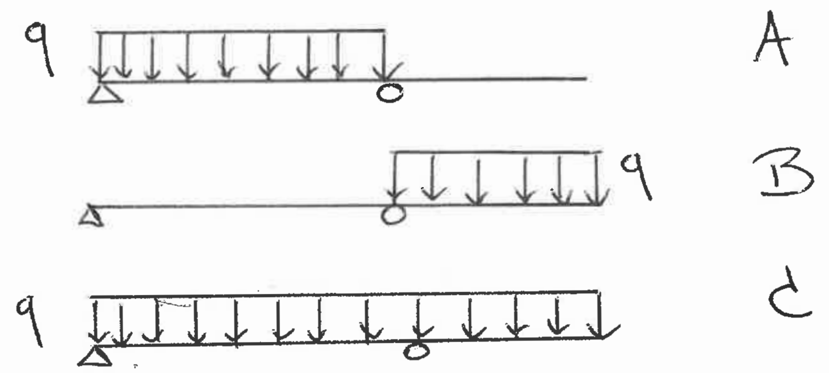
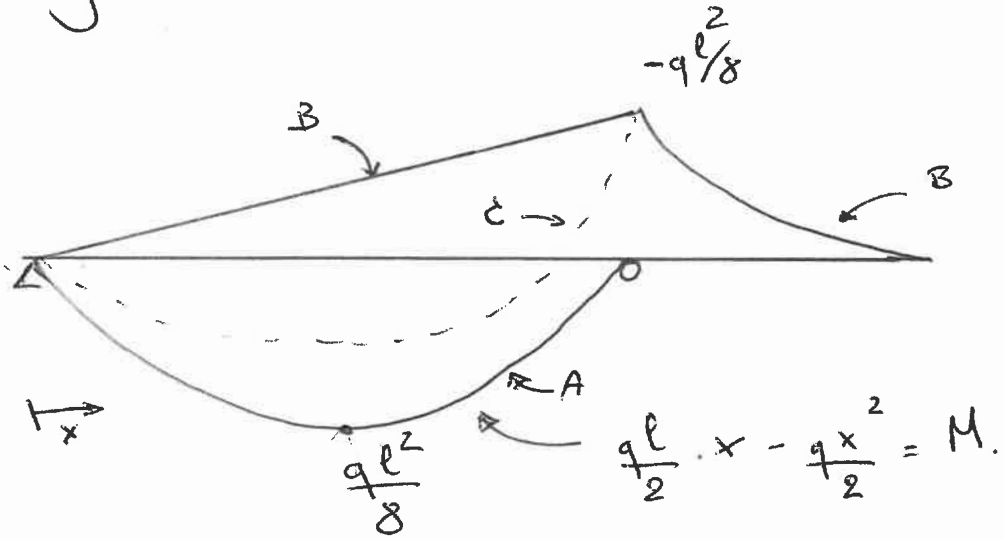
Question 1

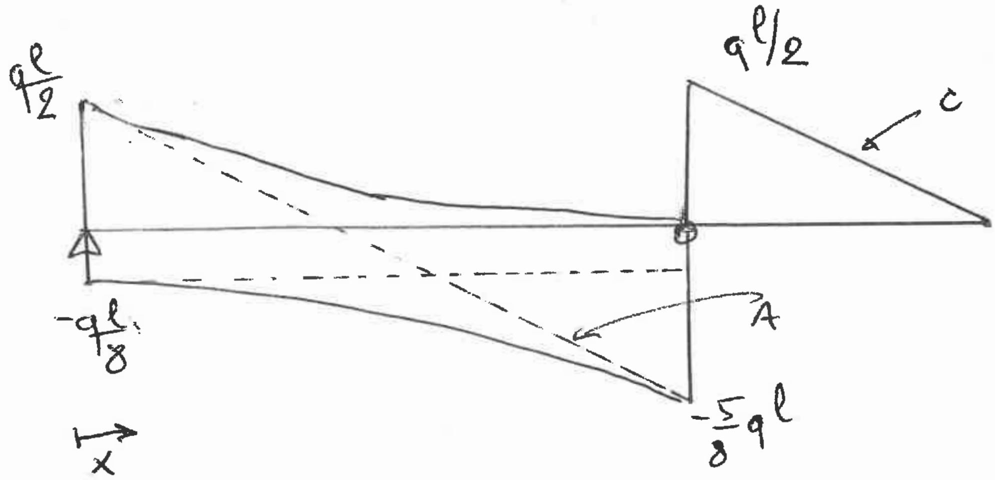
(a) Consider most unfavourable locations for distributed load:



