[ENG16]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BEng (HONS) CIVIL ENGINEERING

SEMESTER ONE EXAMINATION 2023/2024

GEOTECHNICAL ENGINEERING & GROUND IMPROVEMENT

MODULE NO: CIE6003

Date: Wednesday 10th January 2024 **Time: 10:00am – 1:00pm**

INSTRUCTIONS TO CANDIDATES:

There are FOUR questions.

Answer ALL FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Supplementary Geotechnical Information / Formulas are provided on p. 10 to 12.

Question 1

a) Produce a sketch to illustrate the relationship between the three different types of lateral earth pressure and the wall movement. With reference to your sketch, explain what happens when there is no movement of the wall, movement of the wall towards the soil and movement of the wall away from soil. In relation to strain, also explain when the minimum P_a and maximum P_p are achieved.

(5 marks)

b) A concrete retaining wall retains two layers of soil (Figure Q1). With depth the sequence includes: 4.0m of soil 1 and 5.0m of soil 2. Plot the active stress and determine the total thrust and point (line) of action for the wall shown below. The properties of the materials are summarised below:

$$\boldsymbol{q = 40.0kN/m^2}$$

Soil 1:

$z_1 = 4.0m$

$\phi_1 = 27^0$

$\gamma_1 = 17.41kN/m^3$

Soil 2:

$z_2 = 5.0m$

$\phi_2 = 31^0$

$\gamma_2 = 21.5kN/m^3$

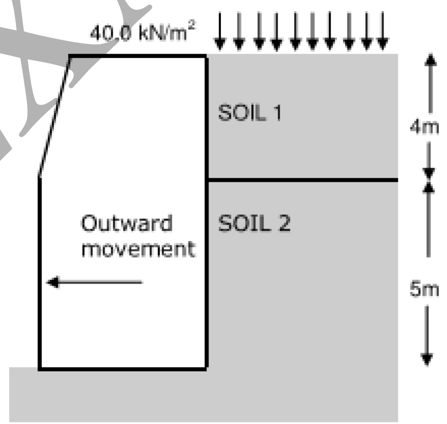

Figure Q1

(20 marks)

Total 25 marks

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Question 2

a) For slope stability of an embankment, what are the main factors that influence slope stability? And what makes a slope globally stable? Explain your answer.
(5 marks)

b) An embankment made from clay is to be constructed upon the ground surface (See Figure Q2). The completed embankment can be assumed to be homogenous and thus will possess constant density and constant shear strength throughout its mass. Determine the factor of safety in the short term (undrained state). Area and angle of base for each slice is calculated in Table 1 below.

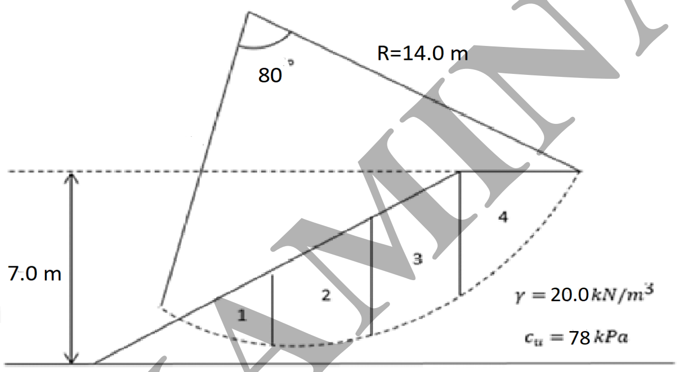

Figure Q2

Slice No.	Area (m^2) A	Angle of base (α °)
1	3.5	-5.0
2	7.5	14.0
3	11.0	30.0
4	7.0	45.0

Table 1

(20 marks)

Total 25 marks

Question 3

a) A wide embankment, 5m high, is to be constructed over a 10m thick layer of very soft to soft clay (m_v = 0.6m^2/MN, c_v = 4m^2/yr). This clay overlies a relatively impermeable layer of mudstone. The embankment is to be formed by compacting granular material to a bulk unit weight of 21kN/m^3.

i) Calculate the total consolidation settlement within the clay layer.

