UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2018/2019

COURSE NAME	:	FOUNDATION ENGINEERING
COURSE CODE	:	BFC 43103
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JUNE / JULY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS IN **SECTION A**, AND ANY **THREE (3)** QUESTIONS IN **SECTION B**

THIS QUESTION PAPER CONSISTS OF **TWELVE (12)** PAGES

SECTION A

Q1 (a) Soil improvement and ground modification techniques are used to improve poor/unsuitable subsurface soils and/or to improve the performance of embankments or structures. **Table Q1(a)** shows the category of the ground improvement techniques and its methods to carry it out. List **ONE (1)** function for each category of the ground improvement techniques.

(6 marks)

(b) List and explain **FOUR (4)** classifications of ground improvement techniques.

(8 marks)

(c) A 5 m wide, 2500 m long, 0.5 m thick road is being constructed at Parit Raja. Therefore, an earth fill has to be carried out. The soil density after compaction was found to be 18 kN/m^3 at an optimum moisture content of 15%. The borrow material imported from Batu Pahat has a bulk unit weight of 16 kN/m^3 and a moisture content 12%.

(i) Determine the required volume of borrow pit excavation from Batu Pahat.

(7 marks)

(ii) Evaluate the shrinkage factor due to the fill compaction.

(4 marks)

SECTION B

Q2 (a) There are two types of soil sampling that can be obtained during subsurface exploration. Explain in detail the types of soil sampling and give **TWO (2)** examples of laboratory test for each type of soil sampling.

(8 marks)

(b) As an experience engineer from an established Geotechnical firm, you are to be interviewed by representatives of the owner of to be constructed high rise building. The interview is related to performing a subsurface investigation at the site. Discuss the various factors that govern the sub soil exploration and propose the guiding principles for deciding the location of boreholes in engineering project.

(10 marks)

(c) A standard penetration test is carried out in sand where the efficiency of the hammer η_H = 80%. The unit weight of the sand is 18 kN/m^3. If the measured N-value at 9.15 m depth is 20, determine N_{60} and friction angle of sand. Assume $\eta_b = \eta_s = \eta_R = 1$.

(7 marks)

Q3 (a) Discuss with the aid of sketches a testing that is used to determine bearing capacity in field.

(7 marks)

(b) A square footing is 2.5 m x 2.5 m in size with depth of foundation of 1.2 m. The footing is buried in 3.7 m thick of sandy gravel layer that has unit weight of 16.5 kN/m^3 and laying on top of 7.5 m thick of clay layer with unit weight of 18.3 kN/m^3 and there is bed rock underneath this clay layer. Water table is exactly at the base of footing as shown in **Figure Q3(b).** Load on raft footing is 2000 kN, initial void ratio of clay layer, e = 1.27, compression index, C_c = 0.69.

i. Estimate the primary consolidation of the clay layer

(14 marks)

ii. Estimate the total consolidation settlement after 25 years and primary consolidation is to be completed in 4 years if secondary compression index, C'_α = 0.02.

(4 marks)

TERBUKA

Q4 (a) There are different ways of installing piles, depending on the types of pile and the ground conditions. List the types of pile driving methods that are available in the construction industry

(5 marks)

(b) Varying soil conditions, unreliable soil parameters, and the assumptions and simplifications in the theoretical model used in the prediction, contributes to the variability in the ultimate load (Q_u). The pile load test is a good way to verify the load-carrying capacity of a pile. **Figure Q4(b)** shows the results of a pile load test. The length of the pile is 15 m and its cross-section is 457 mm x 457 mm. Given the E_p = 30 x 10^6 kN/m^2 and D_r = 300 mm, calculate the ultimate load (Q_u) using Davisson's method with the aid of **Figure Q4(b).**

(8 marks)

(c) Consider 28 meter long concrete pile with a cross section of 0.305 m x 0.305 m that is fully embedded in a combination of sand and clay layers. The site investigation soil information is given in **Table Q4(c).** Determine the allowable load (Q_{all}) that the pile can carry 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)

(12 marks)

Q5 (a) Explain in detail with the aid of sketches, the mechanism on how mechanically stabilized retaining wall using geotextile can improve slope stability.

(4 marks)

(b) With the aid of sketches, explain briefly the sequence of sheet pile construction with an anchor system for a backfill and dredge structure.

