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ESE 2019 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-3: Strength of Materials
Transportation Engineering-1 + Surveying & Geology-1
Geo-technical & Foundation Engg-2 + Environmental Engg-2

Name : ....

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Student's Signature

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	57
Q.2	
Q.3	28 + 8 = 36
Q.4	59
Section-B	
Q.5	42
Q.6	
Q.7	
Q.8	48
Total Marks Obtained	234 + 8 = 242

Good presentation.
Nice accuracy.

Signature of Evaluator: Arpita

Cross Checked by

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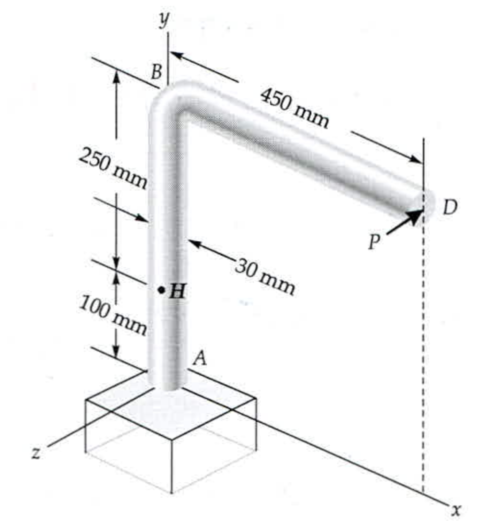
Handwriting can be improved.

Section A : Strength of Materials

Q.1 (a) A single horizontal force P of magnitude 600 N is applied to end D of lever ABD. The diameter of lever ABD is 30 mm. Determine :

(i) The normal and shearing stress on an element located at point H having sides parallel to x and y axis.

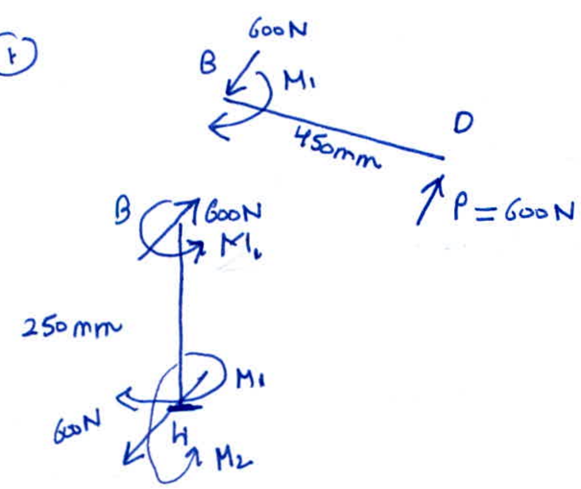
(ii) The directions of principal planes and principal stresses at point H.



$P = 600\text{ N}$

[12 marks]

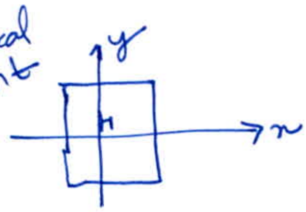
(i)



$M_1 = 600\text{ N} \times 450\text{ mm}$
$= 0.27\text{ kNm}$

$M_2 = 600\text{ N} \times 250\text{ mm}$
$= 0.15\text{ kNm}$

vertical element



on element (H)

(1) τ due to 600 N $= \dfrac{600}{\frac{\pi}{4}(30)^2}$

$\boxed{\tau \text{ on } H = 0}$

2 T ∵ of M_1 on plane $= 0.27\text{ kNm}$

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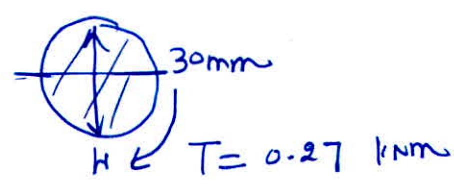
$$\frac{T}{J} = \frac{\tau_{max}}{R}$$



$$\frac{0.27\times10^6}{\frac{\pi}{32}(30)^4} = \frac{\tau_{max}}{15 \text{ mm}}$$

$\tau_{max} =$

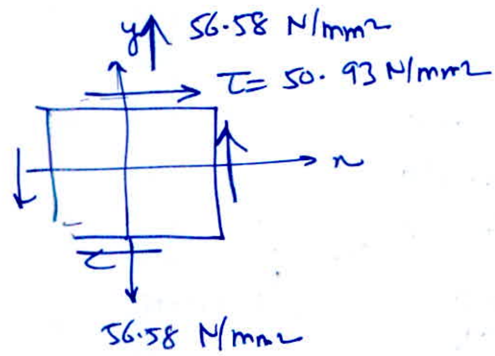
$$\boxed{\tau_{max} = 50.93 \text{ N/mm}^2}$$

(c) Tensile stress on H ∵ of M_z (0.15 kNm)

$$\sigma = \frac{My}{I} = \frac{0.15\times10^6 \times 15 \text{ mm}}{\frac{\pi(30)^4}{64}} = \boxed{56.58 \text{ N/mm}^2}$$

∴ element H

$$\boxed{\begin{aligned} \therefore \sigma_x &= 56.58 \text{ N/mm}^2 \\ \tau &= 50.93 \text{ N/mm}^2 \end{aligned}}$$



(2) $\sigma_{p_1}/\sigma_{p_2} = \frac{\sigma_x+\sigma_y}{2} \pm \frac{1}{2}\sqrt{(\sigma_y-\sigma_x)^2+4\tau^2}$

$$= \frac{0+56.58}{2} \pm \frac{1}{2}\sqrt{(56.58)^2+4\times 50.93^2}$$

$$= 28.29 \pm 58.259$$

$$\boxed{\begin{aligned} \sigma_{p_1} &= 86.549 \\ \sigma_{p_2} &= -29.969 \end{aligned}}$$

$$\tan 2\theta_p = \frac{2\tau_{xy}}{\sigma_x-\sigma_y} = \frac{2(50.93)}{0-56.58}$$ 56.58−0

$$\boxed{\begin{aligned} \theta_{p_1} &= -30.47 \\ \theta_{p_2} &= 59.527 \end{aligned}}$$ 120.47°

$\sigma_x' = \sigma_x \cos^2\theta + \sigma_y \sin^2\theta + 2\tau_{xy} \sin\theta \cos\theta$

$= 0 + 56.58 \sin^2 59.52 + 2 \times 50.93 \sin 59.52 \cos 59.52$

$= 42.02 + 44.52$

$= 86.459$

$$\boxed{\begin{aligned} \therefore\ \sigma_{P_1} &= 86.549\ N/mm^2 \ @\ \theta_{P_1} = 59.527° \\ \sigma_{P_2} &= -29.969\ N/mm^2 \ @\ \theta_P = -30.47° \end{aligned}}$$

9

Q.1 (b) A steel specimen is subjected to the following principal stresses: (i) 120 N/mm² tensile (ii) 60 N/mm² tensile and (iii) 30 N/mm² compressive. The proportionality limit for the steel specimen is 250 N/mm². Find the factor of safety according to

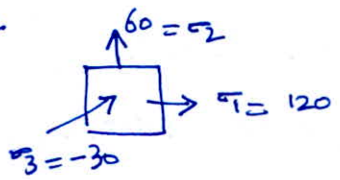
(i) Maximum shear stress theory. *(ii)* Maximum principal strain theory.

(iii) Maximum strain energy theory.

Take Poisson's ratio = 0.3

[12 marks]

Given



$\sigma_1 = 120+$ MPa

$\sigma_2 = +60$ MPa

$\sigma_3 = -30$ MPa

$\sigma_y = 250\ N/mm^2$

$\mu = 0.3$

(i) Maximum shear stress theory:

$$\boxed{\tau_{max} \le \frac{\sigma_y}{2(FOS)}}$$

$\tau_{max} = \max \text{ of } \left[\frac{120-60}{2}, \frac{60-(-30)}{2}, \frac{120-(-30)}{2} \right)$

$[30, 45, 75] = 75$

$75 \le \frac{250}{2(FOS)}$

$FOS \ge \frac{250}{2(75)}$

$$\boxed{FOS \ge 1.667}$$

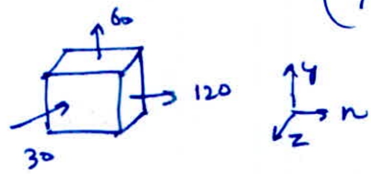
(ii) Maximum principal strain theory $\mu = 0.3$

Max principal strain $\leq \left(\frac{\sigma_y}{FOS}\right)\frac{1}{E}$

$\sigma_1 = 120$

$\sigma_2 = 60$

$\sigma_3 = -30$



$$\epsilon_x = +\frac{120}{E} - \frac{0.3(60)}{E} + \frac{0.3(30)}{E} = \frac{111}{E}$$

$$\epsilon_y = +\frac{60}{E} - \frac{0.3(120)}{E} + \frac{0.3(30)}{E} = \frac{33}{E}$$

$$\epsilon_z = -\frac{30}{E} - \frac{0.3(60)}{E} - \frac{0.3(120)}{E} = -\frac{84}{E}$$

$$\therefore \frac{111}{\cancel{E}} \leq \frac{250}{(FOS)\cancel{E}}$$

$$\boxed{FOS \geq 2.252}$$

(iii) Maxm strain energy theory

$$u \leq \frac{\left(\frac{\sigma_y}{FOS}\right)^2}{2E}$$

$$u = \frac{1}{2E}\left(\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - 2\mu(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1)\right]$$

$$= \frac{1}{2E}\left(120^2 + 60^2 + 30^2 - 0.6\left[120(60) + 60(-30) + 120(-30)\right]\right.$$

$$= \frac{17820}{2E}$$

$$\frac{17820}{\cancel{2E}} \leq \frac{\left(\frac{250}{FOS}\right)^2}{\cancel{2E}}$$

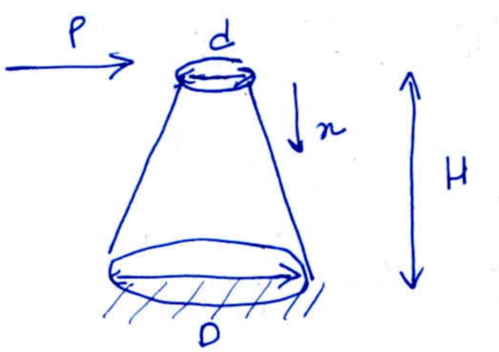
$$133.4915 \leq \frac{250}{FOS}$$

$$\boxed{FOS \geq 1.872}$$

12

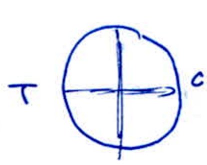
Q.1 (c) A uniformly tapering vertical post of height H having a diameter D at the base and a diameter d at the top is fixed at its base. A horizontal force P is applied at the top of the post. Determine the maximum bending stress for the post and state where it occurs.

