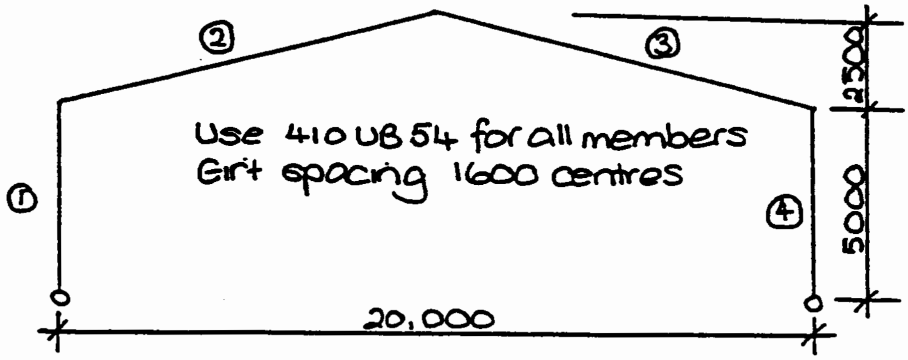
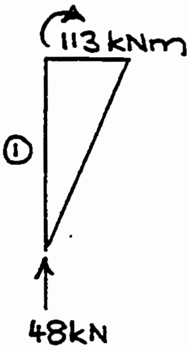
JOB TITLE

EXAMPLE 2 DESIGN OF ELEMENTS OF A PORTAL FRAME



PROBLEM 2.1 Check strength of column ① for the combination of dead load, external cross wind and internal suction using load combination 3.3

First order elastic analysis results indicate that the column is under combined axial compression and bending with flexural compression on the inside flange.



Net horizontal force on frame 56 kN
Net vertical force on frame 51 kN ↓
Computed sway displacement at eave 98 mm
Average axial compressions in:

columns P_c = 40 kN
rafters P_r = 30 kN

SOLUTION

Design axial compression capacity of 410 UB section is:
$0.9\ N_s = 1812$ kN 03
Girt spacing 1600 mm $\frac{L}{r_y} = \frac{1600}{38.6} = 41$

Assume $k_e = 2.2$ in x direction
$\frac{L}{r_x} = \frac{5000 \times 2.2}{165} = 67$ 6.2

First demonstration:
Check moment amplification using simplified criteria.

$$\frac{L}{r_x} = 67 \leq 27 \Big/ \sqrt{\frac{N^*}{0.9 N_s}} = 27 \Big/ \sqrt{\frac{48}{1812}} = 166$$ 4.4.2

$$\frac{\Delta s}{h_s} = \frac{98}{5000} = 0.020$$

$$0.1 \frac{\Sigma V^*}{\Sigma N^*} = 0.1 \times \frac{56}{51} = 0.11$$

$$\frac{\Delta s}{h_s} \leq 0.1 \frac{\Sigma V^*}{\Sigma N^*}$$

Therefore use $M^* = 1.1\, M_m^* = 124$ kNm 4.4.2

Second demonstration:
Check moment amplification using Appendix A to justify a lower amplification factor.

Column effective length $\gamma_T = \dfrac{(I/L)_c}{\beta (I/L)_b} = \dfrac{20}{5} = 4$ 6.5.3

$\gamma_B =$ say 5

Therefore $k_e = 2.2$ $L_e = 11{,}000$ mm

$$N_{omb} = \frac{\pi^2 \times 2 \times 10^5 \times 188 \times 10^6}{(2.2 \times 5000)^2} = 3070 \text{ kN}$$ A1

$$\delta_b = \frac{0.6}{1 - \left(\frac{48}{3070}\right)} = 0.610$$ A1

$$\delta_s = \frac{1}{1 - \left(0.020 \times \frac{51}{56}\right)} = 1.019$$ A2

Member capacity in bending:
(Flexural compression on inside flange → girts are not effective in providing lateral restraint.)

