

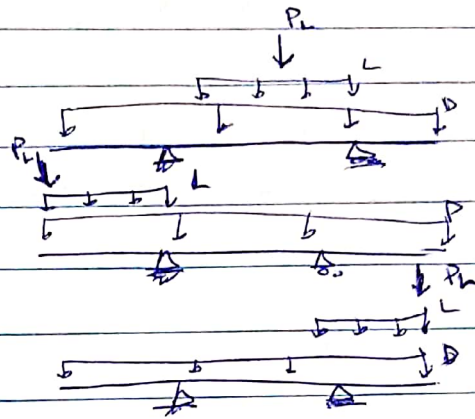
Question 1)

① Load cases 5

Case 1: Max Positive

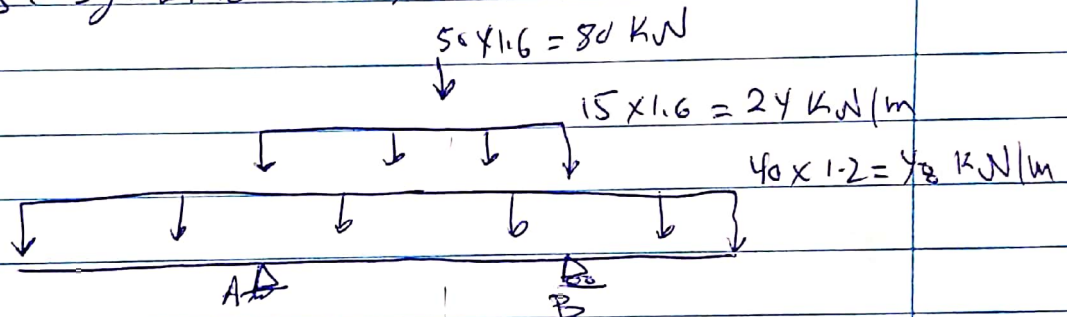
Case 2: Max Negative 1

Case 3: Max Negative 2:



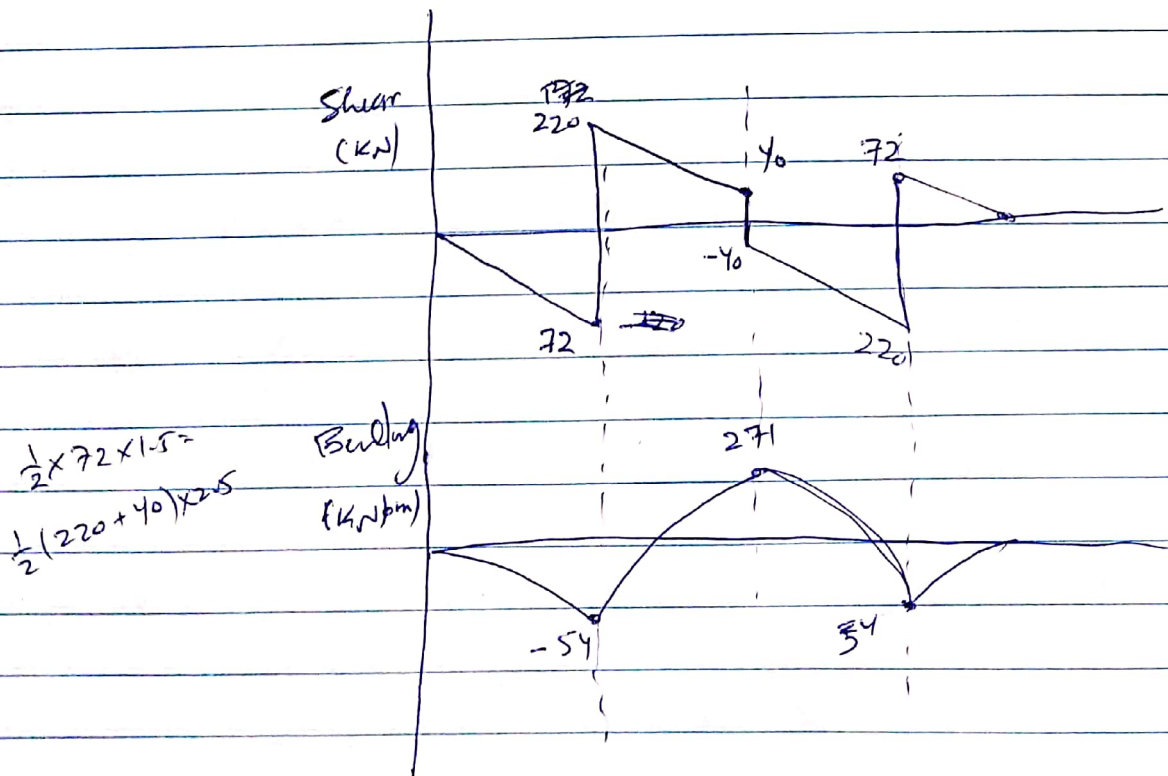
② Analysis: symmetric load, Baum

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$$\sum M_A = 0 \Rightarrow -24 \times 5 \times 2.5 - 48 \times 2.5 \times 2.5 - 80 \times 2.5 + B_y (5) = 0$$

$$B_y = 292 \text{ kN} \quad A_y = 292 \text{ kN}$$



$$\textcircled{3} \rho = 0.75 \rho_{0.005} = 0.75 \times 0.0135 = 0.01013$$

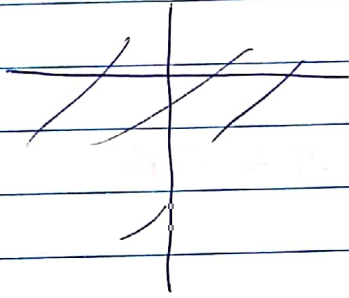
10 from Table A5: $\rho = 0.01013 \rightarrow R = ??$

$$\rho = 0.01 \rightarrow 3.71 \text{ MPa}$$

$$\rho = 0.0105 \rightarrow 3.87 \text{ MPa}$$

$$\frac{3.87 - 3.71}{0.0105 - 0.01} = \frac{3.87 - x}{0.0105 - 0.01013} \Rightarrow R = 3.752 \text{ MPa}$$

$$\phi = 0.9 \rightarrow M_u = \phi R d^2 b \Rightarrow b d^2 = \frac{M_u}{\phi R} \Rightarrow b d^2 = 79957356 \text{ mm}^3$$



$$1.5 B = d \Rightarrow$$

$$b^3 = 35536602$$

$$b = 326.9$$

$$b \approx 350 \text{ mm}$$

$$d = 496$$

$$\frac{65}{1} \Rightarrow H \approx 550$$

$$B = 350, H = 550$$

$$\textcircled{4} M = 270 \Rightarrow H = 550, 1 \text{ layer } \phi = 32 \Rightarrow d = 484 \text{ mm}$$

10 $\frac{M_u}{\phi b d^2} = 3.66 \text{ MPa} \rightarrow \text{Table A5} \rightarrow \rho = 0.00985$

$$A_s = \rho b d = 1669 \text{ mm}^2 \Rightarrow 3 \phi 29 \rightarrow A_s = 1935 \text{ mm}^2$$

$$\rho = 0.0114$$

check $\phi \Rightarrow \rho < \rho_{max}$

check width \Rightarrow Table A7 $\Rightarrow 350 \text{ mm} \rightarrow 4 \text{ Bars } \phi 29$

$$\phi = 0.9$$

$$0.0155$$

$$\rho_{max} > \rho > \rho_{min}$$

$$\times 0.0033$$

check $M_u \Rightarrow M_u = \phi R b d^2 = 343 \text{ kN.m}$

ok

ok

$$M = -190 \text{ kN.m}$$

$$R = 2.55 \text{ MPa} \rightarrow \rho = 0.0066 \rightarrow A_s = 1123 \text{ mm}^2$$