• bending moment envelope:



• shear force envelope:



15%

(b) Shear force $V_{Ed} = 140{,}6\ kN$

$$V_{Rd,s} = \frac{A_{sw}}{s}\, z .\, f_{ywd} .\, \cot\theta$$

with $f_{ywd} = 435\ MPa$

$\cot\theta = 2$

$A_{sw}^{*} = \frac{10^2 \cdot \pi}{4} = 78{,}5\ mm^2$

but 2 legs so $A_{sw} = 157{,}1\ mm^2$

$z = 0{,}9\ d = 0{,}9 . 745 = 670{,}5\ mm$

$$\Rightarrow \quad s = \frac{A_{sw} .\, z .\, f_{ywd} .\, \cot\theta}{140{,}6\ kN}$$

$\approx \frac{5}{8} q L$

$= 814{,}5\ mm$ > max spacing of 300 mm.

$\Rightarrow$ $\underline{s = 300\ mm}$

check concrete strut:

$$V_{Rd,max} = \alpha_{cw} .\, b_w .\, z .\, \nu_1 .\, f_{cd} / (\cot\theta + \tan\theta)$$

using $\nu_1 = 0{,}5$

$> V_{Ed}$ OK ✓

$\rightarrow$ so $\cot(\theta) = 2{,}5$ OK

25%

(c) Calculate bending moment that can be taken by 2 ϕ 20mm → theoretical point 3rd bar no longer needed.

assume $f_s = f_{yd}$. and $A_s = 2 \cdot \frac{20^2 \cdot \pi}{4} = 628 mm^2$

position neutral axis

$$x = \frac{A_s \cdot f_{yd}}{b \cdot \lambda \cdot \eta \cdot f_{cd}}$$

with $b = 400 mm$

$\left.\begin{array}{l} \lambda = 0{,}8 \\ \eta = 1{,}0 \end{array}\right\}$ for $f_c < 50 MPa$.

so $x = 34{,}16$ mm

$$\Rightarrow M_u = A_s \cdot f_{yd} \cdot (d - 0{,}5 \cdot \lambda \cdot x)$$
$$= 199{,}89 \text{ kNm}$$

with $d = h - c - \phi_{st} - \frac{\phi_{long}}{2}$

$= 800 - 35 - 10 - \frac{20}{2} = 745 mm$

→ check $f_s = f_{yd}$ is valid? → YES ✓

find points on bending moment envelope where $M = 199{,}89$ kNm :

$$\frac{q\ell}{2} x - q\frac{x^2}{2} = 199{,}89 \text{kNm}$$

$$\Rightarrow x_1 = 7{,}69 \text{ m}$$
$$x_2 = 2{,}31 \text{ m}$$

40%

(d) anchorage length needed for reinforcement usually dependent on concrete strength, rebar characteristics, bond conditions, etc.

→ rule of thumb for bond length l_b

$$l_b = 35 - 50 \times \phi$$

So $l_b = 35 \times 20$ to 50×20 mm

$= 700$ to 1000 mm

Hence points $x_1 = 7{,}69$ m $+ 700$ mm $= 8{,}39$ m
$+ 1000$ mm $= 8{,}69$ m

$x_2 = 2{,}31$ m $- 700$ mm $= 1{,}61$ m
$- 1000$ mm $= 1{,}31$ m

reinforcement bar runs from 1,31 / 1,61 m to 8,39 / 8,69 m

10%

(e) bond length can be reduced by several factors affecting the bond conditions, including:

- hooks / bended ends
- confinement
- welded transverse reinforcement.

10%

Q2 $P_0 = 350\,kN$, $A_s = 400\,mm^2$ 5%

Initial stress $P_0 = \frac{350\,kN}{400\,mm^2} = \underline{875\,MPa}$.

