UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2017/2018

COURSE NAME	:	FOUNDATION ENGINEERING
COURSE CODE	:	BFC 43103
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	DECEMBER 2017 / JANUARY 2018
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) List and explain in detail the classifications of ground improvement techniques.

(8 marks)

(b) Explain the difference in the mechanism between compaction and consolidation techniques of ground improvement.

(2 marks)

(c) A road embankment was constructed that overlays a clay layer. The clay layer is identified as normally consolidated with two way drainage and has a thickness, H_c of 6 m. The properties for the clay are shown to have $C_c = 0.27$, $e_o = 1.02$, $c_v = 0.52$ m^2/month.

It is calculated that due to the construction of the embankment on the clay, the increase in vertical effective stress, $[\Delta\sigma'_{(p)}]$ will be about 35 kN/m^2. To increase the rate of consolidation settlement, a surcharge $[\Delta\sigma'_{(f)}]$ of 30 kN/m^2 is further placed. **Table 1** shows the variation of degree of consolidation with time factor. The current average effective overburden pressure on the clay is 110 kN/m^2.

(i) With the presence of the load form the embankment, determine the primary consolidation settlement of the clay layer, $\Delta\sigma'_{(p)}$ and the surcharge $\Delta\sigma'_{(f)}$.

(4 marks)

(ii) Determine the time required for 90% of the primary consolidation settlement under the addition of both the embankment and surcharge $\Delta\sigma'_{(f)}$.

(5 marks)

(iii) Determine the "additional" temporary surcharge, $\Delta\sigma'_{(f)}$, that will be required to eliminate the entire primary consolidation settlement calculated in **Q1(c)(i)** above within 6 months using the preloading technique.

(6 marks)

SECTION B

Q2 (a) Syarikat Berjaya proposed to develop a 300 m^2 housing project (single storey and double storey terrace house). Desk study shows that the area is soft clay area with high water table. Propose with explanation the required:

(i) Number of borehole.

(3 marks)

(ii) Type of in-situ testing.

(3 marks)

(iii) Type of sampling.

(2 marks)

(iv) Type of laboratory testing.

(2 marks)

(b) **Table 2** shows result of a seismic refraction field work of a proposed site for a building project.

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

(9 marks)

(ii) Evaluate the advantages and disadvantages of seismic refraction technique in the site investigation works.

(6 marks)

Q3 (a) Explain the differences between 'safe bearing capacity' and 'ultimate bearing capacity'.

(4 marks)

(b) Describe briefly **TWO (2)** methods or procedures for determining the design bearing capacity for shallow foundations. Include the advantages and disadvantages perceived for each methods.

(6 marks)

(c) A 1.5 m x 1.5 m square footing will be constructed as shown in **Figure Q3(c)**. A centric column load on the footing = 250 kN. A unit weight of soil, γ_{soil} = 18.8 kN/m^3 whereas the unit weight of concrete, $\gamma_{concrete}$ = 23.5 kN/m^3. Cohesive soil with unconfined compressive strength, UCS = 143.6 kN/m^3.

(i) Examine the soil contact pressure.

(7 marks)

(ii) Examine the factor of safety against bearing capacity failure.

(8 marks)

Q4 (a) List the types of hammers used for pile driving.

(2 marks)

(b) A structure which was built with a column having a load of 1000 kN needs to be supported by a single pile. As an engineer, you are required to make judgement based on calculations whether the soil has sufficient bearing capacity. Using the modified EN formula with a factor of safety of 6, estimate the allowable pile capacity (Q_{all}) of the precast concrete pile with a dimension of 400 mm x 400 mm using the information given below and comment if the pile is safe.