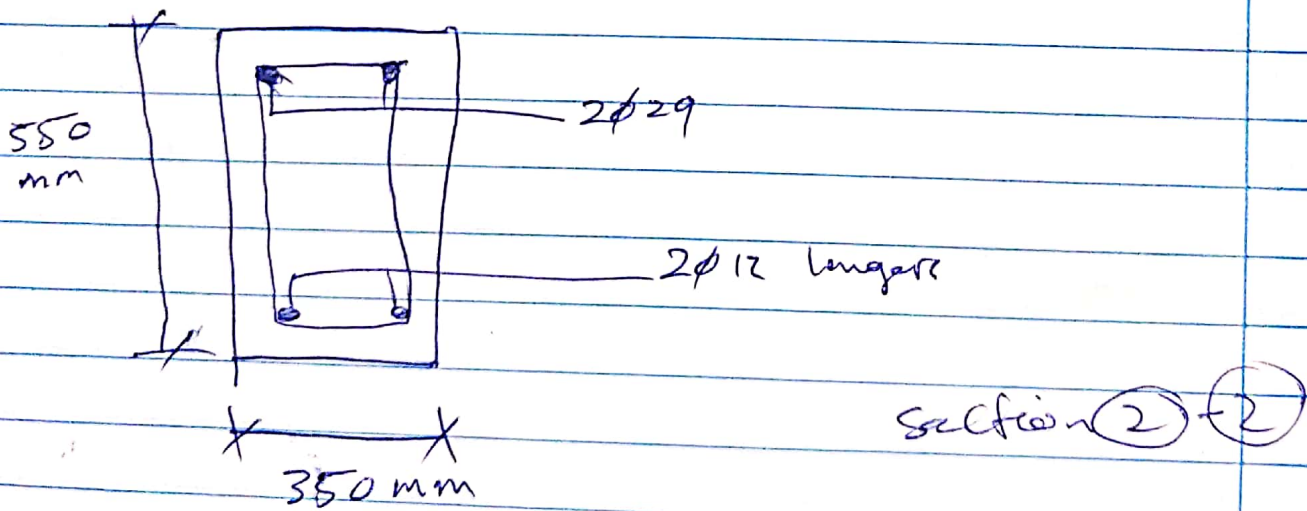
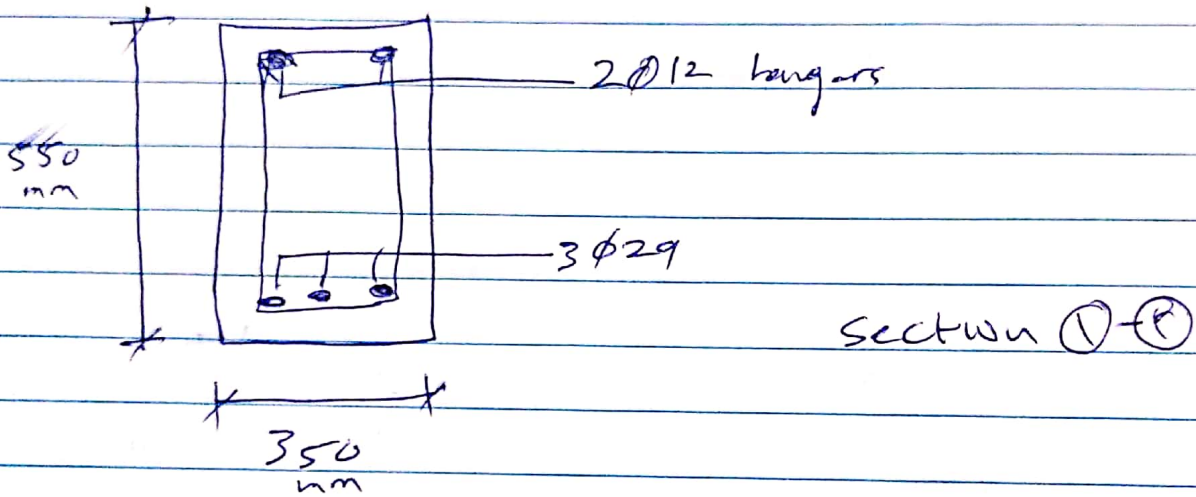
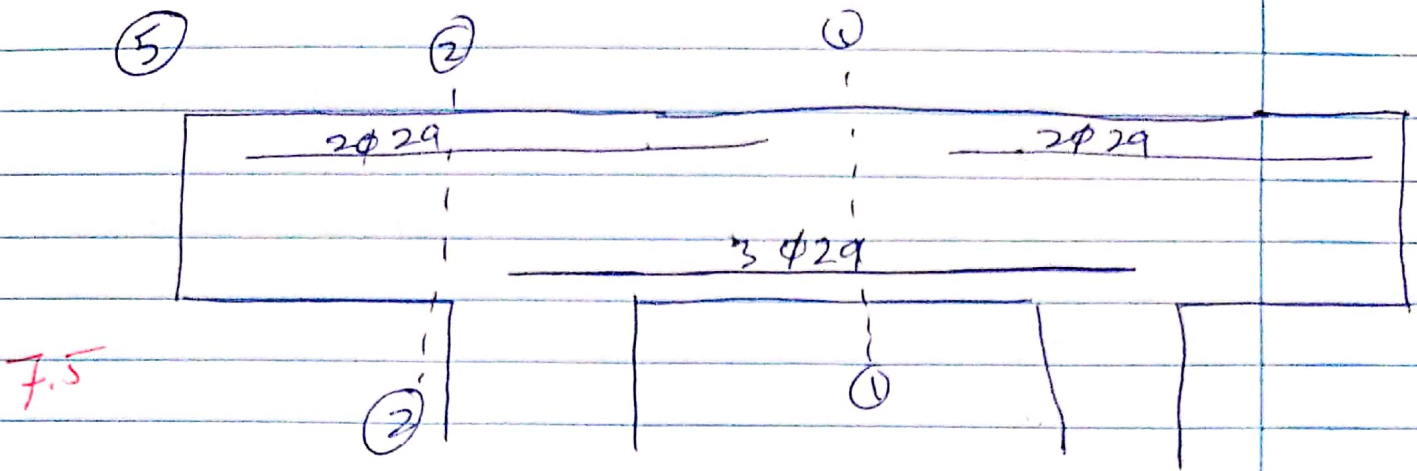
$$\text{Table A} \rightarrow A_s = 1290 \text{ mm}^2$$
$$\rho = 0.0076$$

