UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2018/2019

COURSE NAME	:	FOUNDATION ENGINEERING
COURSE CODE	:	BFC 43103
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	DECEMBER 2018 / JANUARI 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS IN **SECTION A**, AND ANY **THREE (3)** QUESTIONS IN **SECTION B**

THIS QUESTION PAPER CONSISTS OF **FIFTEEN (15)** PAGES

SECTION A

Q1 (a) Briefly, discuss **ONE (1)** mechanical modification and **ONE (1)** hydraulic modification technique for ground improvement.

(4 marks)

(b) The in situ void ratio, e of a borrow pit is 0.72. The borrow pit soil is to be excavated and transported to fill a construction site where it will be compacted to a void ratio of 0.42. The construction project requires 10,000 m^3 of compacted soil fill. Determine the volume of soil that must be excavated from the borrow pit to provide the required volume of fill.

(4 marks)

(c) Refer to **Figure Q1(c)** and **Table Q1(c)** for a large fill operation, the average permanent load ($\Delta\sigma'_{(p)}$) on the clay layer will increase by about 57.5 kN/m^2. The average effective overburden pressure on the clay before the fill operation is 71.88 kN/m^2. For the clay layer, which is normally consolidated and drained from top and bottom, it is also given that $H_c = 4.57$ m, $C_c = 0.30$, $e_o = 1.0$, $c_v = 9.68 \times 10^{-2}$ cm^2/min. Determine the followings:

(i) The primary consolidation settlement of the clay layer caused by the addition of the permanent load, $\Delta\sigma'_{(p)}$.

(2 marks)

(ii) The time required for 80% of primary consolidation settlement under the addition permanent load only.

(4 marks)

(iii) The temporary surcharge, $\Delta\sigma'_{(f)}$, that will be required to eliminate the entire primary consolidation settlement in 12 months by the precompression technique.

(6 marks)

SECTION B

Q2 (a) Site investigation is one of the important process in foundation works. Explain in detail the purposes of doing site investigation or subsurface exploration.

(6 marks)

(b) **Table Q2(b)** shows results of a seismic refraction field work at a Batu Pahat residual soil for proposed new building project.

(i) Sketch of graph distance against time of first arrival.

(6 marks)

(ii) Calculate the seismic velocity and thickness of the material encountered from the survey.

(8 marks)

Q3 (a) Explain types of bearing capacity failure.

(6 marks)

(b) The square footing is 1.5 m x 1.5 m in plan. The soil supporting foundation has a friction angle 29° and cohesive value 92 kN/m^2. The unit weight of soil is 19 kN/m^3. Assume the depth of foundation is 1.8 m depth. The column was located 0.3 m away from the centre of footing in X-axis but remain in the centre for Y-axis, calculate:

i. The ultimate bearing capacity of soil using Meyerhof's method (refer **Table Q3(b)(i)**).

(9 marks)

ii. The ultimate bearing capacity of soil using Prakash & Saran's method (refer **Figure Q3(b)(ii)**).

(5 marks)

Q4 (a) A pile is a slender structural member that is installed in the ground to transfer the structural loads to the foundation soil. Outline how piles are classified according to the type of material, cross sectional geometry, method of installation and load transfer mechanism.

(5 marks)

(b) A building was constructed with concrete piles used for its foundation that is embedded in sand. The building imposed an allowable working load of 338 kN of point load and 280 kN of frictional resistant load on a 0.305 x 0.305 m cross section piles. Site investigation has shown that the sand has a unit weight of (γ) 17 kN/m^3 and a frictional resistance (ϕ) of 38°. It is also given that Ep = 21 x 106 kN/m^2, Es = 30,000 kN/m^2, μs = 0.3, and ξ = 0.62. Calculate the elastic settlement of the pile.

(7 marks)

(c) A group of piles has a section of 3 x 4 with each having a diameter of 500 mm are embedded in clay. The length of the piles is 12 m and the spacing between the piles (d) is 1.2 m. The dry unit weight of the clay is 18 kN/m^3. The water table is located at a depth of 2 m and the saturated unit weight of the clay is 20 kN/m^3. The recorded undrained shear strength (C_u) profile for the ground is shown in **Table Q4(c)**. Evaluate the allowable load bearing capacity of the pile with a factor safety of (FS) of 2.5.

(8 marks)

Q5 (a) Propose and explain the suitable materials used as a backfill of retaining wall.

