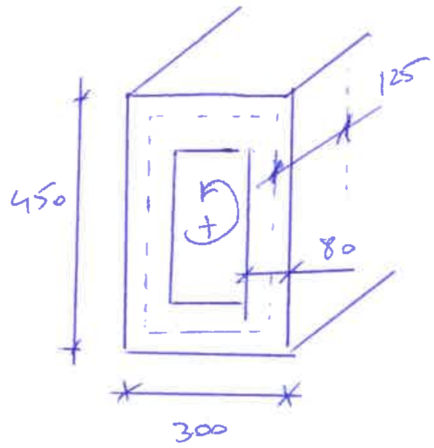
Question

(i)



$$A_s = \frac{\pi . 10^2}{4} = 78{,}5 \text{ mm}^2$$

$$f_{yd} = 435 \text{ MPa}$$

$$A_e = (300-80).(450-80)$$
$$= 81400 \text{ mm}^2$$

$$u = (300-80) \times 2 + (450-80) \times 2$$
$$= 1180 \text{ mm}^2$$

$$q = \frac{T}{2 A_e} = \frac{60 . 10^6}{2 . 81400} = 368{,}55 \text{ N/mm.}$$

and

$$q = f_{yd} \cdot \sqrt{\frac{A_w \Sigma A_e}{s . u}}$$

So

$$\Sigma A_e = \left(\frac{q}{f_{yd}}\right)^2 \cdot \frac{s . u}{A_w}$$

$$= \left(\frac{368{,}55}{435}\right)^2 \cdot \frac{125 . 1180}{78{,}5}$$

$$= \underline{\underline{1617{,}70 \text{ mm}^2}}$$

(ii)

$$\tan^2 \theta = \frac{A_w . u}{s . \Sigma A_e} = \frac{78{,}5 . 1180}{125 . 1617{,}70} = 0{,}382$$

$$\Rightarrow \theta = 31{,}72^\circ$$

$$q = \sigma_c . t . \sin\theta \cos\theta$$

$$\sigma_c = \frac{q}{t \sin\theta \cos\theta} = \frac{368{,}55}{80 . \sin 31{,}7 \cos 31{,}7} = 10{,}30 \text{ MPa}$$

$$\sigma_c < \underset{0{,}5}{\overset{}{\nu}} . f_{cd} \Rightarrow f_{cd} = \frac{\sigma_c}{0{,}5} = \underline{\underline{20{,}60 \text{ MPa}}}$$

(iii) $V_{Rd,s}$?

assume $\cot\theta = 2{,}5$

stirrups are 2legged : $A_{sw} = 2 \cdot 78{,}5 = 157{,}1 \text{ mm}^2$

$f_{ydw} = 435 \text{ MPa}$

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

$$= \frac{157{,}1}{125} \cdot 0{,}9 \cdot (450-40) \cdot 435 \cdot 2{,}5$$

$$= \underline{\underline{420{,}2 \text{ kN}}}$$

check compressive strut :

$\alpha_{cw} = 1$

$\nu_1 = 0{,}5$

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

$$= 1 \cdot \frac{300 \cdot 0{,}9 \cdot (450-40) \cdot 0{,}5 \cdot 20{,}60}{\cot\theta + \tan\theta}$$

$$= \underline{\underline{436{,}9 \text{ kN}}} > 420{,}2 \text{ kN}$$ so $\cot\theta = 2{,}5$ is ok ✓

(iv)

$$\frac{T_{Ed}}{T_{Rd,max}} + \frac{V_{Ed}}{V_{Rd,max}} \leq 1$$

with $T_{Ed} = 30 \text{ kNm}$

$T_{Rd,max} = 60 \text{ kNm}$

$V_{Rd,max} = 420{,}2 \text{ kN}$

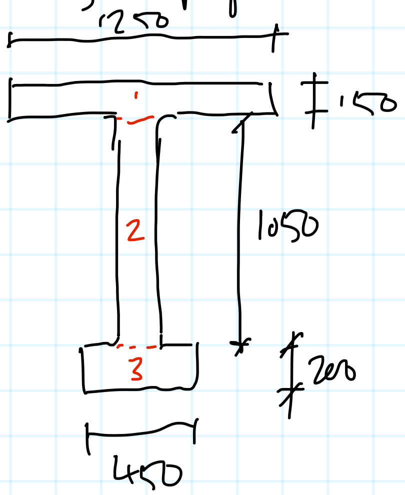
$$\Rightarrow \quad V_{Ed} = \left(1 - \frac{T_{Ed}}{T_{Rd,max}}\right) \cdot V_{Rd,max}$$

$$= \underline{210{,}1 \text{ kN}}$$

Module
Paper

Version 1.0
Date 16/1/26
Page [illegible]

Q2 (a) Any simplification acceptable. e.g:



$A_1 = 187500$
$A_2 = 168000$
$A_3 = 90{,}000$
$\underline{\underline{445{,}500}}$

$\bar{y} = \dfrac{\Sigma A y}{\Sigma A} = \underline{\underline{851\,mm}}$

$I = \Sigma I_{local} + A\bar{y}^2$ (full calc not shown)

$= \underline{\underline{11.6 \times 10^9}}\ mm^4$

(b) $P = 900 \times 3000 = 2.7MN$

$P/A = \dfrac{2.7 \times 10^6}{445{,}500} = \underline{6.06MPa}$

$e = 851 - 125 = \underline{726mm}$

$Z_1 = \dfrac{I}{y_1} = -\dfrac{11.6 \times 10^6}{(1400 - 851)} = -2.03 \times 10^8$ (top)

$Z_2 = \dfrac{I}{y_2} = \dfrac{11.6 \times 10^6}{851} = 1.31 \times 10^8$ (btm)

$\dfrac{P.e}{Z_1} = \dfrac{2.7 \times 10^6 \times 726}{Z_1} = -9.63MPa$

$\dfrac{Pe}{Z_2} = \dfrac{2.7 \times 10^6 \times 726}{Z_2} = 14.9\ MPa$

(b) cont.

