OCD025

UNIVERSITY OF BOLTON

OFF CAMPUS DIVISION

WESTERN INTERNATIONAL COLLEGE

BENG(HONS) CIVIL ENGINEERING

SEMESTER ONE EXAMINATION 2022/2023

GEOTECHNICAL ENGINEERING AND GROUND IMPROVEMENT

MODULE NO: CIE6003

Date: Tuesday, 10 January 2023 **Time: 10:00 – 1:00**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions on this paper.

Answer any FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

This examination paper carries a total of 100 marks.

Formula sheet / supplementary information is provided on page 14.

All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.

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BEng (Hons) Civil Engineering
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Geotechnical Engineering and Ground Improvement
Module No. CIE6003

Q1.

(a) A retaining wall of 6 m height having 2m width at its top and 3m width at its base retains a backfill made up of two strata as shown in **Figure Q1.** Sketch the earth pressure diagram for the retained soil shown, labelling all relevant values.

<u>Relevant Parameters:</u>

Ground water level: 2.0 m below retained surface

Note: State any assumptions you have made.

(4 marks)

(b) For the above case, determine the height of the resultant thrust above the base of the retaining wall and calculate the factors of safety against overturning. Comment on the value obtained.

(15 marks)

(c) Discuss how the introduction of 'Key' in retaining walls is affecting the factor of safety of retaining wall. Explain using suitable diagrams and equations.

(6 marks)

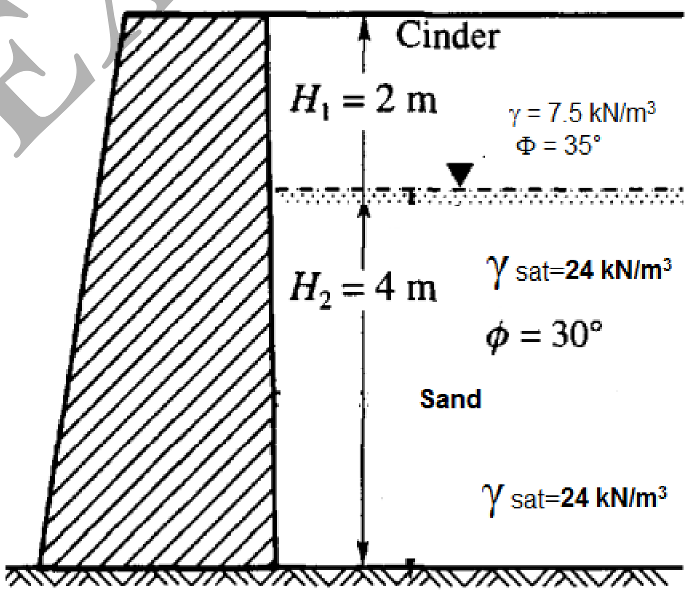

Figure Q1 **Total 25 marks**

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Q2

A clay stratum 8m thick is located at a depth of 6m from ground surface. The natural void ratio of clay is 0.78 and specific gravity is 2.75. The soil stratum between the ground surface and clay consists of fine sand. The water table is located at a depth of 2m below the ground surface.

The submerged unit weight of fine sand (γ_{sub}) 9.09 kN/m³ and its bulk unit weight above water table is (γ_{bulk}) 18.68 kN/m³.

(a) Determine the distribution of Effective stress, Pore Water Pressure and Total Stress at each soil strata. Hence plot the stress diagrams in graph sheet to illustrate the variation of the total stress, effective stress and pore water pressure with respect to the depth of the soil.

(10 marks)

(b) A pad foundation 3.5m square is laid at a depth of 1.8 m in a uniform bearing stratum of firm clay in the proposed land in order to construct a light industrial building. The water table is at an assumed depth of 1.0m below ground level. The soil at the site has the following properties

γ= 20 kN/m^3, γ_{sat}=23 kN/m^3, ϕ'= 32^0 and c'=24kN/m^2.

Determine the net safe bearing capacity of the footing based on the effects of water table variations in Terzaghi's bearing capacity, if

(i) The water table is at 1.8m from the ground level

(7.5 marks)

ii) The water table is 6m below the base of foundation

(7.5 marks)

NOTE: Clearly state any assumptions made in your calculations to determine the safe bearing capacity. Use **Tables Q2 a, Q2 b and Q2 c** and the formulae provided on page 16.