(a) $I = \frac{250 \times 350^3}{12} = \underline{893 \times 10^6\,mm^4}$

(b) Initial stress at the tendon:

$$\sigma = \frac{P_0}{A} + \frac{M \cdot y}{I}$$

$$= \frac{350 \times 10^3}{250 \times 350} + \frac{350 \times 10^3 (70)(70)}{893 \times 10^6} = \underline{5.92\,MPa}$$

$\therefore$ loss due to elastic shortening of concrete $= 5.92 \times \frac{200}{33} = \underline{35.9\,MPa}$ 25%

(c) $\Delta\sigma = E_s \cdot \frac{\Delta}{L}$

$= 200\,GPa \cdot \frac{1.5\,mm}{6\,m} = \underline{50\,MPa}$ 20%

(d) for creep, since $\phi = 1$, and creep strain is a proportion of the elastic strain, the

$\Delta\sigma = \underline{35.9\,MPa}$ 20%

for shrinkage, $0.0002 \times 200\,GPa = \underline{40\,MPa}$

(e) Relaxation $= 3\% \times 875\,MPa = \underline{26.3\,MPa}$ 10%

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2(f) Total = 35.9 + 50 + 35.9 + 40 + 26.3 = 188 MPa

$= \frac{188}{875} = 21\%$ of total.

- seems reasonable - lower typically 10-30%

10%

3(a) This is a slender tower - aspect ratio ~12.

Build nothing - challenge the brief

Build less - can it be shorter / wider

Build clever - use less concrete, consider combinations eg timber + concrete

- performance based design to improve efficiency.

- optimize all members & layouts

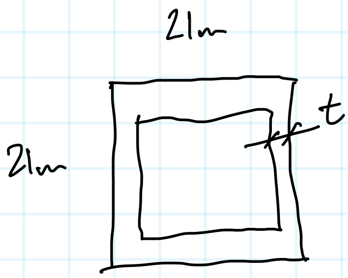
- consider alternatives to CEM1

Build efficient - prefabrication, automation

etc.

30%

(b)



lets say $t = 400$mm.

(i) longitudinal reinforcement ΣA_{sl}

$$\Sigma A_{sl} f_{yd} = \frac{T_{Ed}}{2A_k} \cot\theta \, (u_k)$$

$$A_k = (21 - 0.4)^2 = 424\text{m}^2$$

$$u_k = 4(21 - 0.4) = 82\text{m}$$

$$T_{Ed} = 200\text{MNm}$$

$$\Sigma A_{sl} f_{yd} = \frac{200 \text{MNm}}{2(424 \text{m}^2)} \cdot \cot\theta \,(82 \text{m})$$

lets say $\cot\theta = 1$; since this minimises A_{sl}

$f_{yd} = 500$ MPa

$$\therefore \quad A_{sl} = \frac{19.4 \text{MN}}{500 \text{MPa}} = 38{,}800 \text{mm}^2$$

$\Rightarrow$ 9700 mm^2 per side

Say $\phi 25$mm bars (491mm^2) $\Rightarrow$ spacing ~1m.

(20 bars @ 1m spacing).

(ii) Shear reinforcement

$$V_{Ed,i} = \frac{T_{Ed}}{2A_k} \cdot z_i$$

$$= \frac{200 \text{MNm}}{2(424 \text{m}^2)} \cdot (21 - 0.4) = \underline{\underline{4.85 \text{MN}}}$$

$$V_{Rd,s} = \frac{A_{sw}}{s} z \cdot f_{ywd} \cot\theta$$

$$4.85 \text{MN} = \frac{A_{sw}}{s} \cdot (21 - 0.4)(500)(1)$$

$$\frac{A_{sw}}{s} = 0.47 \text{ (mm)}$$

try $\phi 20$ @ 600 mm $= \frac{314}{600} = 0.52$ ✓ ok.

(not required to check concrete crushing, or T vs V interaction)

60%

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3(c)

- vertical loading
- lateral loading
- the core will have holes in it
- deflection / vibration

etc.

10%