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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2018/2019

COURSE NAME	:	SOFT SOIL ENGINEERING
COURSE CODE	:	BFG40603
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	DECEMBER 2018 / JANUARY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

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Q1 (a) (i) List **SIX (6)** construction methods of earth embankment on soft soil.

(2 marks)

(ii) There are five (5) factors in selecting the ground improvement method such as structural condition, geotechnical condition, environmental constraint, construction condition and reliability and durability. Using your own words, explain in detail **FOUR (4)** of the factors.

(4 marks)

(iii) Discuss in details the advantages and limitation of preloading, vertical drain and vacuum consolidation in soft soil improvement.

(6 marks)

(b) A storage tank with a diameter of 30 m (self weight = 20000 kN) is to be constructed on a normally consolidated soft clay with a thickness of 7.5 m underlain by a dense sand layer as shown in **Figure Q1(b)**. To minimize the service settlement, the tank is filled with water up to 6m in one day to preload the soil for 6 months. Prefabricated vertical drains (PVD) with the dimensions of 100 mm and 5 mm were selected to be penetrated into the soft soil layer. The discharge capacity of the drains are 0.00081 m^3/s under 50 kPa normal stress and 0.00014 m^3/s under 150 kPa respectively. Assume there is no smear effect during the installation of PVDs.

(i) Predict the factor of safety against bearing failure at the end of water filling.

(5 marks)

(ii) Design the spacing of PVDs (in a square pattern) to ensure 80% consolidation by the end of the 6 months preloading.

(8 marks)

Q2 (a) (i) Compare the advantages and disadvantages of in situ and laboratory tests applied to soft soil.

(6 marks)

(ii) Recommend the best procedure to minimize the disturbance of the undisturbed soil sample in term of drilling, tube sampling, tube extraction, transportation and storage, sample extrusion and specimen preparation.

(10 marks)

(b) A cone penetration test (CPT) is conducted in the field with a groundwater table at 1.0 m below the ground surface. The measured tip resistance at a depth of 4.5 m is 5.1 MPa and the sleeve friction is 0.3 MPa. The unit weights of the soil above and below the groundwater table are 17.5 kN/m^3 and 18.5 kN/m^3, respectively.

(i) Classify the type of the soil according to **Figure Q2(b)**.

(2 marks)

(ii) If the soil is a sandy soil, determine the relative density and friction angle. If it is a clayey soil, determine the undrained shear strength and OCR.

(7 marks)

Q3 (a) Consolidation test results of a soil sample taken at a depth of 2.5 m from a field with a groundwater table at the ground surface are shown in **Table 1**. The saturated unit weight and permeability of the soil sample are 19 kN/m^3 and 6.5 x 10^{-7} m/s accordingly.

Table 1: Consolidation test results

Stress (kPa)	5	10	20	40	80	160	320
Void ratio	0.92	0.910	0.851	0.760	0.629	0.490	0.352

Determine:

(i) Effective overburden pressure stress in the field.

(3 marks)

(ii) Preconsolidation stress and overconsolidation ratio (OCR).

(4 marks)

(iii) Coefficient of compression and recompression.

(4 marks)

(iv) Coefficient of volume compressibility in the stress ranges between 100 kPa and 200 kPa.

(2 marks)

(v) Coefficient of consolidation.

(2 marks)

(b) A 8.5 m deep compacted fill is to be placed over the soil profile shown in **Figure Q3(b)**. A consolidation test on a sample from points A and B produce the results as depicted in **Table 2**.

Table 2: Consolidation test results

Parameters	Sample A	Sample B
C_c	0.25	0.20
C_r	0.08	0.06
e_o	0.66	0.45
σ'_c	101 kN/m^2	510 kN/m^2

This sample is representative of the entire soft clay stratum of each layer. Estimate the ultimate consolidation settlement due to the weight of this fill.

(10 marks)

Q4 (a) The selection of an appropriate type of foundation depends on many factors. Describe in detail the selection of pad footing, strip footing, mat footing and deep foundation.

(4 marks)

(b) You are the foundation engineer for a new stadium that is under construction. The design drawings indicate the stadium will be supported on a series of steel H- piles. However, during construction it became necessary to drive many of the piles to greater depths, which resulted in a significant increase of pile numbers in the construction. The owner is very unhappy and refuse to pay the extra pile expense. The construction manager asks you to explain to the owner on the situation and convince him to pay for the additional cost. Justify the reason of the necessity of additional piles.