Total 25 marks

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Q2 continued

Table Q2 a: Minimum factors of safety for shallow foundation

Category	Characteristics of category	Extent of site investigation		Typical Structure
		Thorough	Limited	
A	Maximum design load: likely to occur often. Consequences of failure: disastrous	3.0	4.0	Railway bridges warehouses Blast furnaces Reservoir embankments Retaining walls / silos
B	Maximum design load: May occur occasionally. Consequences of failure: serious	2.5	3.5	Highway bridges Light industrial Public buildings
C	Maximum design load: Unlikely to occur.	2.0	3.0	Apartments Office buildings.

Table Q2 b: 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

Q2 continued over the page

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Q2 continued

Table Q2 c: Bearing capacity factors

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

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Q3.

(a) A concrete pile of 450 mm diameter is driven to a depth of 16 m through a layered system of sandy soil (c = 0). **Water table is close to the ground surface.**

The following data are available:

Top layer 1: Thickness = 8 m, γ = 10.36 kN/m^3 and Φ = 33°

Layer 2: Thickness = 2 m, γ = 10.57 kN/m^3 and Φ = 35°

Layer 3: Extends to a great depth, γ = 10.05 kN/m^3 and Φ = 37°

Determine the safe working load of this pile by adopting factors of safety of 1.5 and 2.5 for the shaft and end bearing resistance respectively .Use **Figure Q3a, Figure 3b and FigureQ3c** and the formulae provided at the end.

(18 marks)

(b) In the above scenario if the second layer of soil is replaced with a soft clay layer of γ = 22 kN/m^3 and C_u = 18 kN/m^2, how will it affect the load-carrying capacity of this pile? Discuss the possible outcomes with suitable reasoning. Use Suitable equations to validate your findings.

(7 marks)

