① $P_{ULS} = 1.25(30) + 1.5(60) = 127.5$ kN

$P_{SLS} = 30 + 60 = 90$ kN

ϕ	0.9	Shear & Bending
f_b	30.6	
K_D	1	
K_H	1	
K_{Sb}	1	
K_T	1	
K_{Sv}	1	
f_v	2.0	
K_x	1	Straight
E	12800	
K_{SE}	1	

$$S = \frac{bd^2}{6} = \frac{0.13 \times 0.76^2}{6} = 0.0125147 \text{ m}^3$$

Since it falls under "any loading", $Le = 1.92a$, with max $a = 3.1$ m

$\therefore Le = 5.952$ m

$$C_B = \sqrt{\frac{5.952 \cdot 0.76}{0.13^2}} = 16.3604372 > 10, \therefore K_L \neq 1$$

$$C_K = \sqrt{\frac{0.97 E K_{SE} K_T}{F_b}} = \sqrt{\frac{0.97 \cdot 12800}{30.6}} = 20.1432776$$

$$10 < C_B < C_K, \therefore K_L = 1 - \frac{1}{3}\left(\frac{C_B}{C_K}\right)^4$$

$$K_L = 1 - \frac{\left(\frac{16.3604372}{20.1432776}\right)^4}{3} = 0.8549$$

$$K_{Zbg} = \left(\frac{130}{130}\right)^{0.1}\left(\frac{610}{760}\right)^{0.1}\left(\frac{9100}{6100}\right)^{0.1} = 1.0182$$

$K_L < K_{Zbg}$, $\therefore K_L$ governs

$$M_r = \phi F_b S K_x K_L$$

$$= 0.9 \cdot 0.8549 \cdot 30.6 \cdot 0.0125147 \times 1000^2 \frac{\text{mm}^2}{\text{m}^2} \times \frac{1 \text{ kN}}{1000 \text{ N}}$$

$$= 294.66 \text{ kN}\cdot\text{m}$$

$A_y = B_y = 127.5$

Moment maximized in midspan. $\therefore M_f = 127.5\left(1.5 + \frac{3.1}{2}\right) - 127.5\left(\frac{3.1}{2}\right)$
$= 191.25$ kN·m

$\therefore M_r > M_f$, OK

Volume of beam $= 0.13 \cdot 0.76 \times 6.1$
$= 0.60268 \text{ m}^3$

$V < 2\text{m}^3$, $\therefore$ $V_r \simeq \phi F_v \cdot \frac{2}{3} A_g$

$V_r \simeq 0.9 \cdot 2 \cdot \frac{2}{3} \cdot 130 \cdot 760 \times \frac{1}{1000}$

$= 118.56 < V_f$, $\therefore$ check W_r

$W_f = \Sigma$ loads applied to beam

$= 127.5 \times 2 = 255 \text{ kN} = 255000 \text{ N}$

$W_r = \phi F_v \cdot 0.48 A_g C_v Z^{-0.18}$

- $F_v = 2$ MPa
- $A_g = 130 \cdot 760 = 98800$

G

$\Sigma G = 2(127500^5 + 127500^5 + 4 \cdot 127500^5)(1500)$
$= 6.06489699E29$

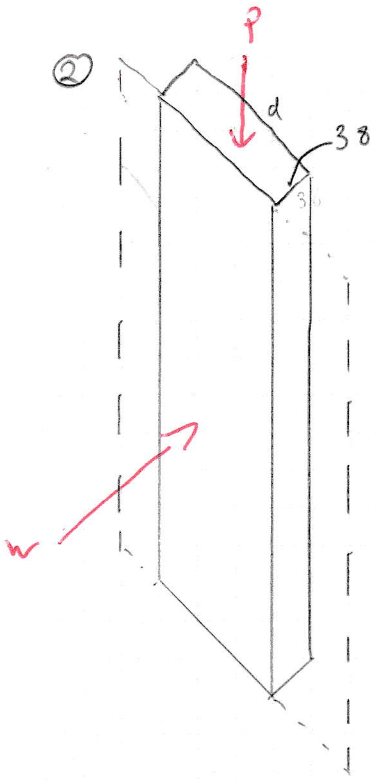
$C_v = 1.825 \cdot 255000 \cdot \left(\frac{6100}{6.06489699E29}\right)^{0.2}$

$= 2.9397$

$W_r = 0.9 \cdot 2 \cdot 0.48 \cdot 98000 \cdot 2.9397 \cdot 0.60268^{-0.18} \times \frac{1 \text{kN}}{1000 \text{N}} = 272.66 \text{ kN}$

