Universiti Tun Hussein Onn Malaysia

# UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## FINAL EXAMINATION
## (ONLINE)
## SEMESTER II
## SESSION2019/2020

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|---|---|---|
| COURSE NAME | : | FOUNDATION ENGINEERING |
| COURSE CODE | : | BFC 43103 |
| PROGRAMME | : | BFF |
| EXAMINATION DATE | : | JULY 2020 |
| DURATION | : | 6 HOURS |
| INSTRUCTION | : | ANSWER **ALL** QUESTIONS IN **PART A**, AND **TWO(2)** QUESTION ONLY IN **PART B** |



THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

## PART A

**Q1** (a) As a geotechnical engineer, the important task is to design foundation of any structures. The foundation can be shallow foundation or deep foundation. Two important factors in design foundation are soil data and also column load. For a given soil data and column load given below, propose the suitable foundation can be used and give **TWO(2)** reason for each condition:

(i) Refer to Table 1

(5 marks)

(ii) Refer to Table 2

(5 marks)

(iii) Refer to Table 3

(5 marks)

(iv) Refer to Table 4

(5 marks)

**Q2** (a) A sampling tube has an outer diameter of 75 mm and wall thickness of 3.4 mm. Determine the ratio of the tube, and give the comment on whether the tube could be used for obtaining undisturbed soil samples.

(5 marks)

(b) As an engineer in consultancy firm, you need to propose a site investigation method to construct new hospital in Pontian, Johor. The area was underlain by soft clay deposits with 500 m by 350 m size. The hospital consists of 3 numbers of 4 storey building, 3 numbers of 2 storey building, 2 numbers of single storey building and also parking area. Your proposal should include numbers of borings, depth of borings, type of sampling (should include disturbed and undisturbed sampler) and also testing involved (in-situ and laboratory testing)

(15 marks)

## PART B

**Q3** (a) Explain the differences between 'safe bearing capacity' and 'ultimate bearing capacity'.

(4 marks)

(b) Describe briefly **TWO (2)** methods or procedures to determine the design of bearing capacity for shallow foundations. Discuss the advantages and disadvantages perceived for each methods.

(8 marks)

(c) A 1.5 m x 1.5 m square footing will be constructed on cohesive soil. A centric column load on the footing is 250 kN. A unit weight of soil, ($\gamma_{soil}$) is 18.8 kN/m$^3$ where as the unit weight of concrete, ($\gamma_{concrete}$) is 23.5 kN/m$^3$. Cohesive soil with unconfined compressive strength, (UCS) is 143.6 kN/m$^3$. Design;

(i) the soil contact pressure.

(9 marks)

(ii) the factor of safety against bearing capacity failure.

(9 marks)

**Q4** (a) Piles can be classified according to the material used; the mode of transfer of load; the method of construction; the application; and the displacement of soil, as illustrated in **FigureQ4(a)**.

(i) List out **FOUR (4)** types of piles that is classified as based on the method of installation.

(4 marks)

(ii) List and discuss **THREE (3)** types of piles based on the application of piles.

(6 marks)

(b) The soil profile and soil properties at a site are shown in the **Table 5**. A group of concrete piles with 24 m in length is used to support a load of 1500 kN.The distance and width of the pile group are 2.75 m and 2.75 m, respectively. The pile cap is located on the ground surface.

(i) Sketch the soil profile to illustrate the location of pile groups and soil layers.

(5 marks)

(ii) Determine the consolidation settlement of the group pile. Use the 2:1 method of stress distribution to estimate the average increase of effective stress in the clay layers.

(10 marks)

(iii) Simply explain without any computation, your judgment regarding **TWO (2)** conditions of settlement in a group pile by comparing your answer in **Q4(b)(ii)**.

**Condition I**: The changes in soil settlement if the ground water is increased and relocated at the ground surface, i.e., from 3 mto 0 m.

**Condition II**: The changes in soil settlement if the infrastructure design load increased from initial the design of 1500 kN to 1750 kN.

(5 marks)

**Q5** (a) There are various types of retaining walls. Normally, these walls are grouped into three categories which are mass, gravity, flexibility, and mechanically stabilized earth walls. Regardless of the category, a geotechnical engineer must ensure that the wall is stable under anticipated loadings.

Briefly explains their differences among these **THREE (3)** categories and how do you analyse a retaining wall to check its stability.

(6 marks)

(b) A cantilever wall is shown in **FigureQ5(b)**. Assume the angle of friction between the soil and the wall (i.e., the angle of wall friction), $\delta'$ is 0°.

(i) Calculate the required extent of the base slab forward from the back of the wall such that a factor of safety of 2.0 against overturning is met.

(7 marks)

(ii) Subsequently check if the required minimum factor of safety of 1.5 is met against base sliding. If not, design a base key, with suggested heightof 1.0 m to 1.5 m.

