UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2022/2023

COURSE NAME	:	ADVANCED FOUNDATION ENGINEERING
COURSE CODE	:	BFG 40103
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	FEBRUARY 2023
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER ALL QUESTIONS 2. THE FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK**. 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK.

THIS QUESTION PAPER CONSISTS OF **THIRTEEN (13)** PAGES

Q1 (a) Properly designed shallow foundations will transfer the loads from the super structure through the sub structure of the foundation. A wrong design can result in shear failure or undesirably excessive structural settlements. Explain in detail the difference on the type of soil and the conditions of the structure wether it is suitable to contruct shallow foundation or mat foundation.

(5 marks)

(b) A square footing is used under a three storey building with a size of 1.5m x 1.5m. The soil condition has an undraided shear strength (c_u) of 200kN/m^2, with an OCR of 2 and plasticity index (PI) of 45. With the depth of the foundation at 2 meter below the ground level, the load per unit area (q_o) of the foundation is 150 kN/m^2. By estimating the elastic settlement of the foundation, determine if that value is acceptable.

(10 marks)

(c) A mat foundation with a structure load of 300kN/m^2 and a size of 5.0m x 4.0m is designed to be safe against excessive settlement. The depth of this mat foundation is at 1.5 m from the ground surface, where the top layer of the soil is a 4 m thick of sandy gravel that has unit weight of 20.0 kN/m^3. A 10 m thick of clay layer with unit weight of 18.0 kN/m^3 underlies this sandy gravel layer followed by a bed rock underneath. Water table is exactly at the top layer of the clay. The initial void ratio of clay layer is (e) 1.27, the compression index, (C_c) is 0.69, secondary compression index, C_α is 0.02 and void ratio at the end of the primary consolidation is 0.67 and the preconsolidation pressure (σ_c) is 120kN/m^2. Measure the consolidation settlement of the clay layer for 10 years time if time for completion of primary consolidation settlement is 1.7 years, assuming that the clay layer is normally consolidated.

(10 marks)

Q2 (a) Piles are manufactured with different materials such as steel, concrete and wood that are used for different soil conditions. Concrete piles are the most used piles for foundation consruction. Explain in great detail with sketches the difference between precast and cast-in-situ bored concrete piles in terms of its construction method.

(9 marks)

(b) A site investigation report is prepared for a construction of a high-rise building as given in **Table Q2 (b)**. With that, the construction uses a 25-meter-long concrete pile with a cross section of 0.4 m x 0.4 m that is fully embedded in a non-homogeneous soil that has a combination of sand and clay layers. Proposed the allowable load (Q_{all}) that the pile are able to hold by considering the soil resistance in all layers in that specific soil condition. Use a factor of safety (FS) of 3. (Note: use the α method for the skin friction in clay)

(16 marks)

Q3 (a) Explain clearly the possible advantages and disadvantages of using ordinary gravity wall as compared to cantilever retaining wall.

(5 marks)

(b) State the lateral earth pressure theories available and discuss in detail the major differences between the two theories.

(5 marks)

(c) A deep excavation work is done to construct a basement of a building. In order to manage this, a 17 m deep braced excavation in clay was designed as shown in **Figure Q3(c).** The unit weight (γ) and cohesion (c) of the soil are 17.5 kN/m^3 and 35 kN/m^2 respectively. The center-to-center spacing of struts in the plan is 10 m and the allowable flexural stress of the sheet pile material, σ_{all} is 200 X 10^3 kN/m^2.

(i) Examine the earth pressure envelope.

(4 marks)

(ii) Analyze the loads in the struts A, B and C.

(7 marks)

(iii) Design the section modulus, *S* of the sheet pile section required.

(4 marks)

Q4 (a) Construction of foundations on difficult soils, frequently will cost a lot due to repair and maintain a structure so it is safe and usable for the public. **Figure Q4(a)** show the settlement occurs on the embankment ramp leading to a bridge resulting to an uneven roadway. This is due to the nature of clay soil that has high compressibility characteristics where settlement occurs exsesively on the embankment as compared to the bridge which are built on piles. Propose **TWO (2)** suitable methods with clear explanation on the construction process in order to solve this problem in improving the condition of the roadway.