(4 marks)

ii) If "finishing works" can be commenced on top of the embankment as soon as <35mm of consolidation settlement of the very sift clay layer remains to be achieved, then calculate the earliest time that "finishing works" can be commenced.

(4 marks)

b) If 250mm diameter vertical sand drains are used then determine the square grid spacing of drains required to achieve the same settlement requirements as stipulated in Q3 a) ii) – ie. only 35mm of consolidation settlement remaining within 3-months.
NOTE: Assume c_h = 9m^2/yr and
Fig Q3 in page 5 and Table Q3 in page 6 are provided for the solution of this question.

(13 marks)

c) Where a section of proposed new high speed rail track is required to be constructed over 6m of loose granular deposits, propose and briefly evaluate **FOUR** ground improvement options that may be considered to ensure a stable platform is achieved. Ensure that you evaluate the advantages and limitations of each option from a geotechnical perspective.

(4 marks)

Total 25 marks

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Fig. Q3

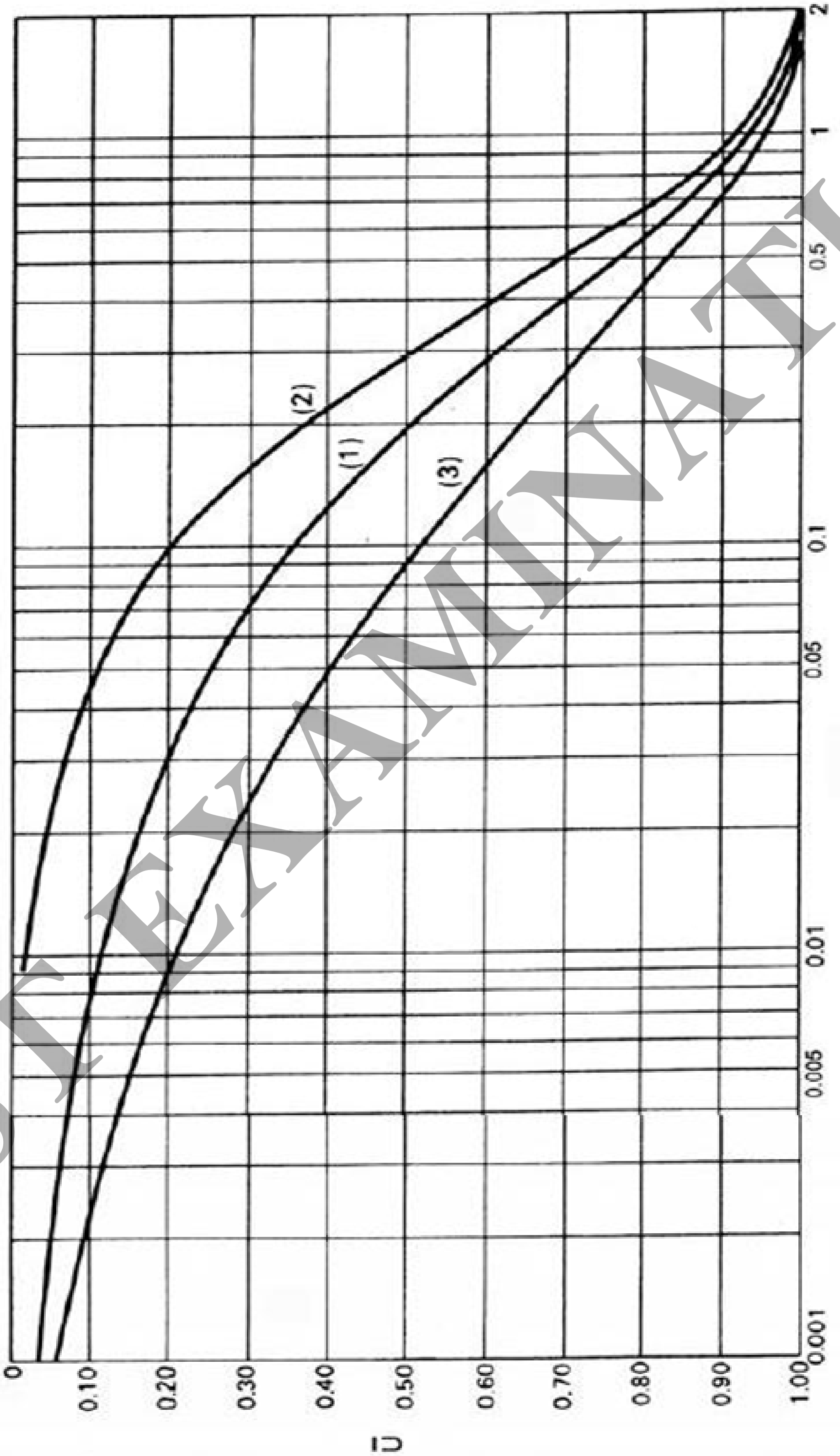
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Ū
0.001
0.005
0.01
0.05
0.1
0.5
1
2
Tv
(1)
(2)
(3)

