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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	FOUNDATION ENGINEERING
COURSE CODE	:	BFC 43103
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JULY/ AUGUST 2023
DURATION	:	3 HOURS
INSTRUCTIONS	1.	ANSWER ALL QUESTIONS
	2.	THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK.**
	3.	STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

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Q1 The pipe pile was embedded at 9 m length in saturated clay soil and the soil properties for each layer of soil as shown in **Figure Q1.**

(a) Estimate the point bearing capacity, Q_p by using.

i) Meyerhof's method

(5 marks)

ii) Vesic's method

(5 marks)

(b) Estimate the frictional resistance, Q_s by using.

i) α method

(5 marks)

ii) λ method

(5 marks)

iii) β method (Use $\phi_R = 31^\circ$ for all clay layers. The top 7 m of clay is normally consolidated. The bottom clay layer has an OCR = 2.1).

(5 marks)

Q2 (a) Many constructions in slope protection using geotextiles as a reinforced earth. List **THREE (3)** advantages and **TWO (2)** disadvantages for using geotextiles in reinforced earth.

(5 marks)

(b) A cantilever retaining wall was constructed in **Figure Q2(b).** Use the unit weight of concrete ($\gamma_{concrete}$) of 23.58 kN/m^2. Determine the factors of safety with respect to;

i) Overturning

(6 marks)

ii) Sliding

(6 marks)

iii) Bearing capacity

(8 marks)

Q3 (a) In site investigation works, there are 2 types of soil samples; disturbed and undisturbed sample. Disturbed samples are generally obtained to determine the soil type, gradation, classification, consistency, density, presence of contaminants and stratification. Undisturbed samples are used to determine the in place strength, compressibility (settlement), natural moisture content, unit weight and permeability. Based on condition given below, proposed type of sampler and also lab test for site investigations works below.

(i) SMS Contractor has been awarded a road construction project from Batu Pahat to Kluang. Samples was taken to identify the soil classification based on AASHTO and USCS soil classification.

(3 marks)

(ii) The housing project in sandy soil area is in design stage. The consultant engineer need soil data to design the foundation of the house.

(3 marks)

(iii) Selia Senggara has been awarded a road construction project from Batu Pahat to Muar, Johor. The proposed road will be through a soft soil area, especially at Muar. They proposed to use a combination of prefabricated vertical drain and embankment as a surcharge.

(4 marks)

(b) The housing project will be construct at Bukit Tinggi area. The project consists of single storey house and double storey shop lots. All columns of the building are supported by square footings that must be placed at a depth of 1.5 m. The result from site investigation shows that the soil is medium dense sand with unit weight (γ) of 18.5 kN/m^3, having a cohesion (c) of 20 kN/m^2 and a friction angle (ϕ) of 27°. Since the columns loads at different location can be varying, produce the chart for estimation of footing size required to support a given load by using simple method. (use factor of safety = 3)

(15 marks)

Q4 (a) Hydraulic modification is one of the method ground improvement that usually used to decrease the water table in fine soil. Many types of hydraulics modification are use such as preloading and also vertical drain.

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

(8 marks)

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

(7 marks)

(b) Shallow compaction in the field is accomplished by rolling or vibrating. Rolling is done with "sheepsfoot" drums, round steel drums and rubber tired vehicle. However, many other factors need to be consider in operational aspects of shallow compaction. Discuss **FIVE (5)** operational aspects of shallow compaction.

(10 marks)

- END OF QUESTIONS -

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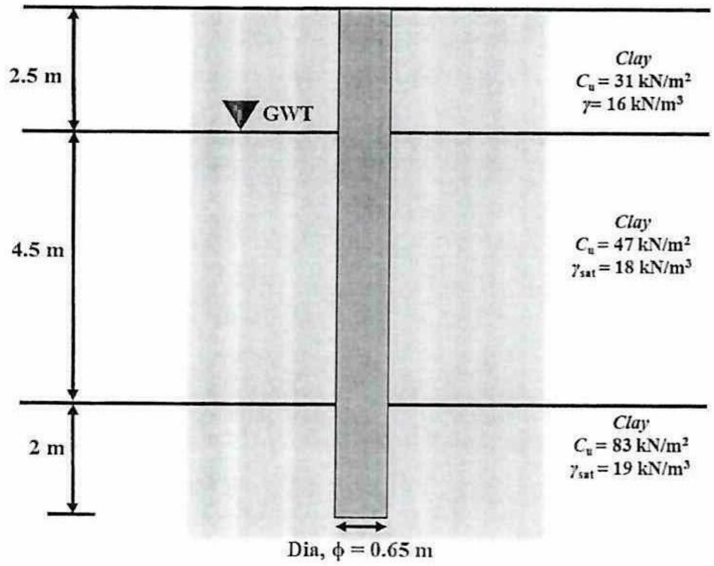

Figure Q1: Pipe pile in saturated clay

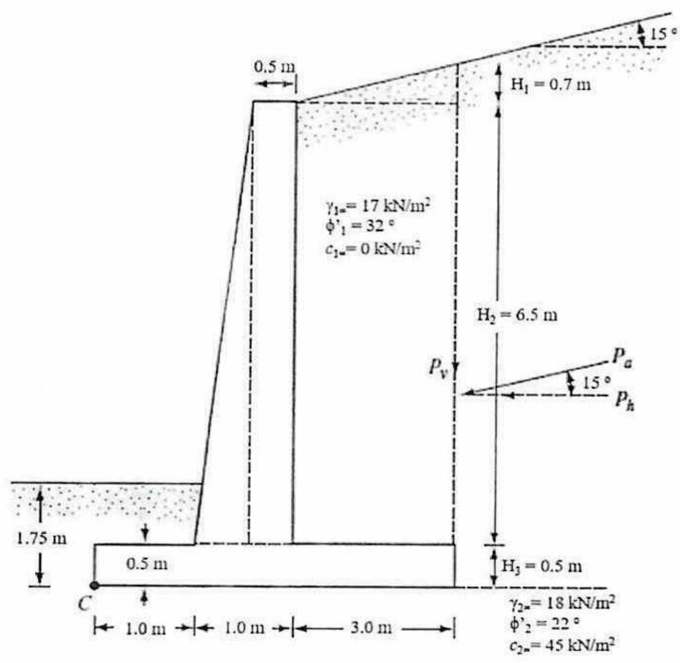

Figure Q2(b): Cantilever retaining wall

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Appendix A: Design Tables and Charts

TABLE 1 : Terzaghi Bearing Capacity factor

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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Appendix A: Design Tables and Charts

TABLE 2: Meyerhof's bearing capacity factor

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				

TABLE 3 : Rigidity Index for Vesic method

$\frac{c_u}{p_a}$	I_r
0.24	50
0.48	150
≥0.96	250−300

Note: p_a = atmospheric pressure ≈ 100 kN/m² or 2000 lb/ft².

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Appendix A: Design Tables and Charts

TABLE 4 : Variation of λ with pile embedment

Table 9.9 Variation of λ with Pile Embedment Length, L

Embedment length, L (m)	λ
0	0.5
5	0.336
10	0.245
15	0.200
20	0.173
25	0.150
30	0.136
35	0.132
40	0.127
50	0.118
60	0.113
70	0.110
80	0.110
90	0.110

TABLE 5 : Variation of α

Table 9.10 Variation of α (Interpolated Values Based on Terzaghi, Peck and Mesri, 1996)

$\frac{c_u}{p_a}$	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 ≈ 100 kN/m^2 or 2000 lb/ft^2

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Appendix A: Design Tables and Charts

Table 6 : Variation of K_a

Table 12.1 Variation of $K_{a(R)}$ [Eq. (12.17)]

α (deg)	θ (deg)	$K_{a(R)}$ φ' (deg) 28	30	32	34	36	38	40
	0	0.361	0.333	0.307	0.283	0.260	0.238	0.217
	2	0.363	0.335	0.309	0.285	0.262	0.240	0.220
	4	0.368	0.341	0.315	0.291	0.269	0.248	0.228
0	6	0.376	0.350	0.325	0.302	0.280	0.260	0.242
	8	0.387	0.362	0.338	0.316	0.295	0.276	0.259
	10	0.402	0.377	0.354	0.333	0.314	0.296	0.280
	15	0.450	0.428	0.408	0.390	0.373	0.358	0.345
	0	0.366	0.337	0.311	0.286	0.262	0.240	0.219
	2	0.373	0.344	0.317	0.292	0.269	0.247	0.226
	4	0.383	0.354	0.328	0.303	0.280	0.259	0.239
5	6	0.396	0.368	0.342	0.318	0.296	0.275	0.255
	8	0.412	0.385	0.360	0.336	0.315	0.295	0.276
	10	0.431	0.405	0.380	0.358	0.337	0.318	0.300
	15	0.490	0.466	0.443	0.423	0.405	0.388	0.373
	0	0.380	0.350	0.321	0.294	0.270	0.246	0.225
	2	0.393	0.362	0.333	0.306	0.281	0.258	0.236
	4	0.408	0.377	0.348	0.322	0.297	0.274	0.252
10	6	0.426	0.395	0.367	0.341	0.316	0.294	0.273
	8	0.447	0.417	0.389	0.363	0.339	0.317	0.297
	10	0.471	0.441	0.414	0.388	0.365	0.344	0.324
	15	0.542	0.513	0.487	0.463	0.442	0.422	0.404
	0	0.409	0.373	0.341	0.311	0.283	0.258	0.235
	2	0.427	0.391	0.358	0.328	0.300	0.274	0.250
	4	0.448	0.411	0.378	0.348	0.320	0.294	0.271
15	6	0.472	0.435	0.402	0.371	0.344	0.318	0.295
	8	0.498	0.461	0.428	0.398	0.371	0.346	0.323
	10	0.527	0.490	0.457	0.428	0.400	0.376	0.353
	15	0.610	0.574	0.542	0.513	0.487	0.463	0.442
	0	0.461	0.414	0.374	0.338	0.306	0.277	0.250
	2	0.486	0.438	0.397	0.360	0.328	0.298	0.271
	4	0.513	0.465	0.423	0.386	0.353	0.323	0.296
20	6	0.543	0.495	0.452	0.415	0.381	0.351	0.324
	8	0.576	0.527	0.484	0.446	0.413	0.383	0.355
	10	0.612	0.562	0.518	0.481	0.447	0.417	0.390
	15	0.711	0.660	0.616	0.578	0.545	0.515	0.488

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Appendix B: Formulas

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 ≥ 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		
$F_{cs} = 1 + \frac{B}{L}.\frac{N_q}{N_c}$	$F_{qs} = 1 + \frac{B}{L}\tan\phi$	$F_{\gamma s} = 1 - 0.4\frac{B}{L}$

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

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

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

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

$$q_u = cN_c + qN_q + 0.5\gamma BN_\gamma ....(strip.foundation)$$

$$q_u = 1.3cN_c + qN_q + 0.4\gamma BN_\gamma ....(square.foundation)$$

$$q_u = 1.3cN_c + qN_q + 0.3\gamma BN_\gamma ....(circular.foundation)$$

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PILE FOUNDATIONS

Ultimate Capacity of Piles and Group Piles in Saturated Clay

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

$$f = \beta \sigma_o'$$

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

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

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

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

$$Q_p = A_p q_p$$

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

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

$$Q_p = 9 c_u A_p$$

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

$$Q_p = 0.4\, A_p\, (q_p) = A_p \left[0.4\, P_a\, N_{60} \frac{L}{D}\right] \leq A_p\, (4\, P_a N_{60})$$

$$I_{rr} = I_r$$

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

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

CONVENTIONAL GRAVITY AND CANTILEVER WALL

Rankine's Theory

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

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

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

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

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

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

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

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

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

$$P_h = P_a \cos \alpha$$

$$P_v = P_a \sin \alpha$$

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

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