(10 marks)

(b) Identify the type or the condition of structures that require pile foundation to resist uplifting forces.

(4 marks)

(c) Negative skin friction on piles exist in certain type of soil conditions. Considering a fill of sand materials with thickness (H_f) of 3 m and a unit weight (γ_f) of 15 kN/m^3 is layed out on top of soft clay soil. The clay has soil properties with friction angle (ϕ) of 30° and saturated unit weight (γ_{sat}) of 18 kN/m^3. The water table coincides with the top of the clay layer. The pile used has a length of 15 m with a diameter of 0.5 m. Assume that $\delta' = 0.6\phi$. Design the negative skin friction on the pile.

(11 marks)

- END OF QUESTIONS -

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Table Q2(b): Site investigation soil information

Depth (m)	Length of each layer (m)	Soil parameters given	Soil Description
0 – 2	2	Cone penetration frictional resistance (f_c) = 73 (kN/m^2)	Sand
2 – 6	4	Cone penetration frictional resistance (f_c) = 122 (kN/m^2)	Sandy soil
6 - 13	8	Cone penetration frictional resistance (f_c) = 254 (kN/m^2)	Sandy gravel
13 – 17	5	c_u = 25, γ = 16 kN/m^3	Silty clay
17 - 24	7	c_u = 40, γ = 17 kN/m^3	Clay
24 - 28	4	c_u = 90, γ = 18 kN/m^3	Hard Clay

Table 1: Variation of α

$\frac{c_u}{p_a}$	α
≤ 0.1	1.00
0.2	0.92
0.3	0.82
0.4	0.74
0.6	0.62
0.8	0.54
1.0	0.48
1.2	0.42
1.4	0.40
1.6	0.38
1.8	0.36
2.0	0.35
2.4	0.34
2.8	0.34

Note: p_a = atmospheric pressure ≈ 100 kN/m^2

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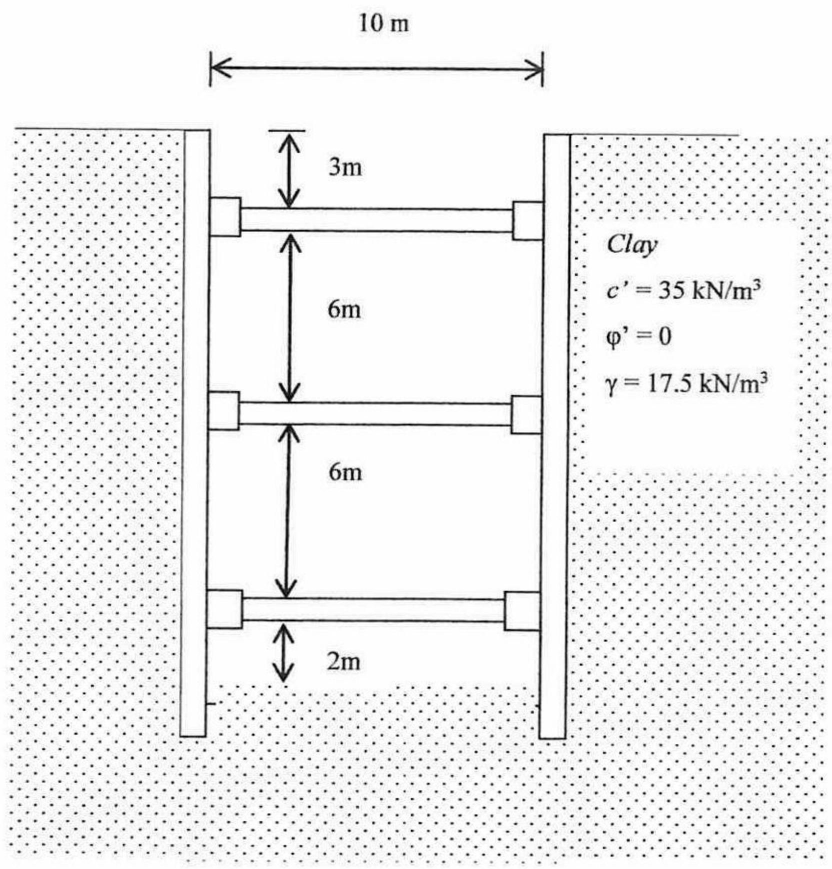