Total 25 marks

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Q3 continued

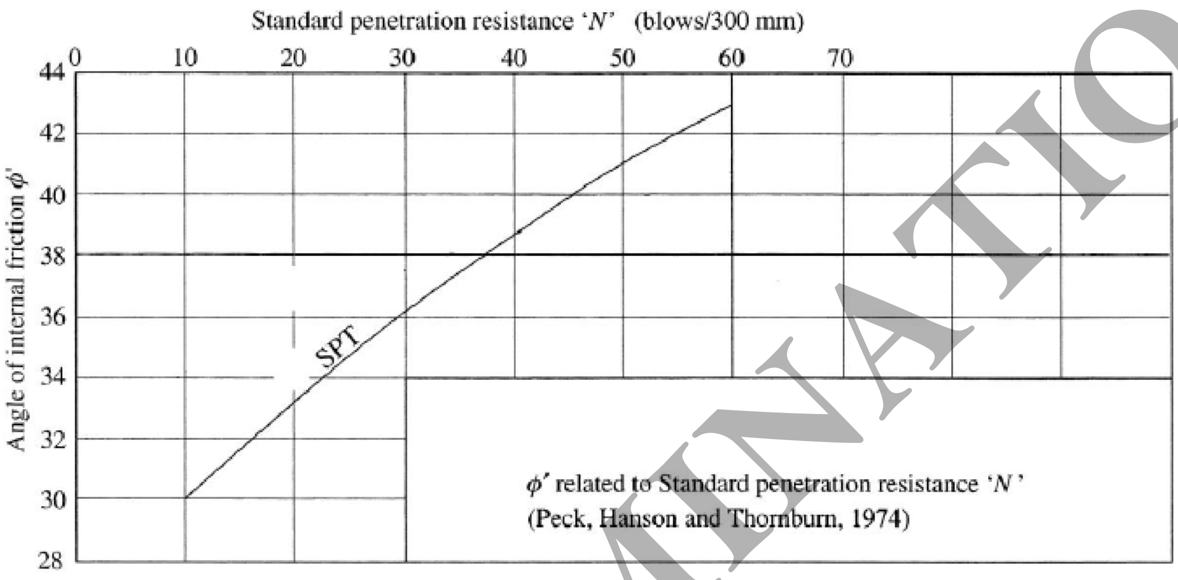

Figure Q3a

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Q3 continued

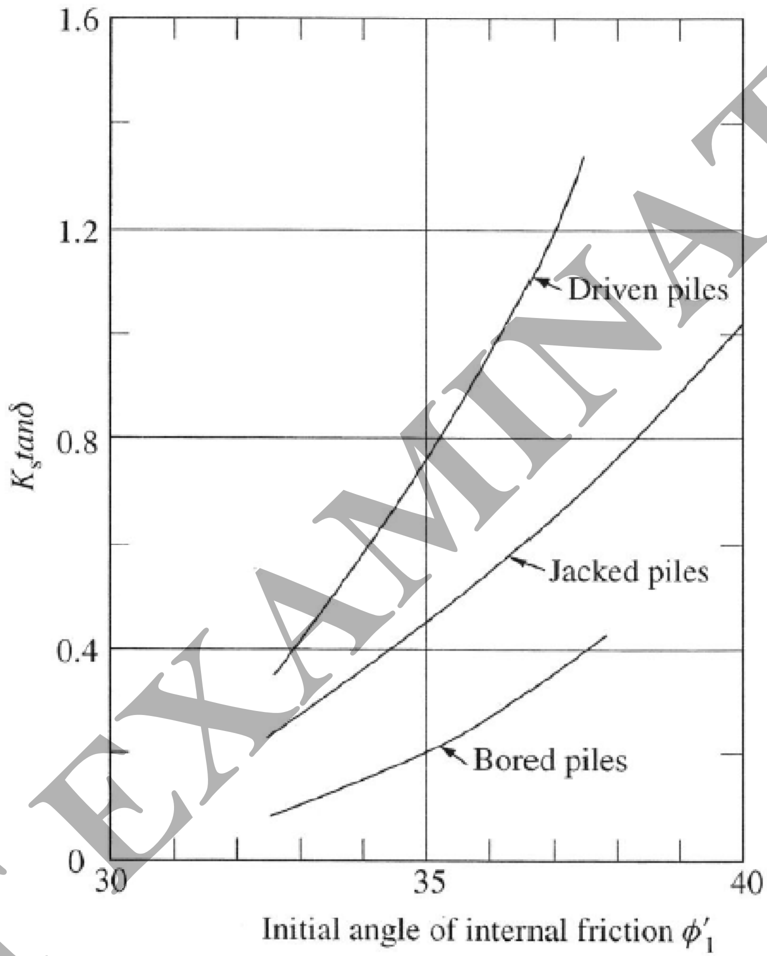

Figure Q3b

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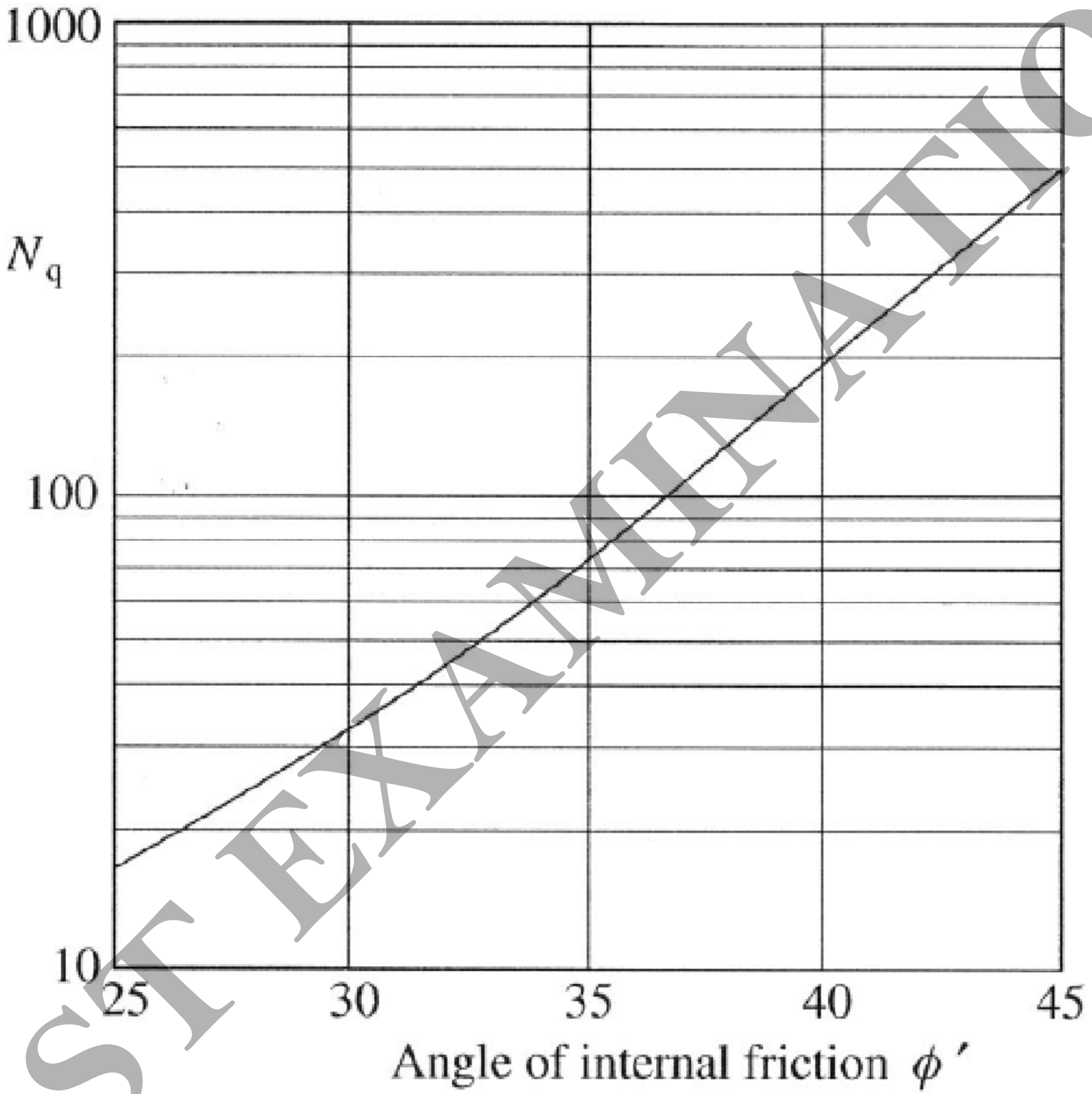
Q3 continued



