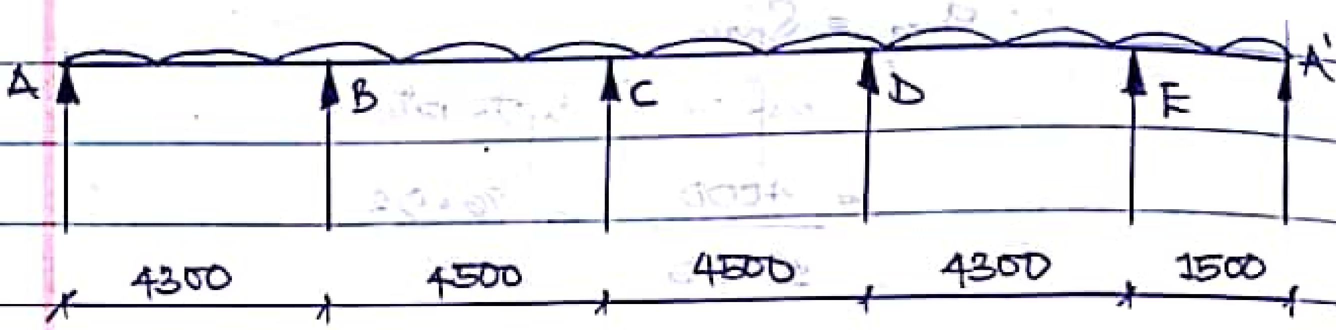
Assignment 2 ; Solutions

1a) Beam A-A'

Using Hardy Cross Method



Slab Loading

Assumed thickness of Slab = 150 mm

25 − 410 N/mm²

Fcu − fy N/mm²

wt. of Slab = 0·15 × 24 = 3·6 kN/m²

Partition = 1·0 kN/m²

Finishes = 1·2 kN/m²

5·8 kN/m²

D·L = 1·4(5·8) + 1·6(3·0)

= 12·92 ≃ 13 kN/m²

Beam Loading

Self wt = 0·225 × 0·6 × 24 = 3·24 kN/m²

Finishes / Screeding = 1·2 kN/m²

Wall = 3.47 × 3 = 10.41 kN/m^2

Gk = 14.85

D.L = 1.4Gk

= 1.4 × 14.85 = 20.79 kN/m^2

Slab load in longer direction = $\frac{1}{2} w l_x \left[1 - \frac{1}{3k^2}\right]$

$k = l_y/l_x = \frac{4300}{4000} = 1.075$, $\frac{4500}{4000} = 1.125$

$$\therefore = \frac{1}{2} \times 13 \times 4.3 \left[1 - \frac{1}{3(1.075)^2}\right] = 19.89\ kN/m^2$$

$$\frac{1}{2} \times 13 \times 4.5 \left[1 - \frac{1}{3(1.125)^2}\right] = 21.55\ kN/m^2$$

Slab load on beam in shorter direction = $\frac{1}{3} w l_x$

$$= \frac{1}{3} \times 13 \times 1.5 = 6.5\ kN/m^2$$

<u>Total load</u> = 19.89 + 20.79 = 40.68 kN/m

21.55 + 20.79 = 42.34 kN/m

6.5 + 20.79 = 27.29 kN/m

Distribution factor (DF) $= \frac{k}{\Sigma k}$

$K_{AB} = \frac{1/L}{\Sigma k} = \frac{\frac{1}{4.3}}{0 + 1/4.3} = 1$

$K_{BA} = \frac{\frac{1}{4.3}}{1/4.3 + 1/4.5} = 0.51$

$K_{BC} = \frac{1/4.5}{1/4.3 + 1/4.5} = 0.49$

$K_{CB} = K_{CD} = 0.5$

$K_{DC} = K_{BC} = 0.49$

$K_{DE} = K_{BA} = 0.51$

$K_{ED} = \frac{1/4.3}{1/4.3 + 1/1.5} = 0.26$

$K_{EA'} = 1 - K_{ED} = 1 - 0.26 = 0.74$

$K_{A'E} = 1$

Fixed End Moments (F.E.M)

