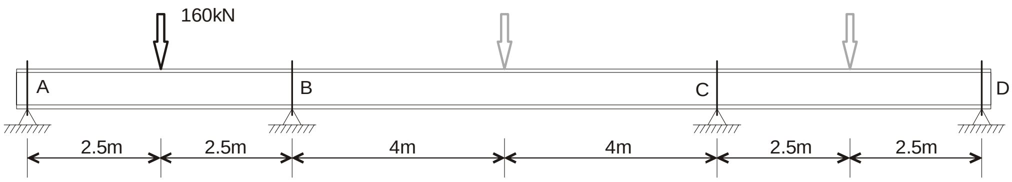
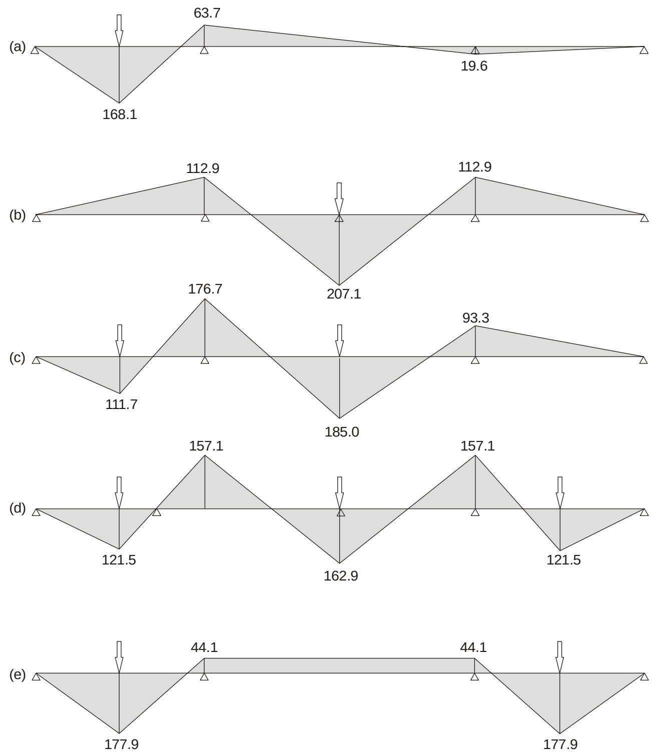
EXAMPLE 3



The continuous beam ABCD is to be designed to carry load-factored midspan live loads of 1.5Q=160kN that may act on any or all spans. The task is to select a suitable grade 300 UB section and suggest appropriate lateral restraint locations.

Restraints:

All supports are assumed to provide full torsional restraint. Loads provide no restraint and are applied to the top flange.



Analysis:

We will ignore self-weight and hope to show that its effect is negligible. This leaves 5 load cases to consider, as shown.

The results could be obtained from just two analyses (by moment distribution, for example):

(a) Load on AB

(b) Load on BC

All other cases can be obtained as combinations of (a) and (b). For example case (c) is simply (a)+(b), and case (d) is (a)+(b)+mirror image of (a).

Maximum design moment (all cases) = 207.1kNm.

First approximation:

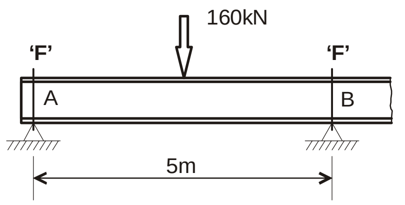
Assume a compact section, and take $Z_e = Z_p$.

For $M^* < \phi Z_e \sigma_y$

Require $Z_p > \dfrac{207.1}{0.9 \times 300{,}000} = 767 \times 10^{-6}\ \mathrm{m}^3 = \underline{767 \times 10^3\ \mathrm{mm}^3}$

Try $\boxed{360\mathrm{UB}44.7,\ Z_p = 777\times10^3\ \mathrm{mm}^3}$ (isn't quite compact, but has only slightly smaller Z_e=770 x10^3 mm^3, more than compensated for by σ_y=320MPa, so that $\phi Z_e \sigma_y = 222\,\mathrm{kNm}$, > 207.1)

Check end spans AB, CD

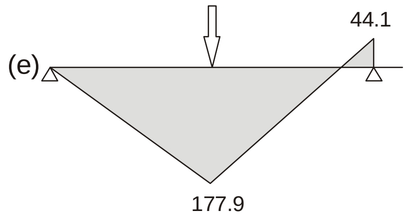


Top flange

Maximum M^*(+ve)=178kNm - load case (e) - top flange critical (compr'n).