(2 marks)

(b) A cantilever sheet pile wall penetrating 3.0 m into the sandy soil. The ground water table is 3 m below the ground surface. The soil properties at site is shown in **Figure Q5(b)**. For design purposes, the factor of safety of 1.5 was applied on the passive earth pressure coefficient.

(i) Determine the stability of the sheet pile wall as shown in **Figure Q5(b)**.

(15 marks)

(ii) According to the answer in **Q5(b)(i)**, if the wall is not stable, propose and explain briefly the conventional and economical method in the construction of sheet pile.

(3 marks)

-END OF QUESTIONS-

FINAL EXAMINATION

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

Table Q1(c): Variation of time factor with degree of consolidation

U (%)	T_v	U (%)	T_v	U (%)	T_v	U (%)	T_v
0	0	26	0.0531	52	0.212	78	0.529
1	0.00008	27	0.0572	53	0.221	79	0.547
2	0.0003	28	0.0615	54	0.230	80	0.567
3	0.00071	29	0.0660	55	0.239	81	0.588
4	0.00126	30	0.0707	56	0.248	82	0.610
5	0.00196	31	0.0754	57	0.257	83	0.633
6	0.00283	32	0.0803	58	0.267	84	0.658
7	0.00385	33	0.0855	59	0.276	85	0.684
8	0.00502	34	0.0907	60	0.286	86	0.712
9	0.00636	35	0.0962	61	0.297	87	0.742
10	0.00785	36	0.102	62	0.307	88	0.774
11	0.0095	37	0.107	63	0.318	89	0.809
12	0.0113	38	0.113	64	0.329	90	0.848
13	0.0133	39	0.119	65	0.304	91	0.891
14	0.0154	40	0.126	66	0.352	92	0.938
15	0.0177	41	0.132	67	0.364	93	0.993
16	0.0201	42	0.138	68	0.377	94	1.055
17	0.0227	43	0.145	69	0.390	95	1.129
18	0.0254	44	0.152	70	0.403	96	1.219
19	0.0283	45	0.159	71	0.417	97	1.336
20	0.0314	46	0.166	72	0.431	98	1.500
21	0.0346	47	0.173	73	0.446	99	1.781
22	0.0380	48	0.181	74	0.461	100	∞
23	0.0415	49	0.188	75	0.477		
24	0.0452	50	0.197	76	0.493		
25	0.0491	51	0.204	77	0.511		

Table Q2(b): Result of a seismic refraction field survey

Distance from the source of disturbance (m)	Time of first arrival of P-wave (sec x 10^{-3})
5	10
10	20
15	30
20	40
30	50
40	60
45	65
60	72
70	76
80	80

FINAL EXAMINATION

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

Table Q3(b)(i): Meyerhof's Bearing Capacity factors for general equation

Ø	N_c	N_q	N_γ	Ø	N_c	N_q	N_γ
0	5.14	1.00	0.00	26	22.25	11.85	12.54
1	5.38	1.09	0.07	27	23.94	13.20	14.47
2	5.63	1.20	0.15	28	25.80	14.72	16.72
3	5.90	1.31	0.24	29	27.86	16.44	19.34
4	6.19	1.43	0.34	30	30.14	18.40	22.40
5	6.49	1.57	0.45	31	32.67	20.67	25.99
6	6.81	1.72	0.57	32	35.49	23.18	30.22
7	7.16	1.88	0.71	33	38.64	26.09	35.19
8	7.53	2.06	0.86	34	42.16	29.44	41.06
9	7.92	2.25	1.03	35	46.12	33.30	48.03
10	8.35	2.47	1.22	36	50.59	37.75	56.31
11	8.80	2.71	1.44	37	55.63	42.92	66.19
12	9.28	2.97	1.69	38	61.35	48.93	78.03
13	9.81	3.26	1.97	39	67.87	55.96	92.25
14	10.37	3.59	2.29	40	75.31	64.20	109.41
15	10.98	3.94	2.65	41	83.86	73.90	130.22
16	11.63	4.34	3.06	42	93.71	85.38	155.55
17	12.34	4.77	3.53	43	105.11	99.02	186.54
18	13.10	5.26	4.07	44	118.37	115.31	224.64
19	13.93	5.80	4.68	45	133.88	134.88	271.76
20	14.83	6.40	5.39	46	152.10	158.51	330.35
21	15.82	7.07	6.20	47	173.64	187.21	403.67
22	16.88	7.82	7.13	48	199.26	222.31	496.01
23	18.05	8.66	8.20	49	229.93	265.51	613.16
24	19.32	9.60	9.44	50	266.89	319.07	762.89
25	20.72	10.66	10.88				