(6 marks)

(c) A retaining wall with a sloping backfill as shown in **Figure Q5(c)**. The retaining wall needs to be designed accordingly to avoid failure.

(i) Calculate the factors of safety with respect to overturning and sliding using Rankine's theory. Comment also whether the wall is safe from failure or not. (note : γ_c = 23.57 kN/m^3 and $k_1 = k_2 = 2/3$)

(12 marks)

(ii) If the desired value of the factor of safety (FS) against sliding is not achieved, explain the several improvements that need to be done on the wall to avoid failure.

(3 marks)

-END OF QUESTIONS-

FINAL EXAMINATION

SEMESTER / SESSION	: SEM II / 2018/2019	PROGRAMME CODE	: 4 BFF
COURSE NAME	: FOUNDATION ENGINEERING	COURSE CODE	: BFC 43103

TABLE Q1(a): Category of ground improvement

Category	Method
Consolidation	prefabricated vertical drains, and surcharge
Load reduction	geofoam, foamed concrete, and lightweight fill
Densification	vibro compaction, and dynamic compaction by falling weight impact
Reinforcement	stone columns
Deep soil mixing	wet and dry mixing methods
Grouting	permeation grouting, and jet grouting
Load transfer	column supported embankment

TABLE Q3(b): Variations of influence value *I*

	n							
m	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
0.1	0.00470	0.00917	0.01323	0.01678	0.01978	0.02223	0.02420	0.02576
0.2	0.00917	0.01790	0.02585	0.03280	0.03866	0.04348	0.04735	0.05042
0.3	0.01323	0.02585	0.03735	0.04742	0.05593	0.06294	0.06858	0.07308
0.4	0.01678	0.03280	0.04742	0.06024	0.07111	0.08009	0.08734	0.09314
0.5	0.01978	0.03866	0.05593	0.07111	0.08403	0.09473	0.10340	0.11035
0.6	0.02223	0.04348	0.06294	0.08009	0.09473	0.10688	0.11679	0.12474
0.7	0.02420	0.04735	0.06858	0.08734	0.10340	0.11679	0.12772	0.13653
0.8	0.02576	0.05042	0.07308	0.09314	0.11035	0.12474	0.13653	0.14607
0.9	0.02698	0.05283	0.07661	0.09770	0.11584	0.13105	0.14356	0.15371
1.0	0.02794	0.05471	0.07938	0.10129	0.12018	0.13605	0.14914	0.15978
1.2	0.02926	0.05733	0.08323	0.10631	0.12626	0.14309	0.15703	0.16843
1.4	0.03007	0.05894	0.08561	0.10941	0.13003	0.14749	0.16199	0.17389
1.6	0.03058	0.05994	0.08709	0.11135	0.13241	0.15028	0.16515	0.17739
1.8	0.03090	0.06058	0.08804	0.11260	0.13395	0.15207	0.16720	0.17967
2.0	0.03111	0.06100	0.08867	0.11342	0.13496	0.15326	0.16856	0.18119

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2018/2019 PROGRAMME CODE : 4 BFF
COURSE NAME : FOUNDATION ENGINEERING COURSE CODE : BFC 43103

