UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2013/2014

COURSE NAME	:	FOUNDATION ENGINEERING
COURSE CODE	:	BFC 4043/BFC 43103
PROGRAMME	:	4 BFF
EXAMINATION DATE	:	DECEMBER 2013/ JANUARY 2014
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **Q1**, AND ANY **THREE (3)** OTHER QUESTIONS

THIS QUESTION PAPER CONSISTS OF **NINETEEN (19)** PAGES

Q1 (a) An Olympic-sized swimming pool is proposed to be constructed in the middle of a very busy city centre. The site is formerly a football field and covered by a cohesive soil. The large distributed load from the swimming pool and the structure may trigger a ground settlement. Therefore, ground improvement should be considered in order to overcome these problems. The local authority instructed that a sustainable technology should be implemented for any construction work in order to comply with the code of practice for noise and vibration. Propose with appropriate justifications:

(i) **TWO (2)** types of suitable ground improvement to be considered.
(5 marks)

(ii) **TWO (2)** types of unsuitable ground improvement to be avoided.
(5 marks)

(b) Refer to Figure **Q1(b)**. For a large fill operation, the average permanent load [$\Delta\sigma'_{(p)}$] on the clay layer will increase by about 83.5 kN/m^2. For the clay layer, which is normally consolidated and drained from top and bottom. Analyze the following:

(i) The average effective overburden pressure in the middle of the clay layer before the fill operation.
(5 marks)

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

(iii) The time required for 90% of primary consolidation settlement under the addition permanent load. Consider variation of degree of consolidation, U for various values of T_v in **Table 1**.
(5 marks)

Q2 (a) In conventional site investigation using the wash boring technique, the samples that can be retrieved at various depths can be classified as disturbed and undisturbed.

Describe the various laboratory tests that can be carried out on the disturbed and undisturbed samples and the usage of the results in the design of geotechnical structures.

(8 marks)

(b) The Standard Penetration Test (SPT) is the routine field or in situ test that is carried out in a borehole at various depths.

Explain the SPT test stating the instruments, the process, the kind of information that can be obtained and examples of usage of the result in the design of geotechnical structures.

(7 marks)

(c) A thin walled-tube (Shelby tube) sampler was pushed into soft clay at the bottom of a borehole a distance of 600 mm. When the tube was recovered, a measurement down inside the tube indicated a recovered sample length of 400 mm.

(i) What is the recovery ratio of the sample?

(2 marks)

(ii) Give your comment about sample quality based on **Q2(c)(i)**.

(3 marks)

(iii) If a Shelby tube sampler was not available during a site investigations work, name any other **TWO (2)** samplers that can be used to obtain soil sample that has almost the same quality as sample retrieve from a Shelby tube sampler.

(5 marks)

Q3 (a) For economic considerations, the depth at which a shallow foundation is located, D_f, is kept as small as possible. In determining this D_f, the influences of several factor should be carefully studied.

List and briefly explains **FIVE (5)** factors that influence the determination of depth of foundation, D_f.

(10 marks)

(b) A 2 m by 2 m square footing is buried 1.5 m below the ground surface. The footing as shown in Figure **Q2(b)** is subjected to a vertical load, P, of 300 kN and a horizontal load, H, of 45 kN.

Compute and draw soil pressure diagram beneath the footing level.

(5 marks)

(c) Considering general shear, compute the safety factor against a bearing capacity failure for the footing in Figure **Q2(b)** above for each of the bearing soils as follows

(i) Cohesionless soil with $\phi = 30°$, $\gamma = 16.5$ kN/m^3, and $c = 0$ kN/m^2.

(5 marks)

(ii) Cohesion soil with $\phi = 0°$, $\gamma = 18$ kN/m^3, and $c = 100$ kN/m^2.

(5 marks)

For each cases, ground water level is 4 m below the base of the footing.

Q4 (a) Jetting and Batter piles are two common driven piles and classified under the vibratory drivers and partial augering, respectively.
Briefly explains these jetting and batter piles in terms of their installations on site.

(6 marks)

(b) In Figure **Q4(b)**, let $H_f = 2.0$ m. The pile is circular in cross section with a diameter of 0.305 m. For the fill that is above the water table, $\gamma_f = 16$ kN/m^3 and $\phi' = 32°$. Determine the total drag force, Q_n (negative skin friction). Use $\delta = 0.6\phi'$.