$L_e = 5000$ $\phi M_{bx} = 132$ kNm D7

Member capacity in compression:

$$\left.\begin{array}{l}\frac{L_e}{r_x} = 67 \\ \frac{L_e}{r_y} = 41\end{array}\right\} \alpha_b = 0 \Rightarrow \alpha_c = 0.73$$ Table 6.3

$0.9N_c = \alpha_c \phi N_s = 0.73 \times 1812 = 1323$ kN D3

Check combined action:

$$\frac{N^*}{0.9N_c} + \frac{M_x^*}{0.9M_{bx}} = \frac{48}{1323} + \frac{124}{132} < 1.0 \quad \text{OK}$$

Commentary

(i) The member capacity in bending could have been increased by a factor of $\alpha_m = 1.75$ (linearly varying moment) but this has been neglected.
($\alpha_m \phi M_{bx} = 1.75 \times 132 = 231$ kNm
$\leq \phi M_{sx} = 305$ kNm)

(ii) The moment amplification has been obtained by approximating pitch roof portal to a rectangular portal. Alternatively for pitch roof portal Appendix A (Para. A3) may be used as follows:

For sway buckling: A3

$$\lambda_c = \frac{3 \times 200{,}000 \times 188 \times 10^6}{10{,}300\,(40 \times 10^3 \times 5000 + 0.3 \times 30 \times 10^{-3} \times 10{,}300)}$$
$$= 37.3$$

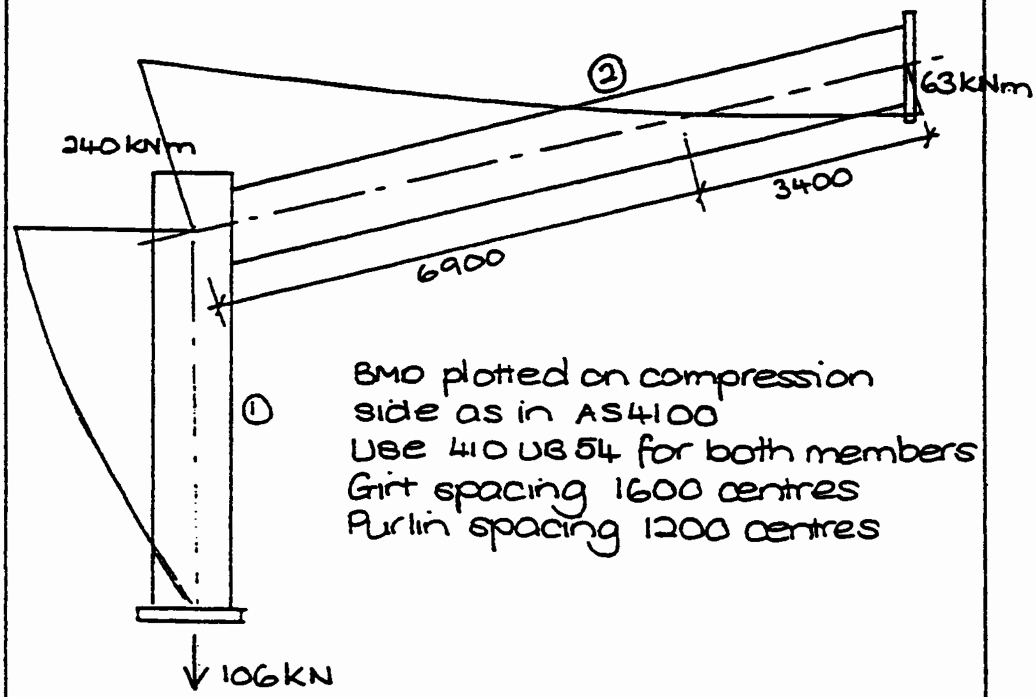
For symmetric buckling: Fig 6.3

$$\gamma_1 = \gamma_2 = \frac{5000}{3 \times 10{,}300} = 0.16 \Rightarrow k_e = 0.55$$

$$\lambda_c = \frac{\pi^2 \times 200{,}000 \times 188 \times 10^6}{(2 \times 0.55 \times 10{,}300)^2 \times 30 \times 10^3} = 96$$

Moment amplification is therefore negligible.