[12 marks]



$$H \rightarrow (D-d)\uparrow$$
$$1 \rightarrow \left(\frac{D-d}{H}\right)\uparrow$$
$$x \rightarrow \left(\frac{D-d}{H}\right)x\uparrow$$
$$\therefore \boxed{D_x = d + \left(\frac{D-d}{H}\right)x}$$

$$M_x = Px$$



$$f = \frac{My}{I} \qquad f_{max} = \frac{M \cdot \frac{D_x}{2}}{\frac{\pi D_x^4}{64}} = \frac{MD_x}{2} \times \frac{64}{\pi D_x^4}$$

$$f_{max} = \frac{32M}{\pi D_x^3}$$

$$f_{max} = \frac{32Px}{\pi\left[d + \left(\frac{D-d}{H}\right)x\right]^3}$$

$$f_{max} = \frac{32P}{\pi}\, x \left[d + \left(\frac{D-d}{H}\right)x\right]^{-3}$$

For Max m f, $\frac{df}{dx} = 0$.

$$\frac{d}{dx}\left\{ x\left[d+\left(\frac{D-d}{H}\right)x\right]^{-3}\right\}=0$$

$$1\cdot\left[d+\left(\frac{D-d}{H}\right)x\right]^{-3}+x\times -3\left[d+\left(\frac{D-d}{H}\right)x\right]^{-4}\left[0+\frac{D-d}{H}\right]=0$$

$$\left[d+\left(\frac{D-d}{H}\right)x\right]^{-3}-3x\left(\frac{D-d}{H}\right)\left[d+\frac{D-d}{H}x\right]^{-4}=0$$

$$\left(d+\frac{D-d}{H}x\right)^{-3}\left[1-3x\left(\frac{D-d}{H}\right)\left(d+\left(\frac{D-d}{H}\right)x\right)^{-1}\right]=0$$

$$1=\frac{\frac{3x(D-d)}{H}}{d+\left(\frac{D-d}{H}\right)x} \Rightarrow d+\frac{D-d}{H}x=\frac{3}{H}(D-d)x$$

$$d=\frac{2}{H}(D-d)x$$

Answer $\boxed{x=\frac{dH}{2(D-d)}}$

$$\sigma_{max}=\frac{32\,Px}{\pi\left[d+\frac{D-d}{H}x\right]^3}$$

$$=\frac{32\,P\times\frac{dH}{2(D-d)}}{\pi\left[d+\frac{D-d}{H}\left(\frac{dH}{2(D-d)}\right)\right]^3}=\frac{\frac{32\,PdH}{2(D-d)}}{\pi\left[d+\frac{d}{2}\right]^3}$$

$$=\frac{16\,PdH}{\pi(D-d)\left(\frac{3d}{2}\right)^3}=\frac{16\,PdH}{\pi d^3(D-d)\times\frac{27}{8}}$$

Answer $\boxed{\sigma_{max}=\frac{128}{27}\frac{PH}{\pi d^2(D-d)}}$

12

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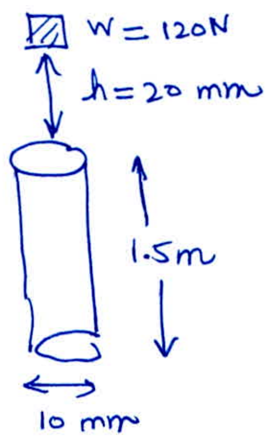
Q.1 (d) A 10 mm diameter mild steel bar of length 1.50 metre is stressed by a weight of 120 N dropping freely through 20 mm before commencing to stretch the bar. Find the maximum instantaneous stress and the elongation produced in the bar.

[Take $E = 2 \times 10^5$ N/mm^2]

[12 marks]



$E = 2\times10^5 \ N/mm^2$

$$\sigma_{max} = \sigma_{static}\left[1 \pm \sqrt{1+\frac{2h}{\delta_{static}}}\right]$$

$$\boxed{\sigma_{max} = \sigma_{static}\left[1 + \sqrt{1+\frac{2h}{\delta_{static}}}\right]}$$

$$\sigma_{static} = \frac{P}{A} = \frac{120\ N}{\frac{\pi}{4}(10)^2} = 1.527\ N/mm^2$$

$$\boxed{\sigma_{static} = 1.527\ N/mm^2}$$

$$\delta_{static} = \frac{PL}{AE} = \frac{120\ N \times 1500\ mm}{\frac{\pi}{4}\times 10^2 \times 2\times10^5} = 0.01146\ mm$$

$$\boxed{\delta_{static} = 0.01146\ mm}$$

$$\therefore \sigma_{max} = 1.527\left[1+\sqrt{1+\frac{2\times 20\ mm}{0.01146\ mm}}\right]$$

$$\boxed{\sigma_{max} = 91.757\ N/mm^2}$$ Answer

$$\delta = \frac{PL}{AE} = \frac{\sigma L}{E}$$

$$\delta_{max} = \frac{\sigma_{max} L}{E}$$

$$\delta_{max} = \frac{91.757 \times 1500}{2 \times 10^5}$$

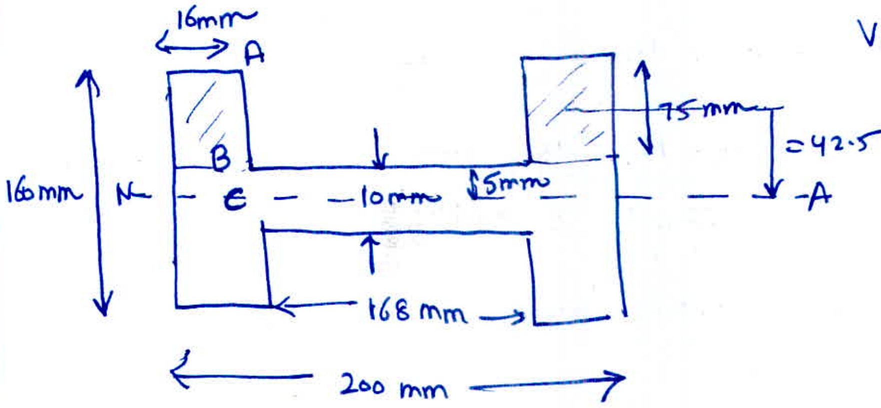
$$\boxed{\delta_{max} = 0.688 \text{ mm}}$$ Answer

12

Q.1 (e) A steel beam of I-section, 200 mm deep and 160 mm wide has 16 mm thick flanges and 10 mm thick web. The beam is subjected to a shear force of 200 kN. Draw the shear stress distribution, if the web of the beam is kept horizontal.

[12 marks]

$V = 200$ kN



$$I_{NA} = \frac{168(10)^3}{12} + \frac{16 \times 160^3}{12} \times 2$$

$$I_{NA} = 10936666.67$$

$$= 10.9366 \times 10^6 \text{ mm}^4$$

$\boxed{\tau_A = 0}$

$$\tau_B = \frac{VQ}{It} = \frac{(200 \times 1000)\,[16 \times 75 \times 2 \times 42.5]}{10936666.67\ t}$$

$$= \frac{1865.28}{t}$$

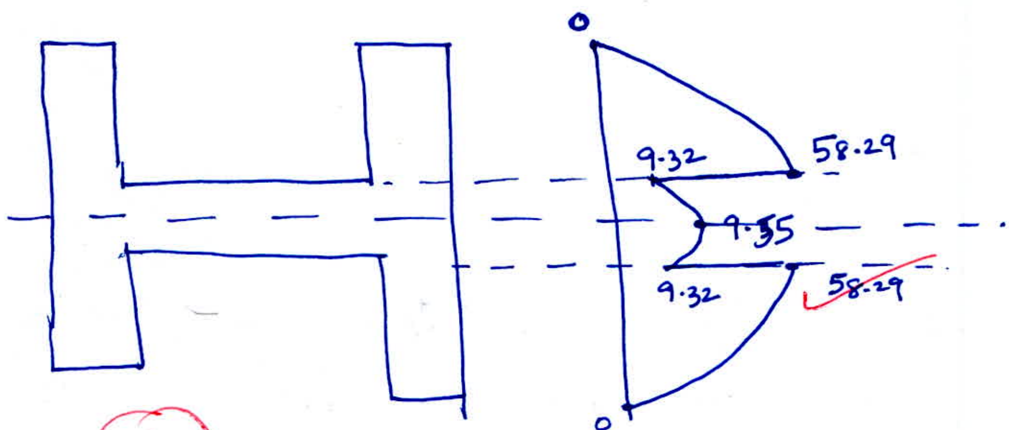
if $t = 2 \times 16 = 32\,m$

if $t = 200$ mm

$\boxed{\begin{aligned} \tau_{B1} &= 58.29\ N/mm^2 \\ \tau_{B2} &= 9.32\ N/mm^2 \end{aligned}}$

$$\tau_c = \frac{VQ}{It} = \frac{200 \times 1000\,[16 \times 75 \times 2 \times 42.5 + 200 \times 5 \times 2.5]}{10936666.67 \times 200}$$

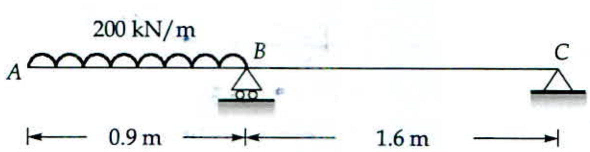
$\boxed{\tau_c = 9.55\ N/mm^2}$



12

Good presentation!