Table Q4(c): Variation of C_u with pile embedment length

Depth (m)	0 - 4	4 - 7	7 - 13
Undrained shear strength, C_u (kN/m^2)	70	85	100

FINAL EXAMINATION

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

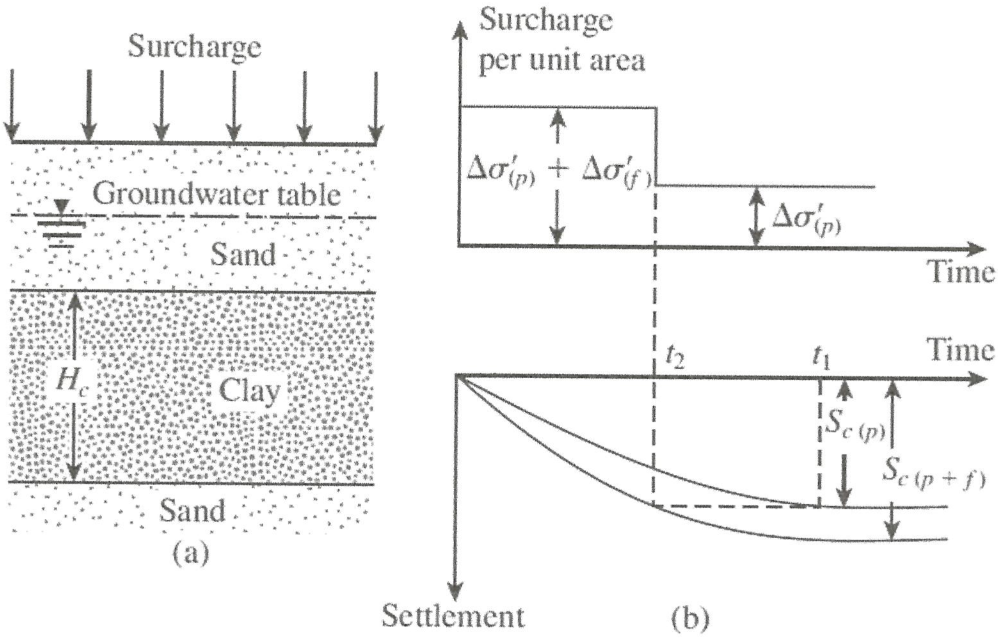

Figure Q1 (c)

