt{300}}, 50 \leq 109.6965 \therefore \text{not class 3}$$

Reduce flange area - Local buckling check

$$\frac{b_{ef}}{16} = \frac{200}{\sqrt{300}}, b_{ef} = 184.752, A_b = 30.5 \text{ mm}$$



$$\bar{y} = \frac{400 \cdot 16.8 + 600 \cdot 12 \cdot 316 + 369.5 \cdot 16 \cdot 624}{400 \cdot 16 + 600 \cdot 12 + 369.5 \cdot 16}$$

$$= 308.30 \text{ mm}$$

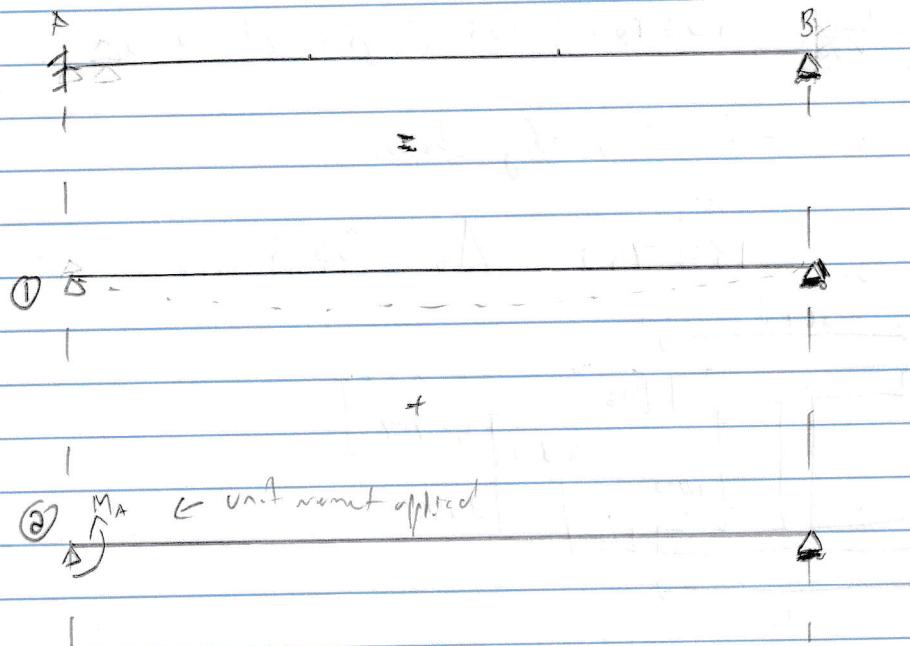
$$I_{yz} = 12 \int_{-212.3}^{307.7} y^2 dy + 323.7 \int_{307.7}^{323.7} y^2 dy + 400 \int_{212.3}^{308.3} y^2 dy \\ = 12 \left[\frac{307.7^3 - (-212.3)^3}{3} \right] + 323.7 \left[\frac{323.7^3 - 307.7^3}{3} \right] + 400 \left[\frac{308.3^3 - 212.3^3}{3} \right] \\ = 1383070409 \text{ mm}^4$$

$$S_e = \frac{I_{xx}}{y_{max}} = \frac{1383070409}{323.7} = 4272692.026 \text{ mm}^3$$

$$M_r = \phi S_e F_y = 0.9 S_e \cdot 300 \\ = 1153.63 \text{ kNm}$$

To check FT-buckling

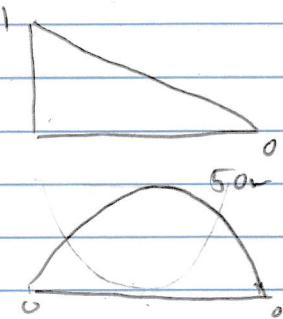
1. Determine moment envelope



$$\textcircled{1} \quad \sum F_y = 0, \quad A_y = B_y = \frac{w \cdot 20}{2} = 10w, \quad \text{from } 111111 \text{ m, } M = 10wx - \frac{wx^2}{2}$$

$$\textcircled{2} \quad \sum M_B = 0, \quad 1 + A_y(20), \quad A_y = -1/20, \quad B_y = 1/20, \quad m = 1 - \frac{x}{20}$$

$$M_{max} = 1, M_{max} = \frac{w l^2}{8} = \frac{w \cdot 20^2}{8} = 50w$$



From product integrals,

$$\int \frac{M_m}{EI} dx = \frac{1}{3} \cdot 1 \cdot 50w \cdot 20 = \frac{1000}{3EI} w$$