Q.2 (a) For the beam shown below, find the deflection at end A, using moment area method. [Take EI = constant]



[20 marks]

Done Drag }

Not 2

↑ $R_B = 230.625$ $R_C = 50.625$

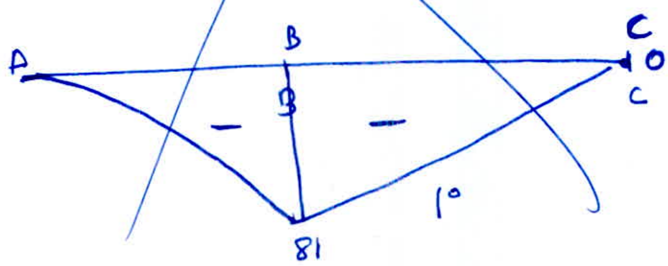
$R_B + R_C = 200\,(0.9) = 180$

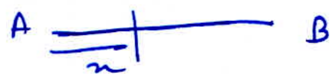
$1.6\,R_B = 200 \times 0.9\left(1.6 + \frac{0.9}{2}\right)$

$R_B = 230.625$ kN

$R_C = 180 - 230.625$
$= 50.625$

BMD





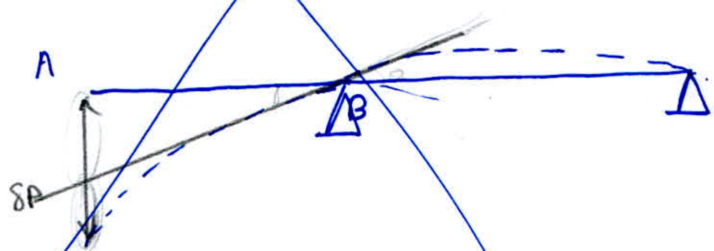
$M_x = -\frac{wx^2}{2} = -\frac{200x^2}{2} = -100x^2$

At $x = 0.9$ $M_x = -100(0.9)^2$

$= \underline{\underline{-81}}$

$\boxed{M_x = -100x^2}$

Slope $= \underline{-200x}$ At $x=0$



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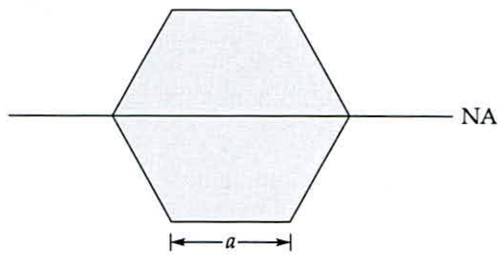
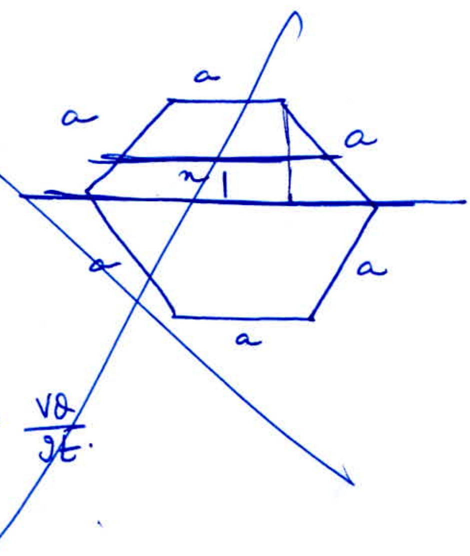
Q.2 (b) A beam section is a regular hexagon of side 'a' and is placed so that one diagonal is horizontal as shown below. If the beam section is subjected to a shear force S, obtain an expression for the shearing stress at any distance x from the horizontal diagonal.



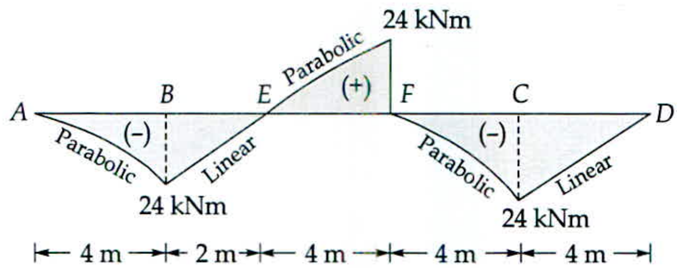
[20 marks]

$V = $ 25kN



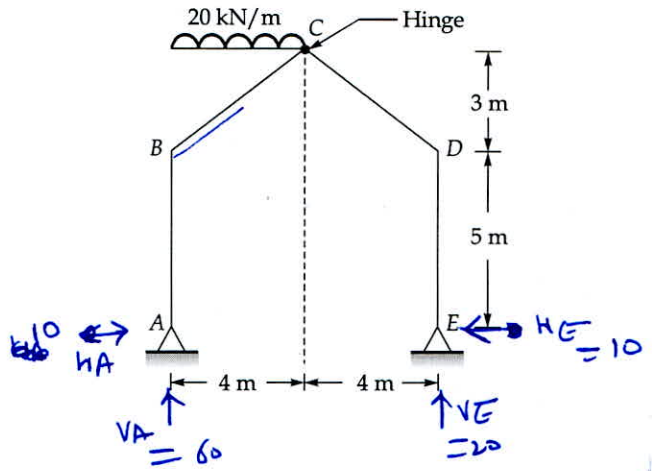
$\tau = \frac{VQ}{It}$.

Q.2 (c) A beam ABCD is supported at B and C and has over-hangs AB and CD. Its bending moment diagram is shown below. Determine the loading diagram and the shear force diagram of the beam.



[20 marks]

Q.3 (a) Draw the bending moment diagram for the frame shown below.



[20 marks]

$$\boxed{VA + VE = 80 \text{ kN}}$$

$$4VE = 8HE$$

$$\boxed{VE = 2HE}$$

$$4VA = 8HA + \frac{20 \times 4 \times 4}{2}$$

$$4VA = 8HA + 160 \qquad HA = HE$$

$$\boxed{VA = 2HA + 40}$$

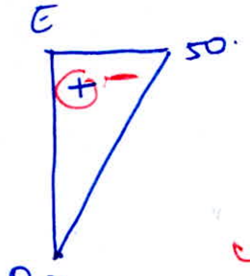
$$2HA + 40 + 2HE = 80$$

$$2(HA + HE) = 40$$

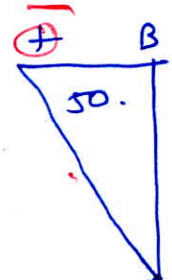
$$2h = 20$$

$$h = 10$$

ED



AD



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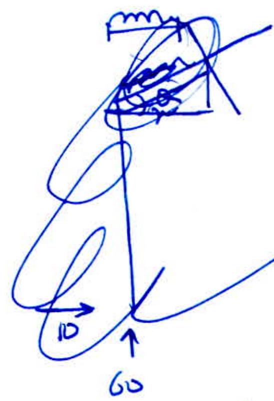
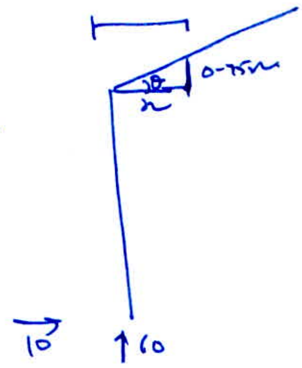
BC



~~$M_x = 60 \times 60 - 10 \; (8 + x \sin\theta) -$~~



$\tan\theta = \frac{3}{4} = \frac{p}{x}$

$M_x = 60(x) - 10\,(5 + 0.75x) - 10x^2$

$= 60x - 50 - 7.5x - 10x^2$

$= -10x^2 + 52.5x - 50$

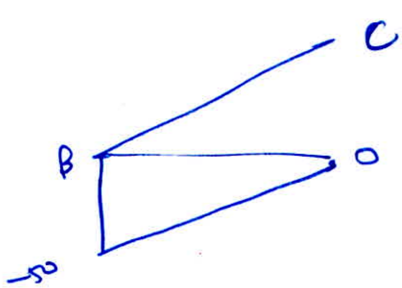
$x = 0 \quad M_x = -50$

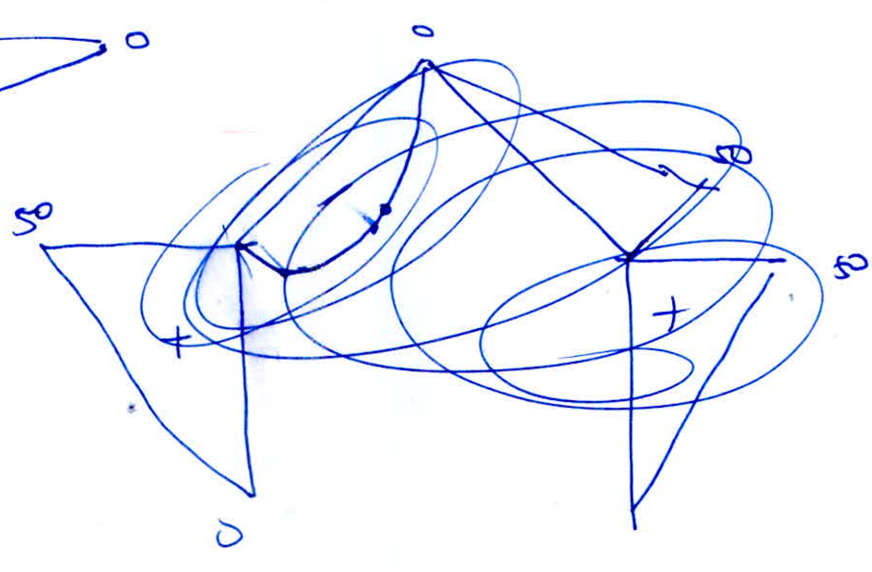
$x = 4 \quad M_x = 0.$

$\frac{dM}{dx} = -20x + 52.5 = 0$

$x = 2.625$

M_x





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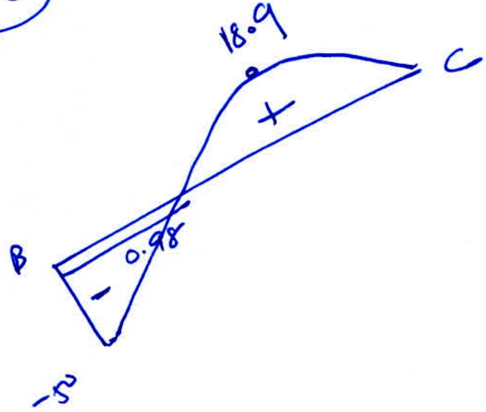
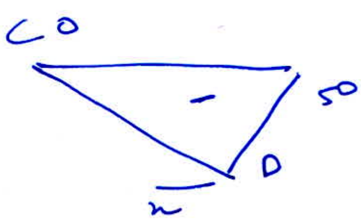
BC



