CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2013/2014

COURSE NAME	:	FOUNDATION ENGINEERING
COURSE CODE	:	BFC 4043/BFC 43103
PROGRAMME	:	4 BFF
EXAMINATION DATE	:	JUNE 2014
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTION IN **SECTION A**, AND **THREE (3)** QUESTIONS IN **SECTION B**

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

SECTION A

Q1 (a) Outline **TWO (2)** applications for each ground improvement technique listed below:

(i) consolidation methods in soft clay;

(ii) compaction methods in loose sand; and

(4 marks)

(b) Two common ground improvement methods are surcharge only, and surcharge combined with sand drain.

Table 1 summarises the soils parameter and sand drain dimension for the analytic purposes.

(i) Simply explain the surcharge method, and surcharge method combined with sand drains.

(5 marks)

(ii) Work out the total primary consolidation settlement of the bridge without any ground improvement methods.

(5 marks)

(iii) Evaluate the surcharge, $\Delta\sigma'_{(f)}$, needed to eliminate the entire primary consolidation settlement in six months by a surcharge only, and surcharge combined with sand drains.

(7 marks)

(iv) Give an explanation for the answers from **Q1(b)(iii)**.

(4 marks)

Assume that this is a no-smear case.

SECTION B

Q2 (a) Explain the design criteria of square and ring forms in shallow foundations.

(5 marks)

(b) Describe **THREE (3)** assumptions made in the derivation of Terzhagi's, and Meyerhof's bearing capacity theory.

(5 marks)

(c) A soil profile with a plan of a foundation 1 m × 2 m is shown in Figure **Q3(c)(i)**. The clay is overconsolidated. Laboratory consolidation tests were conducted on a specimen collected from the middle of the clay layer. The field consolidation curve interpolated from the laboratory test results is shown in Figure **Q3(c)(ii)**.

(i) Determine the preconsolidation pressure, σ'_c, swelling index, C_s, and compression index, C_c from the Figure **Q3(c)(ii)**.

(ii) Estimate the consolidation settlement of the foundation by applying the average increase in pressure method.

(15 marks)

You may refer to Table **2**.

Q3 (a) Identify the correct piles function as shown in Figure **Q3(a)**.

(5 marks)

(b) The soil profile and soil properties at a site are shown in the Table **3**. A group of 12 concrete piles in a 3 × 4 matrix and of length 20 m is used to support a load of 3800 kN. The pile diameter is 0.45 m and pile spacing is 1.5 m. The piles is located at 4 m from the ground surface.

(i) Sketch the soil profile.

(2 marks)

(ii) Determine the group piles efficiency using any **TWO (2)** methods.

(5 marks)

(iii) Determine the allowable load bearing capacity of the pile group for piles acting as a group only. Use FS as 4.00.

(6 marks)

(iv) Determine the consolidation settlement of the piles.

(7 marks)

Q4 (a) Point out for each criteria listed under:

(i) The applicability of auger boring method.

(3 marks)

(ii) The penetration methods of thin wall tube.

(3 marks)

(iii) Typical boring depths for a slope stability works.

(3 marks)

(iv) Type of field tests, and type of sampler to be recorded on Exploratory Logs.

(4 marks)

(b) Figures **Q4(b)(i)** and **Q4(b)(ii)** display a highly compressible soil profile from a geological map and the proposed house plan of a project site obtained during a Phase I investigation. The water table is located at the ground surface. The house can be supported by a concrete slab (foundation) of average width about 1.25 m under each column.

Plan a preliminary soils exploration program for the site, by

(i) Assess the geological profile.

(3 marks)

(ii) Integrate the type of soil investigation required.

(5 marks)

(iii) Report on the sites investigation program together with boreholes location.

(4 marks)

Refer to Tables **4** and **5**, and Figure **Q4(b)(iii)**.

Q5 (a) A retaining wall is to be constructed to provide lateral support for an existing parking lot adjacent to a new site walk in a road widening project. The wall height will be 3.0 m above the sidewalk . For frost and bearing , the base will be placed at D = 1.5 m below the sidewalk. A section of the wall is appears in Figure **Q5** which displays the new road and parking lot after the wall is built.

Other information:

(i) It was specified that the granular backfill in the zone over the heel and the toe of the wall which will be compacted is having a bulk unit weight of 17.5 kN/m^3 and an estimated angle of internal friction of 35°.

(ii) There will be a thin layer of granular soil under the base of the wall compacted prior to concreting of the base. However, it is assumed in the stability analysis that the base is on the original soil having unit weight of 19 kN/m^3, cohesion of 100 kN/m^2 and angle of internal friction of 0°.

(iii) Use a fictitious surcharge of 12 kN/m^2 to represent the parking lot pavement and wheel loads.

(iv) Use a fictitious surcharge of 5 kN/m^2 to represent the load from the sidewalk.

(v) Asssuming unit weight of concrete is 24 kN/m^3.