PROBLEM 2.2 Check strength of column ① and rafter ② for the combination of dead load, external cross wind and internal pressure with bending moments as shown using load combination 3.3



BMO plotted on compression side as in AS4100
Use 410 UB 54 for both members
Girt spacing 1600 centres
Purlin spacing 1200 centres

SOLUTION

Check rafter ②
For 6900 segment with compression on top flange, purlins can be assumed to provide lateral restraint : ie $L_e = 1200$mm

$\therefore \; \phi M_{bx} = 295$ kNm D7

Applied moment at face of column (by scaling)

$M^* = 233$ kNm $< \phi M_{bx}$ OK

For 3400 segment with compression on bottom flange, assume there is restraint at the apex of the frame

$L_e = 3400 \quad \phi M_{bx} = 195$ kNm — D7
$M^* = 63$ kNm $< \phi M_{bx}$ OK

Check strength of column ①:
Member in tension therefore no need to check moment amplification. Design moment at underside of rafter is (by scaling) $M^* = 230$ kNm

Axial tension capacity:
$0.9 N_t = 0.9 \times 6890 \times 320 = 1980$ kN — 7.0

Bending capacity, flexural compression on outside flange, girts are effective in providing lateral restraints.
$L_e = 1600 \quad \phi M_{bx} = 280$ kNm — D7

Check combined action:
$$\frac{N^*}{\phi N_t} + \frac{M^*_x}{\phi M_{bx}} = \frac{106}{1980} + \frac{230}{280} = 0.87 < 1.0 \quad \text{OK}$$ — 8.0

PROBLEM 2.3 Design of a haunch if 310UB40 is used for rafter ② instead of 410 UB54 of problem 2.2.

SOLUTION

Section capacity for 310UB40
$\phi M_{sx} = 182$ kNm
Moment at face of column
$M^* = 233$ kNm
∴ need haunch
Extent of haunch required (from BMD) is 1600 mm → adopt 2000 mm.

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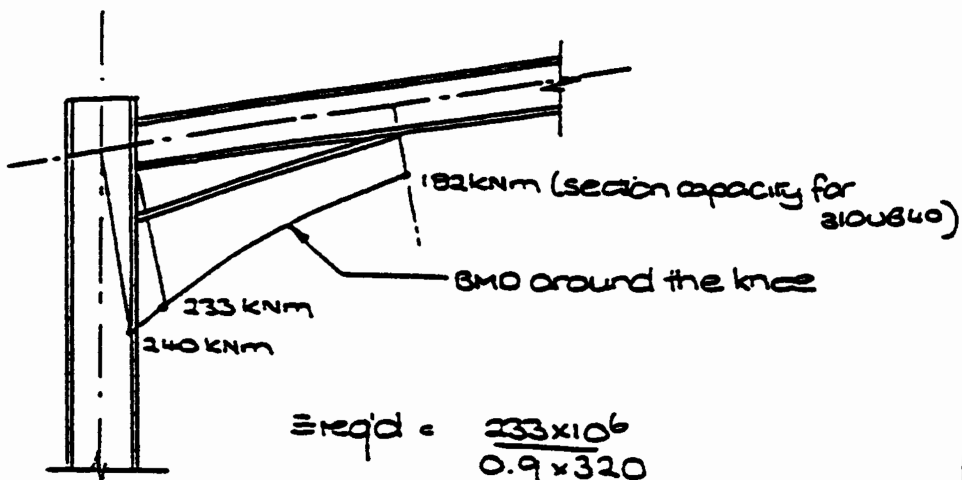
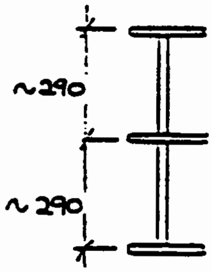


$$Z_{reqd} = \frac{233\times10^6}{0.9\times320}$$

$$= 863\times10^3\ mm^3$$

Cut haunch from 310 UB 40



$$I \approx 2\times(165\times10.2)\times(290)^2$$

$$= 283\times10^6$$

$$Z = 960\times10^3 \quad \text{OK}$$