CD

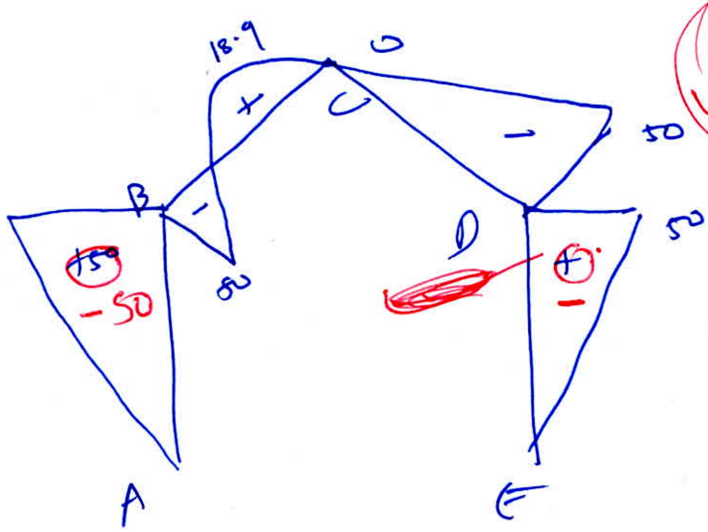


$M_x = 20x - 10(5+x)$

$= 10x - 50$

$x=0 \quad M_x = -50$

$x=4 \quad M_x = 0$



Units

16

Write proper steps.

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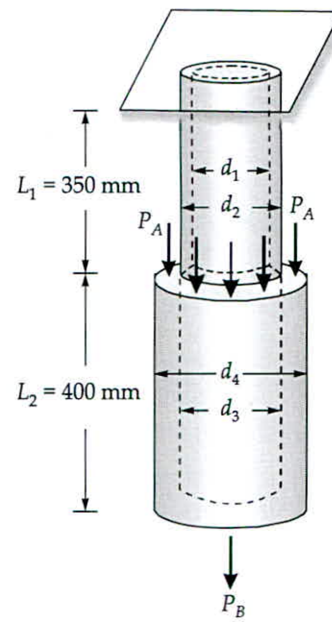
Q.3 (b) A hollow circular nylon pipe as shown in figure supports a load P_A = 7800 N, which is uniformly distributed around a cap plate at the top of lower pipe. A second load P_B is applied at the bottom. The inner and outer diameters of the upper and lower parts of the pipe are d_1 = 51 mm, d_2 = 60 mm, d_3 = 57 mm and d_4 = 63 mm respectively. The upper pipe has a length L_1 = 350 mm and lower pipe has a length L_2 = 400 mm. Neglect the self weight of the pipes.



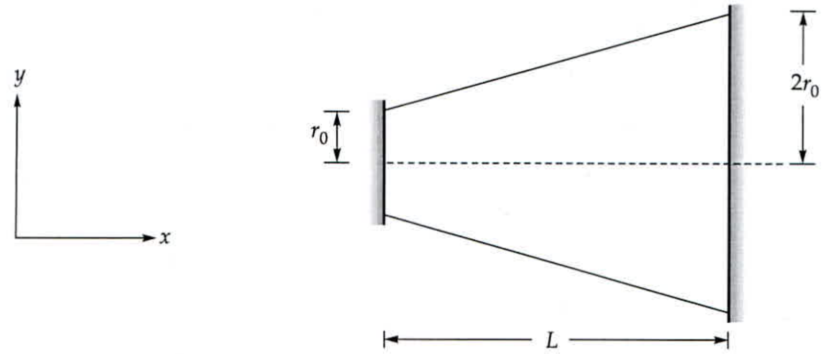
(i) Find P_B so that the tensile stress in the upper pipe is 14.5 MPa. Also determine the resulting stress in lower pipe?

(ii) If P_A remains unchanged, find the new value of P_B so that upper and lower pipes have same tensile stress.

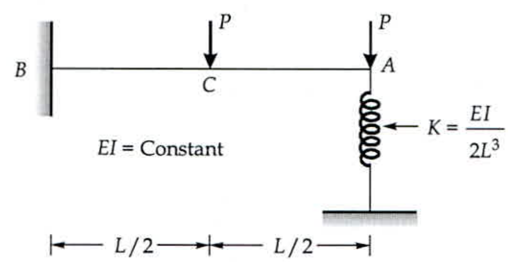
(iii) Find the tensile strains in the upper and lower pipe segments for the loads in part (ii) if the elongation of the upper pipe is 3.56 mm and downward displacement of bottom pipe is 7.63 mm?

[20 marks]

Q.3 (c) **(i)** A bar as shown in figure below is in a shape of a solid, truncated cone of circular cross-section and is situated between two rigid supports. The temperature of the entire bar is then raised by ΔT. Assume that the cross-sections perpendicular to longitudinal axis of symmetry remain plane and neglect localised end effect due to the end supports. Determine the normal stress at any point in the bar.

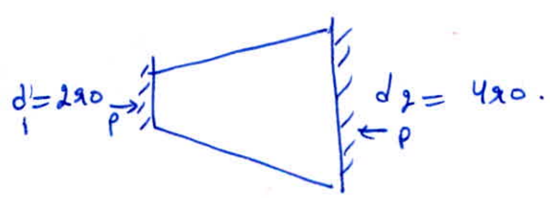


(ii) Determine the bending moment and shear force at support B in the uniform beam AB with flexural rigidity EI shown in the figure. Take spring constant $K = \dfrac{EI}{2L^3}$.



[10 + 10 marks]

(i)



$$\Delta = \frac{4PL}{\pi E d_1 d_2} = \frac{4PL}{\pi E (2r_0)(4r_0)} = \frac{4PL}{8\pi E r_0^2} = \frac{PL}{2\pi E r_0^2}.$$

$$\Delta = L\alpha\Delta T$$

$$\therefore \cancel{L}\alpha\Delta T = \frac{P\cancel{L}}{2\pi E r_0^2}$$

$$\boxed{P = (2\pi E r_0^2)\,\alpha\Delta T}$$

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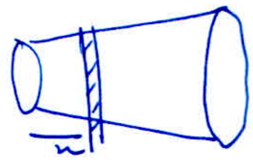
$d = 2r_0$  $d = 4r_0$

$L \rightarrow 2r_0 \uparrow$

$1 \rightarrow \frac{2r_0}{L} \uparrow$

$x \rightarrow \frac{2r_0}{L} x \uparrow$

$$d_x = 2r_0 + \frac{2r_0 x}{L}$$

$$\text{Normal stress at } x = \frac{P}{\frac{\pi}{4} d_x^2}$$

$$= \frac{2\cancel{\pi} E r_0^2 \alpha \Delta T}{\frac{\cancel{\pi}}{4}(2r_0)^2 \left(1+\frac{x}{L}\right)^2}$$

$$= \frac{2E\cancel{r_0^2}\alpha\Delta T}{\cancel{r_0^2}\left(1+\frac{x}{L}\right)^2}$$

Answer

$$\boxed{\sigma_x = 2E\alpha\Delta T\left(1+\frac{x}{L}\right)^{-2}}$$

10

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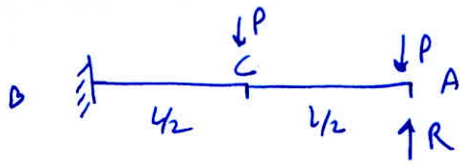
11

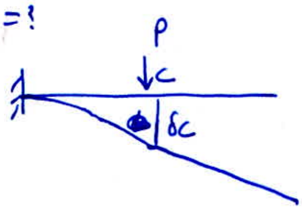


$k = EI/2L^3$

$R = \frac{EI}{2L^3} \cdot \Delta$

$\Delta = \frac{2L^3R}{EI}$

$\delta_A = ?$



$\theta_c = \frac{PL^2}{2EI} = \frac{P\left(\frac{L}{2}\right)^2}{2EI} = \frac{PL^2}{8EI}$

$\delta_c = \frac{P\left(\frac{L}{2}\right)^3}{3EI} = \frac{PL^3}{24EI}$

$\therefore \quad \delta_{A1} = \frac{PL^3}{24EI} + \frac{PL^2}{8EI} \times \frac{L}{2}$

$= \frac{PL^3}{EI}\left(\frac{1}{24} + \frac{1}{16}\right) =$ $\left(\frac{2+3}{48}\right)$

$= \frac{5}{48}\frac{PL^3}{EI}$

$\delta_{A2} = \frac{(P-R)L^3}{3EI}$ | $\cancel{\delta_{A2} = \frac{PL^3}{3EI}}$

$\therefore \frac{(P-R)L^3}{3EI} + \frac{5}{48}\frac{PL^3}{EI} = \frac{2L^3R}{EI}$