(From Berezantsev et al 1961)

Figure Q3c

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Q4.

(a) A deep cut of 40^0 slope is excavated to a depth of 8m in a layer of saturated clay for the construction of a road. On inspection, the slope is found to have tension crack behind the crest of the slope as shown in **Figure Q4a.**

The clay is having strength parameters as follows:

Undrained cohesion c_u = 60 kN/m^2

Saturated unit weight , γ_{sat}= 19 kN/m^3.

Using rotational analysis of the trial slip circle, compare the factor of safety against the short-term failure for the two situations outlined below.

(i) If a dry tension crack is present

(5 marks)

(ii) If a water-filled tension crack is present

(7 marks)

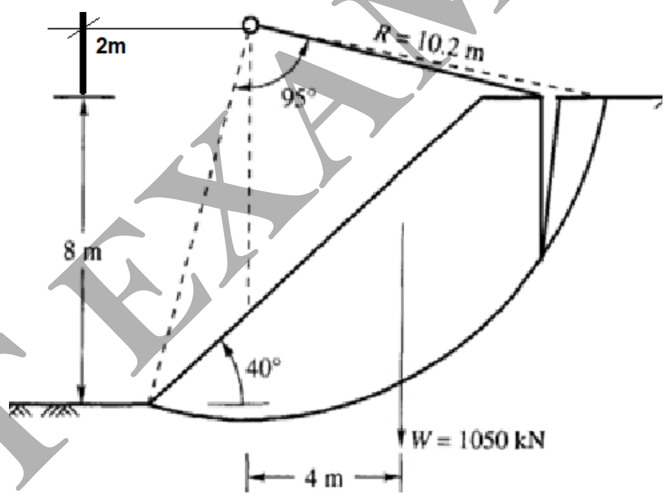

Figure Q4a Slip Circle

(b) Explain how inspection of the above proposed development area can reveal the presence of past or current mass movements.

(6 marks)

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Question 4 continued

(c) An earthen reservoir with side slope is partially submerged throughout the year as shown in **Figure Q4b**. Discuss how this will affect the stability of the slope. Use appropriate equations to support your findings.

(7 marks)