Maximum rated hammer energy, $W_R h$ = 50 kN.m
Hammer efficiency, E = 0.5
Weight of ram, W_R = 23.50 kN
Pile length, L = 18 m
Cofficient of restitution, n = 0.6
Weight of pile cap = 3.65 kN
Number of blows for last 25.4 mm of penetration, N = 9
C = 2.54 mm
Factor of safety, (FS) = 4
Unit weight of concrete, $\gamma_{concrete}$ = 23.58 kN/m^3

(5 marks)

(c) A building has been constructed with a load of 1500 kN being transferred to a foundation of group piles. The piles are precast concrete piles with a length of 9 meters and has a diameter of 0.4 meter. The piles penetrate into medium clay soil (c_u = 40 kN/m^2, γ_{sat} = 18 kN/m^3) with a thickness of 8 meters and are also embedded into 2 meters of stiff clay (c_u = 80 kN/m^2, γ_{sat} = 18.5 kN/m^3) as illustrated in **Figure Q4(c)(i)**. The pile cap is designed so that a spacing of 1.2 meters is allowed for the piles to be constructed as a group. Ground water level (GWL) coincides at the ground surface.

i) Determine if a section of 4 x 4 of group piles is sufficient to sustain the load from the building. Let the factor of safety be 4.

(8 marks)

ii) Also by referring to **Figure Q4(c)(i)**, calculate the consolidation settlement of the piles where all the clays are normally consolidated.

(10 marks)

Q5 (a) To check the stability for a retaining wall, several fundamental theories must be applied. Two theories of Rankine's and Coulumb's earth pressure are used. State the difference in terms of its assumptions in calculation between these two theories.

(4 marks)

(b) A 5.5 meter tall retaining wall supports a backfill as shown in **FIGURE Q5(b)**. The soil behind the wall is fine to medium sand with the following properties, $c_1' = 0$, $\phi_1' = 35^{\circ}$, and $\gamma_1 = 18.0$ kN/m^3. The soil below the footing is also a fine to medium sand and its properties are $c_2' = 0$, $\phi_2' = 38^{\circ}$, and $\gamma_2 = 19.5$ kN/m^3.

(i) Calculate the factors of safety with respect to overturning, sliding and bearing capacity using Rankine's theory. Comment also if the wall is safe from failure or not.

(17 marks)

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

(4 marks)

-END OF QUESTIONS-

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TABLE 1: Variations of U with T_v

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		

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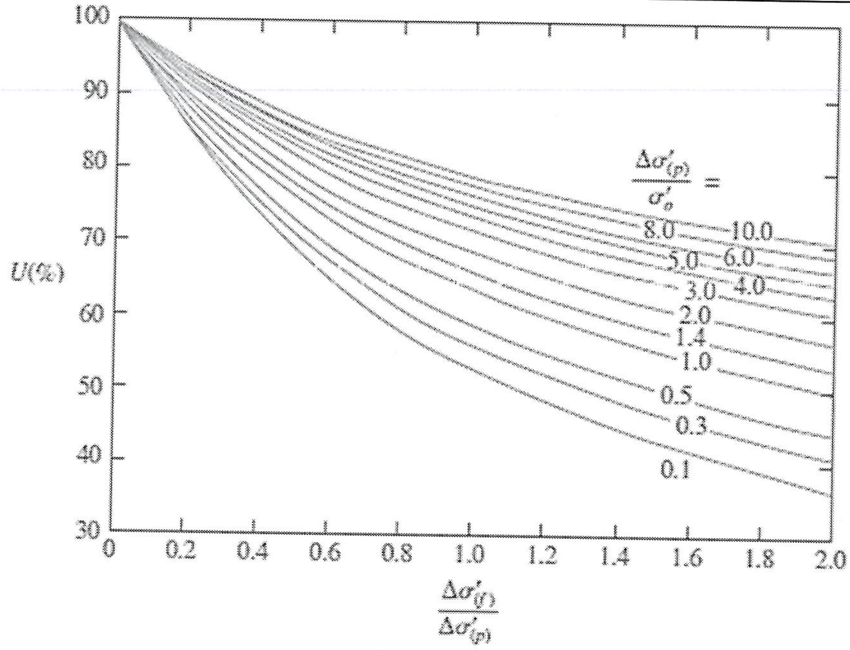

FIGURE Q1(c)

TABLE 2: Result of a seismic refraction field survey

Distance from the point of impact (metres)	Time of first arrival of seismic wave (milliseconds)
2.5	10
5	24
7.5	34
10	42.
15	51
20	57
25	65
30	69
35	71
40	75
50	77