(2 marks)

(iii) Calculate the passive pressure starting from the bottom level of the base slab. Also use $\frac{2}{3}$ of the shear strength parameters of the base soil in your calculations and apply a factor of safety 2.0 for the passive resistance.

(15 marks)

**- END OF QUESTIONS–**

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**TABLE 1**: Soil data and column load for Site A

| Depth (m) | Type of Deposit | SPT Results |
|---|---|---|
| 0 m | Ground surface | |
| 0.5 m | Medium dense sand | 20 |
| 2.0 m | Dense sand | 37 |
| 5.0 m | Very dense sand | 50 |

| Column | Load (kN) |
|---|---|
| C1 | 100 |
| C2 | 150 |
| C3 | 230 |

**TABLE 2:** Soil data and column load for Site B

| Depth (m) | Type of Deposit | SPT Results |
|---|---|---|
| 0 m | Ground surface | |
| 3 m | Loose sand | 5 |
| 12 m | Very soft clay | 0 |
| 25 m | soft clay | 4 |

| Column | Load (kN) |
|---|---|
| C1 | 100 |
| C2 | 150 |
| C3 | 230 |

**TABLE 3**: Soil data and column load for Site C

| Depth (m) | Type of Deposit | SPT Results |
|---|---|---|
| 0 m | Ground surface | |
| 0.5 m | Medium dense sand | 20 |
| 2.0 m | Dense sand | 37 |
| 5.0 m | Very dense sand | 50 |

| Column | Load (kN) |
|---|---|
| C1 | 10000 |
| C2 | 25000 |
| C3 | 50000 |

**TABLE 4**: Soil data and column load for Site D

| Depth (m) | Type of Deposit | SPT Results |
|---|---|---|
| **Depth (m)** | ground surface | |
| 3 m | Loose sand | 5 |
| 12 m | Very soft clay | 0 |
| 25 m | Soft clay | 4 |

| Column | Load (kN) |
|---|---|
| C1 | 10000 |
| C2 | 25000 |
| C3 | 50000 |

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**TABLE 5 :** General Bearing Capacity Factors

| $\phi'$ | $N_c$ | $N_q$ | $N_\gamma^a$ | $\phi'$ | $N_c$ | $N_q$ | $N_\gamma^a$ |
|---|---|---|---|---|---|---|---|
| 0 | 5.70 | 1.00 | 0.00 | 26 | 27.09 | 14.21 | 9.84 |
| 1 | 6.00 | 1.10 | 0.01 | 27 | 29.24 | 15.90 | 11.60 |
| 2 | 6.30 | 1.22 | 0.04 | 28 | 31.61 | 17.81 | 13.70 |
| 3 | 6.62 | 1.35 | 0.06 | 29 | 34.24 | 19.98 | 16.18 |
| 4 | 6.97 | 1.49 | 0.10 | 30 | 37.16 | 22.46 | 19.13 |
| 5 | 7.34 | 1.64 | 0.14 | 31 | 40.41 | 25.28 | 22.65 |
| 6 | 7.73 | 1.81 | 0.20 | 32 | 44.04 | 28.52 | 26.87 |
| 7 | 8.15 | 2.00 | 0.27 | 33 | 48.09 | 32.23 | 31.94 |
| 8 | 8.60 | 2.21 | 0.35 | 34 | 52.64 | 36.50 | 38.04 |
| 9 | 9.09 | 2.44 | 0.44 | 35 | 57.75 | 41.44 | 45.41 |
| 10 | 9.61 | 2.69 | 0.56 | 36 | 63.53 | 47.16 | 54.36 |
| 11 | 10.16 | 2.98 | 0.69 | 37 | 70.01 | 53.80 | 65.27 |
| 12 | 10.76 | 3.29 | 0.85 | 38 | 77.50 | 61.55 | 78.61 |
| 13 | 11.41 | 3.63 | 1.04 | 39 | 85.97 | 70.61 | 95.03 |
| 14 | 12.11 | 4.02 | 1.26 | 40 | 95.66 | 81.27 | 115.31 |
| 15 | 12.86 | 4.45 | 1.52 | 41 | 106.81 | 93.85 | 140.51 |
| 16 | 13.68 | 4.92 | 1.82 | 42 | 119.67 | 108.75 | 171.99 |
| 17 | 14.60 | 5.45 | 2.18 | 43 | 134.58 | 126.50 | 211.56 |
| 18 | 15.12 | 6.04 | 2.59 | 44 | 151.95 | 147.74 | 261.60 |
| 19 | 16.56 | 6.70 | 3.07 | 45 | 172.28 | 173.28 | 325.34 |
| 20 | 17.69 | 7.44 | 3.64 | 46 | 196.22 | 204.19 | 407.11 |
| 21 | 18.92 | 8.26 | 4.31 | 47 | 224.55 | 241.80 | 512.84 |
| 22 | 20.27 | 9.19 | 5.09 | 48 | 258.28 | 287.85 | 650.67 |
| 23 | 21.75 | 10.23 | 6.00 | 49 | 298.71 | 344.63 | 831.99 |
| 24 | 23.36 | 11.40 | 7.08 | 50 | 347.50 | 415.14 | 1072.80 |
| 25 | 25.13 | 12.72 | 8.34 | | | | |