$M_{min} = 600\ \text{kNm}$
$M_{max} = 2850\ \text{kNm}$

Using data book equations, we get:

	Top	Btm
σ_{max}	10·43	-0·72
σ_{min}	-0·63	16·43

(all MPa)

(c) Choose prestressing force, e.g. $\frac{f_c}{2} A = 4\ \text{MN}$

use databook equations to find limits on "e".

Top fibre:

$$\frac{f_c Z_1}{P} - \frac{Z_1}{P} + \frac{M}{P} < e < \frac{f_t Z_1}{P} - \frac{Z_1}{A} + \frac{M}{P}$$

Bottom fibre:

$$\frac{f_c Z_2}{P} - \frac{Z_2}{A} + \frac{M}{P} > e > \frac{f_t Z_2}{P} - \frac{Z_2}{A} + \frac{M}{P}$$

we can then find, for this simplification:

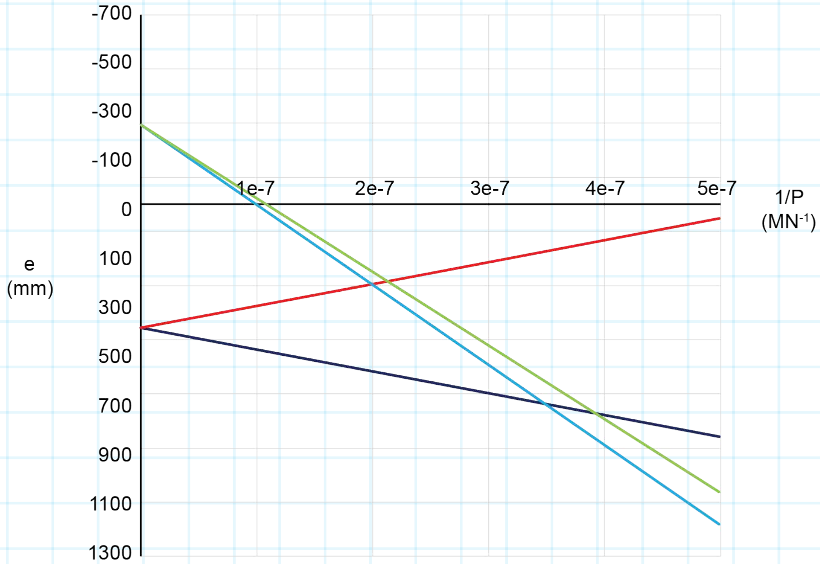
top: $254\text{mm} < e < 657\text{mm}$

bottom: $384\text{mm} < e < 444\text{mm}$

And using equations allows us to plot the Magnel diagram.

(c) contd.

Magnel diagram:



(d) To find P_{max}, set relevant equations equal

$\Rightarrow P_{max} = \underline{\underline{5023 \text{ kN}}}$ ($e = 295$ mm)

& for P_{min}, the same:

$\Rightarrow P_{min} = \underline{\underline{2550 \text{ kN}}}$ ($e = 772$ mm)

(e) Section as proposed close to P_{min}.

Q3(a) Cover = 25mm
@ 60 years average carbonation = 18mm, S.D = 2mm

for average : 17 mm $\propto \sqrt{t}$
25mm $\propto \sqrt{t}$

$$\frac{25}{17} = \sqrt{\frac{t}{60}} \Rightarrow t = 129 \text{ years}$$

$\therefore$ 69 years remain.

Check upper limit at say 95% confidence

$$x = 17 + 1.645(2) = 20.3\text{mm}$$

$$\frac{25}{20.3} = \sqrt{\frac{t}{60}} \Rightarrow t = 91 \text{ years}$$

$\therefore$ 31 years remain

$\therefore$ ambition may be achievable, but may require coatings etc. to reduce carbonation in places
i.e: a cautious approach is warranted.

(b)
- Chloride ingress
- freeze thaw
- ASR reaction
- Sulfate attack
- quality & permeability of original concrete
- existing cracks & repairs.
- inspection & maintenance regime.

etc..

Q3(c)

- structural capacity & code compliance
  - review available drawings
  - SLS & ULS check
  - fire safety
  - seismic capacity.

- repair & protection
  - spalling / cracks
  - patch repairs to carbonated areas
  - corrosion protection / mitigation / inhibitors

- monitoring & maintenance plan
  - inspection schedule
  - inspection of protective systems
  - SHM

- integrating old & new
  - load paths & connections
  - foundation / settlement impact
  - creep / shrinkage
  - dynamics & seismic

- performance testing
  - load test (eg proof load)
  - material testing
  - seismic assessment

- whole life carbon assessment
  - including plans to replace parts
  - documentation
  - calculation to show benefit of retention.

etc.