OCD059

UNIVERSITY OF BOLTON

WESTERN INTERNATIONAL COLLEGE FZE

BENG(HONS) CIVIL ENGINEERING

SEMESTER TWO EXAMINATION 2018/2019

GEOTECHNICAL ENGINEERING AND GROUND IMPROVEMENT

MODULE NO: CIE6003

Date: Wednesday 22 May 2019 **Time: 10.00am -1.00pm**

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 at the end 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 firm of civil engineering contractors installs a well-point dewatering system at one of their sites, to lower the groundwater level by 2m as indicated in **Figure Q1** during the construction in open excavation of a subsurface pumping chamber. After the dewatering system has been in continuous operation for a period of four weeks, the owners of buildings up to a distance of 500m from the site file claims against the contractor for structural damage arising from ground movements which they allege are the result of the dewatering operation. The borehole log which contains the details of the subsoil conditions at a site are shown in **Figure Q1** together with the details of the soil properties.

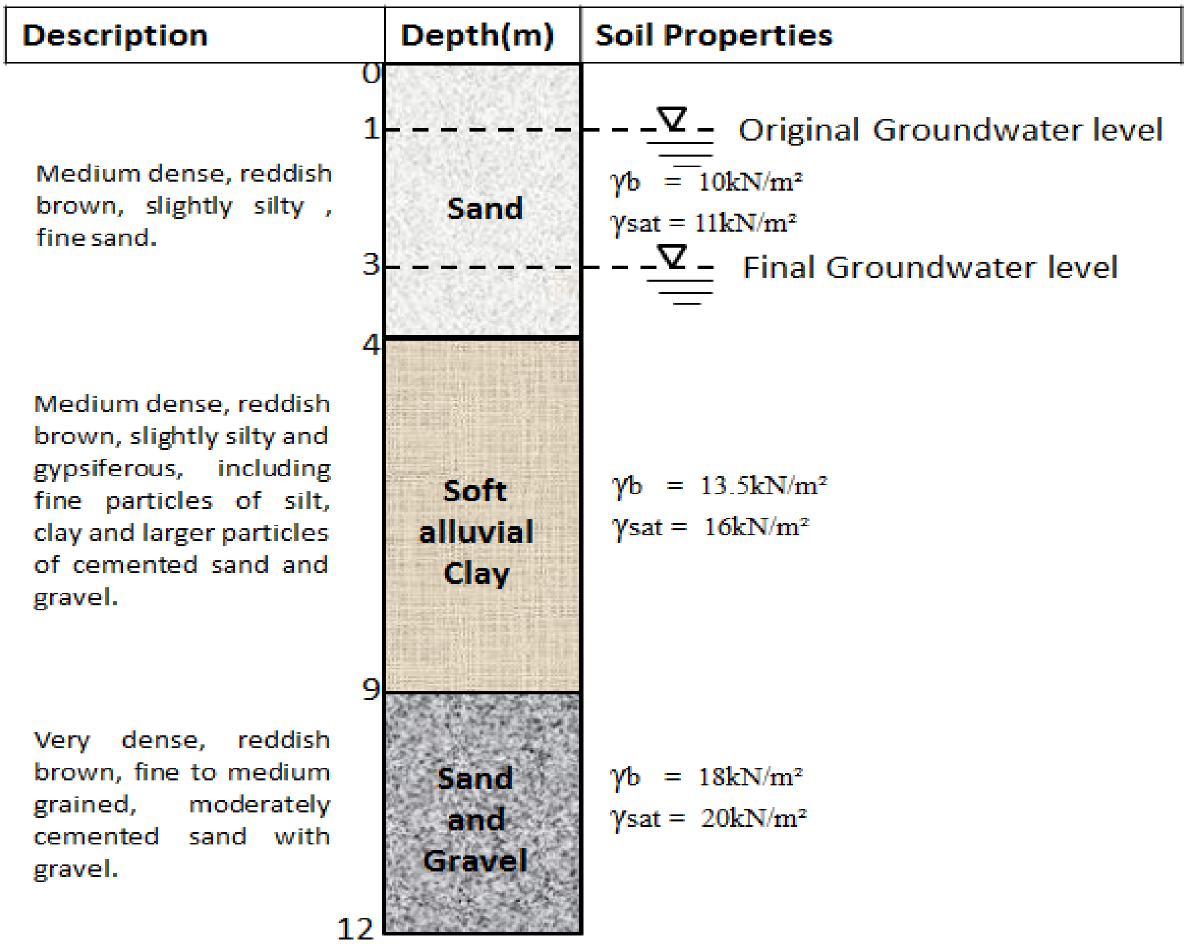

Figure Q1 Borehole log

Question 1 continued over the page

Please turn the page

Question 1 continued.

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

(12 marks)

(b) The following results shown in **Table Q1** were obtained from an oedometer test on a specimen of saturated clay from the soft alluvial clay layer above:

Table Q1

Applied stress σ (kN/m^2)	0	50	100	200	400	800	1000
Void ratio (e)	1.549	1.272	1.121	0.964	0.822	0.697	0.642

Plot the e / σ_v' curve using the values provided in **Table Q2** on the **graph paper provided.**

(5 marks)

(c) Determine the coefficient of compressibility, mv for the effective stress range of $250kN/m^2$ and $625kN/m^2$ with respect to the soil conditions.

(5 marks)

(d) Calculate the consolidation settlement for the layer of clay having a layer thickness of 5m as shown in the Figure Q1. (3 marks)

Total 25 marks

Please turn the page

Question 2

(a) A limited site investigation was conducted in a barren clayey area to build a workshop. Square foundations of 5.5m wide and 5.5m long were designed, which is to be laid at 2.3m below ground level in a thick deposit of firm saturated clay.. The soil at the site has the following properties.

$$\gamma = 18.6 kN/m^3, \gamma_{sat} = 21 kN/m^3, \Phi' = 29^0, \; Cu = 32.5 kN/m^2$$

i. Determine the ultimate bearing capacity and the net safe bearing capacity of soil when the water table is in level with the foundation base.

(8 marks)

ii. Determine the percentage of reduction in the safe bearing capacity of soil when the water table rises to 0.3m below the G.L.

(7 marks)

iii. Comment on the critical situation for soil's bearing capacity

(2 marks)

NOTE: Clearly state any assumptions made in your calculations to determine the safe bearing capacity. Refer the **Tables Q2a, Q2b and Q2c.**

(b) Shallow foundations are generally designed to satisfy bearing capacity and settlement criteria. A shallow foundation is to be founded in a thick deposit of sandy soil. Applied pressure, soil stiffness and the foundation width are the three most important variables affecting the settlements in granular soils. Analyse how the bearing capacity determination of granular soils differs from that of clayey soils.

(8 marks)

Total 25 marks

Question 2 continued over the page

Please turn the page

Question 2 continued.

Table Q2a: 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 Q2b: 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

Question 2 continued over the page

Please turn the page

Question 2 continued.

Table Q2c: 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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Question 3

(a) A bored pile of 25m long and 600mm diameter is to be installed into the following soil profile;

Depth (m)	**Soil type**	**Unit weight, γ, kN/m^3**	**C_u kN/m^2**	**Adhesion factor, α**
0-5	Firm Clay	19	50	0.7
5-15	Stiff clay	22	55	0.4
15-30	Very stiff clay	23.5	125	0.3

i. 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. Assume the factor of end bearing Nc = 9.0.

NOTE: Clearly state any assumptions made in your calculations

(8 marks)

ii. In the above scenario if the the pile boring has depth restrictions after 15 m, then how could a greater carrying capacity be obtained? Ensure that your answer discusses the advantages and disadvantages of using each alternative.

NOTE: Calculations are NOT required for your answer to Q3(b)

(3 marks)

Question 3 continued over the page

Question 3 continued.

(b) A 10 m long concrete pile, 300mm square, is to be driven into a thick deposit of medium dense sand, with an SPT 'N' value of 25 and a bulk unit weight of 19.5 kN/m^3. The water table lies at 5m below ground level.

i. Estimate the working load this length of pile will support assuming an overall factor of safety of 2.5. Use **Figures Q3-1, Q3-2, Q3-3** provided.

(9 marks)

ii. Briefly discuss about the load carrying capacity of the pile, if in the above scenario the pile is replaced by a bored pile. Outline the design philosophy adopted. (5 marks)

Total 25 marks

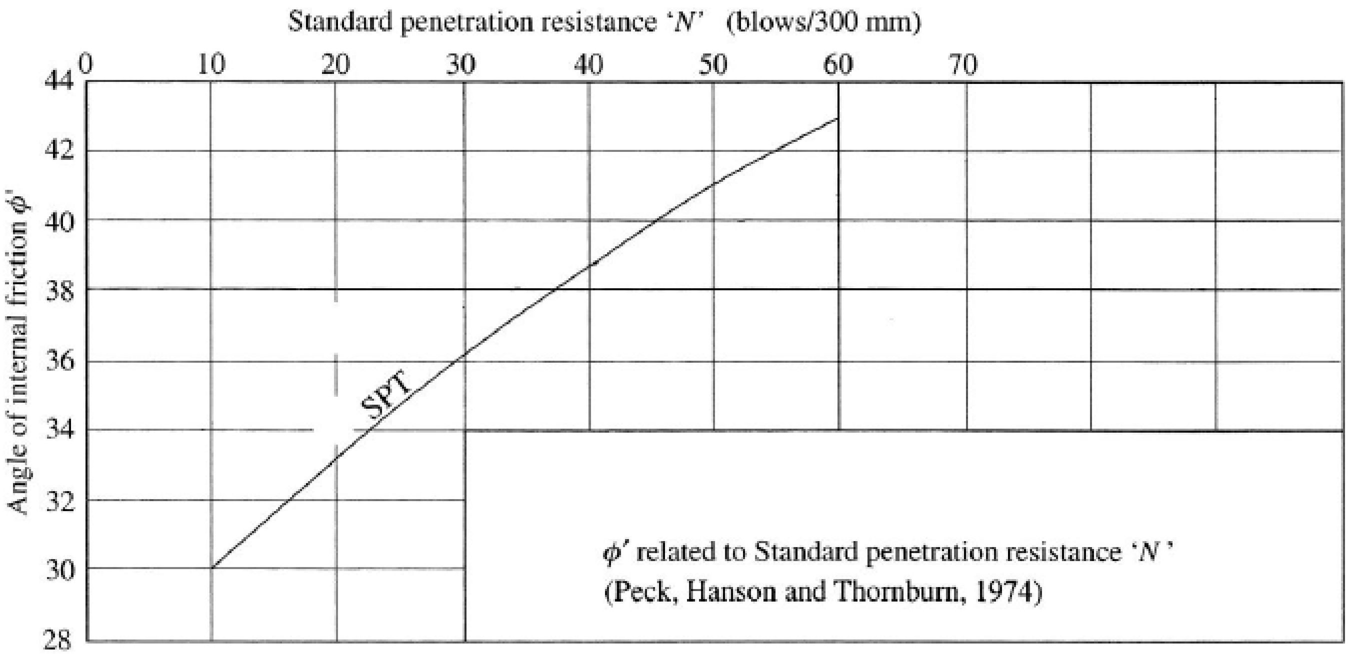

Figure Q3-1

Question 3 continued over the page

Question 3 continued.

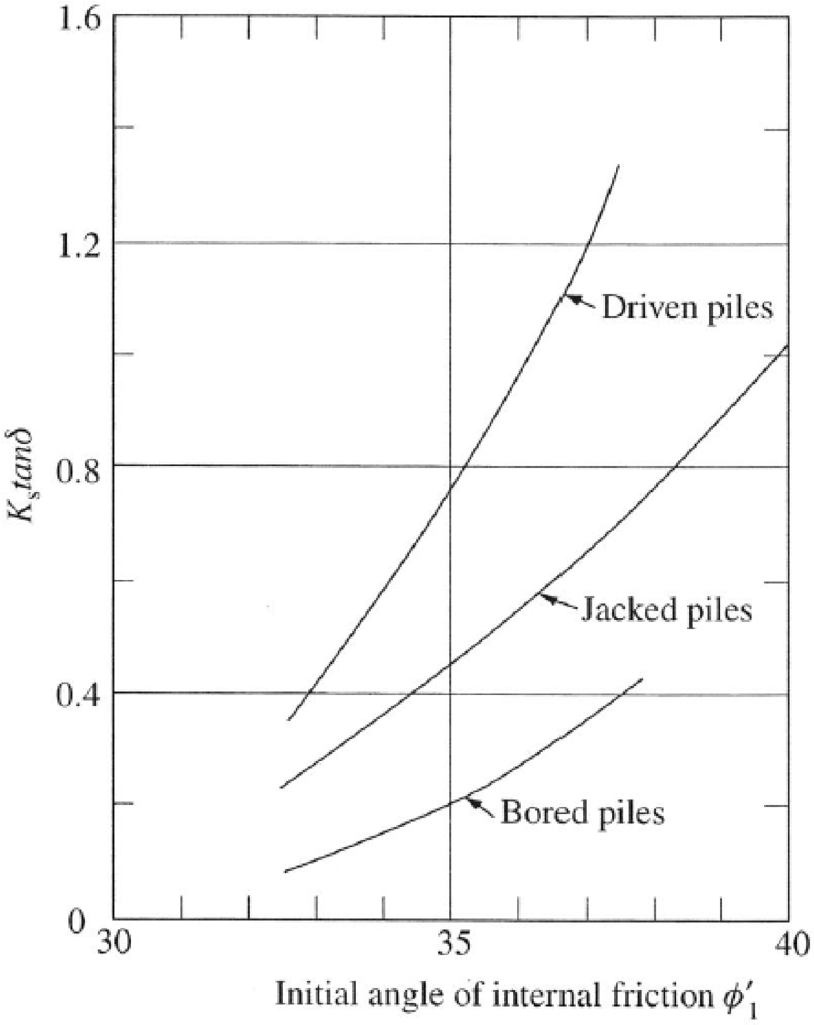

Figure Q3-2

Question 3 continued over the page

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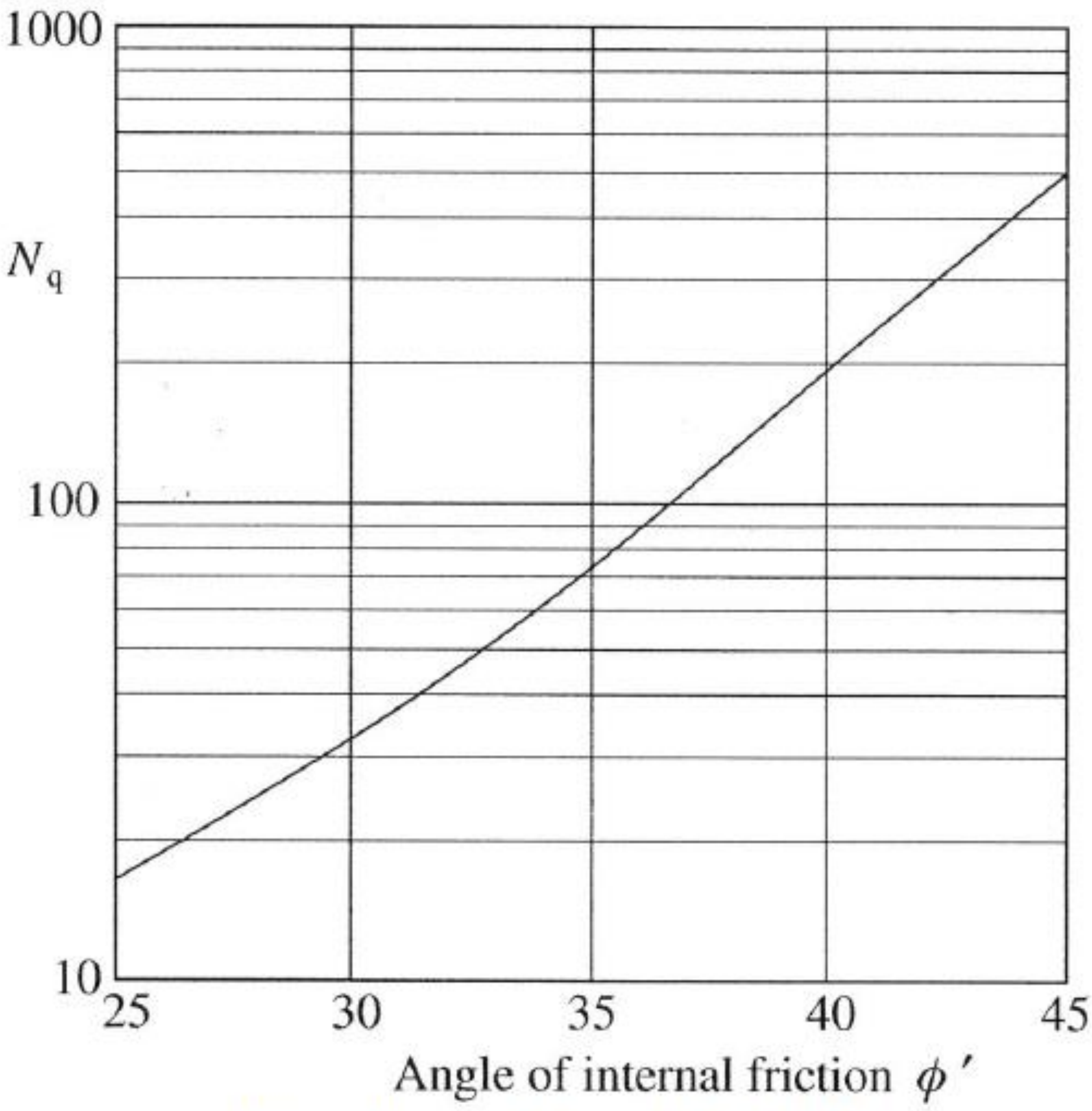
Question 3 continued



(From Berezantsev et al 1961)

Figure Q3-3

Please turn the page

Question 4

(a) A housing development is to be placed on a hillside with a history of instability. The area currently has occasional farm buildings, several access roads and is partly wooded. Explain how inspection of the proposed development area can indicate an impending slop failure. Illustrate your answer with practical examples.

(7 marks)

(b) A 7m height cutting is excavated in a thick stratum of saturated clay with the following properties:

Saturated Unit weight, γ_{sat} = 20 kN/m^3

Strength parameters with respect to effective stress: C' = 20 kN/m^2 , ϕ' = 30^0

A trial slip surface of radius 12m and sector angle 71^0 is dividing the sector into slices as shown in **Figure Q4** on Page 11. Complete the table shown in **Table Q4** on Page 12 and hence determine the long term factor of safety, F, of the trial slip surface using **Swedish (Fellenius)** analysis.

(18 marks)

Total 25 marks

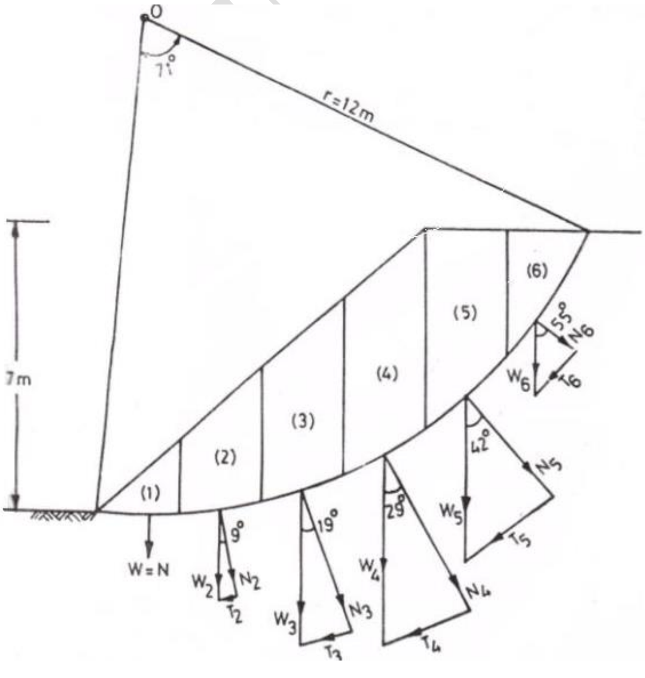


Figure Q4-1

Question 4 continued over the page

Please turn the page

Question 4 continued.

Candidate Number ....

Table Q4.

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
Slice No:	b	h	α	hw	l	u.l	W	sinα	cosα	Wcosα	Wcosα- u.l	Wsinα
	(m)	(m)	(deg)	(m)	(b/cosα)		kN					
1	2.0	0.9										
2	2.0	2.4										
3	2.0	3.6										
4	2.0	4.5										
5	2.0	4.0										
6	2.0	1.80										
										Σ		

Please turn the page

Question 5

(a) The mass concrete gravity wall shown in **Figure Q5a** retains a total thickness of 9.0m of granular soils. An extensive area of uniform surcharge of 35 kN/m^2 is present at ground level. Ground water level is at a considerable depth below the base of the wall.

Soil properties are as follows;

Soil 1

γ = 17.52 kN/m^3

ϕ = 26^o

Soil 2

γ = 20.05 kN/m^3

ϕ = 32^o

i. Determine the total active thrust acting on the wall and its location above the heel by constructing the active earth pressure diagram

(12 marks)

ii. Determine the factors of safety against overturning and comment on the values obtained.

Assume the unit weight of concrete is 24.0 kN/m^3

(8 marks)

Question 5 continued over the page

Question 5 continued.

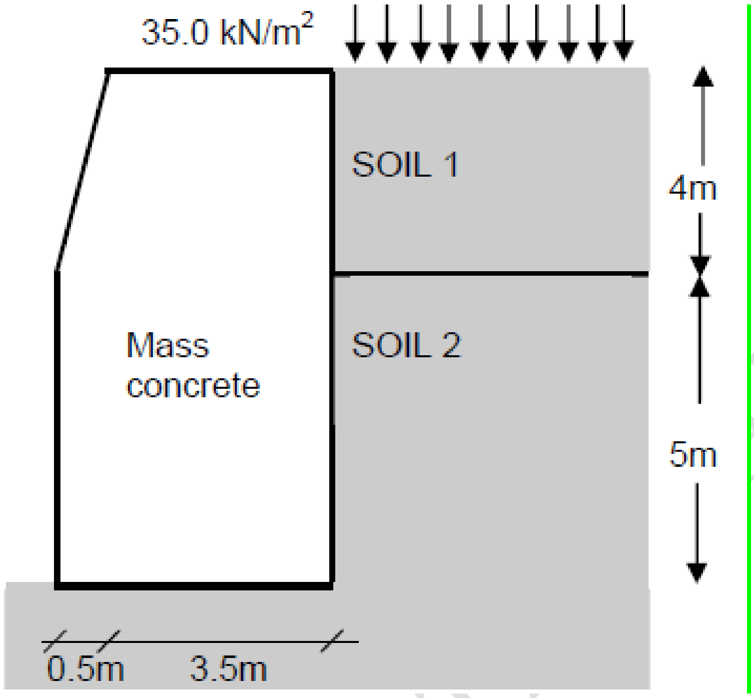


Figure Q5a.

(b)In the situation shown in **Figure Q5a** why might an embedded retaining wall be used instead of a gravity retaining wall? Ensure that your answer discusses construction practicality and also discusses the advantages and limitations of using both a gravity and embedded retaining wall for this retained height. Briefly outline a full range of alternative solutions that could be used (use sketches to illustrate your answer as appropriate).

(7 marks)

Total 25 marks

END OF QUESTIONS

Please turn the Page for Supplementary Geotechnical Information

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<u>Supplementary Geotechnical Information</u>

	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	$\rho_{sat} = \dfrac{\rho_W (G_s + e)}{1 + e}$	$\gamma_{sat} = \dfrac{\gamma_W (G_s + e)}{1 + e}$

Consolidation:

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

$$m_v = \frac{\Delta e}{(1 + e_o)} \times \frac{1}{\Delta\sigma'}$$

Shallow Foundations:

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

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

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

Pile Foundations,

$$Q_u = Q_s + Q_b$$

For Cohesive soils, $Q_b = C_u N_c A_b$, $Q_s = \alpha.\bar{C}_u\, A_s$

For cohesionless soils, $Q_b = N_q.\sigma_v'.A_b$, $Q_s = K_s.\tan\delta.\bar{\sigma}_v.A_b$

$\sigma_v = \gamma.D$

Slope Stability,

$$F = \frac{C^{'}.R.\theta_{rad} + \sum(W\cos\alpha - u.l).\tan\phi')}{\sum W.\sin\alpha}.$$

END OF PAPER