$272.66 > 255$, passes

(2)



3 governing load cases:

1. $1.25D + 1.5S$
2. $1.25D + 1.5S + 0.4W$
3. $1.25D + 1.4W + 0.5S$

1. $P_{f_1} = [1.25(5) + 1.5(10)] \cdot 0.4 = 8.5$ kN $M_{f_1} = 0$

2. $P_{f_2} = [1.25(5) + 1.5(10)] \cdot 0.4 = 8.5$ kN $w_f' = 0.16$ kN/m $M_{f_2} = \dfrac{(0.4 \cdot 1 \cdot 0.4)4.8^2}{8} = 0.4608$ kN·m

3. $P_{f_3} = [1.25(5) + 0.5(10)] \cdot 0.4 = 4.5$ kN $w_f' = 0.56$ kN/m $M_{f_3} = \dfrac{(1.4 \cdot 1 \cdot 0.4)4.8^2}{8} = 1.6128$ kN·m

Try 2x6

Using WDM for 5m lumber, for cases 2 and 3

1. $P_r = 17.1$ kN (WDM pg. 165), $Q_r = 32.4$ kN
   $\therefore P_{r_1} > P_{f_1}$, OK
2. $P_r' = 9.71 > 8.5$, OK (WDM, pg. 259)
   $w_r' = 0.344 > 0.16$, OK
3. $P_r' = 4.85 > 4.5$, OK
   $w_r' = 0.677 > 0.56$, OK

Check Shear

$V_f = \dfrac{0.56 \cdot 4.8}{2} = 1.344$ kN

$V_r = 10.8$ kN (WDM, pg. 259)

$V_r > V_f$, OK

Check Bearing

$Q_r = 32.4$ kN (WDM, pg. 259)

$P_f = 8.5$

$Q_r > P_f$, OK

Check Deflections

$$\Delta = \frac{5wL^4}{384EI}\left(\frac{1}{1-\frac{P}{P_E}}\right)$$

- $w = 0.\overset{J_w}{75} \cdot 1 \cdot 0.4$
  $= 0.3$ kN/m (N/mm)

- $I = \frac{1}{12} \cdot 38 \cdot 140^3$
  $= 8689333.333$ mm^4

- $E = 9500$ N/mm^2

- $P = 5 \cdot 0.4 + 10 \cdot 0.4 \cdot 0.\overset{J_s}{9}$
  $= 5.6$ kN

- $E_{05} = 6500$ N/mm^2
- $K_e = 1$
- $P_E = \dfrac{\pi^2 E_{05}\, I\, K_{SE}\, K_T}{(K_e L)^2}$

$$= \frac{\pi^2 \cdot 6500 \cdot 8689333.333}{4800^2} \times \frac{1\text{ kN}}{1000\text{ N}} = 24.195$$

$$\Delta = \frac{5 \cdot 0.3 \cdot 4800^4}{384 \cdot 9500 \cdot 8689333.333}\left(\frac{1}{1-\frac{5.6}{24.195}}\right)$$

$= 32.68$ mm

$\Delta_{lim} = \frac{4800}{360} = 13.33$ mm, $\therefore$ fails by deflection

$\therefore$ Try 2x8 .. will pass in all categories since 2x6 passed

- $I = \frac{1}{12} \cdot 38 \cdot 184^3$
  $= 19726762.67$

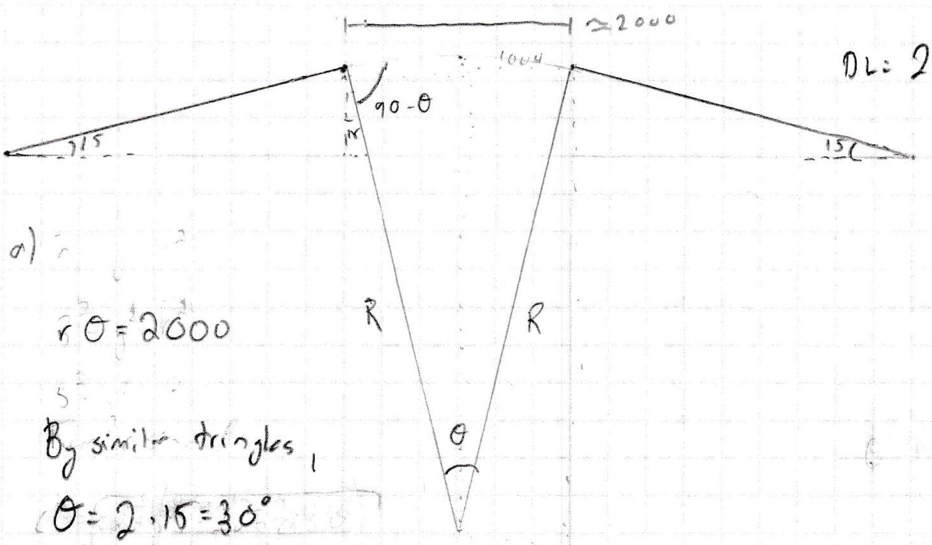
- $P_E = \dfrac{\pi^2 \cdot 6500 \cdot 19726762.67}{4800^2} \times \frac{1}{1000} = 54.927$