for U.D.L $= \pm wl^2/12$

$- \frac{40.68 \times (4.3)^2}{12} = 62.65$ kNm

$- \frac{42.34 \times (4.5)^2}{12} = 71.45$ kNm

$$\frac{-27.29 \times (1.5)^2}{12} = 5.1 \text{ kNm}$$

TABLE	A	AB	BA	B	BC	CB	C	CD	DC	D	DE	ED	E	EA'	A'E	A'
Σ		0	82.88		-82.88	69.06		-69.06	72.06		-72.06	45.47		-45.46	0	
Joints	A			B			C			D			E			A'
Members		AB	BA		BC	CB		CD	DC		DE	ED		EA'	A'E	
D.F		1	0.51		0.49	0.5		0.5	0.49		0.51	0.26		0.74	1	
FEM		-62.68	62.68		-71.45	71.45		-71.45	71.45		-62.68	62.68		-5.1	5.1	
OBM	-62.68			-8.77			0			8.77			57.58			5.1
BM	62.68			8.77			0			-8.77			-57.58			-5.1
DM		62.68	4.47		4.30	0		0	-4.30		-4.41	-14.97		-42.61	-5.1	
TM		2.235	31.34		0	2.15		-2.15	0		-7.49	-2.24		-2.55	-21.305	
OBM	2.235			31.34			0			-7.49			-4.79			-21.305
BM	-2.235			-31.34			0			7.49			4.79			21.305
DM		-2.235	-15.98		-15.36	0		0	3.67		3.82	1.25		3.54	21.31	
TM		-7.99	-1.12		0	-7.69		1.84	0		0.63	1.91		10.66	1.77	
OBM	-7.99			-1.12			-5.85			0.63			12.57			1.77
BM	7.99			1.12			5.85			-0.63			-12.57			-1.77
DM		7.99	0.57		0.55	2.93		2.93	-0.31		-0.32	-3.27		-9.29	-1.77	
TM		0.29	3.40		1.47	0.28		-0.16	1.47		-1.64	-0.16		-0.89	-4.65	
OBM	0.29			4.87			0.12			-0.17			-1.05			-4.65
BM	-0.29			-4.87			-0.12			0.17			1.05			4.65
DM		-0.29	-2.48		-2.39	-0.06		-0.06	0.08		0.09	0.27		0.78	4.65	