(6 marks)

(c) A Spread footing with a dimension of 2.25 m x 2.25 m and thickness of 0.5 m is embedded in soft clay at a depth of 2.0 m to support a 500 kN column load. A CPT is done for the site and the results are shown in **Table 3**. The groundwater table is at a depth of 1.8 m and the unit weights of the soil are 17.5 kN/m^3 and 18.1 kN/m^3 above and below the groundwater table, respectively. The unit weight of concrete is 24 kN/m^3.

Table 3: CPT test results

Layer number	Depth (m)	Average Cone Tip Resistance, q_c (Mpa)
1	2.0 – 3.0	2.4
2	3.0 – 4.0	3.2
3	4.0 – 5.0	4.1
4	5.0 – 7.0	6.5
5	7.0 – 9.0	8.5
6	9.0 – 10.0	6.7
7	10.0 – 12.0	11.0

Design the footing by considering the settlement using the Schmertmann method:

(i) Immediately after construction.

(10 marks)

(ii) 30 years after construction.

(5 marks)

– END OF QUESTIONS –

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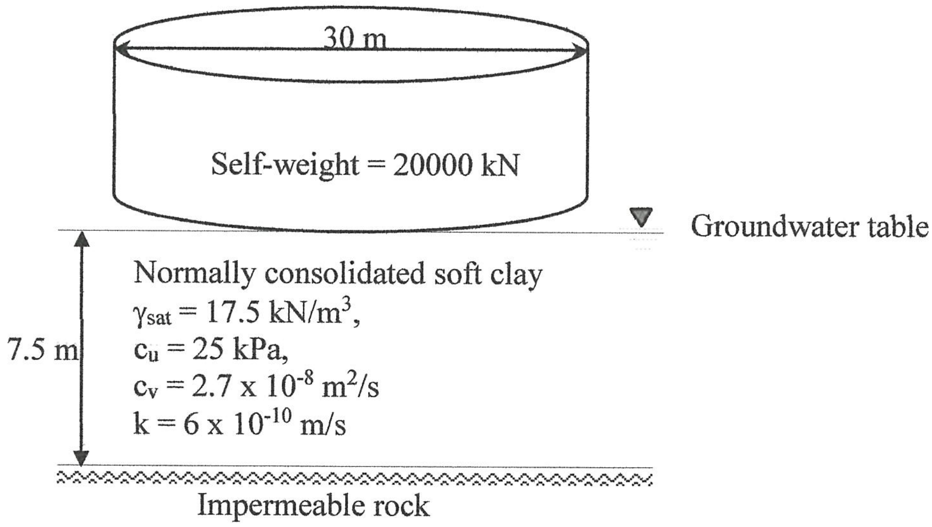
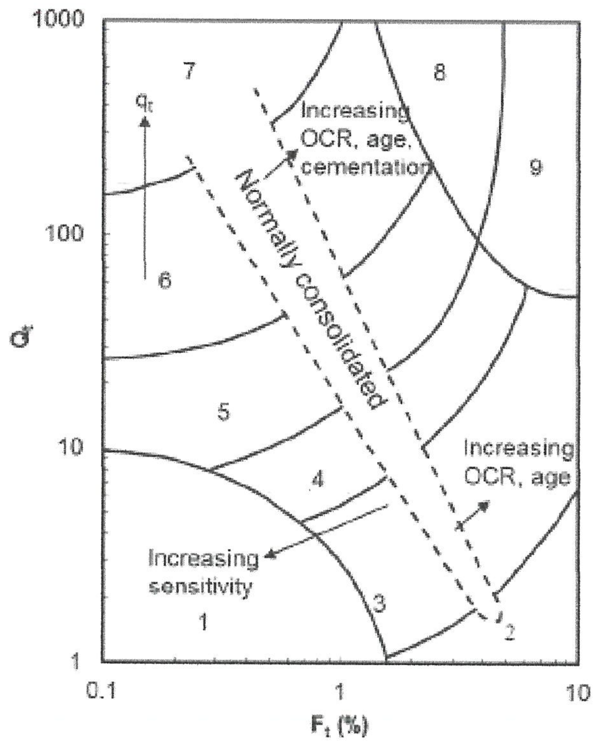