'FF' segment, 5m long. k_t=1, k_L=1.4, k_r=1, L_e = 1.4*5 = 7.0m

α_s = 0.293 (Table A1)



$\beta_m = \dfrac{44.1 \times 16}{3 \times 160 \times 5} = 0.294$ (Table 5.6.1, case 4)

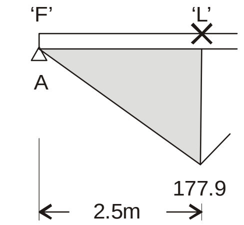
$\alpha_m = 1.35 + 0.15 \times 0.29 = \underline{1.39}$

$\phi M_b = 1.39 \times 0.293 \times 222 = \underline{90.4\mathrm{kNm}} < M^*_{max}\ (178\,\mathrm{kNm}) \Rightarrow \mathrm{NG}$ ☹

Try lateral (L) restraint to top flange, mid-span

This creates two segments, 2.5m long. Considering the left hand segment:

'FL' segment, 2.5m long. k_t=1, k_L=1 (load outside seg), k_r=1, L_e = 1.0*2.5 = 2.5m
α_s = 0.778 (Table A1).

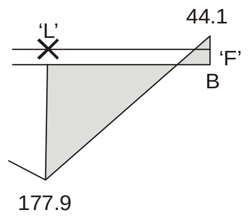


α_m = 1.75 (Table 5.6.1, case 1, β_m = 0, or case 9).

$\phi M_b = 1.75 \times 0.778 \times 222 = \underline{302 kNm}$,

However ϕM_b must be $\leq \phi M_s = \underline{222 kNm} > M^*_{max}$ (178 kNm) $\Rightarrow$ OK ☺

Right segment certain to be less critical as bending moment pattern will give rise to a higher α_m:



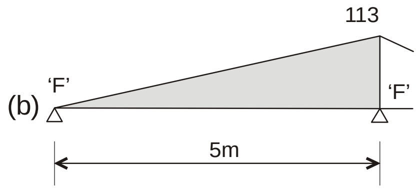
$$\beta_m = \frac{44.1}{178} = 0.25 \text{ (Table 5.6.1, case 1).}$$

$$\alpha_m = 1.75 + 1.05(0.25) + 0.3(.25)^2 = 3.78 = 2.5 (max).$$

$$\alpha_m \alpha_s > 1, \text{ so } \phi M_b \text{ still } = \phi M_s = \underline{\underline{222 kNm}} \Rightarrow OK$$ ☺

Bottom flange

Top flange restraint does not restrain bottom flange. For loading case (b) bottom flange is critical so spans AB and BC revert to 5m segments.



Maximum M*(-ve)=113kNm

'FF' segment, 5m long. k_t=1, k_L=1, k_r=1, L_e = 5.0m
α_s = 0.436 (Table A1)

α_m = 1.75 (Table 5.6.1, case 1, β_m = 0).

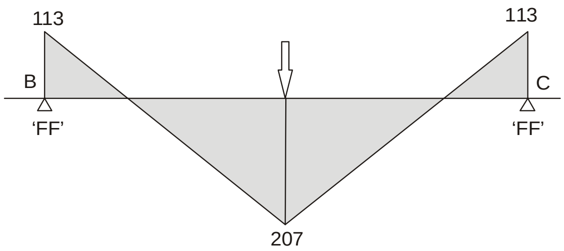
$\phi M_b = 1.75 \times 0.436 \times 222 = \underline{169 kNm} > M^*_{max}$ (113 kNm) $\Rightarrow$ OK ☺

Check middle span, BC

Top flange

Top flange is critical flange for load cases (b), (c) and (d).

Maximum M^*(+ve)=207kNm - load case (b) - top flange critical.