FIGURE Q3(c) : Braced cut

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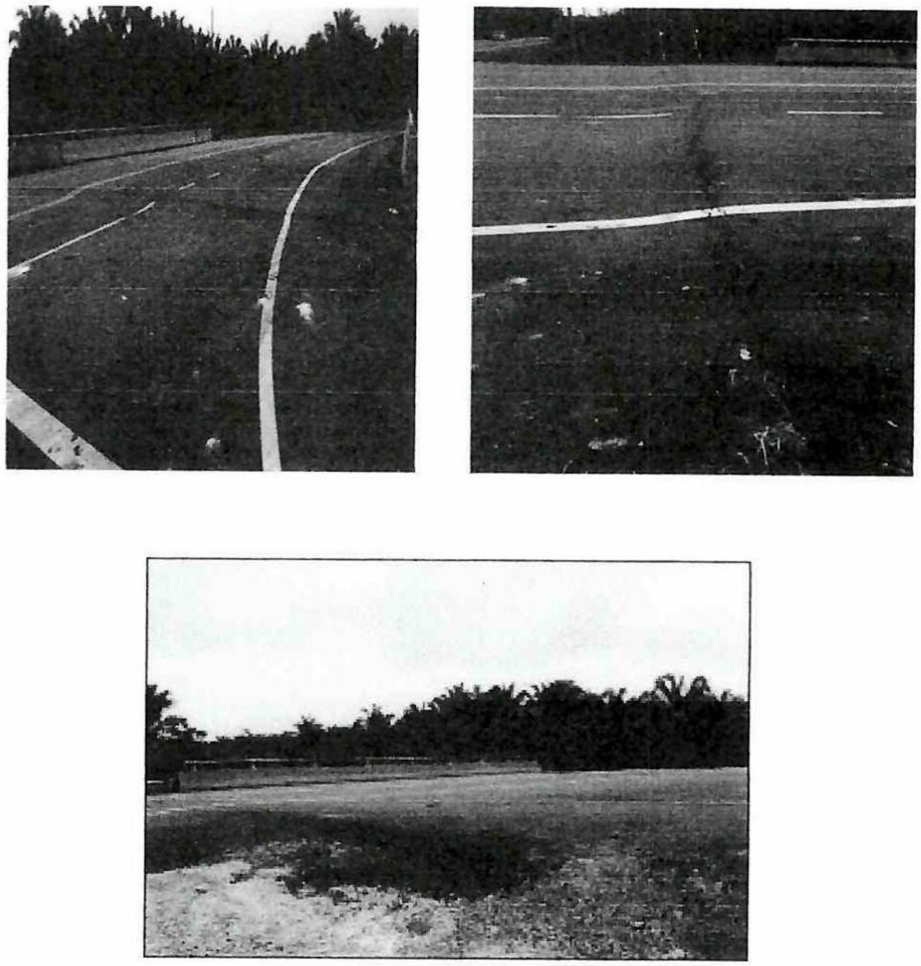