(7 marks)

(c) The section of a 4 x 4 group pile in a layered saturated clay is shown in Figure **Q4(c)**. The piles are square in cross section (356 mm x 356 mm). The center-to-center spacing (d) of the piles is 1 m. Determine the allowable load-bearing capacity of the pile group. Use FS = 3.

(12 marks)

Q5 (a) Based on its structural form and loading system, sheet pile walls can be classified into **TWO (2)** types: cantilever sheet piles and anchored sheet piles.

(i) Briefly discussed with simple sketches for these **TWO (2)** types of sheet pile.

(5 marks)

(ii) The main factor anchors designed is to minimize the depth of penetration required by the sheet piles. There are typical two common methods under the anchored sheet pile walls.
Briefly discussed with simple sketches for these **TWO (2)** common methods.

(5 marks)

(b) Figure **Q5(b)** shows a braced cut system in soft normally consolidated. A uniform loads of 15 kN/m^2 is allocated at the backside of the excavated area. The struts are spaced at 4 m center to center.

(i) Determine the strut loads at each levels.

(10 marks)

(ii) Calculate the factor of safety against heave by using Chang (2000) method.

(5 marks)

-END OF QUESTION-

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Table 1

Variation of T_v with U

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	0.23	80	0.567
3	0.00071	29	0.066	55	0.239	81	0.588
4	0.00126	30	0.0707	56	0.248	82	0.61
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	0.39	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	1.5
21	0.0346	47	0.173	73	0.446	99	1.781
22	0.038	48	0.181	74	0.461		
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		

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Table 2

Variation of α (interpolated values based on Terzaghi, Peck and Mesri, 1996)

c_u/p_a	α
≤ 0.10	1.00
0.20	0.92
0.30	0.82
0.40	0.74
0.60	0.62
0.80	0.54
1.00	0.48
1.20	0.42
1.40	0.40
1.60	0.38
1.80	0.36
2.00	0.35
2.40	0.34
2.80	0.34

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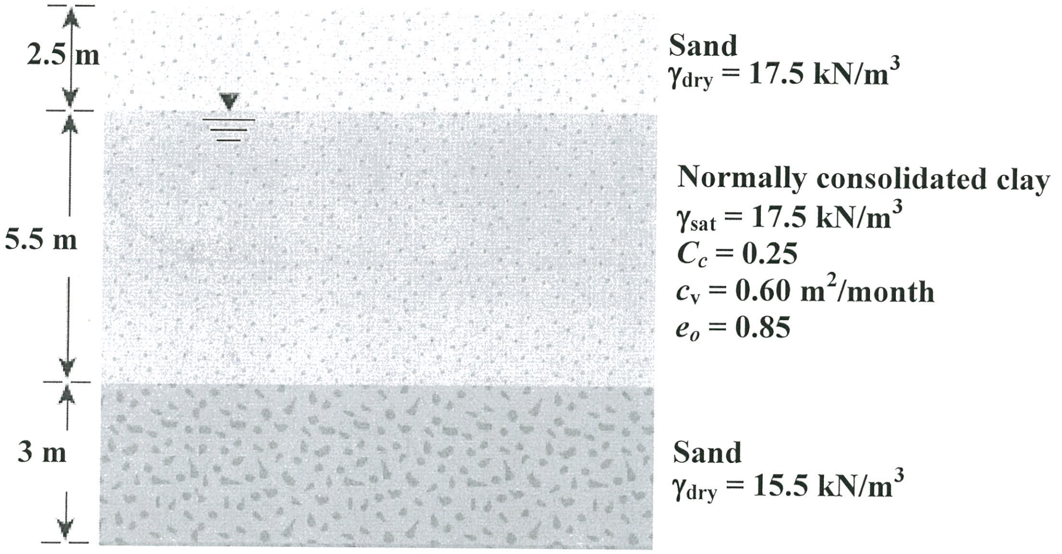

FIGURE Q1(b)