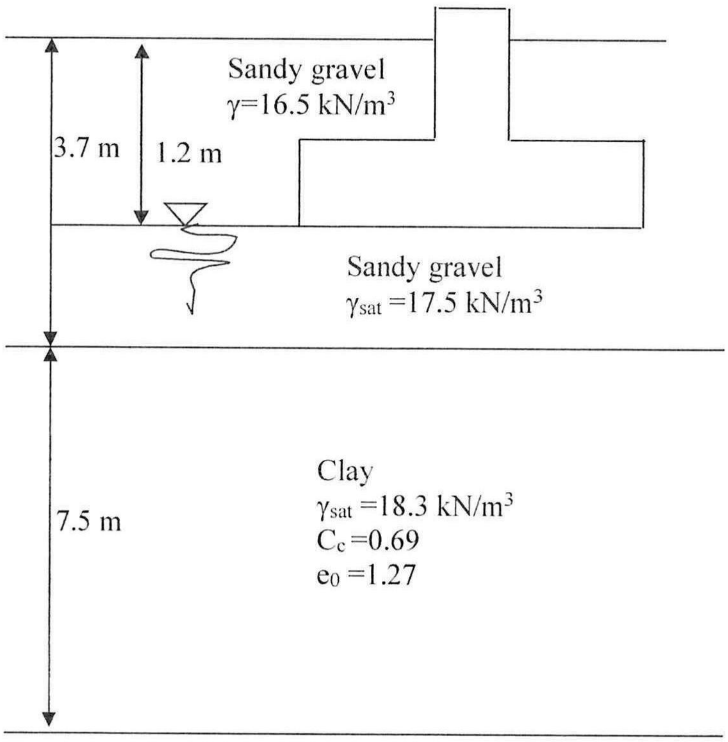

FIGURE Q3(b): Load on raft footing

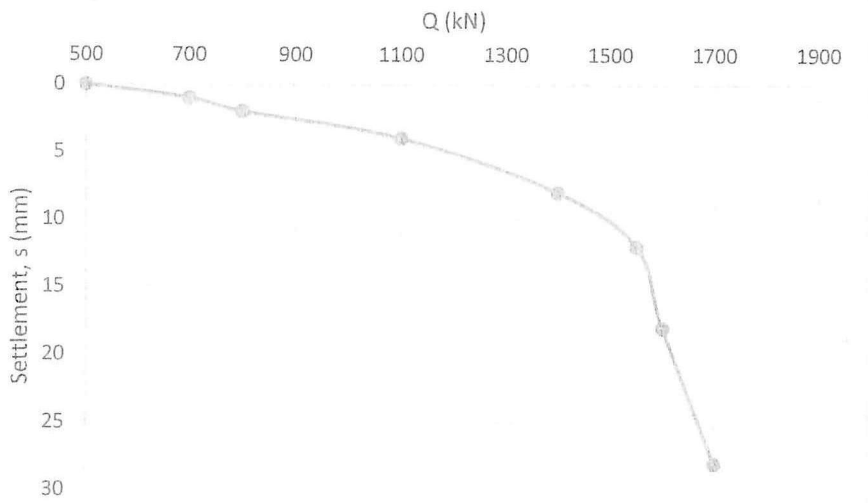

FIGURE Q4(b)

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2018/2019
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME CODE : 4 BFF
COURSE CODE : BFC 43103

TABLE Q4(c): Site investigation soil information

Depth (m)	Length of each layer (m)	Soil parameters given	Soil Description
0 - 4	4	Cone penetration frictional resistance (f_c) = 83 (kN/m^2)	Sand
4 - 8	4	Cone penetration frictional resistance (f_c) = 143 (kN/m^2)	Sandy soil
8 - 13	5	Cone penetration frictional resistance (f_c) = 223 (kN/m^2)	Sandy gravel
13 – 17	5	c_u = 25 kN/m^2 γ = 16 kN/m^3	Silty clay
17 - 24	7	c_u = 40 kN/m^2 γ = 17 kN/m^3	Clay
24 - 28	4	c_u = 90 kN/m^2 γ = 18 kN/m^3	Hard Clay

TABLE Q4(c)(i): 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 $\approx$ 100 kN/m^2 or 2000 lb/ft^2

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2018/2019 PROGRAMME CODE : 4 BFF
COURSE NAME : FOUNDATION ENGINEERING COURSE CODE : BFC 43103

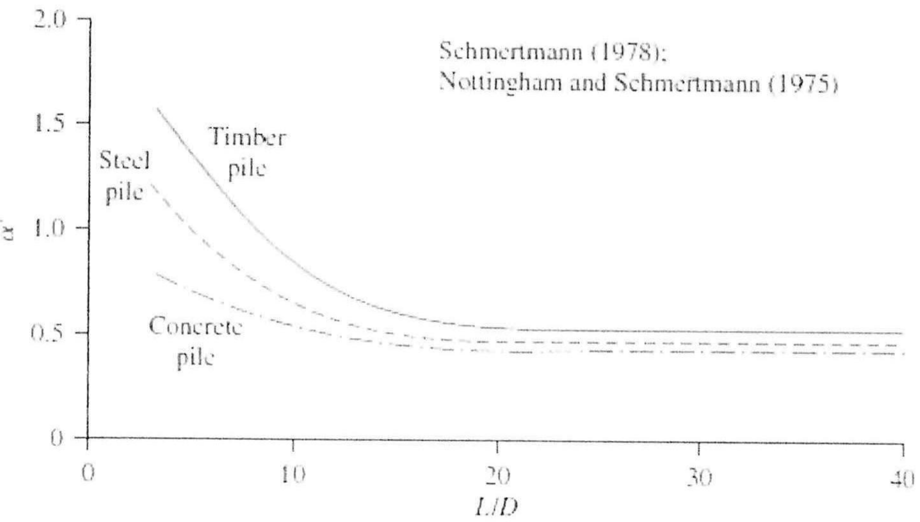

FIGURE Q4(c)