Figure Q4(a) : Settlement on the embankment ramp

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Factor of safety

$$q_{all} = \frac{q_u}{FS} \qquad q_{all(\text{net})} = \frac{q_u - \gamma D_f}{FS}$$

$$\overline{q} = D_1\gamma + D_2(\gamma_2 - \gamma_w) \qquad \overline{q} = \gamma D_f$$

$$\overline{\gamma} = \gamma' + \frac{d}{B}(\gamma - \gamma')$$

Meyerhof's general bearing capacity

$$q_u = c'N_c F_{cs} F_{cd} F_{ci} + \overline{q} N_q F_{qs} F_{qd} F_{qi} + \tfrac{1}{2}\overline{\gamma} B N_\gamma F_{\gamma s} F_{\gamma d} F_{\gamma i}$$

$$F_{cs} = 1 + \frac{B}{L}\cdot\frac{N_q}{N_c} \qquad F_{qs} = 1 + \frac{B}{L}\tan\phi' \qquad F_{\gamma s} = 1 - 0.4\left(\frac{B}{L}\right)$$

$$F_{ci} = F_{qi} = \left(1 - \frac{\beta°}{90°}\right)^2 \quad F_{\gamma i} = \left(1 - \frac{\beta}{\phi'}\right)^2$$

$$\frac{D_f}{B} \le 1 : \phi' = 0°$$

$$F_{cd} = 1 + 0.4\left(\frac{D_f}{B}\right) \qquad F_{qd} = 1 \qquad F_{\gamma d} = 1$$

$$\frac{D_f}{B} \le 1 : \phi' > 0°$$

$$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c \tan\phi'} \quad F_{qd} = 1 + 2\tan\phi'(1 - \sin\phi')^2 \frac{D_f}{B} \qquad F_{\gamma d} = 1$$

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Meyerhof's general bearing capacity

$$\frac{D_f}{B} > 1 : \phi' = 0^\circ$$

$$F_{cd} = 1 + 0.4\tan^{-1}\left(\frac{D_f}{B}\right) \qquad F_{qd} = 1 \qquad F_{\gamma d} = 1$$

$$\frac{D_f}{B} > 1 : \phi' > 0^\circ$$

$$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c \tan\phi'} \qquad F_{qd} = 1 + 2\tan\emptyset'(1 - \sin\emptyset')^2 \tan^{-1}\left(\frac{D_f}{B}\right) \qquad F_{\gamma d} = 1$$

One way eccentricity

$$B' = B - 2e \;\; \& \;\; L' = L \qquad L' = L - 2e \;\; \& \;\; B' = B$$

Elastic settlement for shallow foundations

$$S_e = A_1 A_2 \frac{q_o B}{E_s}$$

$$E_s = \beta c_u$$

Primary consolidation settlement for shallow and pile foundations

normally consolidated clays

$$S_c = \frac{C_c H_c}{1 + e_o} \log \frac{\sigma'_o + \Delta\sigma'_{av}}{\sigma'_o}$$

Over consolidated clays

$$\sigma'_o + \Delta\sigma'_{av} < \sigma'_c : S_c = \frac{C_s H_c}{1 + e_o} \log \frac{\sigma'_o + \Delta\sigma'_{av}}{\sigma'_o}$$

$$\sigma'_o < \sigma'_c < \sigma'_o + \Delta\sigma'_{av} : S_c = \frac{C_s H_c}{1 + e_o} \log \frac{\sigma'_c}{\sigma'_o} + \frac{C_c H_c}{1 + e_o} \log \frac{\sigma'_o + \Delta\sigma'_{av}}{\sigma'_c}$$

average increase in pressure

$$\Delta\sigma'_{av} = \tfrac{1}{6}(\Delta\sigma'_{\text{top}} + 4\Delta\sigma'_{\text{middle}} + \Delta\sigma'_{\text{bottom}}) \qquad \Delta\sigma'_o = q_o I_c$$

$$m_1 = L / B \qquad n_1 = z / (B/2)$$

Site investigations

$$A_R = \frac{D_2^2 - D_1^2}{D_1^2} \times 100\% \qquad R_R = RQD = \frac{L_{\text{recovered}}}{L_{\text{total}}} \times 100\%$$