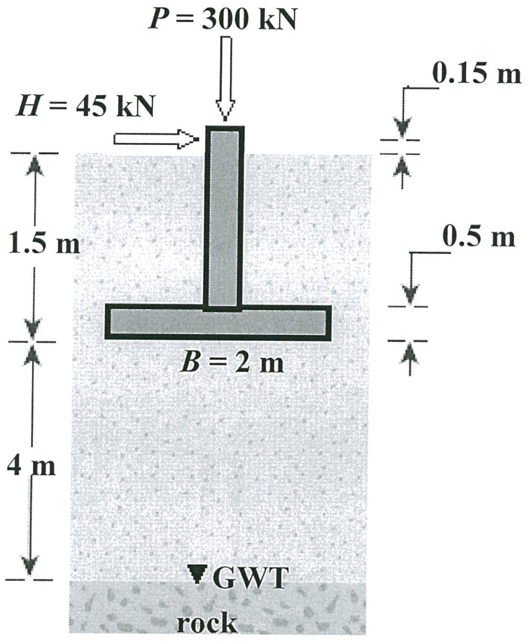

FIGURE Q2(b)

2 m

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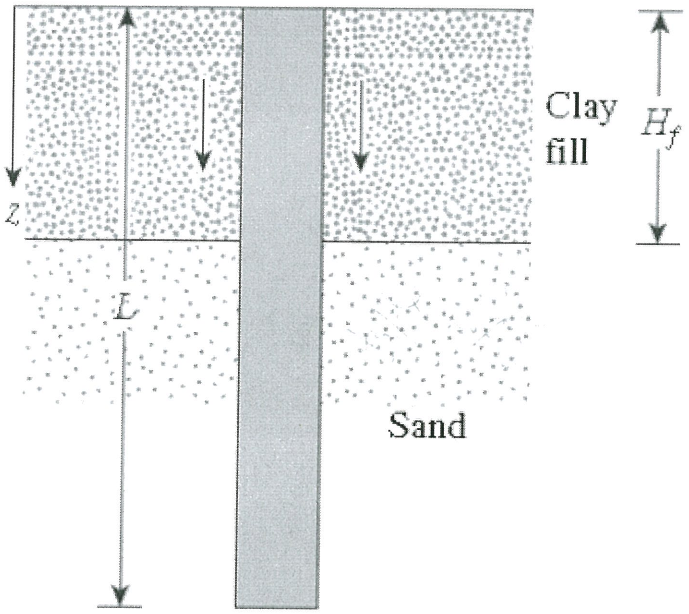

FIGURE Q4(b)

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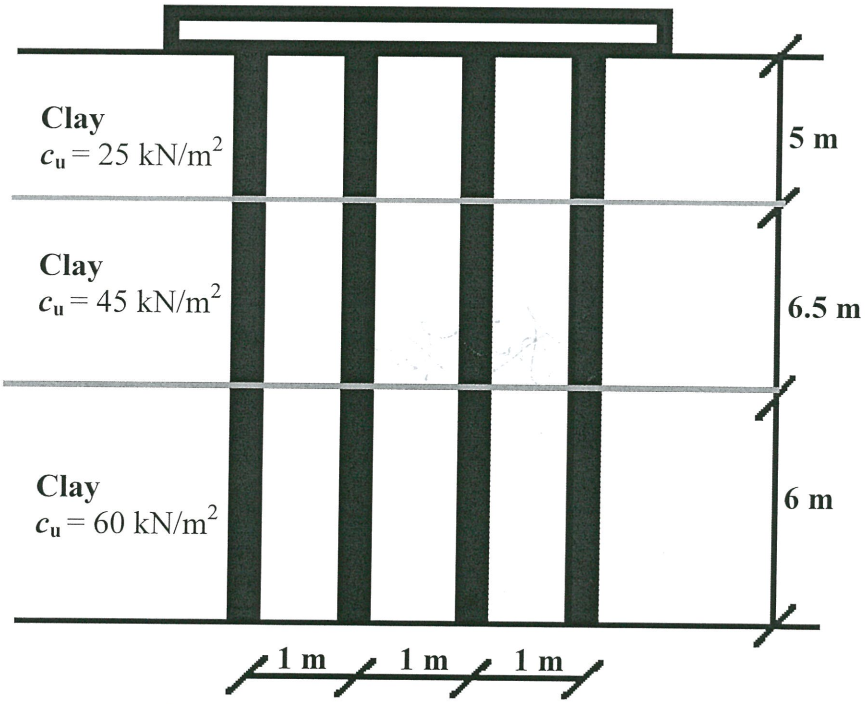

FIGURE Q4(c)