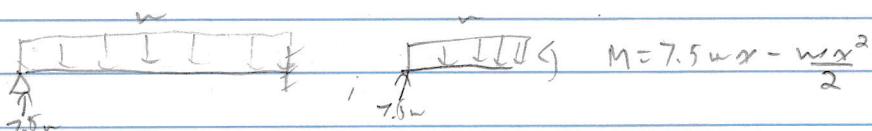
$$\int \frac{mm}{EI} dx = \frac{1}{3} \cdot 1 \cdot 1 \cdot 20 = \frac{20}{3EI}$$

$$\frac{1000}{3EI} w - M_A \left(\frac{20}{3EI} \right) = 0, \quad M_A = 50w$$

$$\{ M_A = 0, 50w - w \cdot 20 - \frac{20}{2} + F_y \cdot 20 = 0$$

$$F_y = 7.5w$$

$$\sum F_y = 0, 20 \cdot w - 7.5w = A_f, A_f = 12.5w$$



$$M_{max}, \frac{dM}{dx} = 0, 7.5w - \frac{2wx}{2}, w = 7.5$$

After looking at all 3 unbowed segments (see excel), segment 3 governed w/ $M_u = 2928.37675 \text{ kNm}$. Next, determine M_y since class 4

$$M_y = S F_y$$

$$I_{xx} = 12 \int_{-300}^{300} y^2 dy + 2 \cdot 400 \int_{-300}^{316} y^2 dy$$

$$\begin{aligned} I_{xx} &= 12 [300^3 + 300^3] + \frac{800}{3} [316^3 - 300^3] \\ &= 1430532267 \text{ mm}^4 \end{aligned}$$

$$S = \frac{1430532267}{316} = 4527000.844$$

$$M_y = S F_y = S \cdot 300$$

$$= 1358.1 \text{ kNm}$$

$$0.67 M_y = 909.93 \text{ kNm} \geq M_u \Rightarrow 0.67 M_y$$

$$M_c = 1.15 \cdot 0.9 \cdot 1358.1 \cdot 1.15 \text{ kNm} > 909.93 \text{ kNm}$$

$$M_c = 1.15 \cdot 0.9 \cdot 1358.1 \cdot \left[1 - \frac{0.28 \cdot 1358.1}{2728.377} \right] \leq 0.9 \cdot 1358.1$$

$$\text{if } x = 1209.723 \leq 1222.291 \quad (1-x)(1-x) = x(1-x)(1+x)$$

$$\therefore M_c = 1209.723 \text{ kNm}$$

Constants

J	1437866,667	mm ⁴
Iy	170753066,7	mm ⁴
Cw	1,45591E+13	mm ⁶
E	200000	MPa
G	77000	MPa
L	6666,67	mm

Section 1

x _{start}	0					
x _{end}	6,666666667					
x		At Start	At 1/4x	At 2/4x	At 3/4x	At End
		0	1,66666667	3,33333333	5	6,66666667
M (in terms of w)		0	11,111111	19,4444444	25	27,7777778
w ₂		1,387584626	<2.5			
M _u		3325,389735				