Evaluate the following stability checks using Rankine's method of estimating the lateral pressure:

(i) Safety factor against overturning;

(ii) Safety Factor against sliding;

(iii) Actual contact pressure under the base of the wall; and

(iv) Safety factor against bearing capacity failure.

(17 marks)

(b) More recently, reinforced earth has been utilized in the design and building of retaining wall.
List and briefly explain **FOUR (4)** reasons to defend the statement such as "reinforced earth wall is more economical compared to conventional retaining wall".

(8 marks)

-END OF QUESTION-

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME : 4 BFF
COURSE CODE : BFC 43103/ BFC 4043

Table 1

Soil Profile for both Improvement Methods	
Thickness of the clay layer, H_c	8 m
Compression index, C_c	0.27
Initial void ratio, e_o	1.02
Coefficent of consolidation, c_v	0.52 m^2/month
Clay is normally consolidated	
The average effective overburden pressure at the middle of the clay layer	110 kN/m^2
other criteria	
surcharge method with the average permanent load on the clay layer is expected to increase, $\Delta\sigma_{(p)}$ is 75 kN/m^2	
surcharge with sand drains r_w is 0.1 m; d_e is 3 m; $c_v = c_{vr}$.	

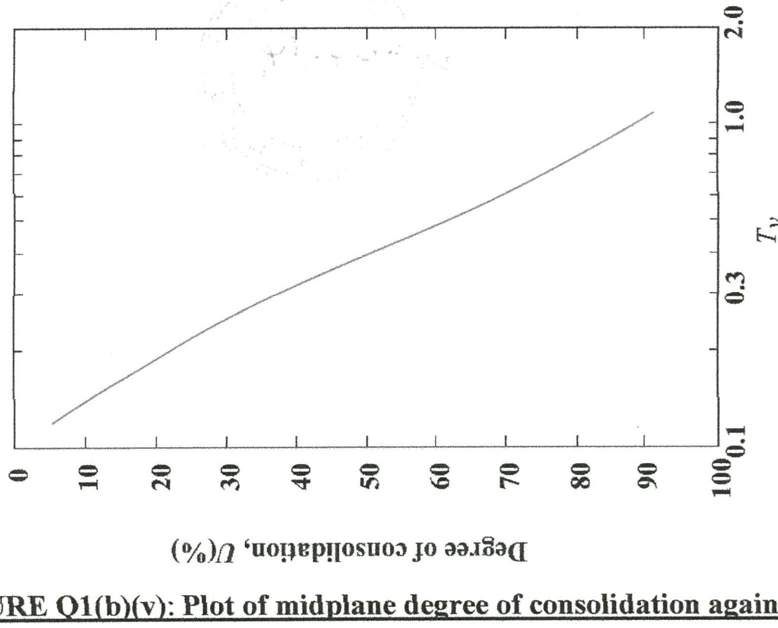


FIGURE Q1(b)(v): Plot of midplane degree of consolidation against T_v

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014
COURSE NAME : FOUNDATION ENGINEERING