Free Moments

U.D.L $\Rightarrow wl^2/8$

$\therefore$ I. $\frac{40.68 \times (4.3)^2}{8} = 94.02\ kNm^2$

II. $\frac{42.34 \times (4.5)^2}{8} = 107.17\ kNm^2$

III. $\frac{27.29 \times (1.5)^2}{8} = 7.68\ kNm^2$

Span Moments

$$M_{AB}^{span} = M_{AB}^{F} - \left(\frac{M_A + M_B}{2}\right)$$

$$= 94.02 - \left(\frac{0 + 82.88}{2}\right) = 52.58\ kNm$$

$$M_{BC}^{span} = M_{BC}^{F} - \left(\frac{M_B + M_C}{2}\right)$$

$$= 107.17 - \left(\frac{82.88 + 69.06}{2}\right) = 31.20\ kNm$$

$$M_{CD}^{span} = M_{CD}^{F} - \left(\frac{M_C + M_D}{2}\right)$$

$$= 107.17 - \left(\frac{69.06 + 72.06}{2}\right) = 36.61\ kNm$$

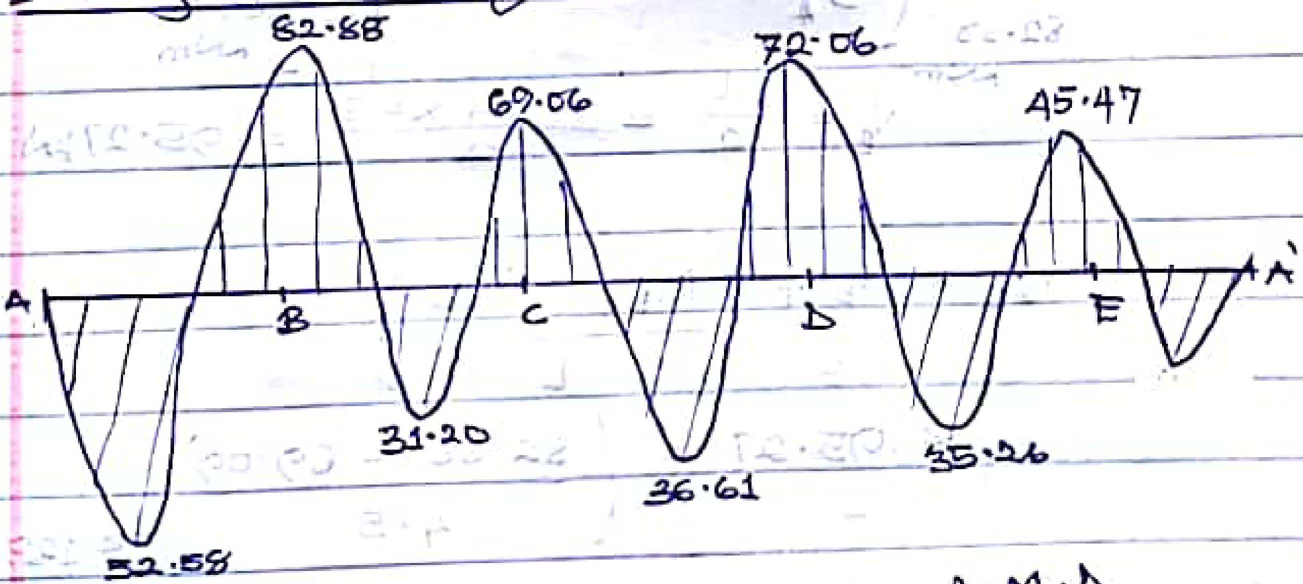
$$M_{DE}^{span} = M_{DE}^{F} - \left(\frac{M_D + M_E}{2}\right)$$

$$= 94.02 - \left(\frac{72.06 + 45.47}{2}\right) = 35.26\ kNm$$

$$M_{EA'}^{span} = M_{EA'}^{F} - \left(\frac{M_E + M_{A'}}{2}\right)$$

$$= 7.68 - \left(\frac{45.47 + 0}{2}\right) = 15.06\ kNm$$

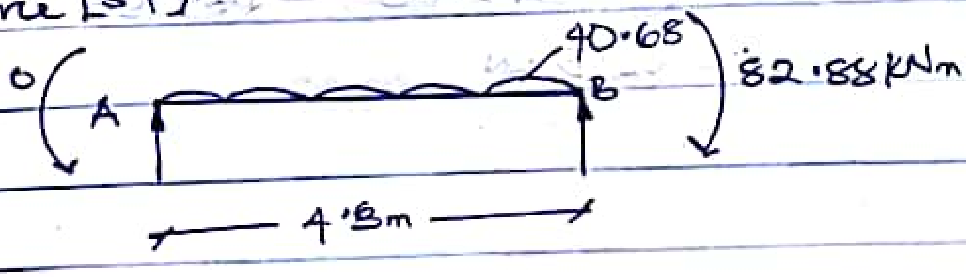
Bending Moment Diagram



B.M.D

Shear Force [S.F]