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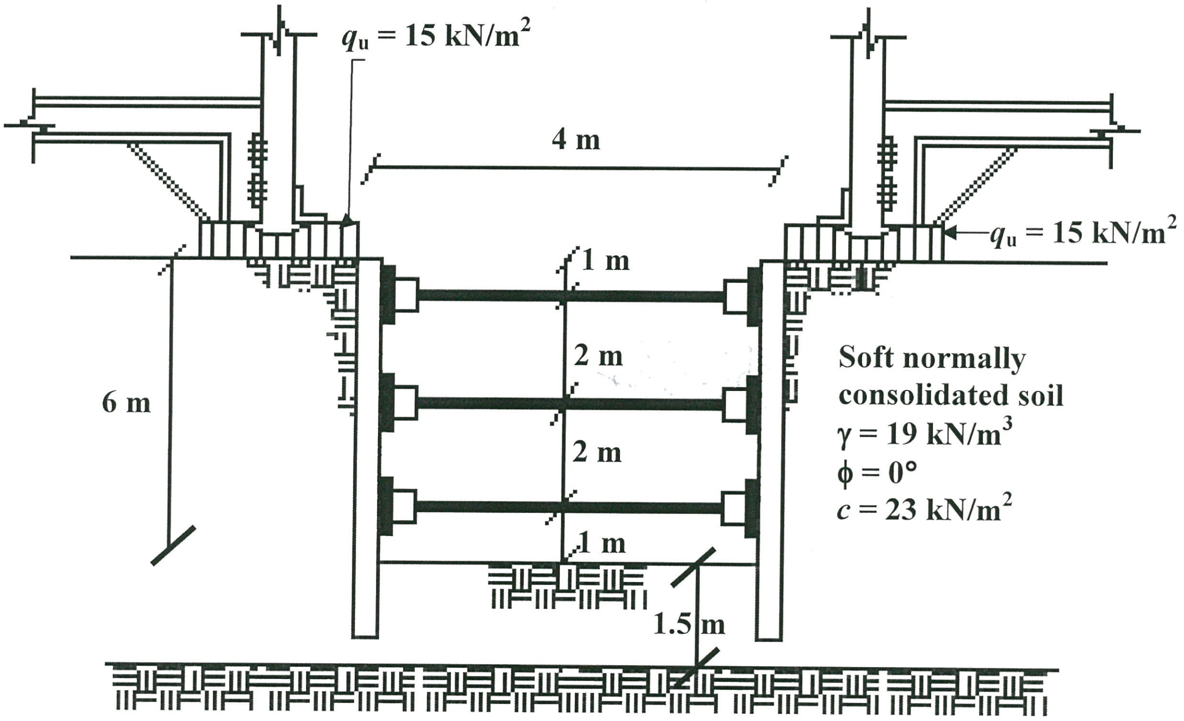

FIGURE Q5(b)

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The following formulae may be helpful in answering the questions. The symbols given are the ones commonly used.

SITE INVESTIGATION

Rock quality designation (RQD)

$$= \frac{\Sigma\text{length of recovered pieces equal to or larger than 101.6 mm}}{\text{theoretical length of rock cored}}$$

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

$$(N_1)_{60} = C_N N_{60}$$

$$C_N = \left[1\Big/\left(\frac{\sigma'_o}{p_a}\right)\right]^{0.5}$$

SHALLOW FOUNDATIONS

$$B^* = \frac{2BL}{B+L}$$

$$B^* = B$$

$$q_u = c'N_c + qN_q + \tfrac{1}{2}\gamma BN_\gamma$$

$$q_u = 1.3c'N_c + qN_q + 0.4\gamma BN_\gamma$$

$$q_u = 1.3c'N_c + qN_q + 0.3\gamma BN_\gamma$$

$$N_c = \cot\phi'(N_q - 1)$$

$$N_\gamma = \frac{1}{2}\left(\frac{K_{p\gamma}}{\cos^2\phi'} - 1\right)\tan\phi'$$