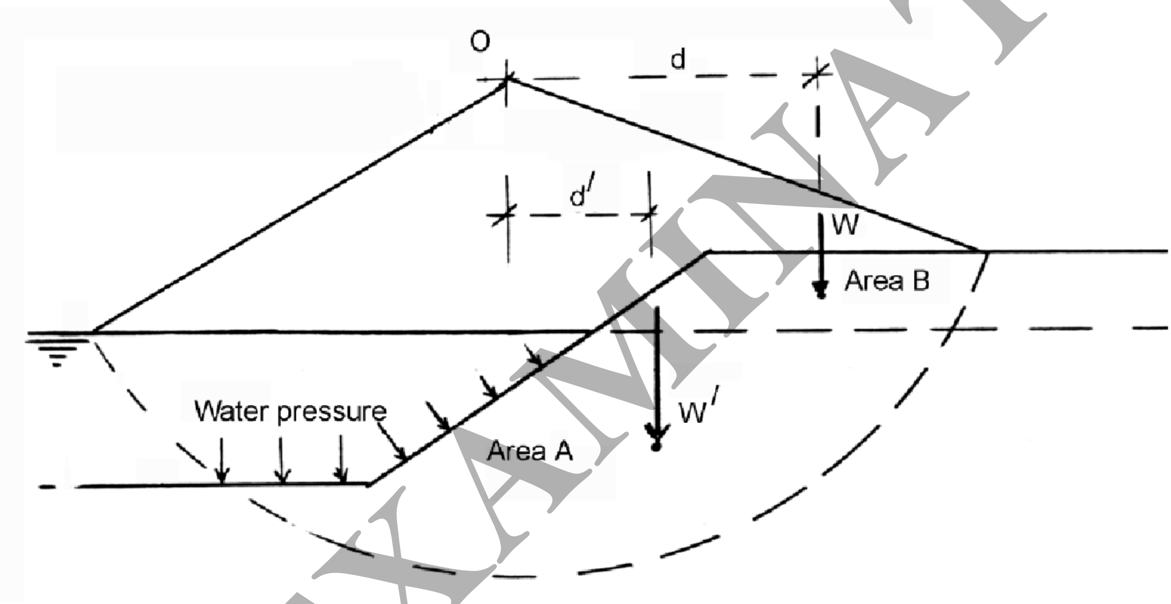

Figure Q4b Partially Submerged Slope

Total 25 marks

Q5

(a) The results on **Table Q5 a** were obtained from an oedometer test on a specimen of saturated clay

Table Q5 a Oedometer Test Result

Applied stress σv' (kN/m2)	0	50	100	200	400	600	800
Void ratio e	1.1	1	0.94	0.82	0.73	0.65	0.58

(i) Plot the e / σv' curve using the graph paper provided as **Figure Q5 on page 13**

(8 marks)

(ii) Using this applied stress and void ratio data, determine the value of m_v for an effective stress range from 90kN/m^2 to 250kN/m^2.

(6 marks)

(iii) Calculate the Consolidation Settlement for the layer of soil whose sample was tested having a layer thickness of 6m.

(4 marks)

(b) Differentiate between normally consolidated soils and over consolidated soils. Provide examples on over consolidation. With the aid of e-σ' graphs discuss how over-consolidation is different from normal consolidation.

(7 marks)