$\frac{P-R}{3} + \frac{5}{48}P = 2R$

$\frac{16P - 16R + 5P}{48} = 2R$

$21P - 16R = 96R$

$21P = 112R$

$\boxed{R = \frac{21}{112}P}$

$\therefore V_B = 2P - \frac{21}{112}P$

$\boxed{V_B = +\frac{203}{112}P}$ Ans

$$M_B = -P\left(\frac{L}{2}\right) - P(L) + R(L)$$

$$= -P\left(\frac{3L}{2}\right) + \frac{21}{112}PL$$

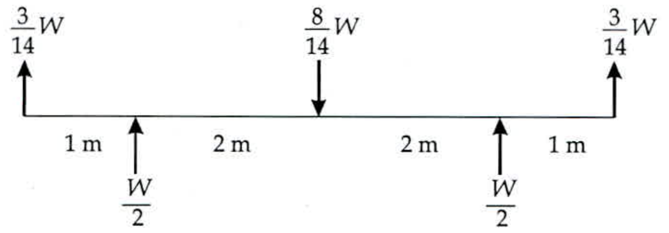
$$= PL\left(\frac{21}{112} - \frac{3}{2}\right)$$

$$= PL\left(\frac{21 - 3\times56}{112}\right)$$

$$\boxed{M_B = \frac{-147}{112}PL}$$

2 + 8 = 10

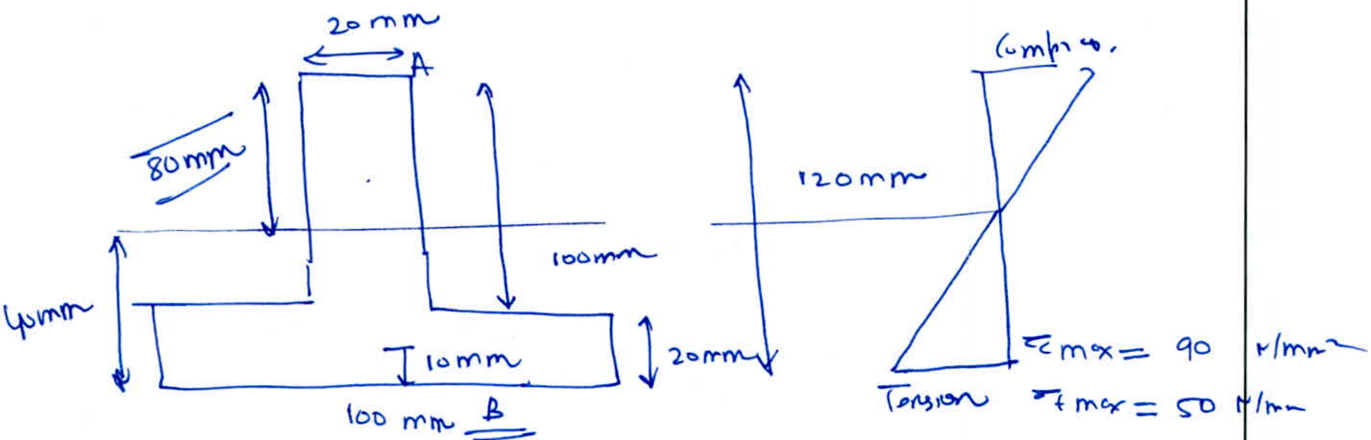
Q.4 (a) **(i)** A beam of T-section 6 m long supports the load system as shown below. The beam has a flange width of 100 mm and an overall depth of 120 mm. The flange and the web are 20 mm thick. The section is placed with flange at the bottom. Find the safe value of W if the stresses in compression and tension shall not exceed 90 N/mm^2 and 50 N/mm^2 respectively.



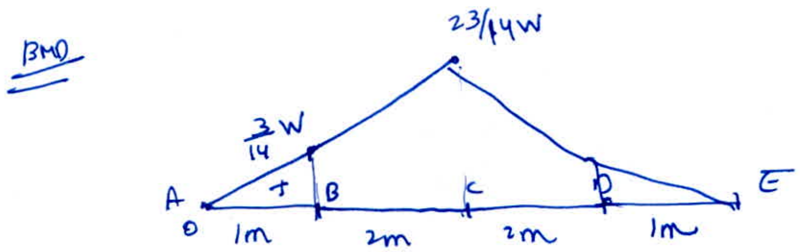
(ii) If a tension test bar is found to taper uniformly from (D – a) diameter to (D + a) diameter, prove that the error involved in using the mean diameter to calculate the Young's modulus is $\left(\frac{10a}{D}\right)^2$ percent.

[10 + 10 marks]

(i)



BMD



$M_B = +\frac{3}{14}W \times 1 = \frac{3}{14}W.$

$M_C = \frac{3}{14}W \times 3 + \frac{W}{2} \times 2 = W + \frac{9}{14}W = \frac{23}{14}W$

$M\ max = \frac{23}{14}W$ kN-m

Let $W =$ W kN

NA $\bar{y} = \frac{20(100)(50) + 20(100)(110)}{(20 \times 100) \times 2} = 80$ mm

$I_{NA} = \frac{20(100)^3}{12} + 20\times100\times(30)^2$

$+ \frac{100(20)^3}{12} + 20\times100\times(30)^2$

$= 5.33\times10^6\ mm^4$

$\delta = \frac{My}{g}$

if $\delta_A = 90\ N/mm^2$ then

$\frac{90}{80} = \frac{\sigma_B}{40}$

$\sigma_B = 45 < 50$ safe

if $\delta_B = 50$ $\quad \frac{x}{80} = \frac{50}{40}$

$x = 100$ (not safe)

$\therefore \delta_A = 90\ N/mm^2$

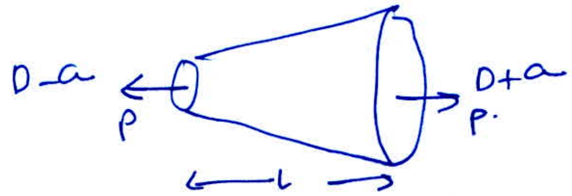
$90 = \frac{\left(\frac{23}{14} W \times \cancel{10^6}\right)\times 80}{5.33\times\cancel{10^6}}$

$90 = \frac{23}{14}\ \frac{W\times80}{5.33}$

$\boxed{W = 3.649\ kN}$

9

11



$\Delta = \frac{PL}{AE}$ $\boxed{\Delta_{actual} = \frac{4PL}{\pi E d_1 d_2}}$

$$E_{actual} = \frac{4PL}{\pi \Delta d_1 d_2} = \frac{4PL}{\pi (\Delta)(D-a)(D+a)}.$$

$$\boxed{E_{actual} = \frac{4PL}{\pi \Delta (D^2-a^2)}} = \frac{k}{D^2-a^2}$$

If D nom used $= \frac{D-a+D+a}{2} = D$

$\Delta = \frac{PL}{\frac{\pi}{4}D^2 E}$ $E' = \frac{4PL}{\pi \Delta D^2} = \frac{k}{D^2}.$

$$\% \text{ error} = \frac{E_{actual} - E'}{E_{actual}} \times 100\%.$$

$$= \frac{\frac{k}{D^2-a^2} - \frac{k}{D^2}}{\frac{k}{D^2-a^2}} \times 100\%.$$

$$= \frac{D^2-(D^2-a^2)}{D^2(\cancel{D^2-a^2})} \times \cancel{D^2-a^2} \times 100\%.$$

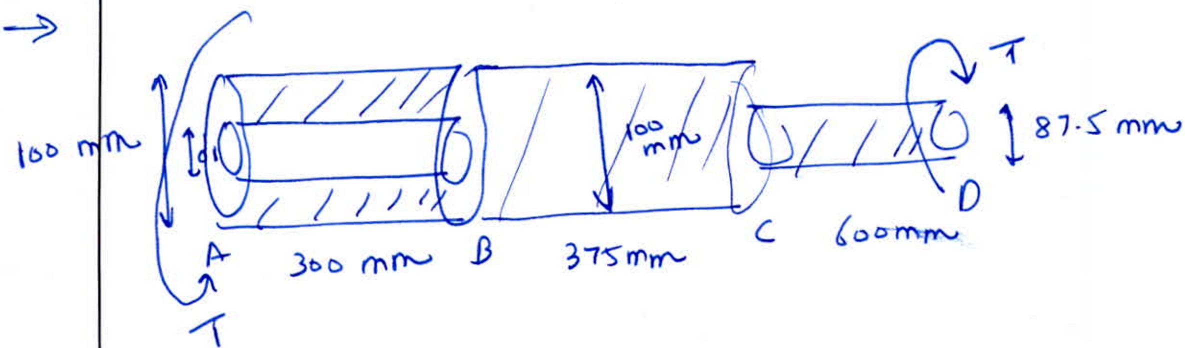
$$= \frac{a^2}{D^2} \times 100\%.$$

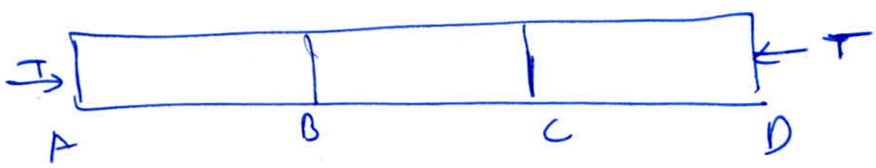
$$= \left(\frac{10a}{D}\right)^2 \%.$$

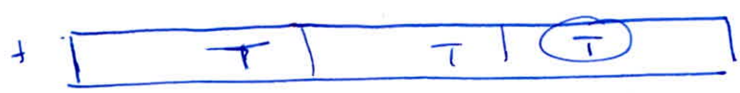
10

Q.4 (b) A steel shaft ABCD has a total length of 1275 mm and is made up as follows: AB = 300 mm, BC = 375 mm and CD = 600 mm. AB is hollow, its outside diameter being 100 mm and inside diameter d_1 mm. BC and CD are solid having diameters of 100 mm and 87.5 mm respectively. If equal and opposite torques are applied at the ends of the shaft, then find the maximum permissible value of d_1 for the maximum shearing stress in AB not to exceed that in CD. If the torque applied to the shaft is 9000 Nm, what is the total angle of twist? Take $G = 8 \times 10^4\ N/mm^2$.

[20 marks]







Let T kNm

τ_{max} in CD = ?