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Mat foundations

$$q_{net} = \frac{N_{60}}{0.08}\left[1 + 0.33\left(\frac{D_f}{B}\right)\right]\left[\frac{S_e}{25}\right] \leq 16.63N_{60}\left[\frac{S_e}{25}\right]$$

$$q = \frac{Q}{A} \pm \frac{M_y x}{I_y} \pm \frac{M_x y}{I_x}$$

$$I_x = \left(\frac{1}{12}\right)BL^3$$

$$I_y = \left(\frac{1}{12}\right)LB^3$$

$$M_x = Qe_y$$

$$M_y = Qe_x$$

$$x^i = \frac{Q_1x_1' + Q_2x_2' + Q_3x_3' + ..}{Q}$$

$$e_x = x' - \frac{B}{2}$$

$$y^i = \frac{Q_1y_1' + Q_2y_2' + Q_3y_3' + ..}{Q}$$

$$e_y = y' - \frac{B}{2}$$

Pile Foundation

Point Bearing

Meyerhof

Sand $Q_p = A_p q' N_q^* \leq A_p q_l$

$q_l = 0.5 p_a N_q^* \tan\phi'$

Clay $Q_p = 9c_u A_p$

Vesic

Sand $Q_p = A_p q_p = A_p \bar{\sigma}_o' N_\sigma^*$

Clay $Q_p = A_p q_p = A_p c_u N_c^*$

Coyle and Castello

Sand $Q_p = q' N_q^* A_p$

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Frictional Resistance

Sand $Q_s = \Sigma p \Delta L f$

$f = K\sigma_o' tan\delta'$

$\delta = 0.8\phi$

Clay

α method, $Q_s = \Sigma \alpha c_u p \Delta L$

λ method, $Q_s = pLf_{av}$

$f_{av} = \lambda(\bar{\sigma}_o' + 2c_u)$

β method $Q_s = \Sigma f p \Delta L$

$f = \beta\sigma_o'$

Correlation with Cone penetration

$Q_p = A_p q_c$

$q_p = q_c$

$Q_s = \Sigma p \Delta L f$

$f = \alpha' f_c$

$f_c = Frictional\ resistance$

Correlation with SPT

$Q_p = A_p q_p$

$q_p = 0.4 p_a N_{60} \frac{L}{D} \leq 4 p_a N_{60}$

$Q_s = pLf_{av}$

$f_{av} = 0.02 p_a N_{60}$

Conventional retaining walls

Rankine active and passive pressure

$P_a = \frac{1}{2} K_a \gamma_1 H^2$ $\qquad P_a = \frac{1}{2} K_a \gamma_1 H^2 + qK_a H$

$P_v = P_a \sin\alpha°$ $\qquad P_h = P_a \cos\alpha°$

$P_p = \frac{1}{2} K_p \gamma_2 D^2 + 2c_2' \sqrt{K_p} D$

$K_a = \tan^2\left(45° - \frac{1}{2}\phi_1'\right)$ $\qquad K_p = \tan^2\left(45° + \frac{1}{2}\phi_2'\right)$

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Factor of safety against overturning

$$FS = \frac{\Sigma W_i X_i}{\Sigma P_{a_i} z_{a_i}} = \frac{\Sigma (A_i \times \gamma_i) X_i}{\Sigma P_{a_i} z_{a_i}}$$

$$FS = \frac{\gamma_{n+i} A_{n+i} x_{n+i} + \mathrm{K} + \gamma_n A_n x_n}{P_a \cos\alpha (H'/3)}$$

Factor of safety against sliding

$$FS = \frac{\Sigma V \tan\left(\frac{2}{3}\phi_2'\right) + \frac{2}{3} B c_2' + P_p}{P_a \cos\alpha}$$