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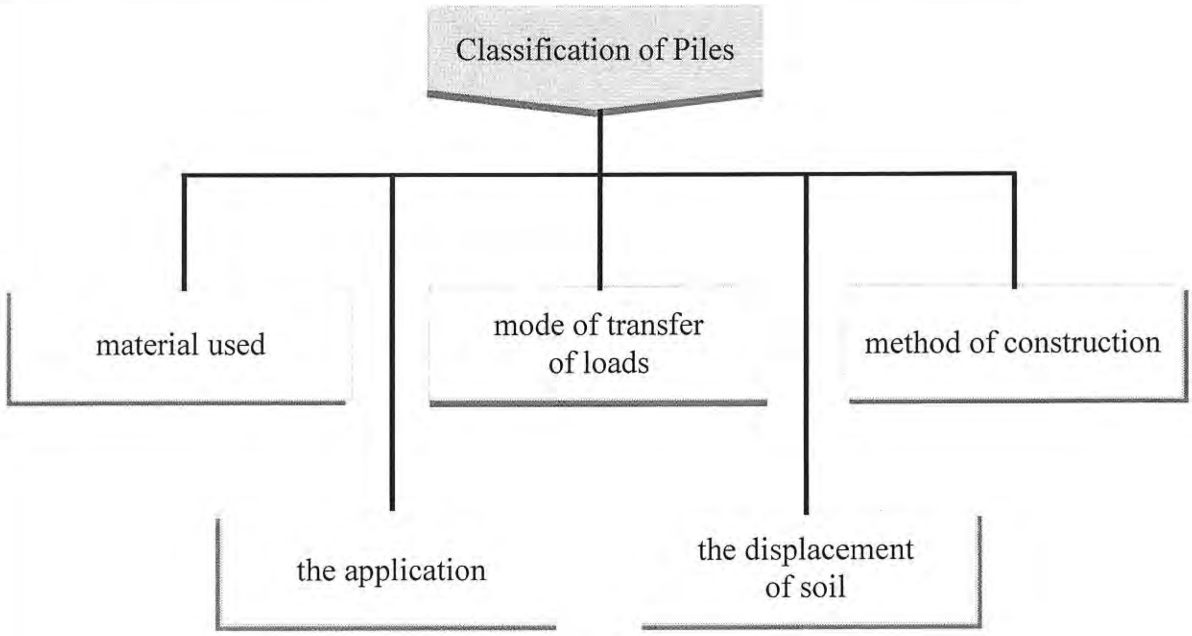


**FIGURE Q4(a)**

**TABLE 5**

| Depth (m) | Type of Deposit | Soil Test Results |
|---|---|---|
| 0 m | ground surface | |
| 3 m | sand | $\gamma = 15.72$ kN/m$^3$ |
| 6 m | sand | $\gamma = 18.55$ kN/m$^3$ |
| 24 m | soft clay | normally consolidated clay<br>$\gamma_{sat} = 19.18$ kN/m$^3$, void ratio, $e_o = 0.8$, and compression index, $C_c = 0.8$ |
| 29 m | soft clay | normally consolidated clay<br>$\gamma_{sat} = 18.08$kN/m$^3$, void ratio, $e_o = 1.0$, and compression index, $C_c = 0.31$ |
| 32 m | soft clay | normally consolidated clay<br>$\gamma_{sat} = 19.51$kN/m$^3$, void ratio, $e_o = 0.7$, and compression index, $C_c = 0.26$ |

groundwater table at 3 m from the ground surface.