$\frac{T}{J} = \frac{\tau_{max}}{R}$ $\tau_{max\,CD} = \frac{16T}{\pi D^3}$

$$\boxed{\tau_{max\,CD} = \frac{16 \times T \times 10^6}{\pi (87.5)^3}}$$

AB

$$\frac{T \times 10^6}{\frac{\pi}{32}(100^4 - d^4)} = \frac{\tau_{max}}{50}$$

$$\frac{50 \times \cancel{T \times 10^6}}{\frac{\cancel{\pi}}{32}(100^4 - d^4)} = \frac{16 \times \cancel{T \times 10^6}}{\cancel{\pi} \times (87.5)^3}$$

$$\frac{50 \times 32}{100^4 - d^4} = \frac{16}{(87.5)^3}$$

$$100^4 - d^4 = 66992187.5$$

$$\boxed{d = 75.79\ mm}$$ Ans

(1) $T = 9000\ Nm = 9\times10^6\ Nmm$

$G = 8\times10^4\ N/mm^2$

$\theta_{D/C} = \frac{TL}{GJ} = \frac{T}{G}\left(\frac{L_1}{J_1}\right)$

$\theta_{C/B} = \frac{TL_2}{GJ_2}$

$\theta_{B/A} = \frac{T \cdot L_3}{GJ_3}$

$\therefore \theta_{net} = \theta_1 + \theta_2 + \theta_3$

$= \frac{T}{G}\left(\frac{L_1}{J_1} + \frac{L_2}{J_2} + \frac{L_3}{J_3}\right)$

$= \frac{9\times10^6}{8\times10^4}\left[\frac{600}{\frac{\pi}{32}(87.5)^4} + \frac{375}{\frac{\pi}{32}(100)^4} + \frac{300}{\frac{\pi}{32}(100^4 - 75.79^4)}\right]$

$=$

$=$ ~~1.398×10~~

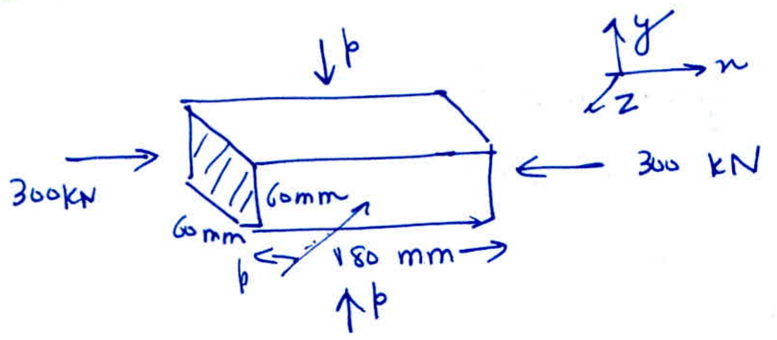
$\boxed{\theta_{net} = 0.02115\ \text{radians}}$

20

Q.4 (c) A steel bar of square section 60 mm × 60 mm and 180 mm long is subjected to an axial compressive load of 300 kN. The lateral strain is prevented by the application of uniform external pressure. If $\mu = 0.3$ and $E = 2 \times 10^5$ N/mm², find the alteration in the length of the bar.

If however, only one-half the lateral strain is prevented then what would be the alteration in the length of bar?

[20 marks]



$\mu = 0.3$
$E = 2 \times 10^5$ N/mm²

$\epsilon_y = 0$

$$\epsilon_y = -\frac{p}{E} + \frac{\sigma_x \cdot \mu}{E} + \frac{\mu p}{E}$$

$$\sigma_x = \frac{300 \times 1000}{60 \times 60} = 83.33 \text{ N/mm}^2$$

$$0 = -p + 0.3(83.33) + \mu p$$

$$p(1-\mu) = 0.3(83.33)$$

$$p = \frac{0.3(83.33)}{0.7} = 35.714 \text{ N/mm}^2$$

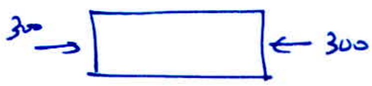
$$\epsilon l = -\frac{83.33}{E} + \frac{0.3(35.714)}{E} + \frac{0.3(35.714)}{E}$$

$$= -\frac{61.9}{E} = -\frac{61.9}{2 \times 10^5}$$

$$\therefore \frac{\Delta L}{180 \text{ mm}} = -\frac{61.9}{2 \times 10^5}$$

$$\boxed{\Delta l = -0.0557 \text{ mm}}$$

Answer

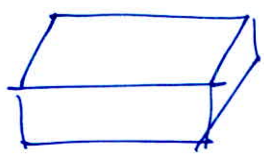
(i)  $\sigma_x = 83.33.$

lateral strain $= \dfrac{\mu\sigma_x}{E} = \dfrac{0.3 \times 83.33}{E}$

$= +1.25 \times 10^{-4}$

Now $\epsilon' = \frac{1}{2} \times 1.25 \times 10^{-4}$

$= +6.25 \times 10^{-5}$



$\epsilon_y = \dfrac{\mu\sigma_x + p(\mu - 1)}{E} = 6.25 \times 10^{-5}$

$0.3 \times 83.33 + p(-0.7) = 12.5$

$p = 17.85$

$\epsilon_l = -\dfrac{83.33}{E} + \dfrac{0.3(17.85)}{E} + \dfrac{0.3(17.85)}{E}$

$\dfrac{\Delta l}{180} = -3.631 \times 10^{-4}$

$\boxed{\Delta l = -0.0653 \text{ mm}}$

Answer

Good 20

Section B : Transportation Engg-1 + Surveying and Geology-1
Geo-technical & Foundation Engg-2 + Environmental Engg-2

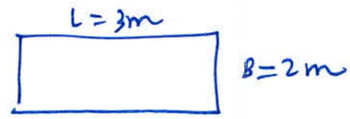
Q.5 (a) A footing 3 m × 2 m in size transmits a pressure of 140 kN/m^2 on a soil having $E = 5 \times 10^4$ kN/m^2 and $\mu = 0.50$. Find the immediate settlement for the footing at the centre. Assuming it to be (i) Flexible footing (ii) Rigid footing
For $L/B = 1.5$, Influence factor = 1.36 for flexible and 1.06 for rigid footing.

[12 marks]

→

① $\boxed{\text{Flexible footing}}$

Given



$q = 140 \text{ kN/m}^2$

$E = 5 \times 10^4 \text{ kN/m}^2$

$\mu = 0.5$

$$S_i = \frac{qB(1-\mu^2)}{E_s} \times I_f$$

$$S_i = \frac{140 \frac{kN}{m^2} \times 2m \, (1-0.5^2)}{5 \times 10^4 \text{ kN/m}^2} \times 1.36$$

$$S_i = 5.712 \times 10^{-3} \text{ m}$$

$$\boxed{S_i = 5.712 \text{ mm}}$$

② $\boxed{\text{Rigid Footing}}$

$$S_i = \frac{qB(1-\mu^2)}{E_s} \times I_f$$

$$S_i = \frac{140 \frac{kN}{m^2} \times 2m \, (1-0.5^2)}{5 \times 10^4} \times 1.06$$

$$= 4.452 \times 10^{-3} \text{ m}$$

$$\boxed{S_i = 4.452 \text{ mm}}$$

12

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Q.5 (b) A column footing of 1.8 m × 1.8 m is to be placed 1.5 m below ground level in a dry cohesionless soil. The unit weight of soil is 21 kN/m^3 and angle of internal friction, $\phi = 36°$. The footing is required to carry a total load of 1350 kN including column load, weight of footing and weight of soil surcharge. Determine the factor of safety against bearing capacity failure assuming:

(i) Ground water table well below the base of footing, and

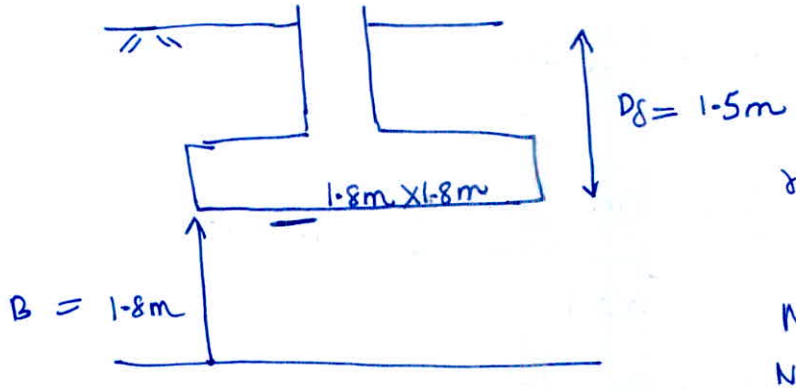
(ii) Ground water table at ground level

Given for $\phi = 36°$, $N_c = 63.53$, $N_q = 47.16$, $N_\gamma = 51.7$

[Assume , $\gamma_{bulk} = \gamma_{saturated} = 21$ kN/m^3]

[12 marks]

→



$\gamma = 21$ kN/m^3

$\phi = 36°$

$N_c = 63.53$

$N_q = 47.16$

$N_\gamma = 51.7$

Given $Q_{safe} = 1350$ kN

To find : (Fos)

(i) GW table well below the base of footing

$$q_{u\,\square} = 1.3\,cN_c + qN_q + 0.4\,B\gamma N_\gamma$$

→ Square
→ General shear failure
→ No WT effect

$$\therefore q_u = \cancel{1.3 \times cN_c}^{\,0} + \gamma D_f N_q + 0.4 B\gamma N_\gamma$$

$$= (21 \times 1.5 \times 47.16) + (0.4 \times 1.8 \times 21 \times 51.7)$$

$$= 2267.244 \text{ kN/m}^2$$

$$q_{safe} = \frac{q_u - \bar{\sigma}_i}{FOS} + \bar{\sigma}_i$$

$$\bar{\sigma}_i = 21(1.5) \text{ kN/m}^2 = 31.5$$

$$q_{safe} = \frac{(2267.244 - 31.5)}{F} + 31.5 = \frac{2235.74}{F} + 31.5$$

$$\left[\frac{2235.74}{F} + 31.5\right] \times (1.8)^2 = 1350 \text{ kN}$$

$$\boxed{FOS = 5.804}$$ Answer

(ii) GW @ Ground level.

$$q_u = \cancel{1.3\,cN_c}^{\,0} + \gamma' D_f N_q + 0.4 B\gamma' N_\gamma$$

$$\gamma' = \gamma_{sat} - \gamma_w = 21 - 9.81 = 11.19 \text{ kN/m}^3$$

$$q_u = (11.19 \times 1.5 \times 47.16) + (0.4 \times 1.8 \times 11.19 \times 51.7)$$

$$= 1208.11 \text{ kN/m}^2$$

$$q_{safe} = \frac{q_u - \bar{\sigma}_i}{F} + \bar{\sigma}_i$$

$$\bar{\sigma}_i = \gamma_{sat} D_f - \gamma_w D_f = \gamma' D_f = 11.19 \times 1.5 = 16.785$$

$$q_{safe} = \frac{1208.11 - 16.785}{F} + 16.785$$

$$= \frac{1191.325}{F} + 16.785$$

$$q_{safe} \times B^2 = Q_{safe}$$

$$\left[\frac{1191.325}{F} + 16.785\right]\left[1.8^2\right] = 1350$$

$$\boxed{FOS = 2.979}$$ Answer

12

Q.5 (c) **(i)** Define the processes involved in MBBR (Moving Bed Biofilm Reactor) used for secondary wastewater treatment?