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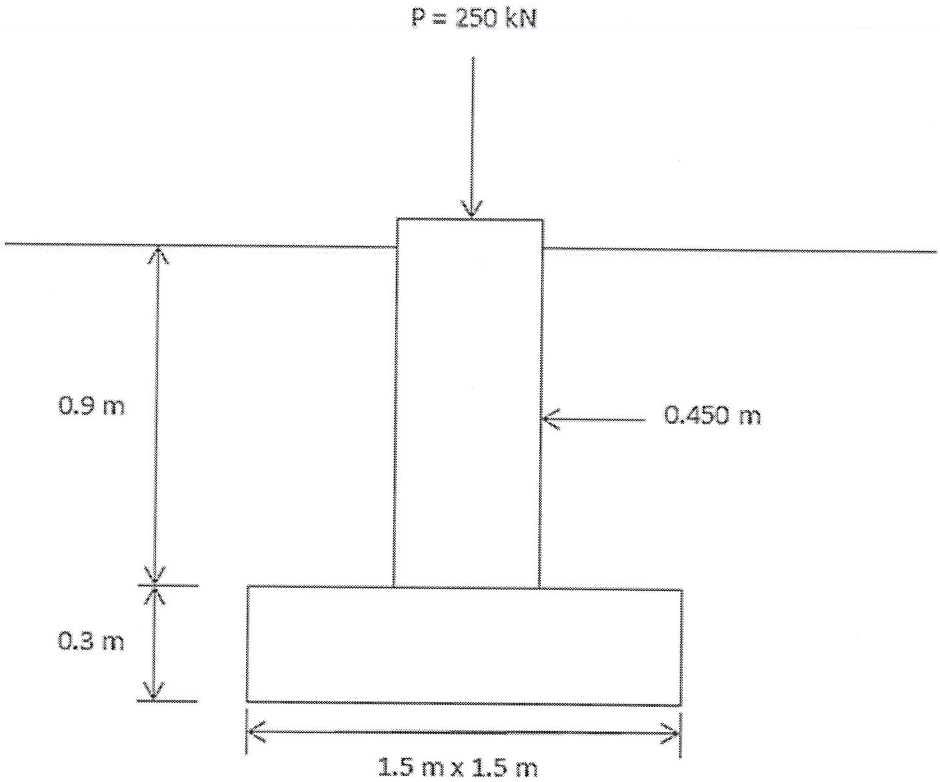

FIGURE Q3(c)

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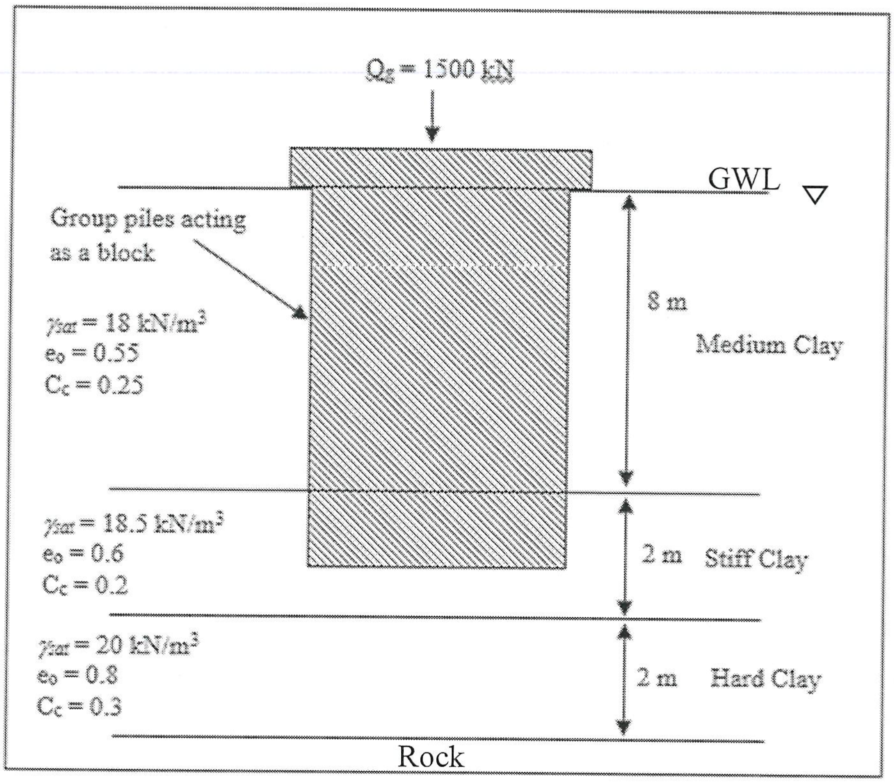