For A



$V_A = \frac{wL}{2} = \frac{40.68 \times 4.3}{2} = 87.462$

$V_{AB} = V_A + \left(\frac{M_{ab} - M_{ba}}{L}\right)$

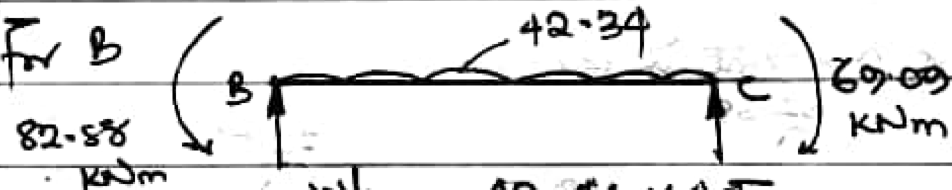
$= 87.462 + \left(\frac{0 - 82.88}{4.3}\right) = \underline{68.19 \text{ kN}}$

$V_{BA} = wL - V_{ab}$

$= [40.68 \times 4.3] - 68.79$

$= \underline{106.73 \text{ kN}}$

For B



$V_B = \frac{wL}{2} = \frac{42.34 \times 4.5}{2} = 95.27 \text{ kN}$

$V_{BC} = V_B + \left(\frac{M_{bc} - M_{cb}}{L}\right)$

$= 95.27 + \left(\frac{82.88 - 69.09}{4.5}\right) = \underline{98.33 \text{ kN}}$