Section 2

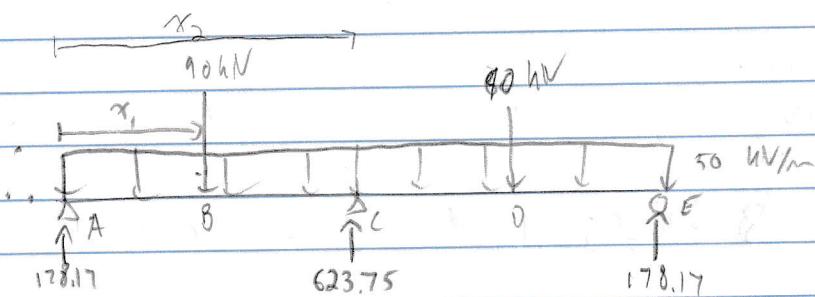
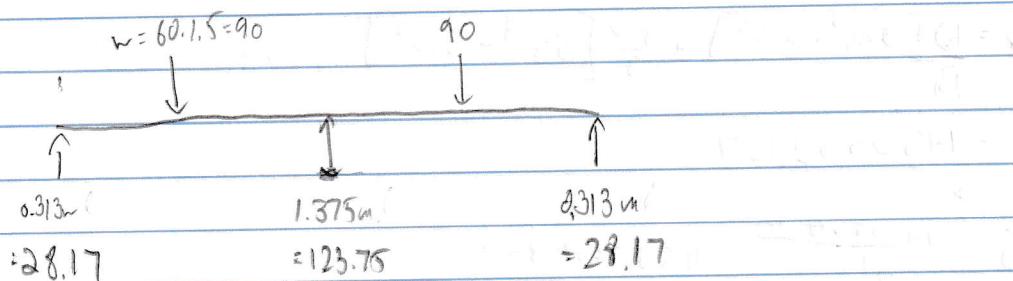
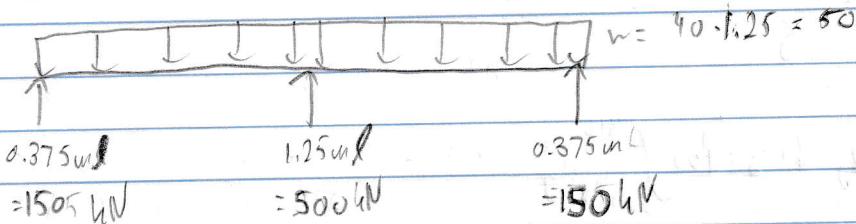
x _{start}	6,666666667					
x _{end}	13,33333333					
x		At Start	At 1/4x	At 2/4x	At 3/4x	At End
		6,666666667	8,33333333		10	11,6666667
M (in terms of w)		27,7777778	27,7777778		25	19,4444444
w ₂		1,138469152	<2.5			
M _u		2728,376749				

Section 3

x _{start}	13,33333333					
x _{end}	20					
x		At Start	At 1/4x	At 2/4x	At 3/4x	At End
		13,33333333	15	16,6666667	18,3333333	20
M (in terms of w)		11,11111111	0	-13,888889	-30,555556	-50
w ₂		2,296443356	<2.5			
M _u		5503,497961				

(14) Using beam table on 5-145, we have the following

$$l = 8 \text{ m}$$

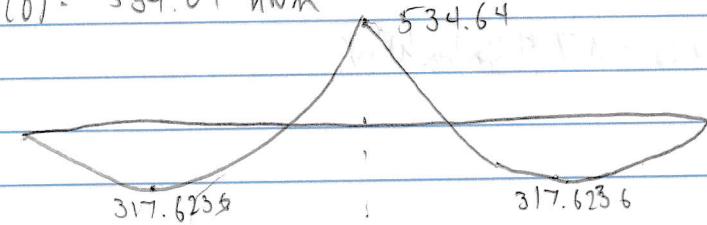


$$M(\gamma) = 178.17x - \frac{50x^2}{2}, \quad \frac{dM}{dx} = 178.17 - 50x, \quad x = 3.5634$$