$$M_u = 218 \text{ kN.m} \text{ ok}$$

width ok

$$\rho_{max} > \rho > \rho_{min} \text{ ok}$$

$$\rho < \rho_{0.005} \rightarrow \phi = 0.9 \Rightarrow \text{OK}$$



⑥ $M_{cr} \rightarrow \sigma = \frac{M y}{I}$

Max $\sigma \rightarrow y = \frac{H}{2} = 275 \text{ mm}$

$I \rightarrow$ ignore reinforcement $\rightarrow I = \frac{B H^3}{12} = 4.85 \times 10^9 \text{ mm}^4$

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Max tension $\rightarrow f_r = 0.62 \sqrt{f_c'} = 2.84 \text{ MPa}$

$f_r = \frac{M_{cr} c}{I} \Rightarrow M_{cr} = 50.1 \text{ kNm}$

⑦ Service Stresses

7.5 $\sigma_c = \frac{M y}{I}$

N.A \Rightarrow

A	y	Ay
$\bar{y} \times 350$	$\bar{y}/2$	$\frac{350 \bar{y}^2}{2}$
22813	484	11041671

$\sigma_s = n \frac{M y_s}{I}$

$E_c = 4700 \sqrt{f_c'} = 21.54 \text{ GPa}$

$n = \frac{E_s}{E_c} = \frac{200 \text{ GPa}}{21.54} = 9.29$

$\bar{y} = \frac{175 \bar{y}^2 + 11041671}{350 \bar{y} + 22813}$

$0 = 175 \bar{y}^2 + 22813 \bar{y} - 11041671$

$\bar{y} = 194.33 \text{ mm}$

I

I	A	D	
$\frac{B H^3}{12}$		ϕ	8.56×10^8
85618×10^8			
0	22813	484 - 194.3	2.066×10^8
		289	1.91×10^9