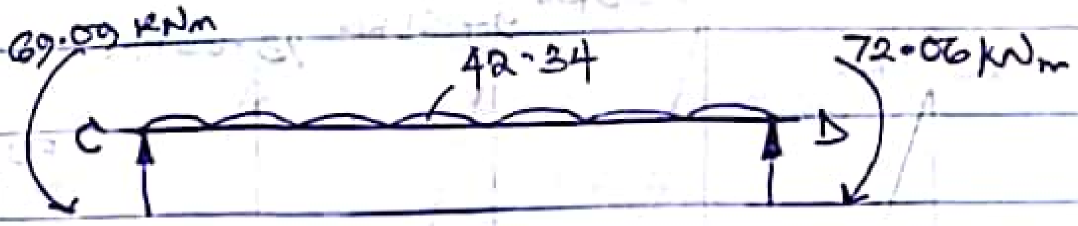
$V_{CB} = wL - V_{bc}$

$= (42.34 \times 4.5) - 98.33$

$= \underline{92.2 \text{ kN}}$

Scanned by CamScanner

For C

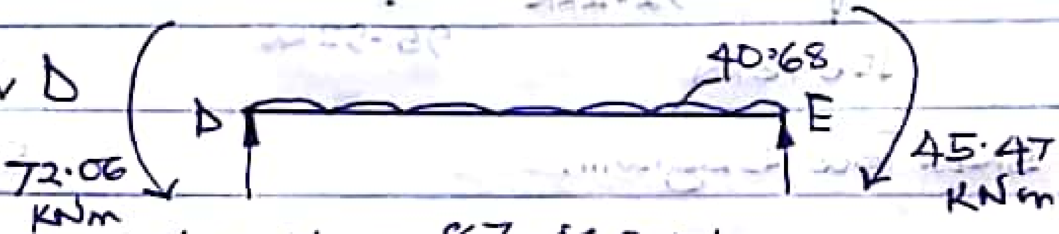


$$V_C = V_B = 95.27\,kN$$

$$V_{CD} = 95.27 + \left(\frac{69.09 - 72.06}{4.5}\right) = 94.61\,kN$$

$$V_{DC} = (42.34 \times 4.5) - 94.61$$
$$= 95.92\,kN$$

For D

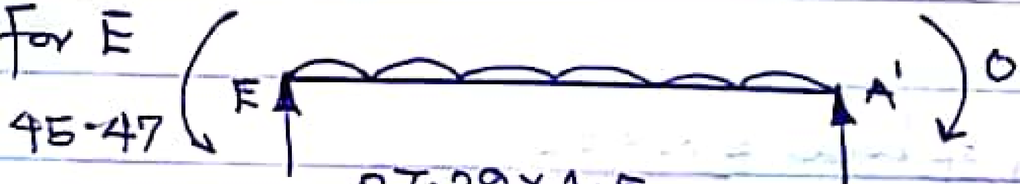


$$V_D = V_A = 87.462\,kN$$

$$V_{DE} = 87.462 - \left(\frac{72.06 - 45.47}{4.3}\right) = 93.65\,kN$$

$$V_{ED} = (40.68 \times 4.3) - 93.65$$
$$= 81.27\,kN$$

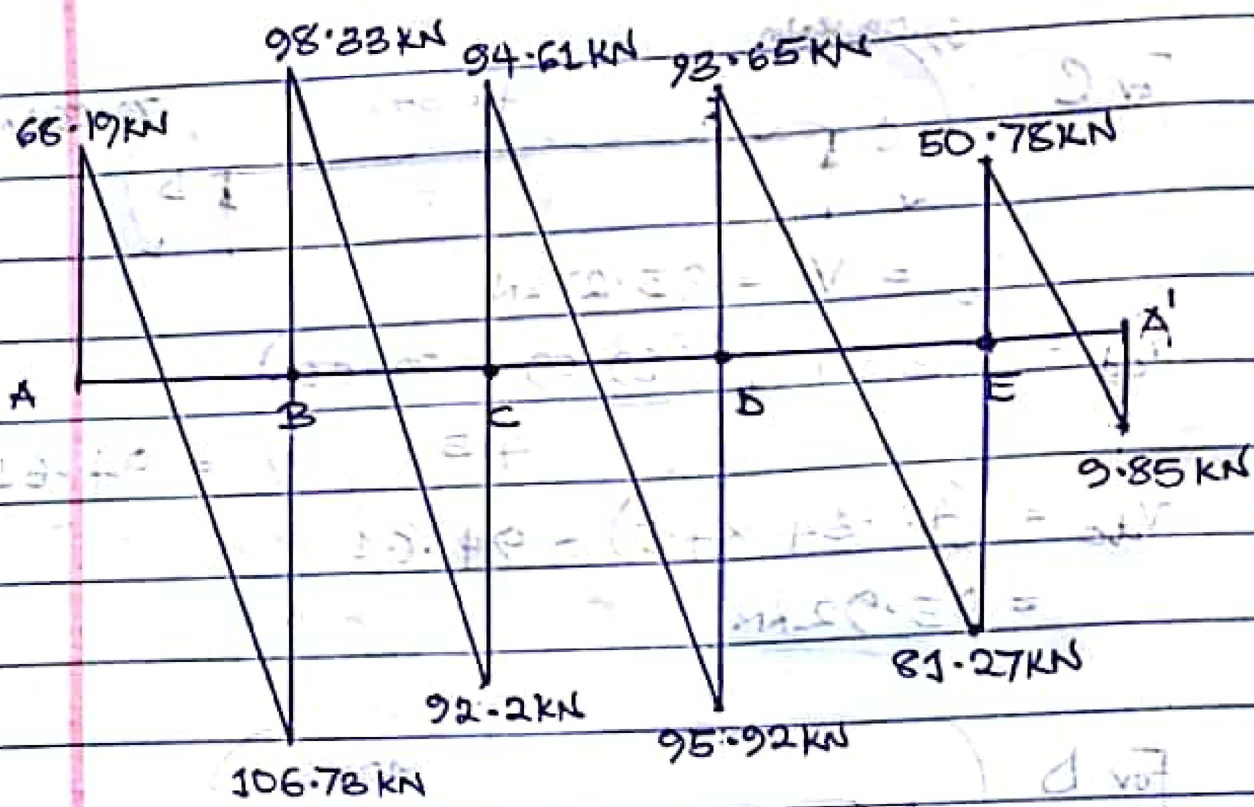
For E



$$V_E = \frac{27.29 \times 1.5}{2} = 20.47\,kN$$

$$V_{EA'} = 20.47 + \left(\frac{45.47 - 0}{1.5}\right) = 50.78\,kN$$

$$V_{A'E} = (27.29 \times 1.5) - 50.78 = -9.85\,kN$$



Shear Force Diagram.