(ii) One hundred cubic meters per day (100 m^3/d) of mixed sludge at 4 percent solids is to be thickened to 8.0 percent solids. What is the approximate volume of the sludge after thickening and also comment on the result?

[6 + 6 marks]

(ii)

$V_1 = 100\ m^3/d$ [Volume of sludge]

solids = 4%

4 kg solids + 96 kg water = 100 kg sludge.

4 kg solids ≡ 100 kg sludge

1 kg sludge ≡ $\frac{4}{100}$ kg solids.

$\frac{kg}{m^3}$ $\rho_{sludge} = \frac{m}{100\ m^3/d}$ mass of sludge = 100ρ kg/d

$\therefore$ mass of solids $= \frac{4}{100} \times 100\rho$ kg/d

$= 4\rho$ kg/day

After sludge thickening, mass of solids remain same

8 kg solids + 92 kg water = 100 kg sludge

8 kg solid ≡ 100 kg sludge

1 kg solid ≡ $\frac{100}{8}$ kg sludge

$\therefore$ 4 S $\frac{kg}{d}$ solid ≡ $\frac{100}{8} \times 4$ S kg/d sludge.

= 50 S ~~kg~~/d sludge

$\rho_{sludge} = S = \frac{m}{V}$

$S = \frac{50\ S\ kg/d}{V}$

$\boxed{\therefore \text{ Volume of sludge} = 50\ m3/d}$

$\therefore$ Sludge volume after thickening = 50 m3/d.

Comment : volume of sludge decrease after sludge thickening by reduction in water content at same solid content. It is done to ease the handling of sludge in subsequent sludge digestion.

6

Q.5 (d) A 4-lane National Highway is passing through a built up area. Design the following geometric features for a horizontal circular curve of radius 350 m for this highway considering design speed as 80 kmph and the length of wheel base of largest truck as 6.0 m:

(i) Superelevation

(ii) Length of transition curve

Also suggest the most suitable shape of curve.

[12 marks]

→ Given
- NH
- $n = 4$ lane
- Built up area $\boxed{(N=100)}$
- $R = 350$ m
- $V_d = 80$ km/hr
- $l = 6$m.

(i) $$e = \frac{V_d^2}{225R} = \frac{(80)^2}{225 \times 350}$$

$$= 8.1269\%$$

$e_{min} < e < e_{max}$

$e_{max} = 7\%$ for Built up area.

$8.1269\ (e) > e_{max}$.

$\therefore$ Restrict $\boxed{e_{max} = e = 7\%}$

Check

$$e + f = \frac{V^2}{127R}$$

$$0.07 + f = \frac{80^2}{127R} = \frac{80^2}{127 \times 350}$$

$$f = 0.0739 \ (< f_{max} = 0.15)$$

$\therefore$ ok

Provide $\boxed{e = 7\%}$

(ii) Length of Transition curve.

(1) $L = \frac{V^3}{RC}$ (Based on rate of change of Centrifugal acceleration)

$$C = \frac{80}{75 + V\ (km/hr)} = \frac{80}{75+80} = 0.516 \in [0.5 - 0.8].$$

$$\therefore L = \frac{\left(\frac{80 \times 5}{18}\right)^3}{350 \times 0.516} = \boxed{60.76\ mm}$$

(2.) Based on rate of change of superelevation.

$\boxed{\text{Assuming Centre line rotation.}}$

$$L = \frac{eN\ (W + W_e)}{2.}$$

$$W_e = \frac{nl^2}{2R} + \frac{V\ (km/h)}{9.5\sqrt{R}} = \frac{4(6)^2}{2(350)} + \frac{80}{9.5\sqrt{350}}$$

$$W_e = 0.655\ m$$

$N = 100$ for Built up area $\qquad W = 4 \times 3.5\ m = 14\ m$

$L = \frac{0.07 \times 100 \, [14.655]}{2}$ $\boxed{L = 51.29 \text{ m}}$

(iii) empirical.

$L = \frac{2.7 v^2}{R} = \frac{2.7 \times 80^2}{350} = \boxed{49.37 \text{ m}}$

$\therefore$ length = Max of [60.76, 51.29, 49.37)

$\boxed{\therefore \text{ length of Transition curve} = 60.76 \text{ m}}$

Most suitable shape of Transition curve is SPIRAL.

12

Q.5 (e) A railway embankment, 500 m long, has a width at formation level of 9 m with side slopes of 2 to 1. The ground levels at every 100 m distance along the centreline are as follows:

Distance, (m)	0	100	200	300	400	500
Ground level, (m)	107.8	106.3	110.5	111.0	110.7	112.2

The embankment has a rising gradient of 1.2 m per 100 m and the formation level is 110.5 m at zero chainage. Assume the ground to be level across the centerline, compute the volume of earthwork using trapezoidal method.

[12 marks]

Q.6 (a) **(i)** For a railway track 7 m high embankment is required. The clay to be used for the embankment was found to have $c = 20$ kN/m^2 and unit weight = 19 kN/m^3. Compute the critical maximum side slope angle for the embankment if a hard rocky stratum was found 3.5 m below the ground level. Assume ϕ for the clay equal to zero. The following values are given from Taylor's chart for depth factor D = 1.5 :

S_n	0.181	0.174	0.164	0.150
β	53°	45°	30°	20°

(ii) Using Terzaghi's method, determine the ultimate bearing capacity of a square footing of size 1.5 m with its base at a depth of 1 m below the ground level, resting on a dry sand stratum.

Take $\gamma_d = 17$ kN/m^3, $\phi' = 38°$, $c' = 0$, $N_q = 60$, $N_\gamma = 75$.

[10 + 10 marks]

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Q.6 (b) Consider the following data for a completely mixed activated sludge system to treat wastewater from a community of 60000 persons:

Sewage flow, Q = 9000 m^3/day

BOD_5 = 360 mg/l (raw)

Assume 30% BOD removal in primary settling and 90% in biological treatment.

Winter temperature of mixed liquor = 10°C

Yield, $y = 0.6$

$k_d = 0.07$/day (BOD$_5$ basis at 15°C)

MLSS = 4000 mg/l, $\frac{VSS}{SS} = 0.8$

Adopt sludge age (θ_c) = 10 days

Determine F/M ratio and oxygen requirement uptake per day for this completely mixed activated sludge system.

[20 marks]

Q.6 (c) **(i)** What are the advantages of photogrammetric techniques in highway location and design? What are the various objectives of highway planning?

(ii) Following five alternate road plan development proposals with particulars as mentioned below are available:

Proposal	Number of towns and villages served along with population range					Total industrial products in thousand tonnes
	<2000	2001-5000	5001-10000	10001-20000	> 20000	
A	80	10	25	5	1	60
B	115	120	30	10	2	370
C	340	230	25	20	4	350
D	150	200	100	35	6	750
E	200	90	70	60	3	500

If the total road length of proposals A, B, C, D and E are respectively 200 km, 380 km, 605 km, 700 km and 400 km, calculate the utility rate per unit length of each road proposal and indicate the priority based on saturation system. Assume the utility units as follows:

For population :

Range		Unit
< 2000	:	0.25
2001 to 5000	:	0.50
5001 to 10000	:	1.00
10001 to 20000	:	2.00
> 20000	:	3.00

For products :

One unit for 1000 tonnes.

[8 + 12 marks]

Q.7 (a) **(i)** What are conditions which necessitate taking up of a realignment project of a highway? Discuss the general principles in the realignment of a highway and explain how the work is carried out.

(ii) Determine the extra width required for a road of carriageway 7.5 m on a horizontal curve of radius 300 m. The longest wheel base of vehicle using the road may be taken as 6.1 m. Design speed is 80 km/hr.

[16 + 4 marks]

Q.7 (b) Design a septic tank with the following data :

(i) Number of users = 200

(ii) Rate of water supply = 150 l/head/day

(iii) Detention period = 18 hours

(iv) Percolating capacity of filter media of soak well = 1250 litres/m^3

(v) Rate of sludge accumulation = 40 litres/person/year

Also find the diameter of soak well. Assume reasonable data, if required.

[20 marks]

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Q.7 (c) Two sets of tacheometric readings were taken from an instrument station A (RL of A = 100 m) to a staff station B as shown below.

Instruments	P	Q
Multiplying constant	100	95
Additive constant	0.30	0.45
Height of instrument	1.40 m	1.45 m
Staff held	Vertical	Normal

Instruments	Instruments station	Staff station	Vertical angle	Stadia readings
P	A	B	5°44′	1.090, 1.440, 1.795
Q	A	B	5°44′	?

Determine:

(i) The distance between instrument station and staff station.

(ii) The R.L. of staff station B.

(iii) Stadia readings with instrument Q.

[20 marks]

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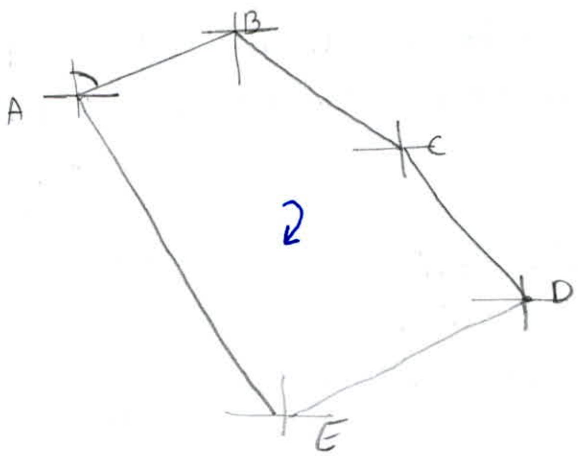
Q.8 (a) The following whole circle bearings were observed in running a closed traverse:

Line	F.B.	B.B.
AB	71°05′	250°20′
BC	110°20′	292°35′
CD	161°35′	341°45′
DE	220°50′	40°05′
EA	300°50′	121°10′

Determine the correct magnetic bearings of the lines.