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

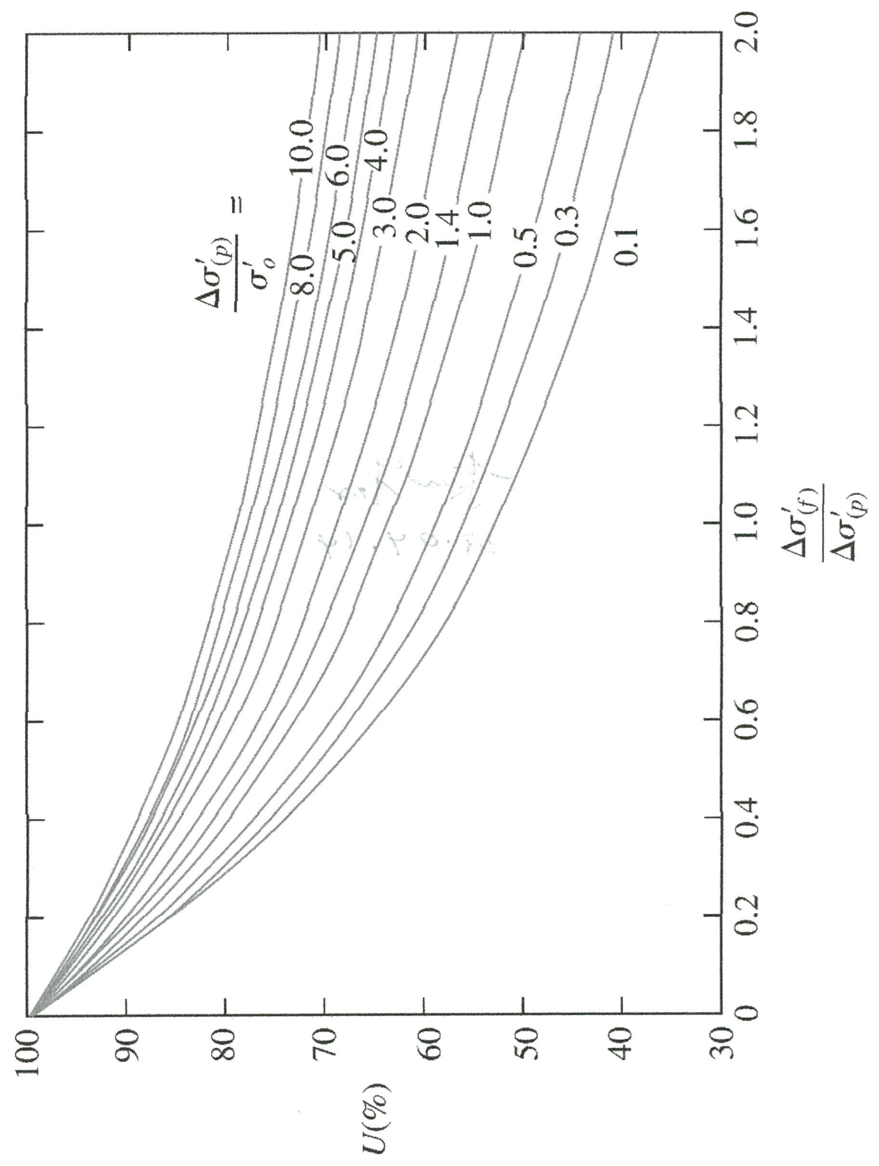


FIGURE Q1(b)(vi): Plot of U against $\Delta\sigma'_{(f)}/\Delta\sigma'_{(p)}$ for Various Values of $\Delta\sigma'_{(p)}/\Delta\sigma'_{(o)}$

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME : 4 BFF
COURSE CODE : BFC 43103/ BFC 4043

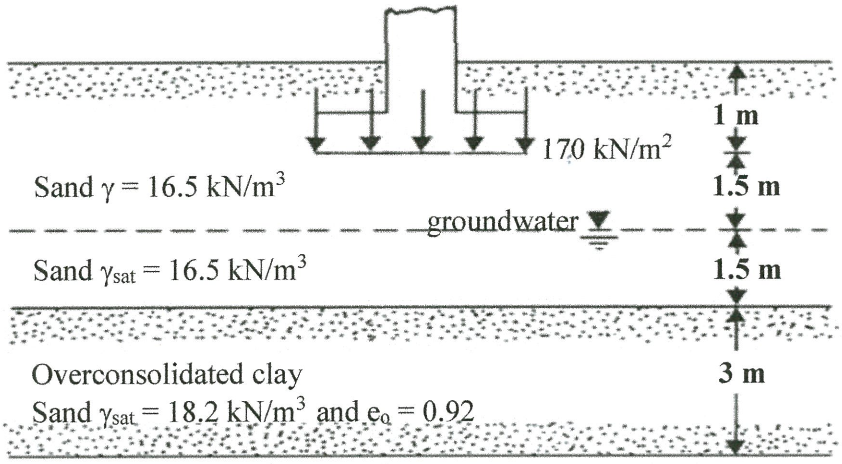


FIGURE Q3(c)(i)

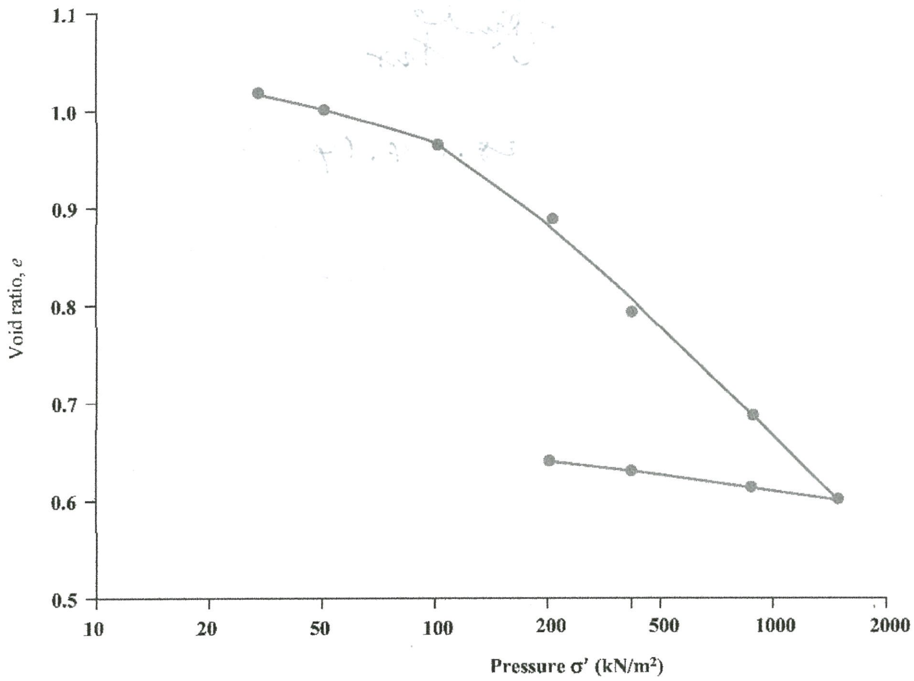


FIGURE Q3(c)(ii)