Retaining walls with geotextile and geogrid reinforcement

$$\sigma_o' = \sigma_{o_1}' + \sigma_{o_2}' \qquad \sigma_{o_1}' = \gamma_1 z$$

$$\sigma_{o_2}' = \frac{qa'}{a' + z} \text{ for } z \le 2b' \qquad \sigma_{o_2}' = \frac{qa'}{a' + \frac{1}{2} z + b'} \text{ for } z > 2b'$$

$$FS_B = \frac{w f_y}{\sigma_a' S_V S_H} \qquad F_R = 2 L_e w \sigma_o' \tan\phi_\mu'$$

$$\sigma_a' = \sigma_{a_1}' + \sigma_{a_2}' \qquad \sigma_{a_1}' = \gamma_1 z K_a$$

$$\sigma_{a_2}' = M\left[\frac{2q}{\pi}(\beta - \sin\beta\cos 2\alpha)\right] \qquad M = 1.4 - \frac{0.4b'}{0.14H} \ge 1$$

$$FS_P = \frac{2 L_e w \sigma_o' \tan\phi_\mu'}{\sigma_a' S_V S_H} \qquad L = \frac{H - z}{\tan(45^\circ + \frac{1}{2}\phi_1')} + \frac{FS_P \sigma_a' S_V S_H}{2 w \sigma_o' \tan\phi_\mu'}$$

overturning factor of safety

$$FS = \frac{M_R}{M_O} = \frac{(W_1 x_1 + W_2 x_2 + \ldots + qa')\left(b' + \frac{1}{2}a'\right)}{P_a z_a}$$

sliding factor of safety

$$FS = \frac{F_R}{F_d} = \frac{(W_1 x_1 + W_2 x_2 + \ldots + qa')[\tan(\phi_1')]}{P_a}$$

bearing capacity factor of safety

$$FS = \frac{q_{ult}}{\sigma_{o_H}'} = \frac{c_2' N_c + \frac{1}{2}\gamma_2 L_2 N_\gamma}{\gamma_1 H + \sigma_{o_2}'}$$

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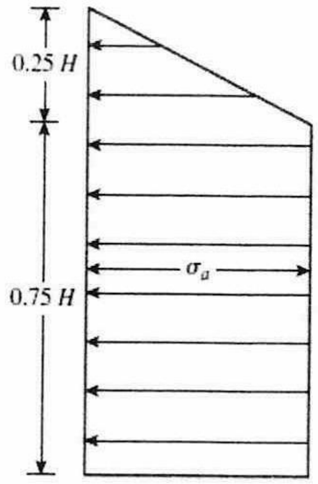
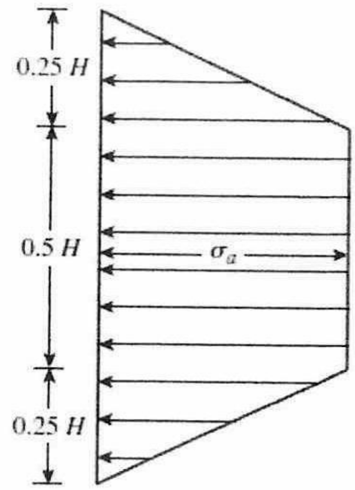


Peck's (1969) apparent-pressure envelope for cuts in soft to medium clay



Peck's (1969) apparent-pressure envelope for cuts in stiff clay

$\sigma_a = 0.65\gamma H K_a$

$\sigma_a = \gamma H \left[1 - \left(\frac{4c}{\gamma H}\right)\right]$

and

$\sigma_a = 0.3\,\gamma\,H,$

$\sigma_a = 0.2\gamma H \text{ to } 0.4\gamma H$

$S = \frac{M_{max}}{\sigma_{all}}$

Equations Machine Vibrations

$W_o = W_b + W_m$

$r_o = \sqrt{\left(\frac{Area}{\pi}\right)}$

$b = \frac{W_o}{\gamma\, r_o^3}$

$f_{res} = \frac{a_o}{2\pi\, r_o}\sqrt{\frac{Gg}{\gamma}}$

$F = (F_p + F_s)\left(\frac{f_{res}}{f_o}\right)^2$

$F = 2\, me\, \omega_{res}^2$

$N' = N\left(\frac{f_o}{f_{res}}\right)^2$

$W_e = 2me$

$X = N\left(\frac{f_o}{f_{res}}\right)^2\left(\frac{W_e}{W_o}\right)$