[20 marks]



① check for observation errors

$\angle A = AE - AB = 121°10' - 71°05' = 50°5'$

$\angle B = BA - BC = 250°20' - 110°20' = 140°$

$\angle C = CB - CD = 292°35' - 161°35' = 131°$

$\angle D = DC - DE = 341°45' - 220°50' = 120°55'$

$\angle E = ED - EA = (40°05' - 300°50') + 360° = 99°15'$

$\Sigma = 541°15'$

error $= 1°15'$
$= 75'$

$\therefore$ correct angles $\angle A = 50°5' - 15' = 49°50'$

$\angle B = 140° - 15' = 139°45'$

$\angle C = 131° - 15' = 130°45'$

$\angle D = 120°55' - 15' = 120°40'$

$\angle E = 99°15' - 15' = 99°$

$537° + 3 = 540°$

$400°5'$
$- 300°50'$
=

(2.)

	$\lvert FB - BB \rvert$		errors = 180 − Δ
AB	250° 20′ − 71° 05′	= 179° 15′	45′
BC	292° 35′ − 110° 20′	= 182° 15′	2° 15′
CD	341° 45′ − 161° 35′	= 180° 10′	10′
DE	220° 50′ − 40° 05′	= 180° 45′	45′
EA	300° 50′ − 121° 10′	= 179° 40′	20′

∴ CD has least error ∴ Distribute half - half

Correct Bearing of DC = 341° 45′ − 5′ = 341° 40′

" " " CD = 161° 35′ + 5′ = 161° 40′

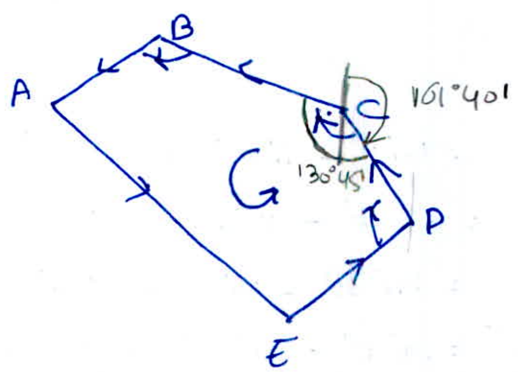
180

(3)

Correct Bearing of DC = 341° 40′

" " " CD = 161° 40′

& using corrected angles in step 1



$\angle A = 49° 50'$
$\angle B = 139° 45'$
$\angle C = 130° 45'$
$\angle D = 120° 40'$
$\angle E = 99°$

FB of CB = FB of CD + ∠C = 161° 40′ + 130° 45′

FB. $\boxed{CB = 292° 25'}$

FB of BA = FB CB + ∠B ± 180

= 292° 25′ + 139° 45′ − 180°

= 251° 70′ = 252° 10′

$\boxed{BA = 252° 10'}$

FB of AE = (FB) BA + ∠A ± 180

= 252° 10′ + 49° 50′ − 180

$\boxed{AE = 122°}$

$FB_{ED} = FB_{AE} + \angle E \pm 180^\circ$

$= 122^\circ + 99 - 180$

$\boxed{ED = 41^\circ}$

$FB_{DC} = FB_{ED} + \angle D \pm 180$

$= 41^\circ + 120^\circ 40' + 180^\circ$

$\boxed{= 341^\circ 40'}$

Answers

$\therefore$ Correct Bearings are.

	FB	BB
AB	72° 10'	252° 10'
BC	112° 25'	292° 25'
CD	161° 40'	341° 40'
DE	221°	41°
EA	302°	122°

Good! 20

Q.8 (b) **(i)** What are the desirable characteristics of grouting material in soils? List some of grouting methods adopted in practice.

(ii) A square pile group of 16 piles penetrates through a filled up soil of 3 m depth. The pile diameter is 250 mm and pile spacing is 0.75 m. The unit cohesion of the material is 18 kN/m^2 and the unit weight of soil is 15 kN/m^3. Draw plan and sectional elevation of the pile group and compute the negative skin friction on the group. [Take α = 0.7]

[6 + 14 marks]

→ Properties

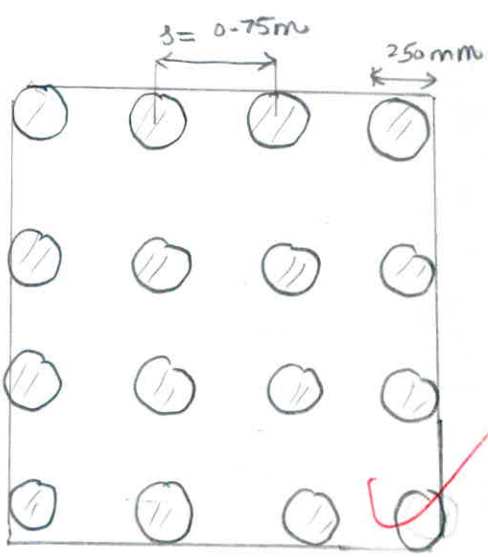
(1) Grouting material must posses sufficient strength.
(2) It should have binding properties.
(3) It should be impermeable.
(4) It should be resistant to attack of pests, insects etc.
(5) It should be water proof.
(6) It should be durable & stable.

Methods

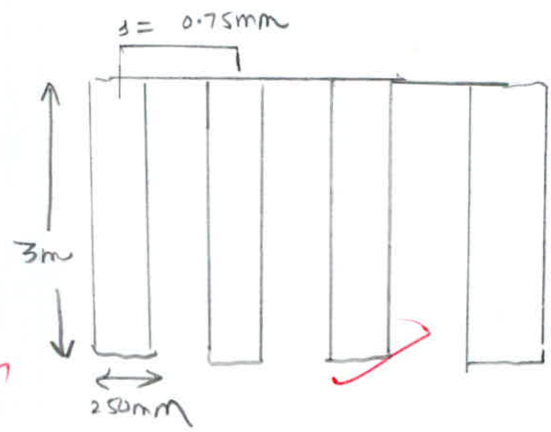
(1) Cement Grouting
(2) Sand + Mortar Grouting
(3) Lime Grouting.

3

(ii)



PLAN



SECTIONAL ELEVATION.

ii)

Given $c = 18\ kN/m^2$ $\alpha = 0.7$

$\gamma = 15\ kN/m^3$.

Negative Skin friction on group:

① Negative skin friction on individual pile

$= \alpha \bar{c} A_s$

$= \alpha \bar{c}\ \pi d l = 0.7 \times 18 \times \pi(0.250) \times 3$

$Q_{nsf} = 29.688\ kN/m^2$

∴ for 16 piles Negative skin friction

$= 16\ Q_{nsf}$

$= 16 \times 29.688$

$= \boxed{475.008\ kN}$

② In Group Action

$Q_{nsfg} = 1 \times \bar{c} \times 4BL$ + weight of soil in negative zone $= (B^2 L \gamma)$

$B = 3s + d$

$= 3(0.75\ m) + 0.250 = 2.5m$

$Q_{nsfg} = 1 \times 18 \times 4 \times 2.5 \times 3 + 15 \times (2.5)^2 \times 3$

$= \boxed{821.25\ kN}$

∴ Negative skin friction = Maximum of [821.25, 475.008]

$= \boxed{821.25\ kN}$ Answer

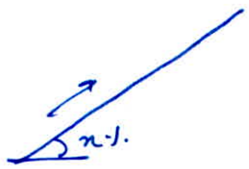
14

Q.8 (c) **(i)** The driver of a vehicle requires 15 m less to stop after he applies the brakes while travelling up a grade than a driver travelling at the same initial speed down the same grade. Consider the coefficient of friction between tyres and pavement as 0.35 and initial speed to be 90 kmph. What is the percent grade?

(ii) Compute the moisture deficit in a landfill for each each cubic meter of waste if the parameters are :
Density of waste at time of deposit = 800 kg/m^3.
Field capacity = 60% by weight.
Water content of waste being deposited = 30% by weight.
Also discuss the result.

[10 + 10 marks]

(i)

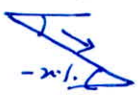


Given $f = 0.35$

$v = 90$ km/hr. $= 25$ m/s

$L_1 =$ braking distance

$$L_1 = \frac{v^2}{2g(f + x\%)} = \frac{25^2}{2g(0.35 + x)}$$



$$L_2 = \frac{v^2}{2g(f - x\%)} = \frac{25^2}{2g(0.35 - x)}$$

$L_2 - L_1 = 15$ m

$$\frac{25^2}{2g}\left(\frac{1}{0.35-x} - \frac{1}{0.35+x}\right) = 15$$

$$\frac{(0.35+x) - (0.35-x)}{0.35^2 - x^2} = 0.47088$$

$$2x = 0.47088(0.35^2 - x^2)$$

$$= 0.05768 - 0.47088x^2$$

$$0.47088x^2 + 2x - 0.05768 = 0$$

$$x = 0.0286$$

$\therefore$ percent grade $= 2.86\%$

84.17
99.11

10

1f)

$V = 1 m^3$

$\rho = 800 \, kg/m^3$.

$mass = 800 \, kg$

$\rho = \frac{m}{V}$

FC = 60% of weight

$w = 60\%$.

~~water content = 60% of weight~~
~~= 0.60 × 800 kg~~

$\frac{w_w}{w_s} = 0.6$ $\quad w_w = 0.6 w_s$.

$w_w + w_s = 800$

$1.6 w_s = 800$

$w_s = \frac{800}{1.6} \, kg = 500 \, kg$

$\therefore \; w_w = 0.6 \times 500$

$\boxed{w_w = 300 \, kg}$ ✗

$w' = 30\%$.

$\frac{w_w}{w_s} = 0.30$

$w_w = 0.30 \, w_s$

$w_s = 500 \, kg$

$w_w = 0.3 (500)$

$\boxed{w_w = 150 \, kg}$ ✗

Wrong approach.

$\therefore$ Moisture deficit = 300 kg − 150 kg
= 150 kg ✗

1

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OOOO

Space for Rough Work

Space for Rough Work