Table Q3

Degree of consolidation U_r (%)	Dimensionless Time Factor, T_r										
	n=5	10	15	20	25	30	40	50	60	80	100
10	0.012	0.021	0.026	0.030	0.032	0.035	0.039	0.042	0.044	0.048	0.051
20	0.026	0.044	0.055	0.063	0.069	0.074	0.082	0.088	0.092	0.101	0.107
30	0.042	0.070	0.088	0.101	0.110	0.118	0.131	0.141	0.149	0.162	0.172
40	0.060	0.101	0.125	0.144	0.158	0.170	0.188	0.202	0.214	0.232	0.246
50	0.081	0.137	0.170	0.195	0.214	0.230	0.255	0.274	0.290	0.315	0.334
55	0.094	0.157	0.197	0.225	0.247	0.265	0.294	0.316	0.334	0.363	0.385
60	0.107	0.180	0.226	0.258	0.283	0.304	0.337	0.362	0.383	0.416	0.441
65	0.123	0.207	0.259	0.296	0.325	0.348	0.386	0.415	0.439	0.477	0.506
70	0.137	0.231	0.289	0.330	0.362	0.389	0.431	0.463	0.490	0.532	0.564
75	0.162	0.273	0.342	0.391	0.429	0.460	0.510	0.548	0.579	0.629	0.668
80	0.188	0.317	0.397	0.453	0.498	0.534	0.592	0.636	0.673	0.730	0.775
85	0.222	0.373	0.467	0.534	0.587	0.629	0.697	0.750	0.793	0.861	0.914
90	0.270	0.455	0.567	0.649	0.712	0.764	0.847	0.911	0.963	1.046	1.110
95	0.351	0.590	0.738	0.844	0.926	0.994	1.102	1.185	1.253	1.360	1.444
99	0.539	0.907	1.135	1.298	1.423	1.528	1.693	1.821	1.925	2.091	2.219

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Question 4

a) A pad foundation, 3.0m square is to be located at a depth of 2.0m in a uniform bearing stratum of firm clay. The clay soil properties are;

Bulk unit weight	γ = 20.0 kN/m^3
Depth of Foundation	D_f = 2.0 m
With respect to Total Stresses	c = 40.0 kN/m^2
	Φ = 30^0

Determine the allowable bearing capacity (q_{all}), the net allowable bearing capacity ($q_{(net)all}$), the allowable load (Q_{all}), and the net allowable load ($Q_{(net)all}$) that the foundation can support in the short-term (in kN). **Use the formulae provided on page 11 and also Figure Q4 in page 8 and/or Table Q4 in page 9 (if appropriate).**

Use Factor of Safety 2.5. State any assumptions made in your calculations.

(12 marks)

b) A bored pile (15m long and 600mm diameter) is to be installed into the following soil profile;

Depth m	Description	Unit Weight kN/m^3	c_u kN/m^2	Adhesion Factor α
0 – 4	Soft CLAY	21.0	30.0	0.52
4 – 8	Firm to stiff CLAY	22.0	75.0	0.48
8 - 30	Stiff to very stiff CLAY	22.5	180.0	0.42

Determine the safe load carrying capacity of the pile (in kN). State any assumptions made in your calculations

(13 marks)

