UNIVERSITY OF BOLTON

OFF CAMPUS DIVISION

WESTERN INTERNATIONAL COLLEGE

BENG (HONS) CIVIL ENGINEERING

SEMESTER ONE EXAMINATION 2024/2025

GEOTECHNICAL ENGINEERING

MODULE NO: CIE6020

Date: Saturday, 4 January 2025 **Time: 10:00 am – 1:00 pm**

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) An 8.5m long concrete pile, 400mm square, is to be driven into a thick deposit of medium-dense sand, with an SPT 'N' value of 25. A water table lies at 2.5m below ground level. The sand above and below the water table has unit weights of 18.0 kN/m^3 and 20.5 kN/m^3 respectively. Estimate the working load this pile will support assuming an overall factor of safety of 2.5.
Use **Figures Q1-1, Q1-2, Q1-3** and the formulae provided on **page 15**.

(12 marks)

b) In the above scenario, if the pile is constructed as a bored and cast-in-situ pile, how will that affect the pile capacity? Estimate the pile load capacity and illustrate your answer with the help of equations if all the other data remain the same.

(6 marks)

c) A pile of diameter 1000mm and length 9 m is driven into a stiff clayey soil of shear strength 150 kN/m^2. Determine the working load of the pile by applying a factor of safety of 3.0 to the base load. Full mobilisation of shaft adhesion can be assumed. Use **Figure Q1-4.**

NOTE: Clearly state any assumptions made in your calculations

(7 marks)