$I = \frac{8.62 \times 10^8 + 27.66 \times 10^8}{9.29} \text{ mm}^4$

$\sigma_c = \frac{140 \times 10^6 \times 194.3}{\frac{8.62 \times 10^8}{9.29}} = 4.28 \text{ MPa}$

13.3

$\sigma_s = \frac{140 \times 10^6 \times 289}{27.66 \times 10^8 \times 9.29}$

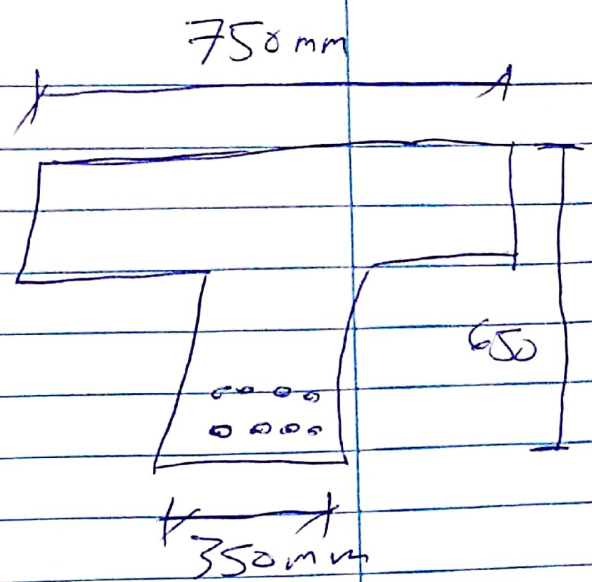
$\sigma_s = 184.4 \text{ MPa}$

Q2:

$$8\phi 32 \text{ Top} = 2012 \text{ mm}^2$$

$$2\phi 32 \text{ Bottom} = 8048 \text{ mm}^2$$

$$f_y = 420 \text{ MPa} \quad f'_c = 28 \text{ MPa}$$



$8\phi 32 \rightarrow$ fits in two layers

$$d = 650 - 40 - 10 - 32 - \frac{32}{2} = 552 \text{ mm}$$

first: check T-section or not

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$$T = C \quad A_s f_y = 0.85 f'_c b_f a \Rightarrow a = 189.36 \text{ mm} > h_f$$

section must be treated as T-section

\Rightarrow As coupled with the flange $\Rightarrow A_{sf}$

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$$T = C_f \Rightarrow A_{sf} f_y = 0.85 f'_c (b_f - b_w) h_f$$

$$A_{sf} = 2266.67 \text{ mm}^2$$

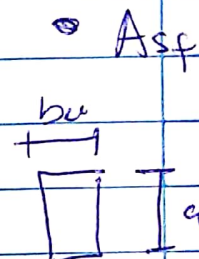
$$\text{remaining } A_{sw} = 5781.33 \text{ mm}^2$$

$$T = C \Rightarrow A_{sw} f_y = 0.85 f'_c b_w a$$

$$a = 291.5 \text{ mm} \rightarrow \bar{y} = 342.94 \text{ mm}$$

$$\rightarrow \epsilon_s \Rightarrow \epsilon_s = \epsilon_u \frac{d - \bar{y}}{y} = 0.0018$$

$$\epsilon_s = 0.0018 < 0.004$$



Section was designed as doubly reinforced

⇒ Compression steel must be taken into consideration

$$d' = 40 + 10 + \frac{32}{2} = 66 \text{ mm}$$

$$\frac{d'}{d} = 0.12 \rightarrow \text{assume comp. steel yields}$$

$$\Rightarrow A_{s1} = 2012 \text{ mm}^2 \quad A_{s2} = 5781.33 \text{ mm}^2 - 2012 =$$

$$A_{s2} = 3769.33 \text{ mm}^2$$

$$\text{find } a \Rightarrow T = C \Rightarrow A_{s1} f_y = A_{s2}' f_y + 0.85 f_c' b w a$$