Total 25 marks

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Q5 continued

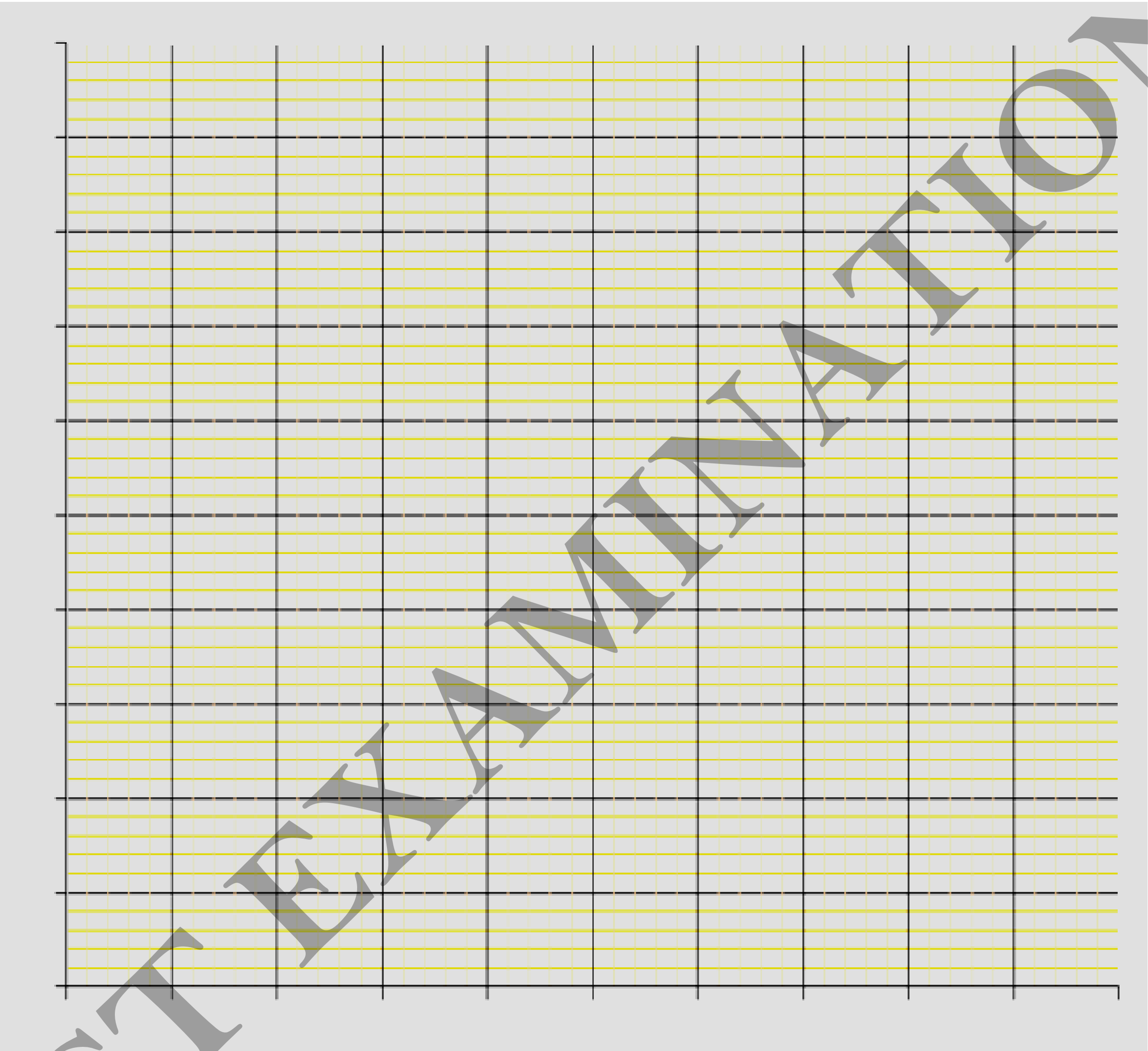

FIGURE Q5.

Candidate Number……………………….

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END OF QUESTIONS

Please turn the page (for Supplementary Geotechnical Information)

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Supplementary Geotechnical Information

	Density kg/m³	Unit weight kN/m³
1	$\rho_b = \dfrac{\rho_W (G_s + e\, S_r)}{1 + e}$	$\gamma_b = \dfrac{\gamma_W (G_s + e\, S_r)}{1 + e}$
2	$\rho_b = \dfrac{\rho_W\, G_s\, (1 + w)}{1 + e}$	$\gamma_b = \dfrac{\gamma_W\, G_s\, (1 + w)}{1 + e}$
3	$\rho_d = \dfrac{\rho_W\, G_s}{1 + e}$	$\gamma_d = \dfrac{\gamma_W\, G_s}{1 + e}$
4	$\rho_{sat} = \dfrac{\rho_W (G_s + e)}{1 + e}$	$\gamma_{sat} = \dfrac{\gamma_W (G_s + e)}{1 + e}$

Shallow Foundations:

Terzaghi's equation:

$$q_u = CN_c S_c + \gamma D N_q S_q + 0.5\gamma B N_\gamma S_\gamma$$

$$q_{net\ safe} = \frac{q_u - \gamma D}{F} + \gamma D$$

$\gamma_{sub} = \gamma_{sat} - \gamma_w$, *when water table is affecting bearing capacity*

Consolidation, $$m_v = \frac{\Delta e}{1 + e_0} \cdot \frac{1}{\Delta \sigma}$$

$\Delta H = m_v\, \Delta\sigma\, H_o$

Earth Pressure: $$k_a = \frac{1 - \sin\phi}{1 + \sin\phi}$$

Pile Foundations,

$$Q_u = Q_s + Q_b$$

For Choesive Soil, $Q_b = C_u N_c A_b$, $Q_s = \alpha . C_u^{-} A_s$ *For Cohesionless soil,* $Q_b = N_q . \sigma_v' . A_b$, $Q_s = K_s . \tan \tan \delta . \sigma_v^{-} . A_b \sigma_v = \gamma . D$

Slope Stability, $$F = \frac{C_u . R^2 . \theta_c . (\Pi/180)}{W_t . d_t + 0.5 . \gamma_w . z_c^{\ 2} . y_c}$$

$$Z_c = \frac{2C_u}{\gamma}$$

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