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME : 4 BFF
COURSE CODE : BFC 43103/ BFC 4043

Table 2: Variation of I_c

	m									
n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0.2	0.994	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997
0.4	0.96	0.976	0.977	0.977	0.977	0.977	0.977	0.977	0.977	0.977
0.6	0.892	0.932	0.936	0.936	0.937	0.937	0.937	0.937	0.937	0.937
0.8	0.8	0.87	0.878	0.88	0.881	0.881	0.881	0.881	0.881	0.881
1	0.701	0.8	0.814	0.817	0.818	0.818	0.818	0.818	0.818	0.818
1.2	0.606	0.727	0.748	0.753	0.754	0.755	0.755	0.755	0.755	0.755
1.4	0.522	0.658	0.685	0.692	0.694	0.695	0.695	0.696	0.696	0.696
1.6	0.449	0.593	0.627	0.636	0.639	0.64	0.641	0.641	0.641	0.642
1.8	0.388	0.534	0.573	0.585	0.59	0.591	0.592	0.592	0.593	0.593
2	0.336	0.481	0.525	0.54	0.545	0.547	0.548	0.549	0.549	0.549
3	0.179	0.293	0.348	0.373	0.384	0.389	0.392	0.393	0.394	0.395
4	0.108	0.19	0.241	0.269	0.285	0.293	0.298	0.301	0.302	0.303
5	0.072	0.131	0.174	0.202	0.219	0.229	0.236	0.24	0.242	0.244
6	0.051	0.095	0.13	0.155	0.172	0.184	0.192	0.197	0.2	0.202
7	0.038	0.072	0.1	0.122	0.139	0.15	0.158	0.164	0.168	0.171
8	0.029	0.056	0.079	0.098	0.113	0.125	0.133	0.139	0.144	0.147
9	0.023	0.045	0.064	0.081	0.094	0.105	0.113	0.119	0.124	0.128
10	0.019	0.037	0.053	0.067	0.079	0.089	0.097	0.103	0.108	0.112

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME : 4 BFF
COURSE CODE : BFC 43103/ BFC 4043

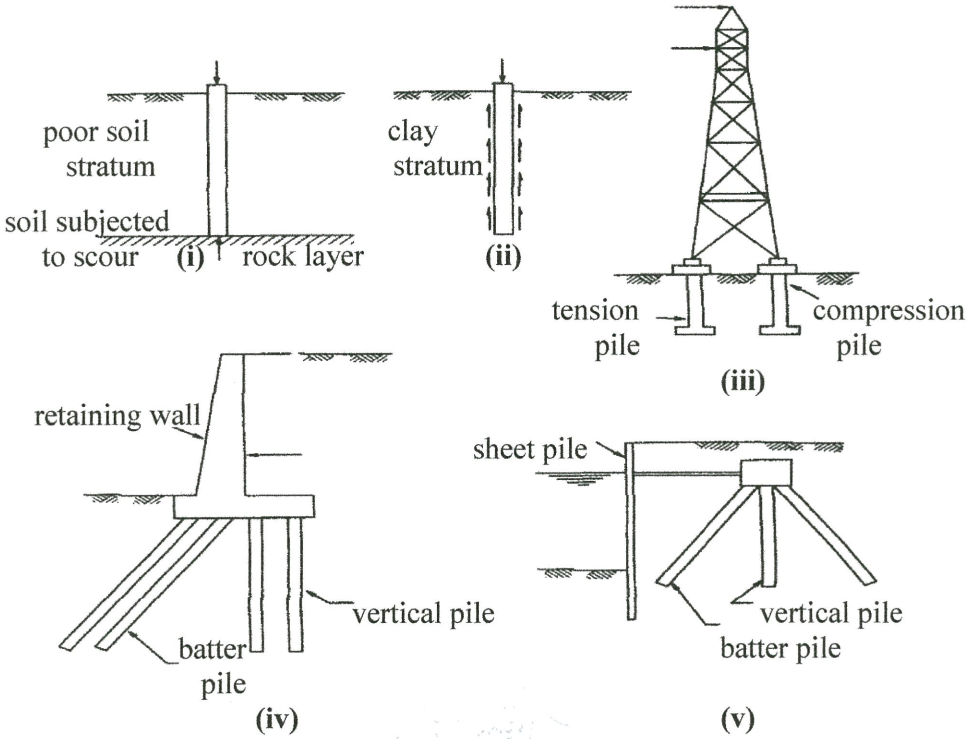


FIGURE Q3(a)