FINAL EXAMINATION

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

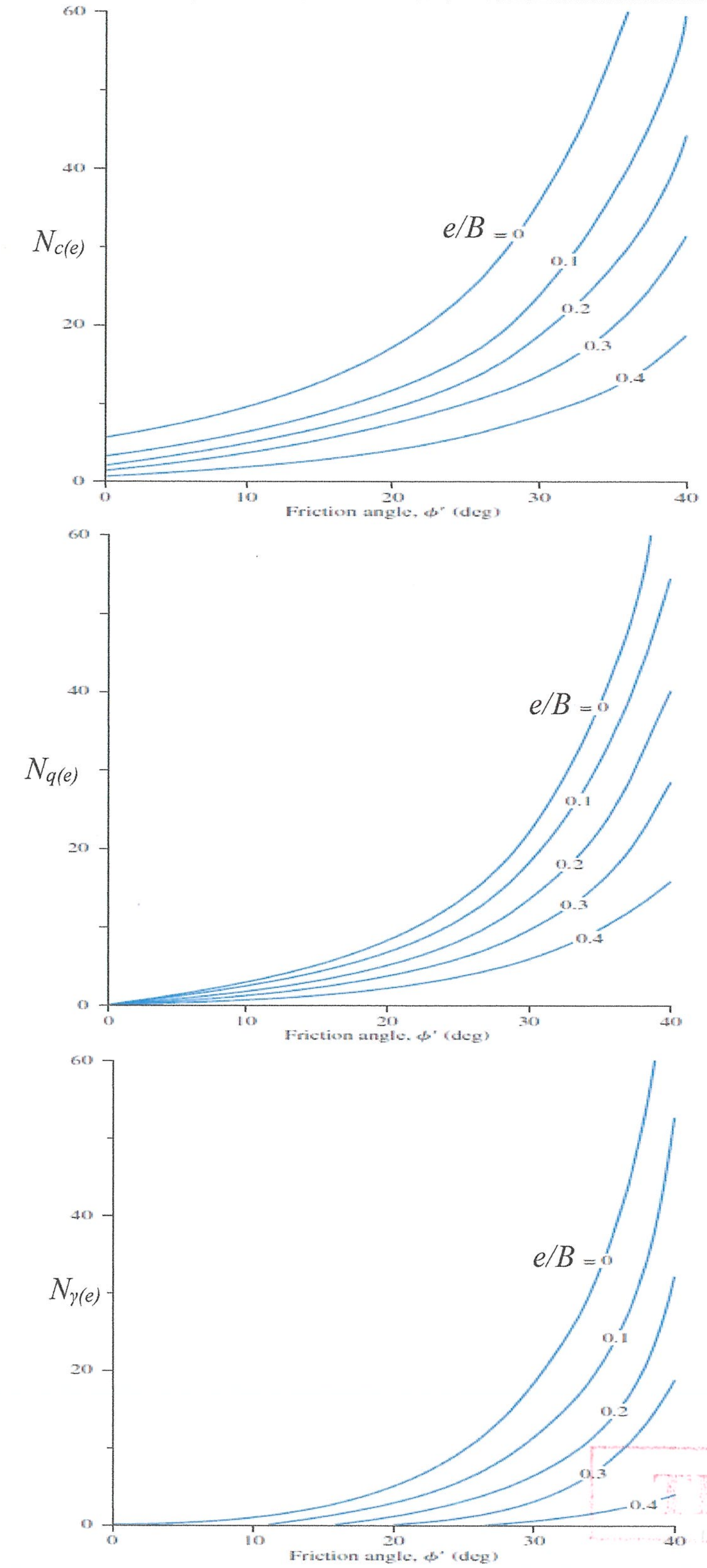

Figure Q3(b)(ii): Variation of $N_{c(e)}$, $N_{q(e)}$ and $N\gamma_{(e)}$ with soil friction angle ϕ