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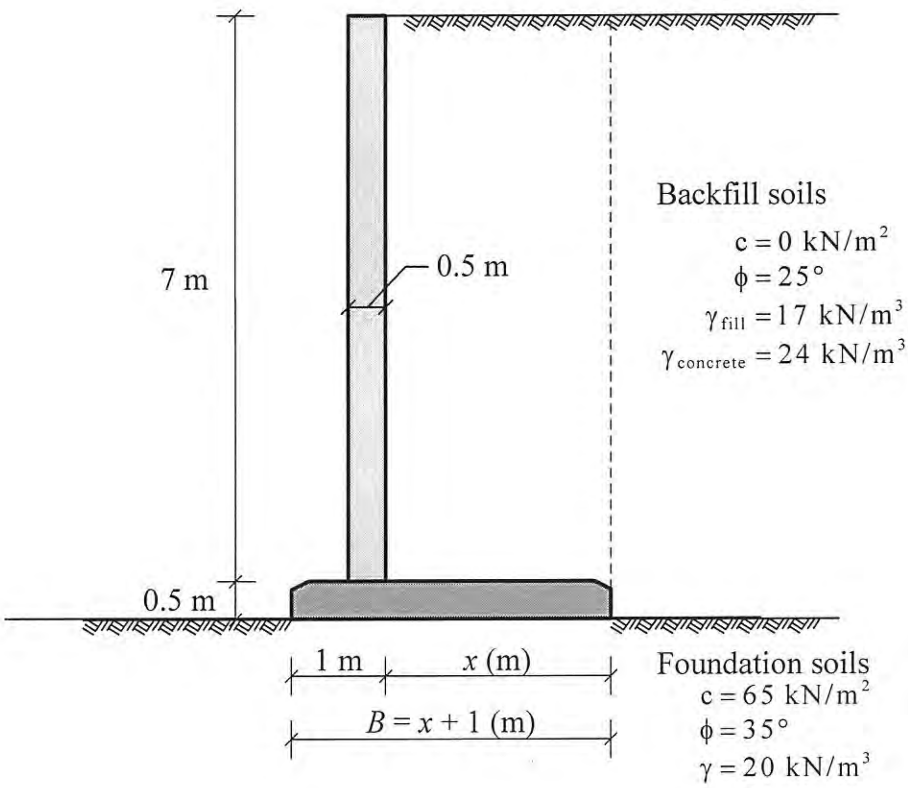


**FIGURE Q5 (b)**

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*Retaining structures*

*retaining walls with geotextile and geogrid reinforcement*

$$\sigma'_o = \sigma'_{o_1} + \sigma'_{o_2} \qquad \sigma'_{o_1} = \gamma_1 z$$

$$\sigma'_{o_2} = \frac{qa'}{a'+z} \text{ for z} \leq 2b' \qquad \sigma'_{o_2} = \frac{qa'}{a'+\frac{1}{2}z+b'} \text{ for z} > 2\text{b}'$$

$$FS_B = \frac{wf_y}{\sigma'_a S_V S_H} \qquad F_R = 2L_e w\sigma'_o \tan\phi'_\mu$$

$$\sigma'_a = \sigma'_{a_1} + \sigma'_{a_2} \qquad \sigma'_{a_1} = \gamma_1 z K_a$$

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

$$FS_P = \frac{2L_e w\sigma'_o \tan\phi'_\mu}{\sigma'_a S_V S_H} \qquad L = \frac{H-z}{\tan(45° + \frac{1}{2}\phi'_1)} + \frac{FS_P \sigma'_a S_V S_H}{2w\sigma'_o \tan\phi'_\mu}$$

*overturning factor of safety*

$$FS = \frac{M_R}{M_O} = \frac{(W_1x_1 + W_2x_2 + \ldots + qa')\left(b' + \frac{1}{2}a'\right)}{P_a z_a}$$

*sliding factor of safety*

$$FS = \frac{F_R}{F_d} = \frac{(W_1x_1 + W_2x_2 + \ldots + qa')[\tan(\phi'_1)]}{P_a}$$

*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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*Terzhagi's bearing capacity*

*general shear failure*

$$q_u = c'N_c + \bar{q}N_q + \tfrac{1}{2}\bar{\gamma}BN_\gamma \qquad q_u = 1.3c'N_c + \bar{q}N_q + 0.4\bar{\gamma}BN_\gamma$$

$$q_u = 1.3c'N_c + \bar{q}N_q + 0.3\bar{\gamma}BN_\gamma$$

*local shear failure*

$$q_u = \tfrac{2}{3}c'N_c' + \bar{q}N_q' + \tfrac{1}{2}\bar{\gamma}BN_\gamma' \qquad q_u = 0.867c'N_c' + \bar{q}N_q' + 0.4\bar{\gamma}BN_\gamma'$$

$$q_u = 0.867c'N_c' + \bar{q}N_q' + 0.3\bar{\gamma}BN_\gamma'$$

*Factor of safety*

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

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

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

*Meyerhof's general bearing capacity*

$$q_u = c'N_cF_{cs}F_{cd}F_{ci} + \bar{q}N_qF_{qs}F_{qd}F_{qi} + \tfrac{1}{2}\bar{\gamma}BN_\gamma F_{\gamma s}F_{\gamma d}F_{\gamma i}$$

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

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

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

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

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

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

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cont.

*Meyerhof's general bearing capacity*

$$\frac{D_f}{B} > 1 : \phi' = 0°$$

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

$$\frac{D_f}{B} > 1 : \phi' > 0°$$

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

*One way eccentricity*

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

*Primary consolidationsettlementfor 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*

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

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

*Site investigations*

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