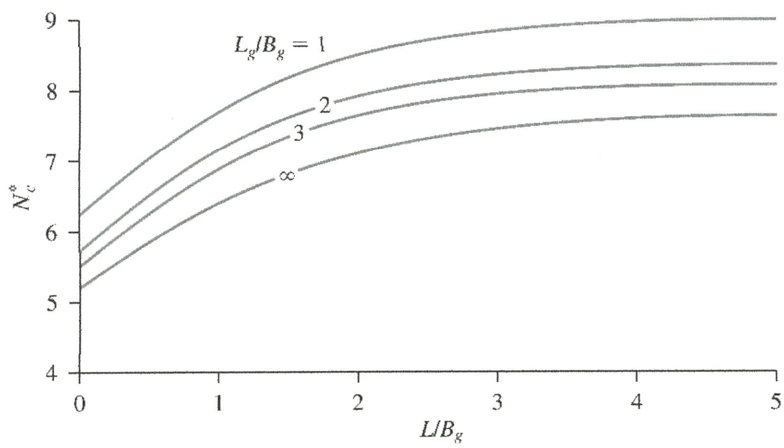
Table 3

Depth (m)	**Type of Deposit**	**Soil Parameter**
0 to 4	Sand	γ_{dry} = 18 kN/m^3
Groundwater level at 4 m		
4 to 22	Clay	γ_{sat} = 19 kN/m^3, e_o = 0.81, C_c = 0.30
22 to 30	Clay	γ_{sat} = 22 kN/m^3, e_o = 0.76, C_c = 0.28
30 to 40	Soft Clay	γ_{sat} = 20 kN/m^3, e_o = 0.56, C_c = 0.22
> 40	Rock	

All clays are normally consolidated.

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME : 4 BFF
COURSE CODE : BFC 43103/ BFC 4043



variation of N_c* with L_g/B_g and L/B_g

FIGURE Q3(a)(i)

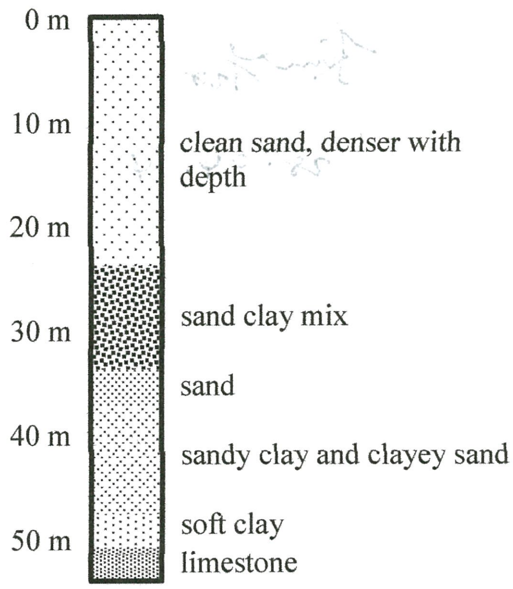


FIGURE Q4(b)(i)

FINAL EXAMINATION

SEMESTER/SESSION	: SEM II/2013/2014	PROGRAMME	: 4 BFF
COURSE NAME	: FOUNDATION ENGINEERING	COURSE CODE	: BFC 43103/ BFC 4043

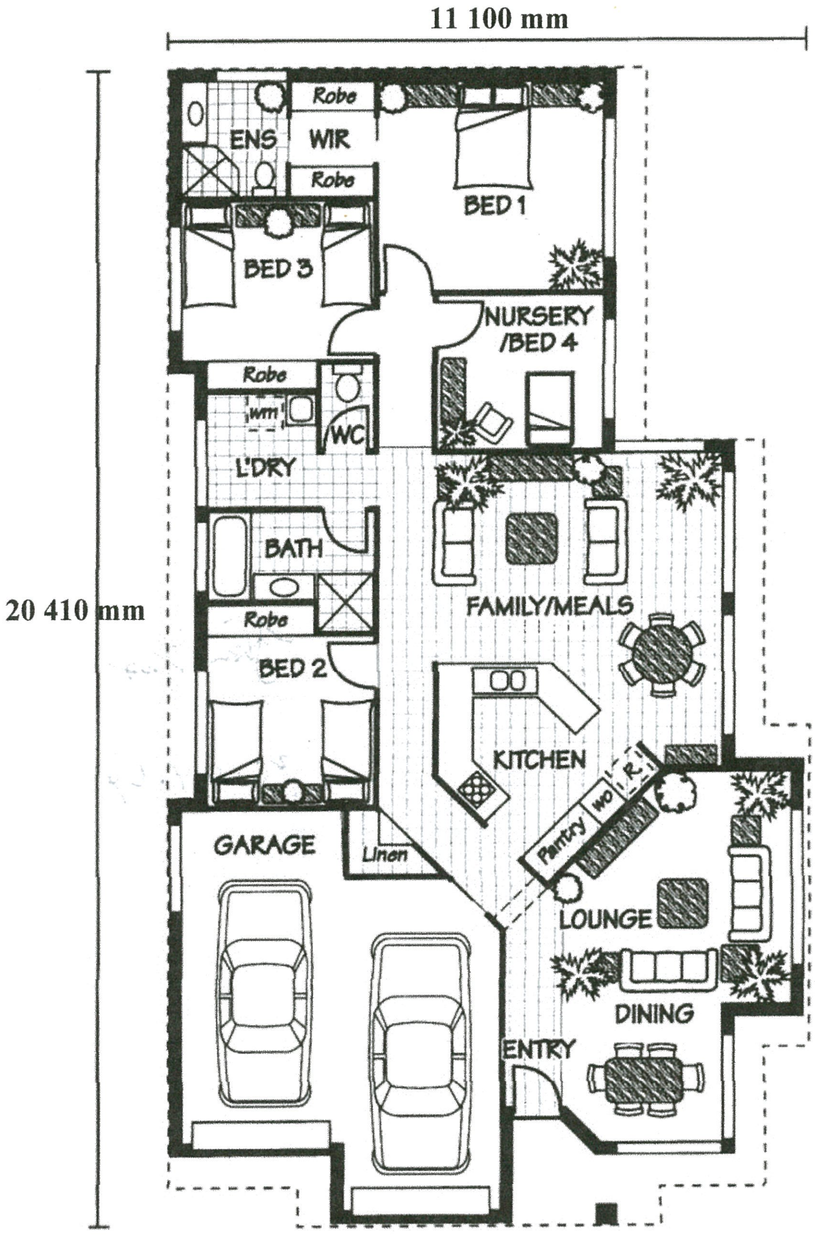


FIGURE Q4(b)(ii)

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME : 4 BFF
COURSE CODE : BFC 43103/ BFC 4043

Table 4: Guidelines for the Minimum Number of Boreholes for Buildings and Subdivisions

Buildings		Subdivisions	
Area (m^2)	No. of boreholes (min.)	Area (m^2)	No. of boreholes (min.)
< 100	2	< 4000	2
250	3	8000	3
500	4	20 000	4
1000	5	40 000	5
2000	6	80 000	7
5000	7	400 000	15
6000	8		
8000	9		
10 000	10		

Table 5: Guidelines for the Minimum Number of Boreholes for Buildings and Subdivisions

- In compressible soils such as clays the borings should penetrate at least between 1 to 3 times the width of the proposed foundation below the depth of embedment or until the stress increment due to the heaviest foundation load is less than 10%, whichever is greater.
- In very stiff clay and dense coarse grained soils drilling should penetrate 5 m to 6 m to prove that the thickness of the stratum is adequate.
- Borings should penetrate at least 3 m into rock.
- Borings must penetrate below any fills or very soft deposits below the proposed structure.
- The minimum depth of boreholes should be 6 m unless bedrock or very dense material is encountered.

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME : 4 BFF
COURSE CODE : BFC 43103/ BFC 4043

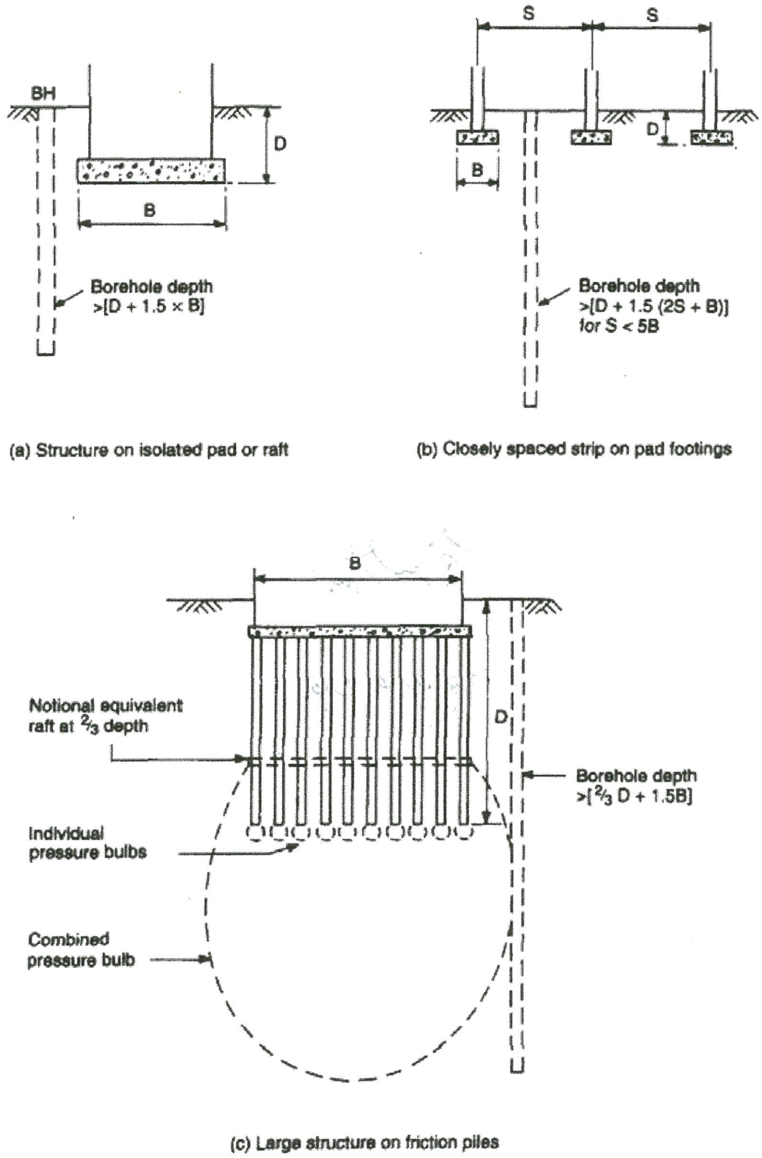


FIGURE Q4(b)(iii)

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME : 4 BFF
COURSE CODE : BFC 43103/ BFC 4043

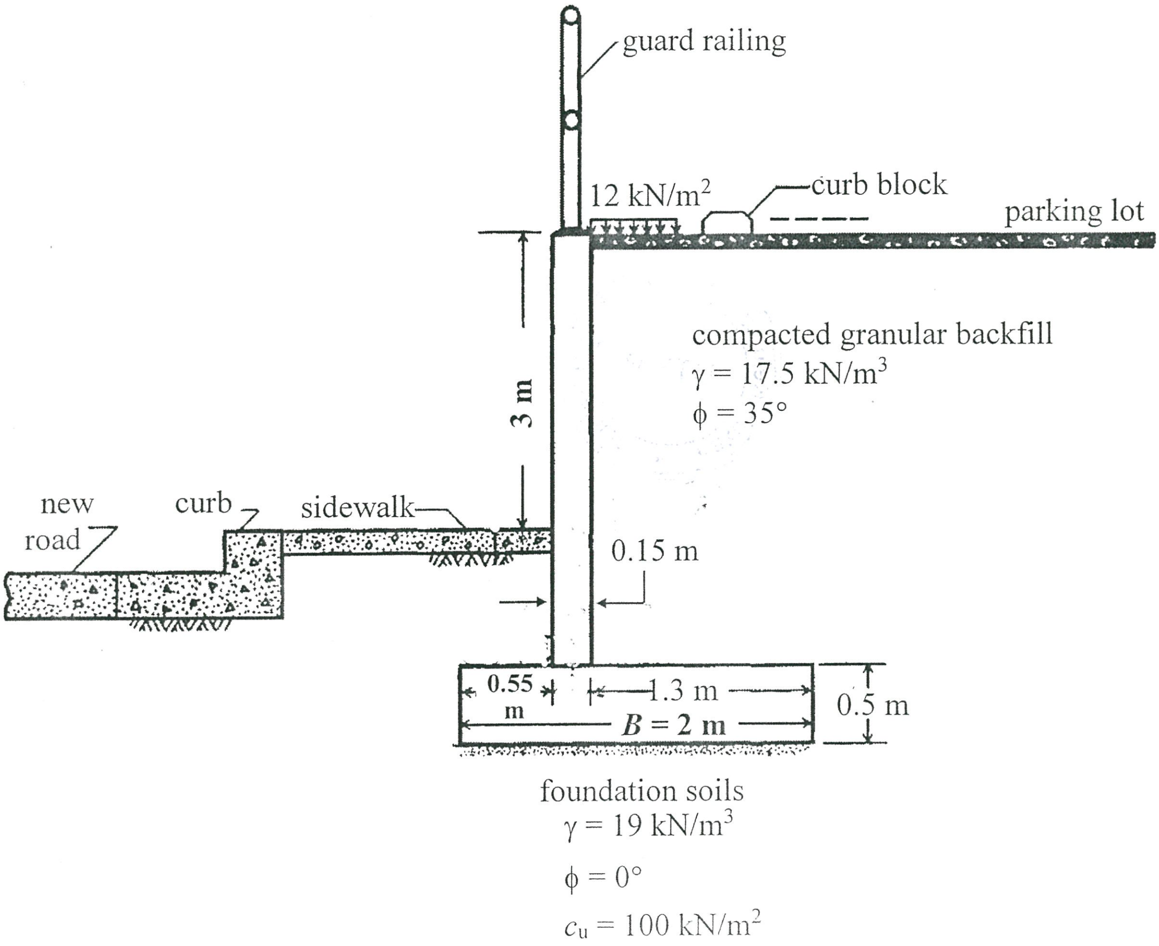


FIGURE Q5

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME : 4 BFF
COURSE CODE : BFC 43103/ BFC 4043

Table 8: Bearing Capacity Factors

ϕ'	N_c	N_q	N_γ	ϕ'	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	20.63	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				

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME : 4 BFF
COURSE CODE : BFC 43103/ BFC 4043

Formulae

SOIL IMPROVEMENT AND GROUND MODIFICATION

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

$$S_{c(p)} = \frac{C_s H_c}{1+e_o} \log \frac{\sigma'_o + \Delta\sigma'_{(p)}}{\sigma'_o} \quad \left(\sigma'_o + \Delta\sigma'_{(p)} < \sigma'_c\right)$$