'FF' segment, 8m long. k_t=1, k_L=1.4, k_r=1, L_e = 1.4*8 = 11.2m

α_s < 0.190 (Table A1; α_s = 0.19 is for L_e=10m)

$$\beta_m \frac{FL}{8} = 113; \quad \beta_m = \frac{113 \times 8}{160 \times 8} = 0.706 \text{ (Table 5.6.1, case 4)}$$

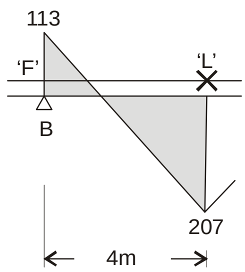
$$\alpha_m = 1.35 + 0.36 \times 0.706 = \underline{1.60}$$

$\phi M_b = 1.6 \times 0.19 \times 222 = \underline{67.5 kNm} < M^*_{max}$ (207 kNm) $\Rightarrow$ NG ☹

Try lateral (L) restraint to top flange, mid-span

This creates two segments, 4m long. Considering the left hand segment:

'FL' segment, 4m long. k_t=1, k_L=1 (load outside seg), k_r=1, L_e = 1.0*4 = 4m
α_s = 0.55 (Table A1).



$$\beta_m = \frac{113}{207} = 0.546 \text{ (Table 5.6.1, case 1).}$$

$$\alpha_m = 1.75 + 1.05(0.55) + 0.3(.55)^2 = 2.42 .$$

$\alpha_m \alpha_s = 1.33$, so $\phi M_b = \phi M_s = \underline{222 kNm} > M^*_{max}$ (207kNm) $\Rightarrow$ OK ☺

Bottom flange

Predominantly –ve bm in loading cases (e) and (a) results in critical bottom flange. Since bottom flange is unrestrained it becomes an 8m segment.

Load case (e):

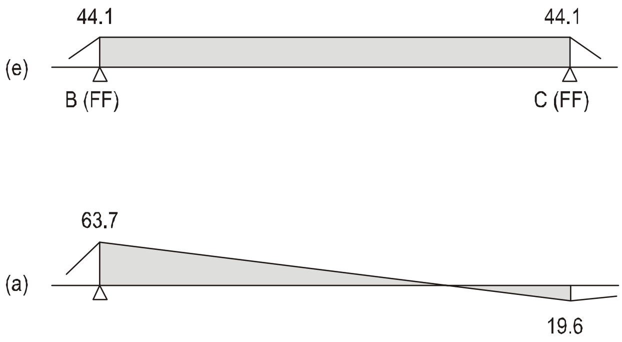
Maximum M*(-ve)=44 kNm

'FF' segment, 8m long. k_t=1, k_L=1, k_r=1, L_e = 8.0m

α_s = 0.248 (Table A1)

α_m = 1.0 (Table 5.6.1, case 8)

$\phi M_b = 1.0 \times 0.248 \times 222 = \underline{55\,\text{kNm}} > M^*_{max}\ (44\,\text{kNm}) \Rightarrow OK$ ☺



Load case (a):

Maximum M*(-ve)=64 kNm

'FF' segment, 8m long. k_t=1, k_L=1, k_r=1, L_e = 8.0m

α_s = 0.248 (Table A1)

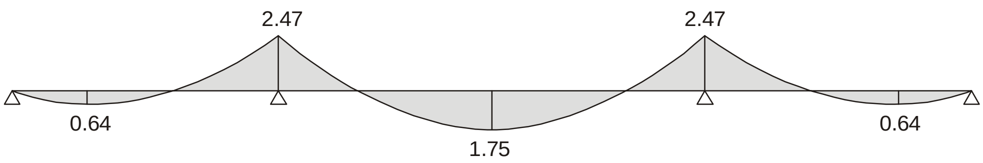
$\beta_m = \dfrac{19.6}{63.7} = 0.31$ (Table 5.6.1, case 1).

$\alpha_m = 1.75 + 1.05(0.31) + 0.3(.31)^2 = 2.1$

$\phi M_b = 2.1 \times 0.248 \times 222 = \underline{115\,\text{kNm}} > M^*_{max}\ (64\,\text{kNm}) \Rightarrow OK$ ☺

Check that dead load IS negligible:

Dead load is 44.7 kg/m giving $w_{dead} = 1.2 \times 0.45 = 0.53\,\text{kN/m}$. Applying a uniform spread load of 0.53kN/m gives the bm's shown below.



These are insignificant compared with the 1.6Q (live load) bm's which ranged up to 207 kNm.

Final configuration: