UNIVERSITY OF GREATER MANCHESTER

OFF CAMPUS DIVISION

WESTERN INTERNATIONAL COLLEGE, RAS AL KHAIMAH

BENG (HONS) CIVIL ENGINEERING

SEMESTER ONE EXAMINATION 2025/2026

GEOTECHNICAL ENGINEERING

MODULE NO: CIE6020

Date: Tuesday, 13th January 2026 **Time: 1:00pm – 4:00pm**

INSTRUCTIONS TO CANDIDATES:

There are FIVE (5) questions on this paper.

Answer any FOUR (4) 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 at the end of question paper.

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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QUESTION 1

a) A soil profile is found to have two layers. A 500 mm diameter concrete pile is driven to a depth of 12.0 m into layered sandy soils. The soil profile and corresponding parameters are provided in **Table 1.**

Table 1: The soil profile and parameters

Soil Type	Thickness (m)	Unit Weight (kN/m³)	N Value (SPT)
Medium dense sand	4.0	18	25
Dense sand	20.0	19.5	35

The groundwater table is located at a greater depth below the ground surface. Determine the safe working load of this pile, using factors of safety of 1.75 for shaft resistance and 2.25 for end bearing resistance. Use **Figure 1, Figure 2 and Figure 3** provided on **Pages 4-5.**

(10 marks)

b) A bored pile, 15 m in length and 800 mm in diameter, is to be installed in the soil profile presented in Table 2.

Table 2: Soil Profile

Depth (m)	Description	Unit Weight (kN/m³)	cu (kN/m²)	Adhesion Factor 'α'
0 – 6	Very Soft clay	20.5	20.0	0.50
6 – 20	Firm to Stiff CLAY	21.5	90.0	0.46

Question1 continued over the page

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Question 1 continued

(i) Determine the ultimate capacity and the safe load-carrying capacity of the pile (in kN). Use Nc = 9.0 and assume a factor of safety of 2.5.

(10marks)

(ii) Given the very soft clay layer highlighted above from ground level down to 6m, discuss the impact that will have on the scheme and describe the geotechnical issues that might arise and propose ways to mitigate against such geotechnical issues to provide a stable platform for the scheme.

(5 marks)

NOTE: Clearly state any assumptions made in your calculations

[Total 25 marks]

Question 1 continued over the page

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Question1 continued

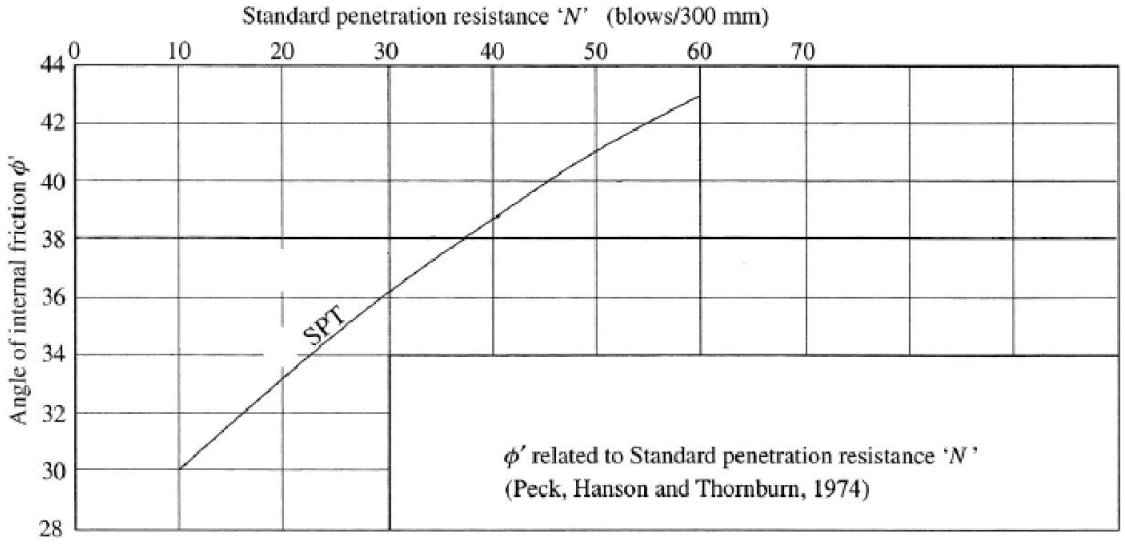

Figure 1. Angle of friction Values

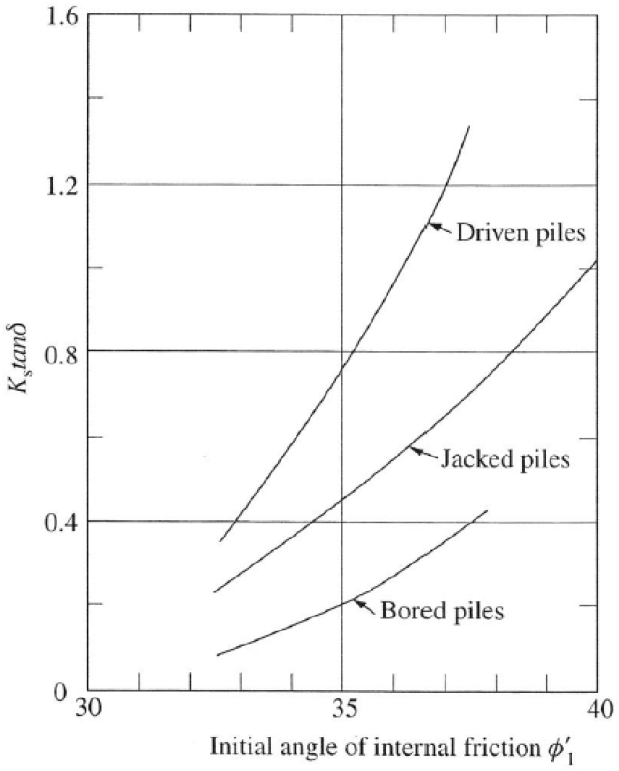

Figure 2. Ks tanδ values

Question1 continued over the page

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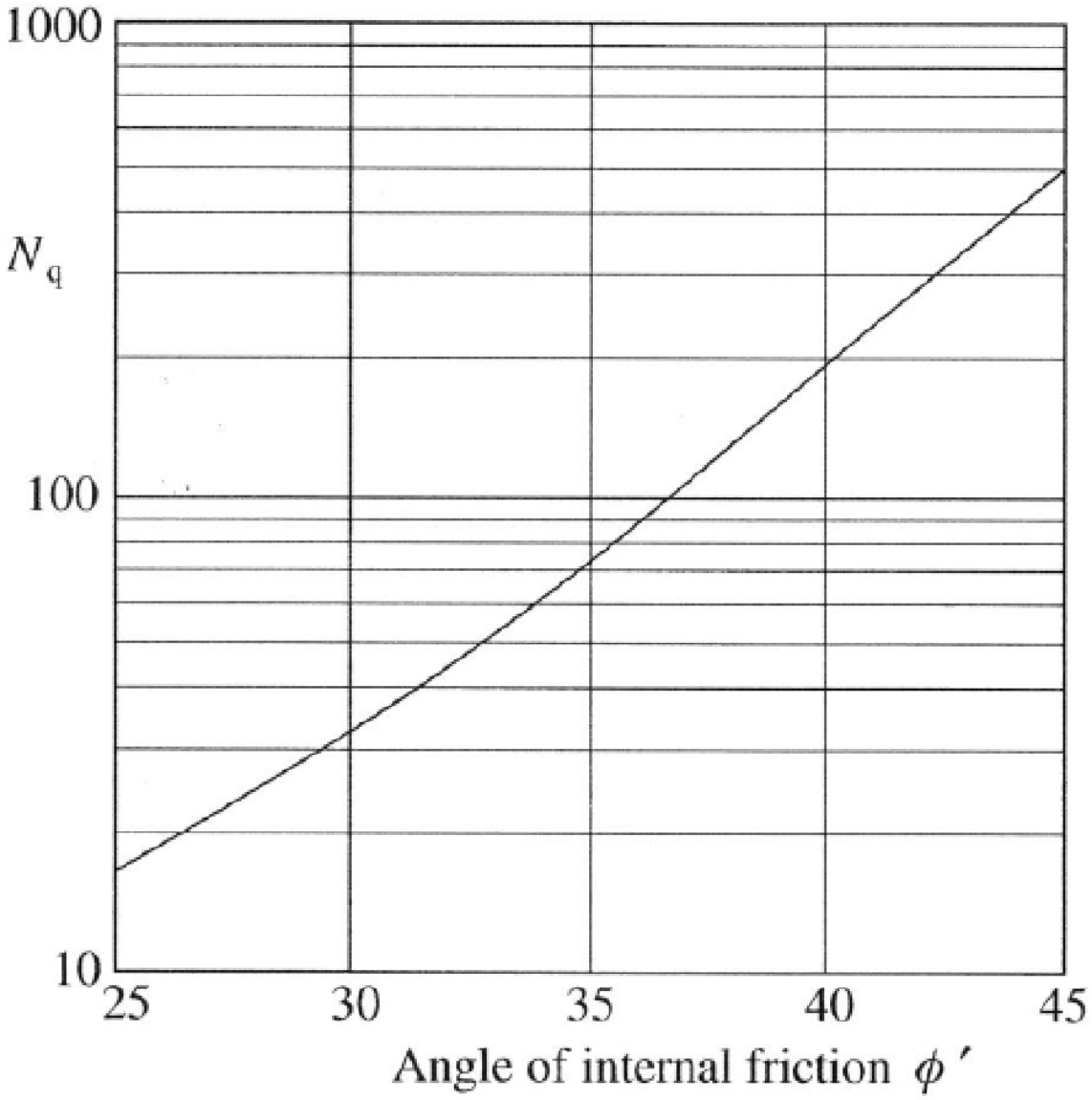

Figure 3. Nq Values

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QUESTION 2

a) A 7.5 m high road embankment with slopes of 1V:1.5H is built using compacted clay fill. After heavy rainfall, the upper portion becomes saturated and develops a tension crack.

Soil properties: $c_u = 38\,kN/m^2$, $\gamma = 18.6\,kN/m^3$.

Using the given trial slip circle in **Figure 4** (Sector Angle, $\theta_C = 88.7°$, Area of slipped mass, A = 98.3 m², Lever arm, Dt = 6.2 m), determine the Factor of Safety,

i) For dry tension crack

(8 marks)

ii) with a water-filled tension crack

(9 marks)

(Total 17 marks)

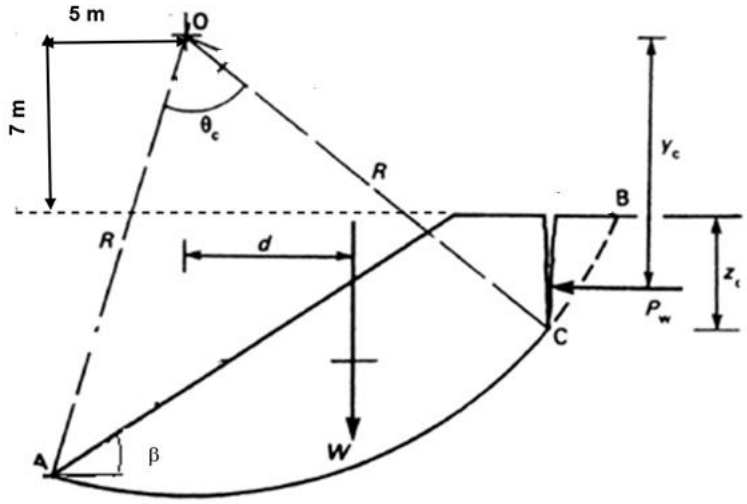

Figure 4. Trial Slip Surface

Question 2 continued over the page

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Question 2 continued

b) For a submerged slope (i.e., where pore water pressures act throughout the soil mass), critically compare the suitability of the Swedish Circle Method and Bishop's Simplified Method for effective stress analysis of slope stability.

(8 marks)

[Total 25 marks]

QUESTION 3

a) **Figure 5** shows a 15 m deep soil profile consisting of three distinct layers below the ground level (GL).

—The top 4 m consists of gravely sand with a unit weight γ = 17.8 kN/m^3. The water table is located at a depth of 4 m below the GL.

— Below this level, the gravely sand extends for another 2 m with a saturated unit weight γ_{sat}= 18.5 kN/m^3.

—4 m of sand (from 6 m to 10 m depth), fully saturated with γ_{sat}= 19.5 kN/m^3.

—The bottom layer consists of 5 m of sandy gravel (from 10 m to 15 m depth), also fully saturated, with γ_{sat}= 19.0 kN/m^3. Consider γ_w = 9.81 kN/m^3.

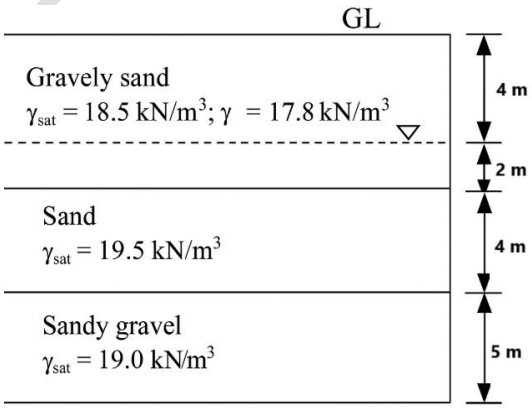

Figure 5. Subsoil Profile

Question 3 continued over the page

Question 3 continued

(i) Calculate the Total Stress, Effective Stress and Neutral Stress at depths of 4 m, 6 m, 10 m and 15 m below the ground level.

(10 marks)

(ii) Draw the diagram showing the variation of Total Stress, Effective Stress and Neutral Stress.

(8 marks)

b) The following data were obtained from a consolidation test on a clay sample with double drainage conditions: Void ratio at 100 kPa = 1.37, Void ratio at 200 kPa = 1.25, Thickness of the soil sample at 100kPa = 20mm, Coefficient of permeability = $5\ X\ 10^{-7}$ mm/sec. Calculate the Compression index, Coefficient of volume change, and Coefficient of consolidation in $mm^2/year$.

(7 marks)

[Total 25 marks]

Please turn the page

QUESTION 4

a) Allowable bearing pressure is governed by both shear failure and settlement criteria. Critically evaluate how these two criteria interact in foundation design and discuss how the choice of factor of safety (FOS) influences the final allowable bearing pressure.

(10 marks)

b) A strip footing at a depth of l m is required to transmit an inclusive load of 175 kN/m to a dry loose sand having the following properties: γ_d, = 17.0 kN/m^3, c= 0, ∅= 26^0. Adopting a factor of safety against shear failure of 3.0, determine the width of the footing. Use Terzaghi's bearing capacity factors.

NOTE: Clearly state any assumptions made in your calculations to determine the safe bearing capacity. Use **Table 3** on **page 10**.

(15 marks)

[Total 25 marks]

Question 4 continued over the page

Question 4 continued

Table 3 Terzaghi's bearing capacity factors

ϕ	N_c	N_q	$N\gamma$
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

Please turn the Page

QUESTION 5

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 6**. Assume the backfill above the water table remains dry. State any assumption you have made.

Relevant Parameters: **Groundwater level:2.0 m below the retained surface**

i) Construct an active earth pressure diagram and find the magnitude and point of application of the resultant thrust. **(13 marks)**

ii) Determine the Factor of Safety against overturning (ignore water pressures on the base of the foundation). Comment on the value obtained. **(5 marks)**

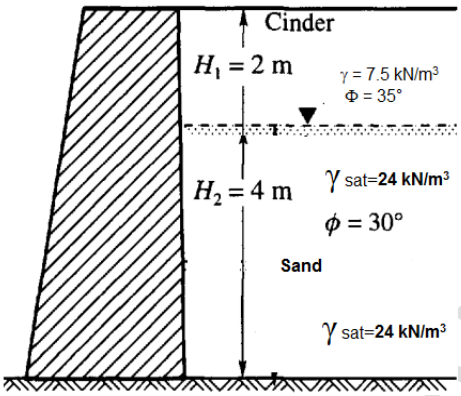

Figure 6: Retaining Wall

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

(7 marks)

[Total 25 marks]

END OF QUESTIONS

Please turn the Page for Supplementary Geotechnical Information

Supplementary Geotechnical Information

$$\gamma_b = \gamma_w \frac{(G_s + eS_r)}{1 + e}$$

$$\gamma_d = \frac{\gamma_w G_s}{1 + e}$$

$$\gamma_{sat} = \gamma_w \frac{(G_s + e)}{1 + e}$$

Consolidation

$$a_v = \frac{\Delta e}{\Delta \sigma}$$

$$C_V = \frac{T_{50} \, . H^2}{t_{50}}$$

$$C_v = \frac{k}{m_v \, . \gamma_w}$$

$$k = \frac{C_v \, . \, a_v \, . \gamma_w}{1 + e_0}$$

$$C_c = \frac{e_0 - e}{log_{10} \frac{\sigma'}{\sigma_0}}$$

$\Delta H = mv \, \Delta\sigma' \, Ho$

$$m_v = \frac{\Delta e}{(1 + e_0)} \; x \; \frac{1}{\Delta\sigma'}$$

Time factor, $T = \frac{c_v . t}{H^2}$

when U < 60%, $T = (\frac{\pi}{4})U^2$

when U> 60%, $T = \; - 0.9332 \; log_{10}(1 - U) - 0.0851$

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Shallow Foundations

Terzaghi's equation: $q_u = CN_cS_c + \gamma DN_qS_q + 0.5\gamma BN_\gamma S_\gamma$

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

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

Shape of footing	Sc	Sq	Sr
Strip	1.0	1.0	1.0
Rectangle	$1.0 + \left(\frac{B}{L}\right)\left(\frac{N_q}{N_c}\right)$	$1.0 + \left(\frac{B}{L}\right) tan\emptyset'$	$1.0 - \left(\frac{B}{L}\right)$ 0.4
Circle or Square	$1.0 + \left(\frac{N_q}{N_c}\right)$	$1.0 + tan\emptyset'$	0.6

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

Pile Foundations

$$Q_u = Q_s + Q_b$$

$$For\ Cohesive\ Soil, \quad Q_b = C_u N_c A_b\ , \quad Q_s = \alpha . \overline{C_u} . A_s$$

$$For\ Cohesionless\ soil, \quad Q_b = N_q . \sigma_v' . A_b, \quad Q_s = K_s . tan\ \delta\ . \overline{\sigma_v} . A_s$$

$$\sigma_v = \gamma . D$$

Slope Stability

$$F = \frac{CuR^2\theta_c . \pi/180}{Wt . Dt + 0.5\gamma_w {z_c}^2 y_c}$$

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

END OF PAPER