Total 25 marks

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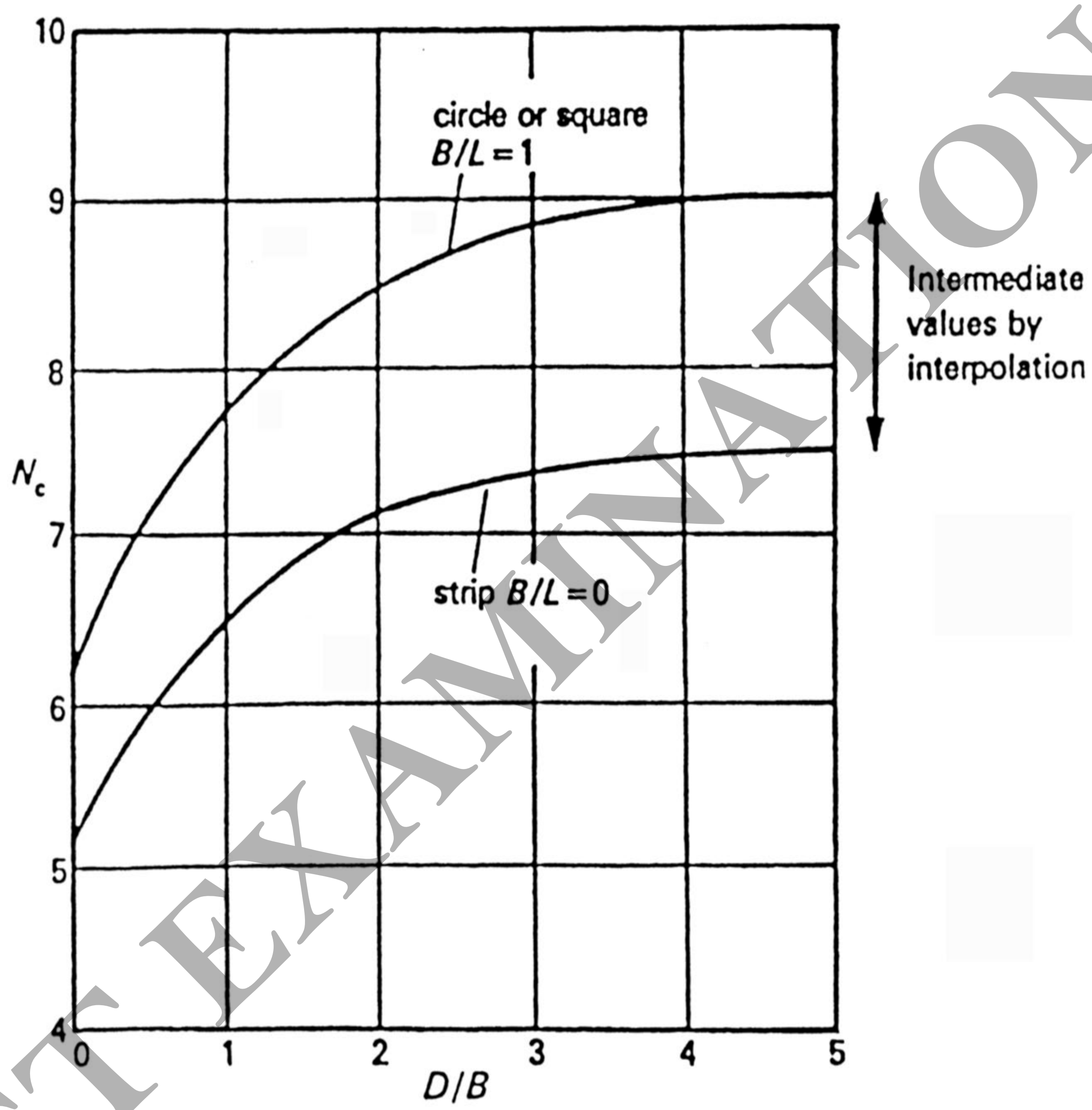

Figure Q4

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ϕ	N_c	N_q	N_γ
0	5.14	1.0	0
1	5.4	1.1	0
2	5.6	1.2	0
3	5.9	1.3	0
4	6.2	1.4	0
5	6.5	1.6	0.1
6	6.8	1.7	0.1
7	7.2	1.9	0.2
8	7.5	2.1	0.2
9	7.9	2.3	0.3
10	8.4	2.5	0.4
11	8.8	2.7	0.5
12	9.3	3.0	0.6
13	9.8	3.3	0.8
14	10.4	3.6	1.0
15	11.0	3.9	1.2
16	11.6	4.3	1.4
17	12.3	4.8	1.7
18	13.1	5.3	2.1
19	13.9	5.8	2.5
20	14.8	6.4	3.0
21	15.8	7.1	3.5
22	16.9	7.8	4.1
23	18.1	8.7	4.9
24	19.3	9.6	5.7
25	20.7	10.7	6.8
26	22.3	11.9	7.9
27	23.9	13.2	9.3
28	25.8	14.7	10.9
29	27.9	16.4	12.8
30	30.1	18.4	15.1
31	32.7	20.6	17.7
32	35.5	23.2	20.8
33	38.6	26.1	24.4
34	42.2	29.4	28.8
35	46.1	33.3	33.9
36	50.6	37.8	40.0
37	55.6	42.9	47.4
38	61.4	48.9	56.2
39	67.9	56.0	66.8
40	75.3	64.2	79.5

Table Q4

END OF QUESTIONS
Supplementary Geotechnical Information / Formulas follow over the page

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Supplementary Geotechnical Information

Retaining Walls (Q1)

$$P_A = K_A(\gamma z + q) - 2c\sqrt{K_A} \qquad P_P = K_P(\gamma z + q) + 2c\sqrt{K_P}$$

$$K_A = \frac{1 - \sin\phi}{1 + \sin\phi} = \tan^2\left(45 - \frac{\phi}{2}\right) \qquad K_P = \frac{1 + \sin\phi}{1 - \sin\phi} = \tan^2\left(45 + \frac{\phi}{2}\right)$$

($\boldsymbol{P_A, P_P, K_A}$ **and** $\boldsymbol{K_P}$ ***are the active and passive pressures and coeffecients respectively,*** $\boldsymbol{z}$ ***is the depth,*** $\boldsymbol{\gamma}$ ***is the unit weight and*** $\boldsymbol{q}$ ***is the surcharge***)

Slope stability (Q2)

$$F = \frac{c_u R\theta}{\sum T} \qquad F = \frac{c_u R\theta}{\sum W \sin\alpha}$$

(***R is the radius of the slip circle,*** $\boldsymbol{\theta}$ ***is the included angle,***
$\boldsymbol{\alpha}$ ***is the base angle and W is the weight of soil for each slice***)

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3-d Consolidation (Q3)

$\Delta h = \Delta\delta' \, m_v \, H$ $\Delta\delta' = \gamma z$

$(1 - U) = (1 - U_v)(1 - U_r)$

$T_v = c_v \, t / d^2$ $T_r = c_h \, t / 4R^2$

R = 0.564 S for square grid pattern

$n = R/r_d$

Shallow Foundations and Piles (Q4)

q_{all} = allowable bearing capacity = q_u / F

$q_{net(all)}$ = net allowable bearing capacity = $(q_u - \gamma D)/F$

c_u soil ($\phi_u = 0$)

Skempton : $q_f = c_u N_c + \gamma D$

c , ϕ soil

Terzaghi: $q_u = c N_c s_c + \gamma D N_q s_q + 0.5 B \gamma N_\gamma s_\gamma$

Where N_c ; N_q ; N_γ ; s_c ; s_q ; s_γ are bearing capacity and shape factors

Shape of footing	s_c	s_q	s_γ
Strip	1.0	1.0	1.0
Rectangle	$1.0 + (B/L)(N_q/N_c)$	$1.0 + (B/L)\tan\phi'$	$1.0 - (B/L)0.4$
Circle or square	$1.0 + (N_q/N_c)$	$1.0 + \tan\phi'$	0.6

Shaft Resistance $Q_s = \alpha\, c_u\, \pi\, d\, L$

Base Resistance $Q_b = c_u\, N_c\, \pi\, d^2 / 4$

$Q_{safe} = Q_b/3 + Q_s$ OR $Q_{safe} = (Q_b + Q_s) / 2.5$

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