FIGURE Q4(c)(i)

TABLE 3: Variation of α

$\frac{c_u}{p_a}$	α
$\leq$ 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

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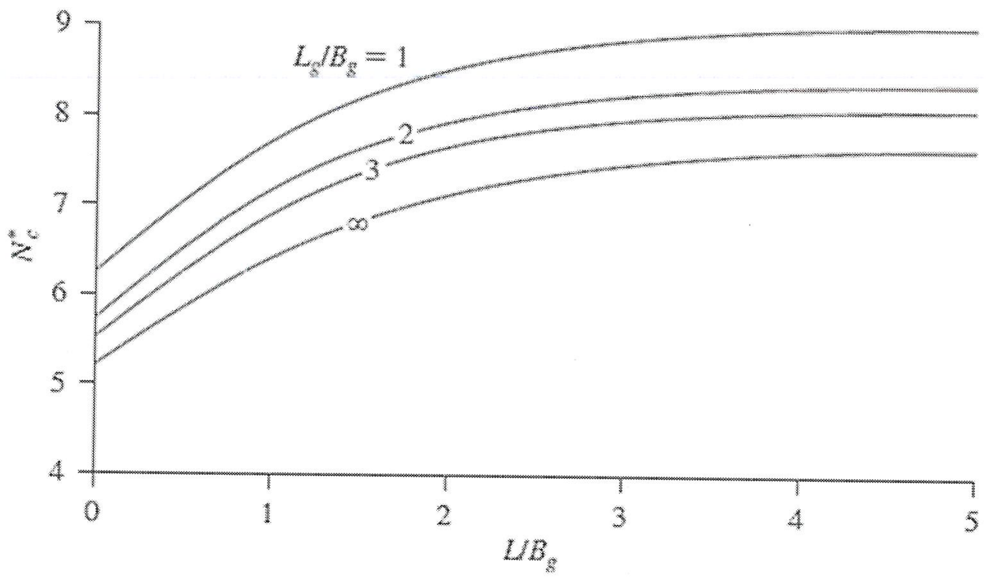

FIGURE Q4(c)(ii)