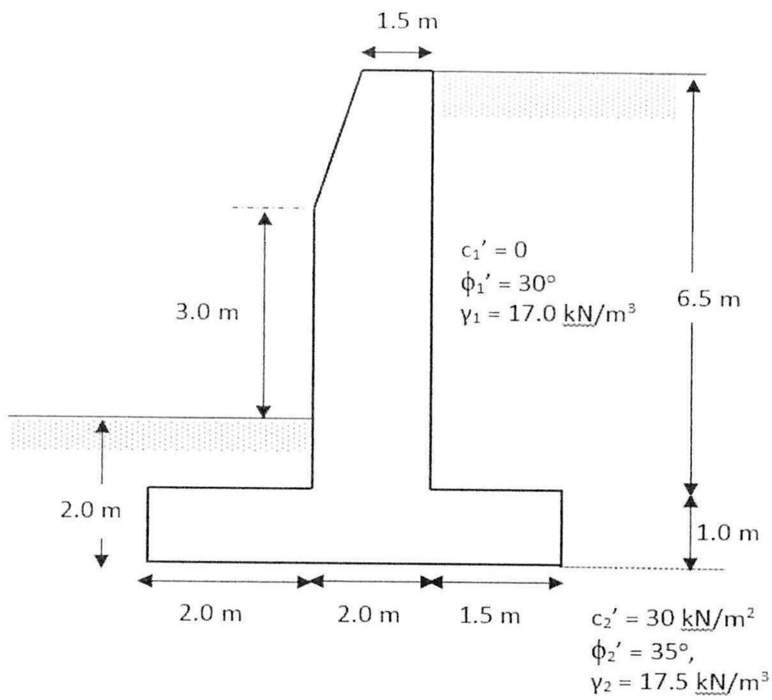

FIGURE Q5(c): Retaining wall

FINAL EXAMINATION

SEMESTER / SESSION	: SEM II / 2018/2019	PROGRAMME CODE	: 4 BFF
COURSE NAME	: FOUNDATION ENGINEERING	COURSE CODE	: BFC 43103

The following information may be useful. The symbols have their usual meaning.

SOIL IMPROVEMENT AND GROUND MODIFICATION

$$S_{c(p)} = \frac{C_c H_c}{1+e_o} \log \frac{\sigma_o' + \Delta\sigma_{(p)}'}{\sigma_o'}$$

$$S_{c(p+f)} = \frac{C_c H_c}{1+e_o} \log \frac{\sigma_o' + \left[\Delta\sigma_{(p)}' + \Delta\sigma_{(f)}'\right]}{\sigma_o'}$$

$$U = \frac{\log\left[\dfrac{\sigma_o' + \Delta\sigma_{(p)}'}{\sigma_o'}\right]}{\log\left[\dfrac{\sigma_o' + \Delta\sigma_{(p)}' + \Delta\sigma_{(f)}'}{\sigma_o'}\right]}$$

$$T_v = \frac{c_v t}{H_c^2}$$

For U%: 0% to 60%; $T_v = \frac{\pi}{4}\left(\frac{U\%}{100}\right)^2$

For U% > 60%;

$T_v = 1.781 - 0.931 \log(100 - U\%)$

$$U = \frac{\log\left[1 + \dfrac{\Delta\sigma_{(p)}'}{\sigma_o'}\right]}{\log\left[1 + \dfrac{\Delta\sigma_{(p)}'}{\sigma_o'}\left(1 + \dfrac{\Delta\sigma_{(f)}'}{\sigma_{(p)}'}\right)\right]}$$

SITE INVESTIGATION

$$A_R(\%) = \frac{D_o^2 - D_i^2}{D_i^2}(\%)$$

$$N_{corrected} = C_N * N_{field}$$

$$C_N = 0.77 \log_{10} \frac{1915}{p_o'}$$

$$N_{60} = \frac{N \eta_H \eta_B \eta_S \eta_R}{60}$$

where

N_{60} = Standard penetration number, corrected for field conditions.

