UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	FOUNDATION ENGINEERING
COURSE CODE	:	BFC 43103
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS IN **SECTION A**, AND ONLY **ONE (1)** QUESTIONS IN **SECTION B**

THIS QUESTION PAPER CONSISTS OF **TEN (10)** PAGES

SECTION A

Q1 (a) Explain in detail **THREE (3)** factors that affecting soil pressure at the back of the retaining wall.

(6 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.

(9 marks)

(c) As a design engineer, you are in charge in designing a 10 m high reinforce earth retaining structure with the following specification.

The soils parameter for the wall backfill
unit weight of soil, γ, is 18.5 kN/m^3
soil internal friction angle, ϕ', is 36°

Galvanised steel reinforcement
Width of strip, w = 60 mm
F_y = 250,000 kN/m^2
$FS_{(B)}$= 3
$FS_{(P)}$= 3
S_v = 1 m center-to-center
S_H = 1 m center-to-center
ϕ'_μ = 24°

(i) Calculate the appropriate tie thickness for the steel-strip reinforcement. Assume the corrosion rate of the galvanised steel to be 0.02 mm/year and the life span of the structure to be 50 years.

(10 marks)

(ii) Calculate the tie length at 2m, 4m, 6m, 8m and 10m below the top of the retaining structure.

(5 marks)

(iii) Assess the overturning stability for the retaining structure.

(5 marks)

Q2 (a) Discuss the differences between preloading and vertical drain and give the major benefial effects of both techniques in civil engineering work.

(10 marks)

(b) Define the meaning of smear effect and evaluate the factors caused by smear effect after applying the vertical drains into the soft clay.

(10 marks)

(c) As an engineer in consultancy firm, you need to propose a soil improvement method of 30 km long highway project from Batu Pahat to Pontian. It is a new highway with two lanes in each direction constructed largely in areas that are underlain by soft clay deposits. Your proposal should include the reasons that associate with cost, time and the efficiency of the method

(15 marks)

SECTION B

Q3 (a) Define ultimate bearing capacity

(2 marks)

(b) List **TWO (2)** characteristic of shallow foundation

(4 marks)

(c) A square foundation 4.5 m x 4.5 m is founded at 2.4 m in a soil with the following properties:

$\gamma = 17.6\ kN/m^3$

$\gamma_{sat} = 20.4\ kN/m^3$

$c = 32.0\ kN/m^2$

$\varphi = 28°$

(i) Compute the ultimate bearing capacity in kN/m^2 by using Terzaghi's and Meyerhof's methods when the water table is level with the foundation base (FS=3).

(16 marks)

(ii) Using Terzaghi's method, determine the percentage reduction in bearing capacity when the water table rises to 0.5 m below ground level.

(8 marks)

Q4 (a) List and explain 3 types of testing in pile load test

(9 marks)

(b) **FIGURE Q4(b)** shows the section of 4 x 4 group pile in layered saturated clay. The piles are square in cross section (350 mm x 350 mm). The center-to-center spacing, d of the piles is 700 mm. Determine the allowable load-bearing capacity of the pile group. Use FS = 3

(21 marks)

-END OF QUESTIONS-

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TABLE Q3 (c): Terzaghi's Bearing Capacity Factors

ϕ'	N_c	N_q	N_γ^a	ϕ'	N_c	N_q	N_γ^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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Table Q3(c)(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(b): 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

Note: P_a = atmospheric pressure $\approx$ 100 kN/m^2 or 200lb/ft^2

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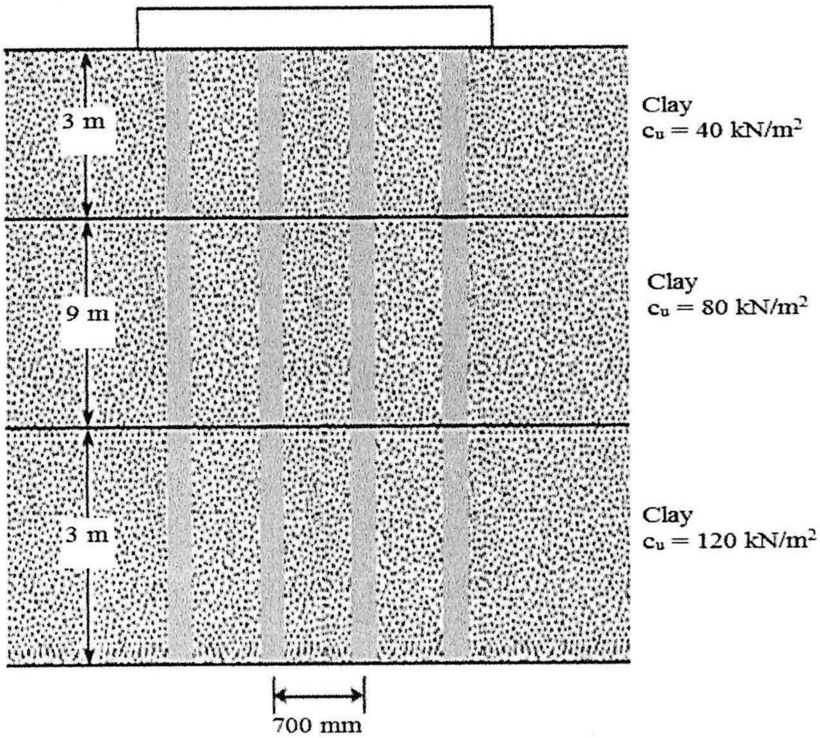