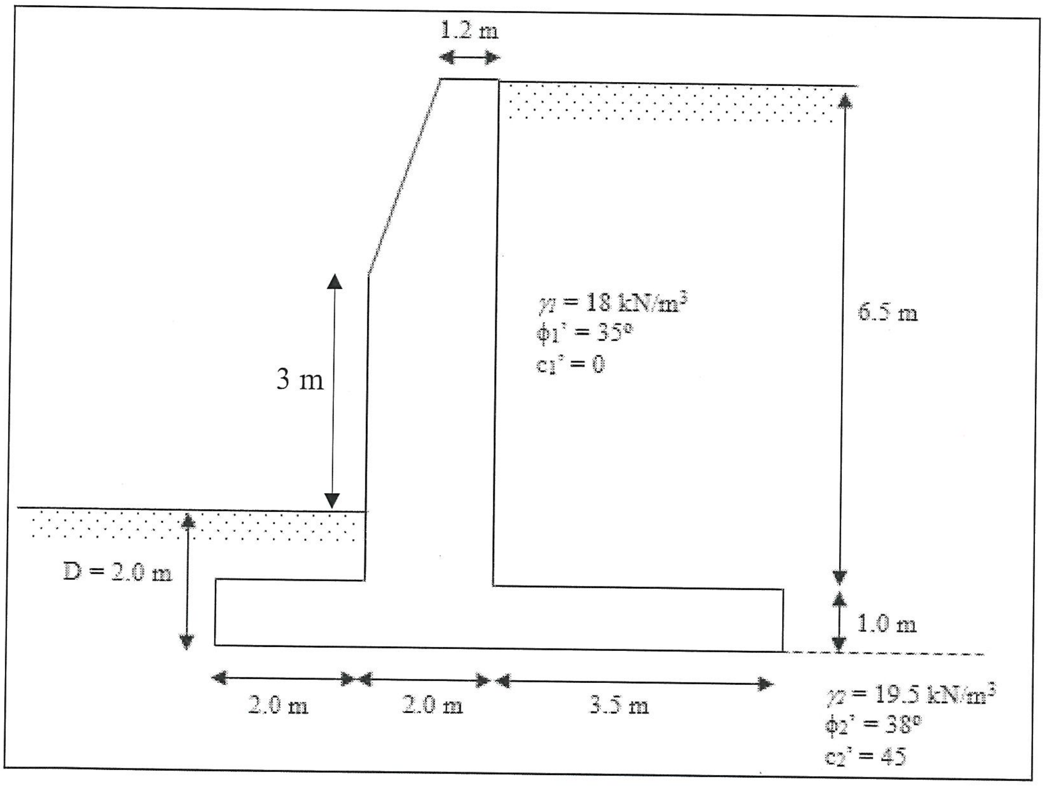

FIGURE Q5(b)

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List of formula

SOIL IMPROVEMENT AND GROUND MODIFICATION

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

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

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

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

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

Rock quality designation (RQD)

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

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

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

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

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SHALLOW FOUNDATIONS

Modification of Bearing Capacity Equations for Water Table

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

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

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

$D_f/B \le 1, for\ \phi = 0$

$F_{cd} = 1 + 0.4(D_f/B)$	$F_{qd} = 1$	$F_{\gamma d} = 1$

$D_f/B \le 1, for\ \phi > 0$

$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c \tan\phi'}$	$F_{qd} = 1 + 2\tan\phi'(1 - \sin\phi')^2\frac{D_f}{B}$	$F_{\gamma d} = 1$

$D_f/B > 1, for\ \phi = 0$

$F_{cd} = 1 + 0.4\,\underbrace{\tan^{-1}\left(D_f/B\right)}_{\text{radians}}$	$F_{qd} = 1$	$F_{\gamma d} = 1$

$D_f/B > 1, for\ \phi > 0$

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

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

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

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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:

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

Method 3:

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

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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

$$\Delta\sigma'_{av} = \tfrac{1}{6}\left(\Delta\sigma'_{top} + 4\Delta\sigma'_{medium} + \Delta\sigma'_{bottom}\right)$$

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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

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

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

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

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

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

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

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

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

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

$$P_h = P_a \cos \alpha$$

$$P_v = P_a \sin \alpha$$

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

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LATERAL EARTH PRESSURE AND RETAINING WALLS

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

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

$$L_3 = \frac{\sigma_2'}{\gamma'(K_p-K_a)}$$

$$\sigma_5' = (\gamma L_1+\gamma' L_2)K_p+\gamma' L_3(K_p-K_a)$$

$$A_1 = \frac{\sigma_5'}{\gamma'(K_p-K_a)}$$

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

$$A_3 = \frac{6P\left[2\bar{z}\gamma'(K_p-K_a)+\sigma_5'\right]}{\gamma'^2(K_p-K_a)^2}$$

$$A_4 = \frac{P\left[6\bar{z}\sigma_5'+4P\right]}{\gamma'^2(K_p-K_a)^2}$$

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

$$\sigma_4' = \sigma_5'+\gamma' L_4(K_p-K_a)$$

$$\sigma_3' = L_4(K_p-K_a)\gamma'$$

$$L_5 = \frac{\sigma_3' L_4-2P}{\sigma_3'+\sigma_4'}$$

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

Free Earth Support

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

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

$$L_3 = \frac{\sigma_2'}{\gamma'(K_p-K_a)}$$

$$\sigma_8' = \gamma'(K_p-K_a)L_4$$

$$L_4^3+1.5L_4^2(l_2+L_2+L_3)-\frac{3P[(L_1+L_2+L_3)-(\bar{z}+l_1)]}{\gamma'(K_p-K_a)}=0$$

$$P-\frac{1}{2}[\gamma'(K_p-K_a)]L_4^2-F=0$$

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