η_H = Hammer Effiency (%)

η_B = Correction for borehole diameter

η_S = Sampler correction

η_R = Correction for rod length

Variation of η_B

Diameter (mm)	η_B
60 – 120	1
150	1.05
200	1.15

Variation of η_S

Rod lenght (mm)	η_B
Standard sampler	1.0
With liner for dense sand and clay	0.8
With liner for loose sand	0.9

Schmertmann's (1975) theory

$$\phi = tan^{-1}\left[\frac{N_{60}}{12.2 + 20.3\left(\frac{\sigma_0'}{P_a}\right)}\right]^{0.34}$$

where, σ_0' = effective overburden pressure (kPa) = γH

P_a = atmospheric pressure = 100 kPa

FINAL EXAMINATION

SEMESTER / SESSION	: SEM II / 2018/2019	PROGRAMME CODE	: 4 BFF
COURSE NAME	: FOUNDATION ENGINEERING	COURSE CODE	: BFC 43103

SHALLOW FOUNDATIONS

Modification of Bearing Capacity Equations for Water Table

Case I for water within $0 \le D_1 \le D_f$; $q = D_1\gamma_{dry} + D_2(\gamma_{sat} - \gamma_w)$ $\gamma' = \gamma_{sat} - \gamma_w$	Case II for water within $0 \le d \le B$; $q = D_1\gamma_{dry}$ $\bar{\gamma} = \gamma' + \frac{d}{B}(\gamma_{dry} - \gamma')$	Case III when the water table is located so that $d \ge B$, the water will have no effect on the ultimate bearing capacity.

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

Shape Factor

$F_{cs} = 1 + \frac{B}{L}\cdot\frac{N_q}{N_c}$	$F_{qs} = 1 + \frac{B}{L}\tan\phi$	$F_{\gamma s} = 1 - 0.4\frac{B}{L}$

Depth Factor

$D_f/B \le 1, for\ \phi = 0$		
$F_{cd} = 1 + 0.4(^{D_f}/_B)$	$F_{qd} = 1$	$F_{\gamma d} = 1$
$^{D_f}/_B \le 1, for\ \phi > 0$		
$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c tan\phi'}$	$F_{qd} = 1 + 2tan\phi'(1 - sin\phi')^2\frac{D_f}{B}$	$F_{\gamma d} = 1$
$D_f/B > 1, for\ \phi = 0$		
$F_{cd} = 1 + \underbrace{0.4\ tan^{-1}\left(^{D_f}/_B\right)}_{\text{radians}}$	$F_{qd} = 1$	$F_{\gamma d} = 1$
$D_f/B > 1, for\ \phi > 0$		
$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c tan\phi'}$	$F_{qd} = 1 + 2\tan\phi'\ (1 - sin\phi')^2 \underbrace{tan^{-1}(\frac{D_f}{B})}_{\text{radians}}$	$F_{\gamma d} = 1$

where L is the length of the foundation and L>B.

Inclination Factor

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

β is the inclination of the load on the foundation with respect to vertical

Eccentric Loading in Shallow Foundations

$q_{max} = \frac{Q}{BL} \pm \frac{6M}{B^2L}$ $q_{max} = \frac{4Q}{3L(B - 2e)}$	$e = \frac{M}{Q}$ $FS = \frac{Q_{ult}}{Q}$

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2018/2019 PROGRAMME CODE : 4 BFF
COURSE NAME : FOUNDATION ENGINEERING COURSE CODE : BFC 43103

SHALLOW FOUNDATIONS

$$q'_u = c'N_cF_{cs}F_{cd}F_{ci} + qN_qF_{qs}F_{qd}F_{qi} + \tfrac{1}{2}\gamma' B' N_\gamma F_{\gamma s}F_{\gamma d}F_{\gamma i}$$