$$\Delta = \frac{5 \cdot 0.3 \cdot 4800^4}{384 \cdot 9500 \cdot 19726762.67}\left(\frac{1}{1-\frac{5.6}{54.927}}\right)$$

$= 12.32$ mm

$\therefore$ 2x8 passes Δ requirement.

③



DL: 2kN/m, LL = 4kN/m, 24f-E D.Fir-L

w/ = 130mm

a)

$r\theta = 2000$

By similar triangles,

$\theta = 2 \cdot 15 = 30°$

$= \pi/6$

$\therefore r = \dfrac{2000}{\pi/6}$

$= 3819.7186\ mm$ ← to centre

b) From table A.7, 19 ok if R to innermost lamination ≥2800.

Since beam will not be 2m thick, 19mm okay

c) $w_f = (2 \cdot 1.25 + 4 \cdot 1.5) = 8.5\ kN/m$

Max reaction $= \dfrac{8.5 \times 8}{2} = 34\ kN\ [\uparrow]$

Max shear = 34 kN

Max moment $= \dfrac{8.5 \cdot 8^2}{8} = 68\ kN \cdot m$

d) Try 130×342 $\quad \Delta_{max} = 8000/360 = 22.22$

$\Delta_{max} = \dfrac{5(0.9 \cdot 4)(8000)^4}{384 \cdot 5500 EI}$ = 34.91, Fails

N/mm; N/mm²

Try 130×380

$\Delta = \dfrac{5(0.9)4(8000)^4}{384 \cdot 7610E9} = 25.23$, Fails

Try 130×418

$$\Delta = \frac{5(0.9)(4)(8000)^4}{384 \cdot 10100E9} = 19\text{mm}, \text{ Passes}$$

$M_r' = 104$ kN·m (WDM pg. 80)

$V_r = 65.2$ (WDM page 80)

Shear Check

Volume ≈ $0.13 \times 0.418 \times 8 = 0.43472 < 2$, OK

$65.2 > 34$, passes

Moment Check - Normal Bending

$\cos 18 = \frac{A}{H}$

$$K_x = 1 - 2000\left(\frac{19}{3819.72 - \frac{418}{2}}\right)^2 = 0.945$$

approximate

$$L = \left(\frac{3000}{\cos 15}\right) \times 2 + 2000$$

$= 8211.657$

$$K_{zbg} = \left(\frac{130}{130}\right)^{0.1}\left(\frac{610}{418}\right)^{0.1}\left(\frac{9100}{8211.657}\right)^{0.1}$$

$= 1.049 \leq 1.3$, OK

$K_L = 1$

$\therefore M_r = 104 \cdot 1 \cdot 0.945 = 98.28$ kN·m > 68, OK

Moment Check - Radial Bending

$$M_r = \phi F_{tp} \cdot \frac{2A}{3} R K_{ztp}$$

0.9

- $f_{tp} = 0.83$ MPa
- Curved, double-tapered $\therefore$ UDL

$$K_{ztp} = \frac{35}{(ARB)^{0.2}},$$

A in mm² & R in m, B in radians

R to centreline

$$= \frac{35}{(130 \cdot 418 \cdot 3819.7186 \cdot \pi/6)^{0.2}} = 0.865$$

$$= 0.9(0.83) \cdot 2 \cdot \frac{130 \cdot 418}{3} \cdot \frac{3.819719 \cdot 0.865}{1000}$$

$= 89.412$ kN·m > 68 kN·m, OK

$\therefore$ Use 130 × 418

e) $\Delta_V = \dfrac{5(0.9\cdot 4+2)(18000)^4}{384\cdot 101006E9}$

$= 29.57\,mm$

$\Delta_H = \Delta_V \cdot \dfrac{2\tan\alpha}{\cos\alpha}$, $\alpha = 15^\circ$

$= 29.57\cdot\dfrac{2\tan(15)}{\cos(15)}$

$= 16.406\ mm$