FINAL EXAMINATION

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

$\frac{c_u}{p_a}$	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

Figure Q4(i): Variation of α

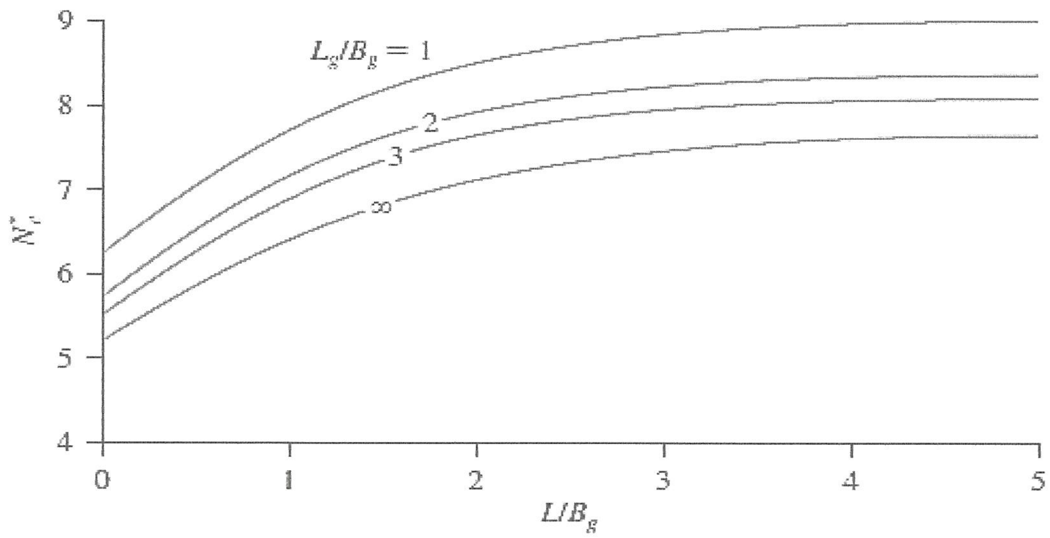

Figure Q4(ii): variation of N_c with L/B_g

FINAL EXAMINATION

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

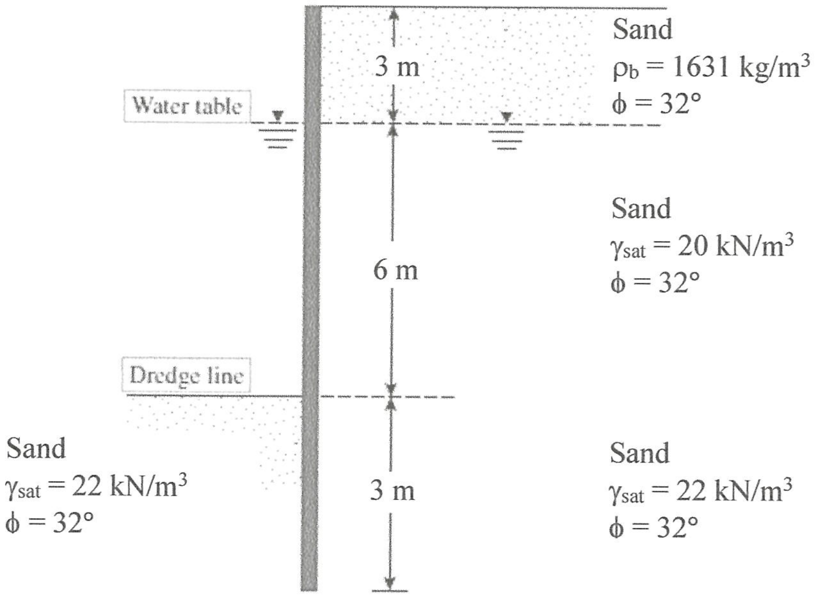

Figure Q5(b): Sheet Pile Wall

FINAL EXAMINATION

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

List of formula

SOIL IMPROVEMENT AND GROUND MODIFICATION

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

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

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

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

For U% > 60%;

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

$$U = \frac{\log\left[\frac{\sigma'_o + \Delta\sigma'_{(p)}}{\sigma'_o}\right]}{\log\left[\frac{\sigma'_o + \Delta\sigma'_{(p)} + \Delta\sigma'_{(f)}}{\sigma'_o}\right]}$$

$$U = \frac{\log\left[1 + \frac{\Delta\sigma'_{(p)}}{\sigma'_o}\right]}{\log\left[1 + \frac{\Delta\sigma'_{(p)}}{\sigma'_o}\left(1 + \frac{\Delta\sigma'_{(f)}}{\sigma'_{(p)}}\right)\right]}$$

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

FINAL EXAMINATION

SEMESTER / SESSION : SEM I / 2018/2019 PROGRAMME CODE : 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		
$D_f/B \le 1, for\ \phi = 0$		
$F_{cd} = 1 + 0.4(^{D_f}/_B)$	$F_{qd} = 1$	$F_{\gamma d} = 1$
$^{D_f}/_B \le 1, for\ \phi > 0$		
$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c tan\phi'}$	$F_{qd} = 1 + 2tan\phi'(1 - sin\phi')^2\frac{D_f}{B}$	$F_{\gamma d} = 1$
$D_f/B > 1, for\ \phi = 0$		
$F_{cd} = 1 + \underbrace{0.4\ tan^{-1}(^{D_f}/_B)}_{radians}$	$F_{qd} = 1$	$F_{\gamma d} = 1$
$D_f/B > 1, for\ \phi > 0$		
$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c tan\phi'}$	$F_{qd} = 1 + 2\tan\phi'(1 - sin\phi')^2 \underbrace{tan^{-1}(\frac{D_f}{B})}_{radians}$	$F_{\gamma d} = 1$
where L is the length of the foundation and L>B.		

Inclination Factor	
$F_{ci} = F_{qi} = \left(1 - \frac{\beta°}{90°}\right)^2$	$F_{\gamma i} = \left(1 - \frac{\beta}{\phi'}\right)^2$
β is the inclination of the load on the foundation with respect to vertical	

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

TERBUKA

FINAL EXAMINATION

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

SHALLOW FOUNDATIONS

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

One Way Eccentric Loading in Shallow Foundations

Method 1:

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

Method 2:

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

Method 3:

$$R_k = 1 - \frac{q_{u(eccentric)}}{q_{u(centric)}}$$
$$R_k = a\left(\frac{e}{B}\right)^k$$
$$q_{u(eccentric)} = q_{u(centric)}\left(1 - R_k\right)$$
$$q_{u(centric)} = qN_q F_{qd} + \tfrac{1}{2}\gamma B N_\gamma F_{\gamma d}$$
$$Q_{ult} = B q_{u(eccentric)}$$