One Way Eccentric Loading in Shallow Foundations

Method 1:

$$B' = B - 2e$$
$$L' = L$$
$$q'_u = c'N_cF_{cs}F_{cd}F_{ci} + qN_qF_{qs}F_{qd}F_{qi} + \tfrac{1}{2}\gamma' B' N_\gamma F_{\gamma s}F_{\gamma d}F_{\gamma i}$$
$$Q_{ult} = q'_u B' L'$$

Method 2:

$$Q_{ult} = B\left[c'N_{c(e)} + qN_{q(e)} + \frac{1}{2}\gamma B N_{\gamma(e)}\right]$$
$$Q_{ult} = BL\left[c'N_{c(e)}F_{cs(e)} + qN_{q(e)}F_{qs(e)} + \frac{1}{2}\gamma B N_{\gamma(e)}F_{\gamma s(e)}\right]$$
$$F_{cs(e)} = 1.2 - 0.025\frac{L}{B}$$
$$F_{qs(e)} = 1.00$$
$$F_{\gamma s(e)} = 1.0 + \left(\frac{2e}{B} - 0.68\right)\frac{B}{L} + \left[0.43 - \left(\frac{3}{2}\right)\left(\frac{e}{B}\right)\right]\left(\frac{B}{L}\right)^2$$

Primary Consolidation Settlement for Normally Consolidated Clays

$$S_{c(p)} = \frac{C_cH_c}{1+e_o}\log\frac{\sigma'_o + \Delta\sigma'_{av}}{\sigma'_o}, \text{ for 2:1 method } \Delta\sigma'_{(1)} = \frac{Q_g}{(L_g+z_1)(B_g+z_1)}$$

Primary Consolidation Settlement for OverConsolidated Clays

for $\sigma'_o + \Delta\sigma'_{av} < \sigma'_c$

$$S_{c(p)} = \frac{C_sH_c}{1+e_o}\log\frac{\sigma'_o + \Delta\sigma'_{av}}{\sigma'_o}$$

for $\sigma'_o < \sigma'_c < \sigma'_o + \Delta\sigma'_{av}$

$$S_{c(p)} = \frac{C_sH_c}{1+e_o}\log\frac{\sigma'_c}{\sigma'_o} + \frac{C_cH_c}{1+e_o}\log\frac{\sigma'_o + \Delta\sigma'_{av}}{\sigma'_c}$$

Average Increase in Pressure

$$\Delta\sigma'_{av} = \tfrac{1}{6}\left(\Delta\sigma'_{top} + 4\Delta\sigma'_{medium} + \Delta\sigma'_{bottom}\right), \Delta\sigma'_{top/middle/bottm} = 4q_oI$$
$$m = \frac{B}{z}, n = \frac{L}{z}$$

Secondary Consolidation Settlement

$$S_{c(s)} = C'_aH_c\log(t_2/t_1)$$

FINAL EXAMINATION

SEMESTER / SESSION	: SEM II / 2018/2019	PROGRAMME CODE	: 4 BFF
COURSE NAME	: FOUNDATION ENGINEERING	COURSE CODE	: BFC 43103

PILE FOUNDATIONS

Ultimate Capacity of Piles

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 $Q_p = 9 c_u A_p$

Vesic

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

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

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

$Q_p = A_p q_c$

$q_p = q_c$

$Q_s = \Sigma p \Delta L f$

$f = \alpha' f_c$

$f_c = Frictional\ resistance$

Pile Load Test (Davisson's method)

$$s_u(mm) = 0.012 D_r + 0.1\left(\frac{D}{D_r}\right) + \frac{Q_u L}{A_p E_p}$$

$D_r = reference\ pile\ diameter\ (= 300mm)$

$D\ is\ in\ mm$

CONVENTIONAL GRAVITY AND CANTILEVER WALL

Rankine's Theory

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

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

$P_v = P_a \sin\alpha°$

$P_h = P_a \cos\alpha°$

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

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

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

$$FS_{overturning} = \frac{\sum M_R}{\sum M_O}$$

$$\sum M_O = P_h\left(\frac{H'}{3}\right)$$

$P_h = P_a \cos\alpha$

$P_v = P_a \sin\alpha$

$$FS_{sliding} = \frac{\sum F_{R'}}{\sum F_d} = \frac{\left(\sum V\right)\tan\left(k_1\phi_2'\right) + Bk_2c_2' + P_p}{P_a \cos\alpha}$$