$$N_q = \frac{e^{2(3\pi/4 - \phi'/2)\tan\phi'}}{2\cos^2(45 + 0.5\phi')}$$

$$q_u = \tfrac{2}{3}c'N'_c + qN'_q + \tfrac{1}{2}\gamma BN'_\gamma$$

$$q_u = 0.867c'N'_c + qN'_q + 0.4\gamma BN'_\gamma$$

$$q_u = 0.867c'N'_c + qN'_q + 0.3\gamma BN'_\gamma$$

$$q_{all} = \frac{q_u}{FS}$$

$$q_{net(u)} = q_u - q$$

$$q_{net(u)} = \frac{q_u - q}{FS}$$

$$q = D_1\gamma + D_2(\gamma_{sat} - \gamma_w)$$

$$q = \gamma D_f$$

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

$$\gamma' = \gamma_{sat} - \gamma_w$$

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SHALLOW FOUNDATIONS

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

$$N_q = \tan^2(45+0.5\phi)e^{\pi\tan\phi'}$$

$$N_c = \cot\phi'(N_q-1)$$

$$N_\gamma = 2(N_q+1)\tan\phi'$$

Shape Factors by DeBeer (1970)

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

Depth Factors by Hansen (1970) for $D_f/B \le 1$

for $\phi = 0°$;

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

$$F_{qd} = 1$$

$$F_{\gamma d} = 1$$

for $\phi > 0°$;

$$F_{cd} = F_{qd} - \frac{1-F_{qd}}{N_c\tan\phi'}$$

$$F_{qd} = 1+2\tan\phi'(1-\sin\phi')^2(D_f/B)$$

$$F_{\gamma d} = 1$$

Depth Factors by Hansen (1970) for $D_f/B > 1$

for $\phi = 0°$;

$$F_{cd} = 1+0.4\left(\tan^{-1}\frac{D_f}{B}\right)_{radians}$$

$$F_{qd} = 1$$

$$F_{\gamma d} = 1$$

for $\phi > 0°$;

$$F_{cd} = F_{qd} - \frac{1-F_{qd}}{N_c\tan\phi'}$$

$$F_{qd} = 1+2\tan\phi'(1-\sin\phi')^2\underbrace{\tan^{-1}\left(\frac{D_f}{B}\right)}_{radians}$$

$$F_{\gamma d} = 1$$

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SHALLOW FOUNDATIONS

Inclination Factors by Meyerhof (1963); Hanna and Meyerhof (1981)

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

$\beta =$ inclination of the load on the foundation with respect to the vertical

ECCENTRICALLY LOADED FOUNDATIONS

$$q_{\text{max or min}} = \frac{Q}{BL} \pm \frac{6M}{B^2L}$$

$$q_{\text{max or min}} = \frac{Q}{BL}\left(1 \pm \frac{6e}{B}\right) \text{ with } e < B/6$$

$$q_{\text{max}} = \frac{4Q}{3L(B-2e)} \text{ with } e > B/6$$

$B' = B - 2e$; and $L' = L$

$L' = L - 2e$; and $B' = B$

$Q_{ult} = q'_u B'L'$

$$Q_{ult} = B\left[c'N_{c(e)} + qN_{q(e)} + 0.5\gamma BN_{\gamma(e)}\right]$$

$$F_{\gamma s(e)} = \begin{cases} 1 + \left(\frac{2e}{B} - 0.68\right)\frac{B}{L} \\ + \left[0.43 - \left(\frac{3}{2}\right)\left(\frac{e}{B}\right)\right]\left(\frac{B}{L}\right)^2 \end{cases}$$

$$F_{cs(e)} = 1.2 - 0.025\frac{L}{B} \quad (\text{min of } 1.0)$$

$F_{qs(e)} = 1$

$$FS = \frac{Q_{ult}}{Q}$$

PRIMARY CONSOLIDATION SETTLEMENT

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

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

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

$$\Delta\sigma'_{\text{av}} = \tfrac{1}{6}\left(\Delta\sigma'_t + 4\Delta\sigma'_m + \Delta\sigma'_b\right)$$