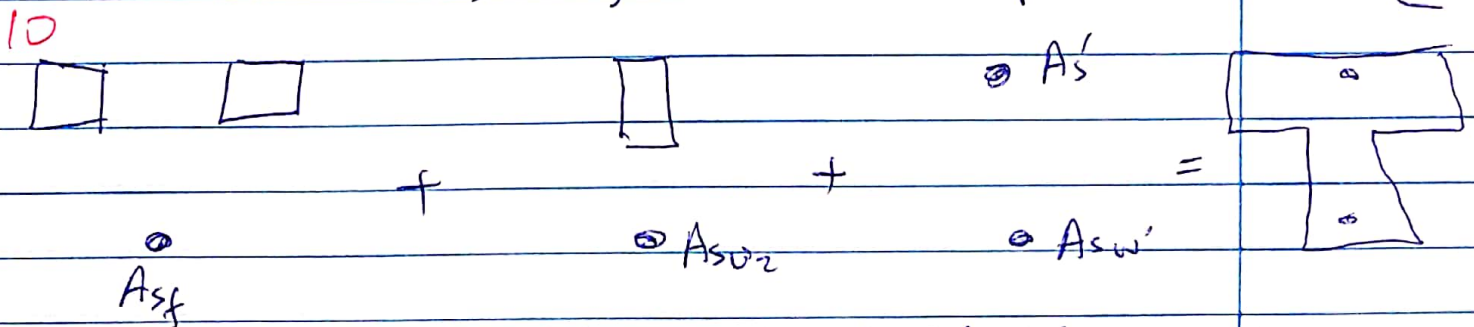
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$$a = 190 \text{ mm} \rightarrow \bar{y} = 223.6 \text{ mm}$$

$$e_s = 0.0044 > 0.004 \text{ ok}$$

$$< 0.005 \rightarrow \phi = 0.85$$

$$e_s' = 0.00213 > e_y = 0.0021 \rightarrow \text{comp. steel yield ok}$$



$$\phi M_{n1} = \text{couple with flange} = \phi A_{s1} f_y \left(d - \frac{w_f}{2} \right) = 406.2 \text{ kW.m}$$

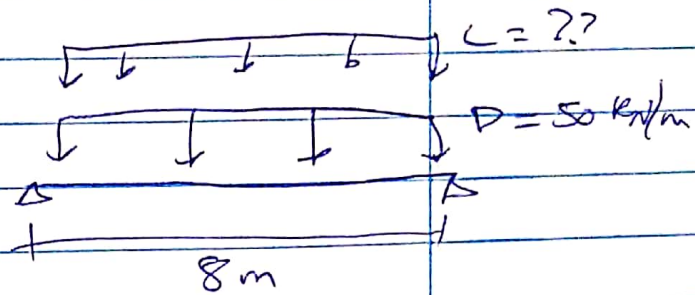
$$\phi M_{n2} = \text{couple with web} = \phi A_{s2} f_y \left(d - \frac{a}{2} \right) = 615 \text{ kW.m}$$

$$\phi M_{n3} = \text{couple with comp steel} = \phi A_{s2}' f_y (d - d') = 349.1 \text{ kW.m}$$

$$\phi M_n = 1370.3 \text{ kNm}$$

Part 2: 5

$$\phi M_n = 1370.3 \text{ kNm}$$



\Rightarrow Max moment at Mid span $M_u = \frac{w_u l^2}{8}$

$$\Rightarrow 1370.3 = \frac{w_u (8)^2}{8} \Rightarrow w_u = 171.3 \text{ kN/m}$$

$$w_u = 1.2 D + 1.6 L \Rightarrow 171.3 = 1.2(50) + 1.6(L)$$

$$L = 69.55 \text{ kN/m}$$