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

$$T_v = \frac{c_v t_2}{H_d^2} \quad (H_d = 0.5 H_c \text{ for two ways, } H_d = H_c \text{ for one ways})$$

$$T_v = \frac{\pi}{4}\left[\frac{U_v(\%)}{100}\right] \quad (\text{for } U = 0\% \text{ to } 60\%)$$

$$n = \frac{d_e}{2r_w}$$

$$T_v = 1.781 - 0.933\log(100 - U\%) \quad (\text{for } U > 60\%)$$

$$T_r = \frac{c_{vr} t_2}{d_e^2}$$

$$U_{vr} = 1 - (1 - U_v)(1 - U_r)$$

SHALLOW FOUNDATIONS: PRIMARY CONSOLIDATION SETTLEMENT

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

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

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

$$\Delta\sigma'_{av} = \tfrac{1}{6}\left(\Delta\sigma'_t + 4\Delta\sigma'_m + \Delta\sigma'_b\right) \qquad m = \frac{L}{B} \qquad n = \frac{z}{\frac{B}{2}} \qquad \Delta\sigma' = q_o I_c$$

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014 PROGRAMME : 4 BFF
COURSE NAME : FOUNDATION ENGINEERING COURSE CODE : BFC 43103/ BFC 4043

Formulae

GROUP PILES EFFICIENCY

$$\eta = \left[1 - \left(\frac{11d}{7(d^2-1)}\right)\left(\frac{n_1+n_2-2}{n_1+n_2-1}\right)\right] + \frac{0.3}{n_1+n_2}$$ where d is in ft, 1 mm = 0.00328084 ft.

$$\eta = 1 - \frac{D}{\pi d n_1 n_2}\left[n_1(n_2-1) + n_2(n_1-1) + \sqrt{2}(n_1-1)(n_2-1)\right]$$

$$\eta = 1 - \left[\frac{(n_1-1)n_2 + (n_2-1)n_1}{90 n_1 n_2}\right] \times \tan^{-1}\left(\frac{D}{d}\right)$$

ULTIMATE CAPACITY OF GROUP PILES IN SATURATED CLAY

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

$$L_g = (n_1-1)d + 2(D/2) \qquad \Delta\sigma'_{(1)} = \frac{Q_g}{(L_g+z_1)(B_g+z_1)}$$

SITE INVESTIGATIONS: SAMPLE DISTURBANCE

$$A_r = \frac{D_2^2 - D_1^2}{D_1^2} \times 100\% \qquad C_i = \frac{D_3 - D_1}{D_1} \times 100\% \qquad C_o = \frac{D_2 - D_4}{D_4} \times 100\%$$

EARTH RETAINING STRUCTURES

$P_a = \frac{1}{2}K_a\gamma_1 H'^2$ (soil only) $\quad P_a = K_a q H'$ (surcharge) $\quad P_v = P_a \sin\alpha$

$P_h = P_a \cos\alpha \quad P_p = \frac{1}{2}K_p\gamma_2 D^2 + 2c'_2\sqrt{K_p}D$ (soil only)

$P_p = K_p q D$ (surcharge) $\quad K_p = \tan^2(45 + \phi'_2/2) \quad K_a = \tan^2(45 - \phi'_2/2)$

FINAL EXAMINATION

SEMESTER/SESSION : SEM II/2013/2014
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME : 4 BFF
COURSE CODE : BFC 43103/ BFC 4043

formulae

EARTH RETAINING STRUCTURES

$$\text{FS}_{\text{overturning}} = \frac{\sum M_R}{\sum M_o} \qquad \sum M_o = P_h\left(\frac{H'}{3}\right) \qquad M_v = P_v B$$

$$\text{FS}_{\text{sliding}} = \frac{\sum F_{R'}}{\sum F_d} \qquad \sum F_{R'} = \sum V \tan\left(\tfrac{2}{3}\phi_2'\right) + \tfrac{2}{3}Bc_2' + P_p$$

$$M_R = M_1 + M_2 + \ldots + M_n + M_v \qquad \Sigma F_d = P_a \cos\alpha$$

$$\frac{q_{\max}}{q_{\min}} = \frac{\Sigma V}{B}\left(1 \pm \frac{6e}{B}\right) \qquad q_u = c_2' N_c F_{cd} F_{ci} + \bar{q} N_q F_{qd} F_{qi} + \tfrac{1}{2}\gamma_2 B' N_\gamma F_{\gamma d} F_{\gamma i}$$

$$\bar{q} = \gamma_2 D \qquad B' = B - 2e \qquad F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c \tan\phi_2'}$$

$$F_{\gamma d} = 1 \qquad F_{qd} = 1 + 2\tan\phi_2'(1 - \sin\phi_2')^2 \frac{D}{B'}$$

$$F_{ci} = F_{qi} = \left[1 - \frac{\tan^{-1}\left(\frac{P_a\cos\alpha}{\Sigma V}\right)}{90^\circ}\right]^2 \qquad F_{\gamma i} = \left[1 - \frac{\tan^{-1}\left(\frac{P_a\cos\alpha}{\Sigma V}\right)}{\phi_2'}\right]^2$$

$$\text{FS}_{\text{bearing capacity}} = \frac{q_u}{q_{\max}}$$