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PILE FOUNDATIONS IN GENERAL

$$Q_s = A_s f_s$$

$$Q_s = A_s f_s + A_c f_c$$

$$Q_s = A_c f_c$$

$$Q_s = A_p f_{av}$$

$$Q_u = Q_p + Q_s$$

$$Q_{all} = A_p q_p = A_p \left(c' N_c^* + q' N_q^* \right)$$

$$Q_s = \Sigma\, p \Delta L f$$

$$Q_{all} = \frac{Q_u}{FS}$$

PILE POINT BEARING CAPACITY – METHOD A

$$Q_p = A_p q_p = A_p q' N_q^* \le A_p q_l$$

$$q_l = 0.5 p_a N_q^* \tan \phi'$$

$$Q_p \approx N_c^* c_u A_p = 9 c_u A_p$$

PILE POINT BEARING CAPACITY – METHOD B

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

$$\bar{\sigma}_o' = \left(\frac{1 + 2K_o}{3} \right) q'$$

$$K_o = 1 - \sin \phi'$$

$$N_\sigma^* = \frac{3 N_q^*}{\left(1 + 2K_o\right)}$$

$$N_\sigma^* = f\left(I_{rr}\right)$$

$$I_{rr} = \frac{I_r}{1 + I_r \Delta}$$

$$I_r = \frac{E_s}{2\left(1 + \mu_s\right) q' \tan \phi'} = \frac{G_s}{q' \tan \phi'}$$

$$\frac{E_s}{p_a} = m$$

$$\mu_s = 0.1 + 0.3 \left(\frac{\phi' - 25}{20} \right)$$

$$\Delta = 0.005 \left(1 - \frac{\phi' - 25}{20} \right) \frac{q'}{p_a}$$

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

$$N_c^* = \tfrac{4}{3}\left(\ln\, I_{rr} + 1\right) + 0.5\pi + 1$$

$$I_r = \frac{E_s}{3 c_u}$$

$$I_r = 347 \left(\frac{c_u}{p_a} \right) - 33 \le 300$$

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FRICTIONAL RESISTANCE IN SAND

$$L' \approx 15D$$

$$f = K\sigma'_o \tan\delta'$$

$$Q_s = f_{\text{av}} pL = \left(K\bar{\sigma}'_o \tan\delta'\right) pL$$

$$Q_s = K\bar{\sigma}'_o \tan\left(0.8\phi'\right) pL$$

$$f_{\text{av}} = 0.02 p_a\left(\bar{N}_{60}\right)$$

$$f_{\text{av}} = 0.01 p_a\left(\bar{N}_{60}\right)$$

$$f_{\text{av}} = 0.224 p_a\left(\bar{N}_{60}\right)^{0.29}$$

$$Q_s = \sum p\left(\Delta L\right)\alpha' f_c$$

FRICTIONAL RESISTANCE IN CLAY

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

$$Q_s = pLf_{\text{av}}$$

$$\bar{\sigma}' = \frac{A_1 + A_2 + A_3 + \ldots}{L}$$

$$f = \alpha c_u$$

$$\alpha = C\left(\frac{\bar{\sigma}'_o}{c_u}\right)^{0.45}$$

$$Q_s = \sum \alpha c_u pL$$

$$f = \beta\sigma'_o$$

$$K = 1 - \sin\phi'_R$$

$$K = \left(1 - \sin\phi'_R\right)\sqrt{OCR}$$

$$f = \left(1 - \sin\phi'_R\right)\tan\phi'_R \sigma'_o$$

$$f = \left(1 - \sin\phi'_R\right)\tan\phi'_R \sqrt{OCR}\sigma'_o$$

$$f = \alpha' f_c$$

POINT BEARING CAPACITY ON ROCKS

$$q_p = q_u\left(N_\phi + 1\right)$$

$$N_\phi = \tan^2\left(45 + 0.5\phi'\right)$$

$$q_{u(design)} = \frac{q_{u(lab)}}{5}$$

$$Q_{p(all)} = \frac{\left[q_{u(design)}\left(N_\phi + 1\right)\right]A_p}{FS}$$

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PILE FOUNDATIONS UNDER LATERAL LOADS

1 $$p_{\mathrm{xu}} = \sigma_{\mathrm{vx}} K_q + cK_c$$

NEGATIVE SKIN FRICTION

$$f = K'\sigma'_o \tan\delta'$$

$$Q_n = \frac{pK'\gamma'_f H_f^2 \tan\delta'}{2}$$

$$L_1 = \frac{\left(L - H_f\right)}{L_1}\left[\frac{L - H_f}{2} + \frac{\gamma'_f H_f}{\gamma'}\right] - \frac{2\gamma'_f H_f}{\gamma'}$$

$$Q_n = \left(pK'\gamma'_f H_f \tan\delta'\right) L_1 + \frac{L_1^2 pK'\gamma'_f \tan\delta'}{2}$$

GROUP PILES

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

$$q_{u(design)} = \frac{q_{u(lab)}}{5}$$

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

$$Q_{p(all)} = \frac{\left[q_{u(design)}\left(N_\phi + 1\right)\right] A_p}{FS}$$

$$\eta = \frac{Q_{g(u)}}{\Sigma Q_u}$$

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

$$\eta = \left[\frac{2\left(n_1 + n_2 - 2\right)d + 4D}{pn_1 n_2}\right]\Sigma Q_u$$

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

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

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The following formulae may be helpful in answering the questions. The symbols given are the ones commonly used.