FIGURE Q4(b)

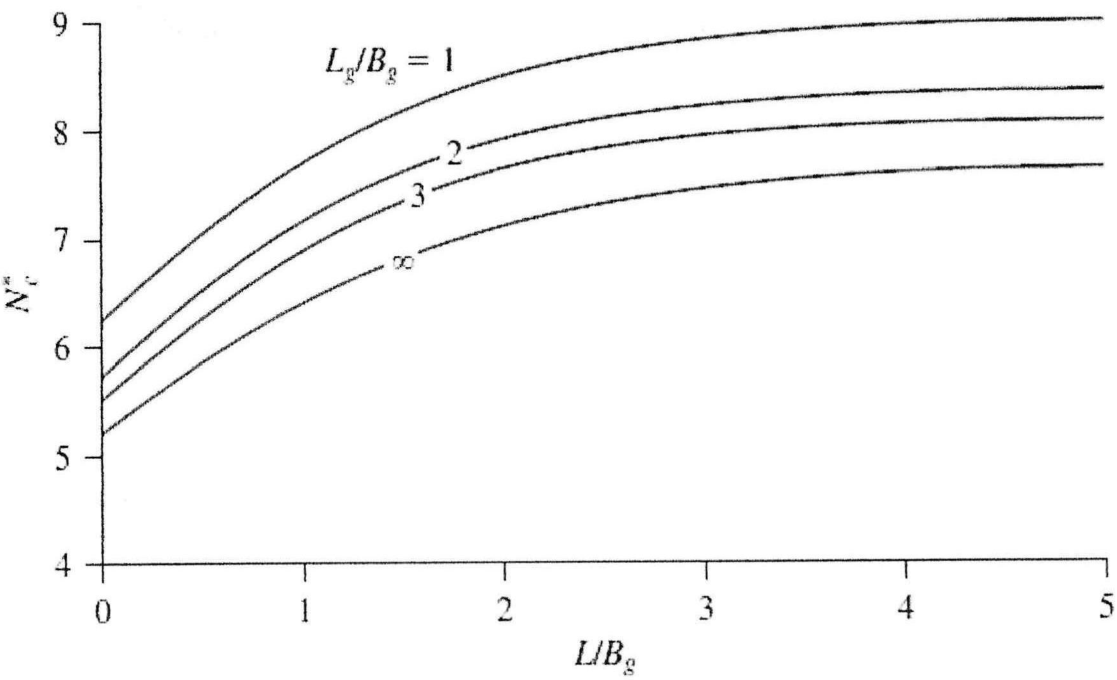

FIGURE Q4(b)(i) Variation of N_c with L_g/B_g and L/B_g

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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

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SHALLOW FOUNDATIONS

Modification of Bearing Capacity Equations for Water Table

Case I	Case II	Case III
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

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

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

Inclination Factor

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

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

Eccentric Loading in Shallow Foundations

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

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SHALLOW FOUNDATIONS

Terzaghi's Method

$$q_u = 1.3\,c'N_c + qN_q + 0.4\gamma BN_\gamma \quad \text{(square foundation)}$$

$$q_u = 1.3\,c'N_c + qN_q + 0.3\gamma BN_\gamma \quad \text{(circular foundation)}$$

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:

$$Q_{ult} = B\left[c'N_{c(e)} + qN_{q(e)} + \frac{1}{2}\gamma BN_{\gamma(e)}\right]$$

$$Q_{ult} = BL\left[c'N_{c(e)}F_{cs(e)} + qN_{q(e)}F_{qs(e)} + \frac{1}{2}\gamma BN_{\gamma(e)}F_{\gamma s(e)}\right]$$

$$F_{cs(e)} = 1.2 - 0.025\frac{L}{B}$$

$$F_{qs(e)} = 1.00$$

$$F_{\gamma s(e)} = 1.0 + \left(\frac{2e}{B} - 0.68\right)\frac{B}{L} + \left[0.43 - \left(\frac{3}{2}\right)\left(\frac{e}{B}\right)\right]\left(\frac{B}{L}\right)^2$$

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

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

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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 $Q_s = \Sigma f p \Delta L$

$f = \beta \sigma_o'$

Group Pile

$\Sigma Q_u = n_1 n_2 (Q_p + Q_s)$

$L_g = (n_1 - 1)d + 2(D/2)$

$B_g = (n_2 - 1)d + 2(D/2)$

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

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)

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

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

$D\ is\ in\ mm$

RETAINING WALL

Metallic Strip reinforcement

$T_{max} = \sigma_{a(max)} S_V S_H$

$\sigma_{a(max)} = \gamma_1 H K_a$

$$K_a = tan^2\left(45 - \frac{\emptyset'_1}{2}\right)$$

$$t = \frac{(T_{max})[FS_{(B)}]}{wf_y}$$

$$L = \frac{(H - z)}{tan^2\left(45 + \frac{\emptyset'_1}{2}\right)} + \frac{FS_{(P)} \gamma_1 z K_a S_V S_H}{2w\gamma_1 z\ tan\emptyset'_\mu}$$

$$FS_{(overturning)} = \frac{W_1 x_1}{P_a z'}$$

$$FS_{(sliding)} = \frac{W_1 tan(k\emptyset'_1)}{P_a}$$