▷ Question 2

Base Design

N = 1200 KN

grade stress = 25 − 410 N/mm²

Fb S.B.C = 150 kN/m²

$$\text{Area of base} = \frac{N \times 1.1}{\lambda \cdot F_b}$$

$$= \frac{1200 \times 1.1}{1.46 \times 150} = 6.027 m^2$$

$A = l^2$, ∴ $b = \sqrt{A}$

$B = \sqrt{6.027} = 2.45$ [Assuming a square base]

$\therefore L = B$

$F_{net} = \frac{N \times 1.1}{B} - 1.4 \rho_{conc} \times d$

$= \frac{1200 \times 1.1}{2.45} - 1.4 \times 24 \times 0.660$

$= 516.6 \text{ kNm}$

$M = \frac{F_{net} \cdot l^2}{2}$

$l = \frac{1}{2}(b - h) = \frac{1}{2}[2.45 \times 0.660] \simeq 0.9\text{m}$

$\therefore M = \frac{516.6 \times (0.9)^2}{2} = 209.223 \text{ kNm}$

$d = h - \text{cover} - \frac{1}{2}\phi$

$= 660 - 50 - 10 = 600\text{mm}$

$K = \frac{M}{bd^2 F_{cu}} = \frac{209.233 \times 10^6}{1000 \times 600^2 \times 25} = 0.023$

$I_a = 0.5 + \sqrt{0.25 - \frac{0.023}{0.9}}$

$= 0.97 \quad (\leq 0.95)$

$Z_i = I_a d = 0.95 \times 600 = 570 \text{ mm}$

$$A_s = \frac{M}{0.95 f_y z_u} = \frac{209.223 \times 10^6}{0.95 \times 410 \times 570}$$

$$= 942.4 \, mm^2$$

Provide Y12 @ 100 c/c [1130]

Punching Shear

Column size ⇒ (225 × 450) mm

f_{ck} – f_y N/mm²

25 – 410 N/mm²

Area of footing = 6.027 m²

Size of footing = 2500 × 2500

Net pressure = 516.6 kN/m

depth = 600 mm

critical section; d/2 = 300 mm

300 + 300 + 225 = 825 mm

300 + 300 + 450 = 1050 mm

Shear force, $V_u = q_u \times [\text{Area of footing} - (0.3 + d)^2]$

$= 516.6 \times [(2.5 \times 2.5) - (0.3 + 0.6)^2]$

= 2810.30 kN

Nominal Shear Stress, $\tau_u = V_u / b.d$

b → perimeter of critical section

d → effective span

$$\tau_v = \frac{2810.30 \times 10^3}{[(2 \times 825) + 2(1050)) \times 600]}$$

$\tau_v = 1.25 \; N/mm^2$

Permissible Shear Stress

$\tau_c' = k_s + \tau_c$

$k_s = (0.5 + \beta_c) < 1$

β_c = Ratio of shorter to longer direction of column

$\tau_c = 0.25 \sqrt{F_{cu}}$

$k_s = 1$, $\tau_c' = ?$

$\tau_c' = 0.25 \sqrt{25} = 1.25$

$\therefore \; \tau_v = \tau_c'$ → depth is okay

Check for Fo with actual size of footing

Unit wt. of conc. $= 24 \; KN/mm^2$

Unit wt. of Soil $= 1.091 \times 10^{-6} \; KN/mm^2$

$q = (1200 / (2.5 \times 2.5)) + (24 \times 0.660) + (1.091 \times 10^{-6} \times 0.660$

$q = 214.94 \; kN/m^2 > 150 \; kN/m^2$ ∴ Size of footing is ok