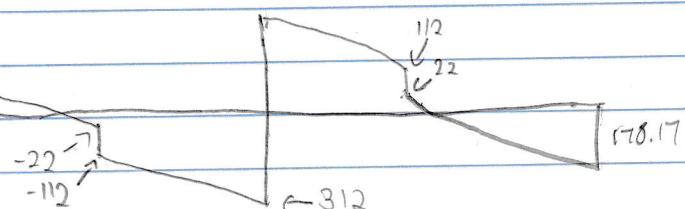
$$M(3.5634) = 817.6236$$

$$M(x_2) = 178.17x - 25x^2 - 90(x - 4), \quad M(0) = 178.17 \times 4 - 90 \times 4 = 534.64 \text{ kNm}$$

BMD



SFD



$$\therefore V_{fmax} = 312 \text{ kN}, M_{fmax} = 534.64 \text{ kNm}$$

From beam selection table, we have

$$W530 \times 85, M_r' = 446 \text{ kNm}$$

$$W530 \times 92, M_r' = 621 \text{ kNm} \leftarrow \text{Lhd to go on}$$

To verify

1. find moments @ $1/4\alpha, 2/4\alpha, 3/4\alpha$

for α_1

$$M(1) = 178.17 \cdot 1 - 25(1)^2, M(2) = 178.17(2) - 25(2)^2 \\ = 153.17 \quad = 256.34$$

$$M(3) = 178.17 \cdot 3 - 25(3)^2, M_{max} = 317.6236 \\ = 309.51$$

$$\therefore u_2 = \frac{4.317.6236}{\sqrt{4M_{max}^2 + 4M(1)^2 + 7M(2)^2 + 4M(3)^2}} \neq u_2 = 1.0973$$

for α_2

$$M(5) = 175.85 \text{ kNm}$$

$$u_2 = \frac{4.534.64}{\sqrt{4M_{max}^2 + 4M(5)^2 + 7M(6)^2 + 4M(7)^2}} = 1.7383$$

$$M(6) = -10.98 \text{ kNm}$$

$$M(7) = -247.81 \text{ kNm}$$

$$M(8) = -534.64 \text{ kNm}$$

W530x92

$$I_y = 23.8 \text{E}6 \text{ mm}^4$$

$$G = 77000$$

$$J = 762 \text{E}3 \text{ mm}^4$$

$$C_w = 1590 \text{E}9 \text{ mm}^6$$

$$\frac{b}{w} = \frac{502}{10.2} = 49.21 \leq \frac{1700}{\sqrt{345}}, \text{ Not Ok}$$

$$\frac{b+l}{L} = \frac{2072}{15.6} = 131.1 \leq \frac{1700}{\sqrt{345}} = 9.1824$$

Not Ok

$$M_u = \frac{1.0973 \cdot \pi}{4000} \sqrt{20000 \cdot 23.8 \text{E}6 \cdot 77000 \cdot 762 \text{E}3 + \left(\frac{\pi \cdot 290000}{4000} \right)^2 \cdot 23.8 \text{E}6 \cdot 1590 \text{E}9}$$
$$= 3331.058 \text{ kNm}$$

$$M_p \approx 2360 \text{E}3 \text{ mm}^3$$

$$M_p = 2360 \text{E}3 \cdot 345 \cdot 0.9 \cdot \left(\frac{1}{1000} \right)^2$$
$$= 732.78 \text{ kNm}$$

$M_u > 0.67 M_p$, ∴ inelastic buckling

$$M_r = 1.15 \cdot 0.9 \cdot 732.78 \cdot \left(1 - \frac{0.28 \cdot 732.78}{3331.058} \right)$$

$$= 711.704 \text{ kNm} \neq 0.9 \cdot 732.78 = 659.502$$

∴ $M_r = 659.502 > 534.64$, OK

Check Shear

$$F_s = 0.66 \cdot 345 \quad A_w = 533 \cdot 10.2 = 5436.6 \text{ mm}^2$$
$$= 227.7 \text{ MPa}$$

$$V_r = 0.9 \cdot A_w \cdot F_s \cdot [2.2 - 1.6 \text{ MPa/mm}]$$
$$= 0.9 \cdot 5436.6 \cdot 227.7 \cdot [2.2 - 1.6 \cdot \frac{534.64}{659.502}]$$
$$= 1005.97 > 312, \text{ OK}$$