Figure Q1(b): Soft soil improved PVD



Zone	Soil behavior type
1	Sensitive, fine grained
2	Organic soil; peat
3	Clay; clay to silty clay
4	Silt mixture; clayey silt to silty clay
5	Sand mixture; silty sand to sandy silt
6	Sand; clean sands to silty sand
7	Gravelly sand to sand
8	Very stiff sand to clayey sand
9	Very stiff fine grained

$$Q_t = \frac{q_t - \sigma_{zo}}{\sigma'_{zo}}$$

$$F_t = \left(\frac{f_s}{q_t - \sigma_{zo}}\right) \times 100\%$$

Figure Q2(b): CPT soil type classification

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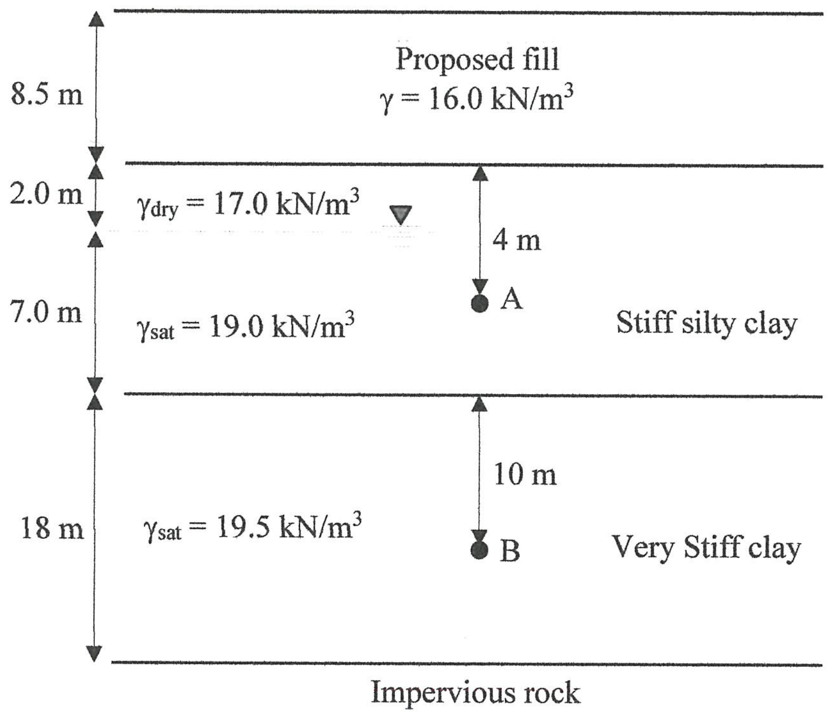

Figure Q3(b): Soil profile

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Appendix

Equation for CPT

Relative density of sand (Kulhawy & Mayne, 1990)

$$D_r(\%) = \sqrt{\frac{q_c}{30500 \times OCR^{0.18}}\sqrt{\frac{100}{\sigma'_{zo}}}}$$

Effective friction angle of sand sand (Kulhawy & Mayne, 1990)

$$\phi' = \tan^{-1}\left[0.1 + 0.38\log\left(\frac{q_c}{\sigma'_{zo}}\right)\right]$$

The undrained shear strength of clay (Salgado, 2006)

$$c_u = \frac{q_c - \sigma_{zo}}{11}$$

Preconsolidation pressure of clay (Kulhawy & Mayne, 1990)

$$\sigma_c = 0.33\left(q_c - \sigma_{zo}\right)$$

Settlement of shallow foundation (Schmertmann et al., 1978)

$$s_e = C_1 C_2 C_3 p_n \sum \frac{I_\varepsilon}{E_s}\Delta h$$

where C_1 = correction factor for embedment depth foundation, $C_1 = 1 - 0.5\left(\sigma'_D / P_n\right)$

C_2 = correction factor for soil creep, $C_2 = 1 + 0.2\log\left(t/0.1\right)$, t is time after load is applied

C_3 = correction factor for foundation shape, $C_3 = 1.03 - 0.03\left(L_f / B_f\right) \geq 0.73$

$I_{\varepsilon p} = 0.5 + 0.1\sqrt{\left(P_n / \sigma'_{zp}\right)}$

I_ε = Influence factor at midpoint of each soil sublayer

Δh = thickness of each soil sublayer

E_s = soil elastic modulus at midpoint of each sublayer

Table A: Soil Elastic Modulus Estimated by CPT tip resistance

Soil Type	E_s
Sand (normally consolidated)	(2 – 4) q_c
Sand (over consolidated)	(6 – 30) q_c
Clayey sand	(3 – 6) q_c
Silty sand	(1 – 2) q_c
Soft clay	(3 – 8) q_c