CONVENTIONAL GRAVITY AND CANTILEVER WALL – RANKINE'S THEORY

$$P_p = \tfrac{1}{2} K_p \gamma_2 D^2 + 2c'_2 \sqrt{K_p} D$$

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

$$K_p = \tan^2\left(45° + {}^{\phi'_2}\!/_{2}\right)$$

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

$$P_h = P_a \cos\alpha$$

$$P_v = P_a \sin\alpha$$

$$FS_{sliding} = \frac{\sum F_{R'}}{\sum F_d} = \frac{\left(\sum V\right)\tan\left(k_1 \phi'_2\right) + Bk_2 c'_2 + P_p}{P_a \cos\alpha}$$

$$K_a = \tan^2\left(45° - {}^{\phi'_2}\!/_{2}\right)$$

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

1 $$e = \frac{B}{2} - \frac{\sum M_R - \sum M_o}{\sum V}$$

$$FS_{\text{bearing capacity}} = \frac{q_u}{q_{toe}}$$

$$q_{heel}^{toe} = \frac{\sum V}{B}\left(1 \pm \frac{6e}{B}\right)$$

$$q_u = c'_2 N_c F_{cd} F_{ci} + q N_q F_{qd} F_{qi} + \tfrac{1}{2} \gamma B' N_\gamma F_{\gamma d} F_{\gamma i}$$

CONVENTIONAL GRAVITY AND CANTILEVER WALL – COULOMB'S THEORY

1 $$k_a = \cos\alpha \frac{\cos\alpha - \sqrt{\cos^2\alpha - \cos^2\phi'}}{\cos\alpha + \sqrt{\cos^2\alpha - \cos^2\phi'}}$$

10 $$k_p = \cos\alpha \frac{\cos\alpha + \sqrt{\cos^2\alpha - \cos^2\phi'}}{\cos\alpha - \sqrt{\cos^2\alpha - \cos^2\phi'}}$$

FINAL EXAMINATION

SEMESTER/SESSI0N : SEM I/2013/2014
COURSE NAME : FOUNDATION ENGINEERING

PROGRAMME : 4 BFF
COURSE CODE : BFC 4043/BFC 43103

The following formulae may be helpful in answering the questions. The symbols given are the ones commonly used.

BRACED CUTS – PRESSURE ENVELOPES

$$\sigma_a = \left.\begin{array}{c} \gamma H\left[1-\left(\dfrac{4c}{\gamma H}\right)\right] \\ \text{and} \\ 0.3\gamma H \end{array}\right\} \text{ for } \frac{\gamma H}{c} > 4$$

$$\sigma_a = 0.65\gamma H K_a$$

$$\sigma_a = 0.2\gamma H \text{ to } 0.4\gamma H \text{ for } \frac{\gamma H}{c} \leq 4$$

BRACED CUTS – BOTTOM HEAVE

$$q = \gamma H + q - \frac{cH}{B'}$$

$$FS = \frac{cN_c}{\left(\gamma + \dfrac{q}{H} - \dfrac{c}{B'}\right)H}$$

$$FS = \frac{cN_c\left(1 + 0.2\dfrac{B'}{L}\right)}{\left(\gamma + \dfrac{q}{H} - \dfrac{c}{B'}\right)H}$$

$$FS = \frac{5.14c\left(1 + \dfrac{0.2B''}{L}\right) + \dfrac{cH}{B'}}{\gamma H + q}$$

$$P = 0.7\left(\gamma HB - 1.4cH - \pi cB\right) \quad \text{for } d > 0.47B$$

$$P = 1.5d\left(\gamma H - \frac{1.4cH}{B} - \pi c\right) \quad \text{for } d < 0.47B$$