Primary Consolidation Settlement for Normally Consolidated Clays

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

Primary Consolidation Settlement for OverConsolidated Clays

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

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

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

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

Average Increase in Pressure

$$\Delta\sigma'_{av} = \tfrac{1}{6}\left(\Delta\sigma'_{top} + 4\Delta\sigma'_{medium} + \Delta\sigma'_{bottom}\right), \Delta\sigma'_{top/middle/bottm} = q_o I_c$$
$$m_1 = \frac{L}{B}, n_1 = \frac{z}{(B/2)}$$

FINAL EXAMINATION

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

PILE FOUNDATIONS

Ultimate Capacity of Piles and Group Piles in Saturated Clay

$$Q_s = \sum f p \Delta L$$

$$f = \beta \sigma_o'$$

$$\beta = K \tan \phi_R'$$

$$K = 1 - \sin \phi_R'$$

$$K = 1 - \sin \phi_R' \sqrt{OCR}$$

$$OCR = \frac{p_c}{P_o}$$

$$Q_p = A_p q_p$$

$$Q_p = A_p q' N_q^*$$

$$Q_p \approx N_c^* c_u A_p$$

$$Q_p = 9 c_u A_p$$

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

$$\sum Q_u = n_1 n_2 \left[9 A_p c_{u(p)} + \sum \alpha p c_u \Delta L \right]$$

$$L_g = (n_1 - 1) d + 2\left(\frac{D}{2}\right)$$

$$B_g = (n_2 - 1) d + 2\left(\frac{D}{2}\right)$$

$$\sum Q_u = L_g B_g c_{u(p)} N_c^* + \sum 2 (L_g + B_g) c_u \Delta L$$

$$\Delta s_{c_i} = \left[\frac{\Delta e_i}{1 + e_{o_i}}\right] H_i$$

$$\eta = \frac{[2(n_1 + n_2 - 2)d + 4D]}{p n_1 n_2}$$

CONVENTIONAL GRAVITY AND CANTILEVER WALL

Rankine's Theory

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

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

$$P_v = P_a \sin \alpha^\circ$$

$$P_h = P_a \cos \alpha^\circ$$

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

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

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

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

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

$$P_h = P_a \cos \alpha$$

$$P_v = P_a \sin \alpha$$

$$FS_{sliding} = \frac{\sum F_{R'}}{\sum F_d} = \frac{(\sum V) \tan(k_1 \phi_2') + B k_2 c_2' + P_p}{P_a \cos \alpha}$$

$$q_u = c'^{N_c} + q N_q + \frac{1}{2} \gamma B N_\gamma$$

FINAL EXAMINATION

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

LATERAL EARTH PRESSURE AND RETAINING WALLS

$$K_a = \tan^2\left(45 - \frac{\phi}{2}\right)$$

$$K_p = \tan^2\left(45 + \frac{\phi}{2}\right)$$

$$L_3 = \frac{\sigma'_2}{\gamma'(K_p - K_a)}$$

$$\sigma'_5 = (\gamma L_1 + \gamma' L_2)K_p + \gamma' L_3(K_p - K_a)$$

$$A_1 = \frac{\sigma'_5}{\gamma'(K_p - K_a)}$$

$$A_2 = \frac{8P}{\gamma'(K_p - K_a)}$$

$$A_3 = \frac{6P\left[2\bar{z}\gamma'(K_p - K_a) + \sigma'_5\right]}{\gamma'^2(K_p - K_a)^2}$$

$$A_4 = \frac{P\left[6\bar{z}\sigma'_5 + 4P\right]}{\gamma'^2(K_p - K_a)^2}$$

$$L_4^4 + A_1L_4^3 - A_2L_4^2 - A_3L_4 - A_4 = 0$$

$$\sigma'_4 = \sigma'_5 + \gamma' L_4(K_p - K_a)$$

$$\sigma'_3 = L_4(K_p - K_a)\gamma'$$

$$L_5 = \frac{\sigma'_3 L_4 - 2P}{\sigma'_3 + \sigma'_4}$$

$$K_{p(design)} = \frac{K_p}{FS}$$

$$S_V = \frac{T_{all}}{\gamma_1 z K_a [FS_{(B)}]}$$

$$L = \frac{H - z}{\tan\left(45 + \frac{\phi'_1}{2}\right)} + \frac{S_V K_a [FS_{(B)}]}{2\tan\phi'_F}$$

$$l_l = \frac{S_V K_a [FS_{(P)}]}{4\tan\phi'_F}$$

TERBUKA