Question 1 continued over the page…

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Question 1 continued…

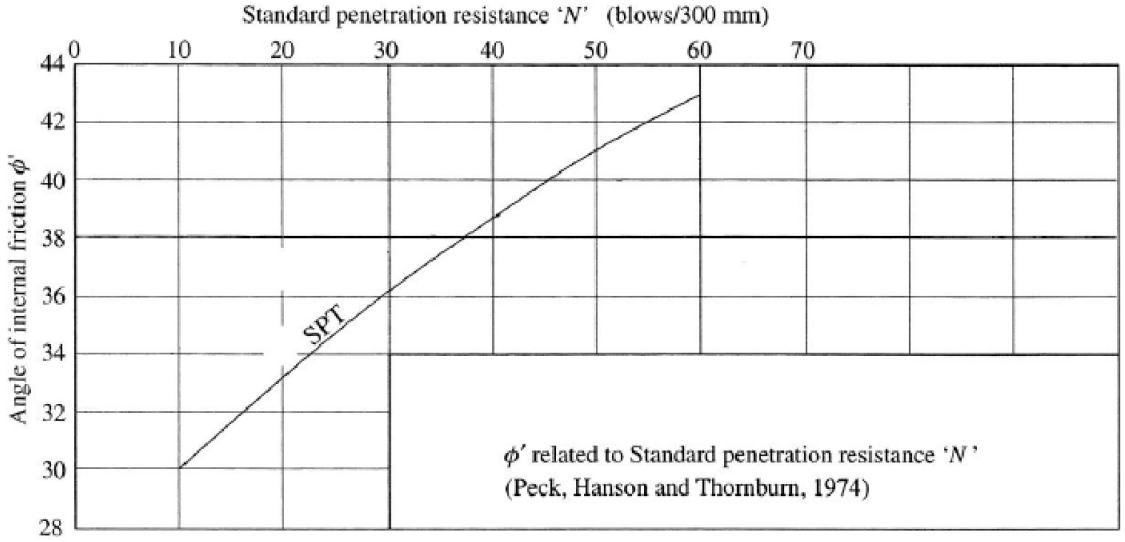

Figure Q1-1

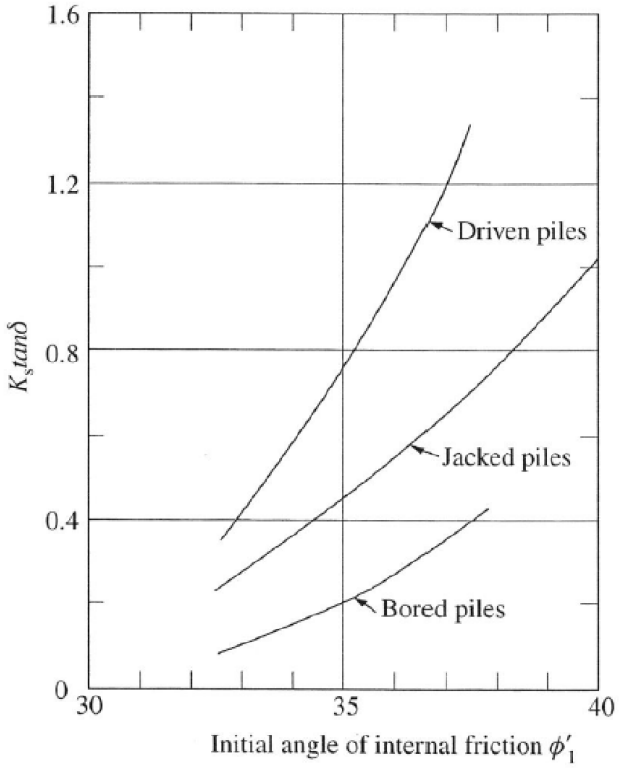

Figure Q1-2

Question 1 continued over the page…

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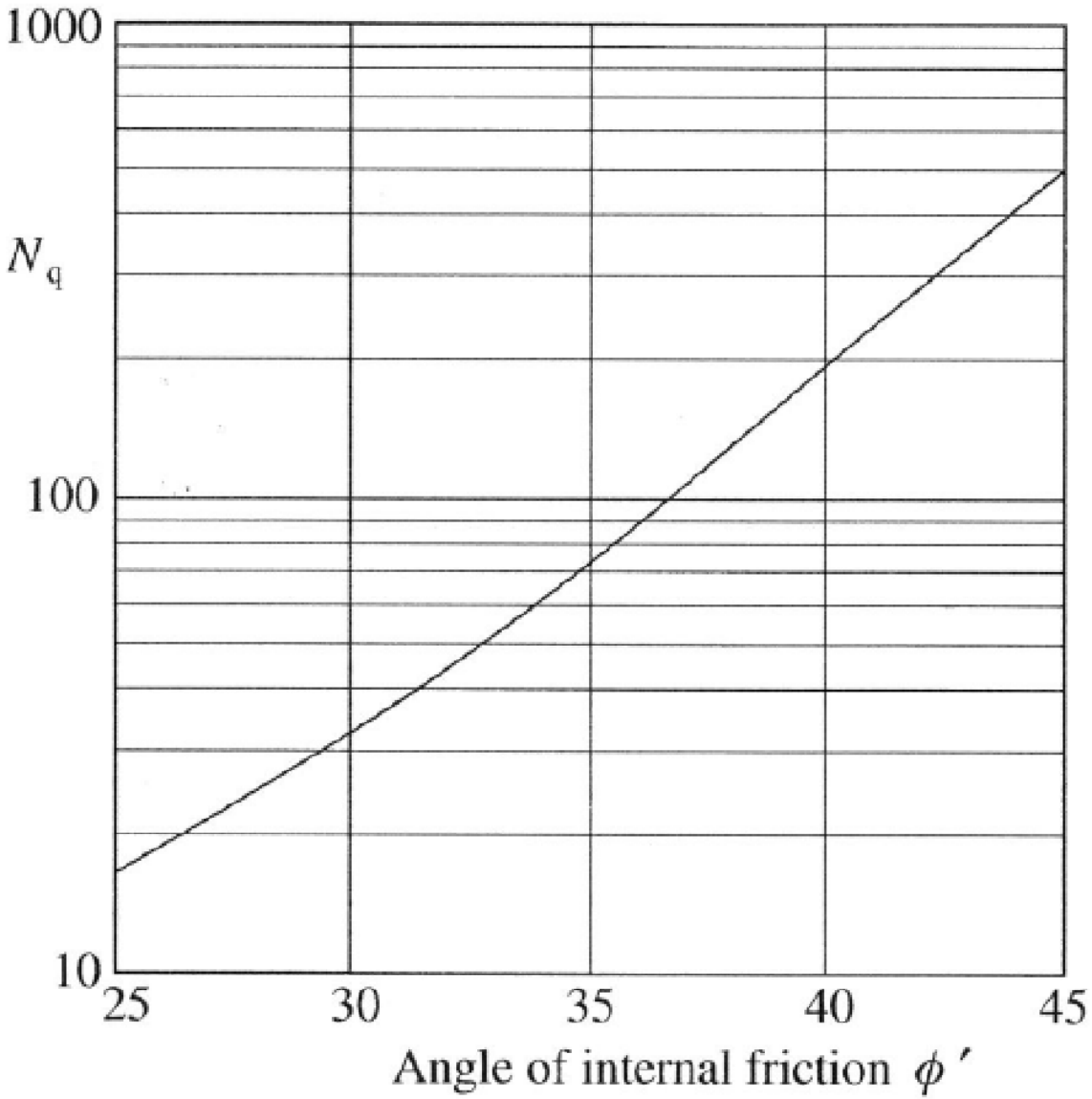

(From Berezantsev et al 1961)

Figure Q1-3

Question 1 continued over the page…

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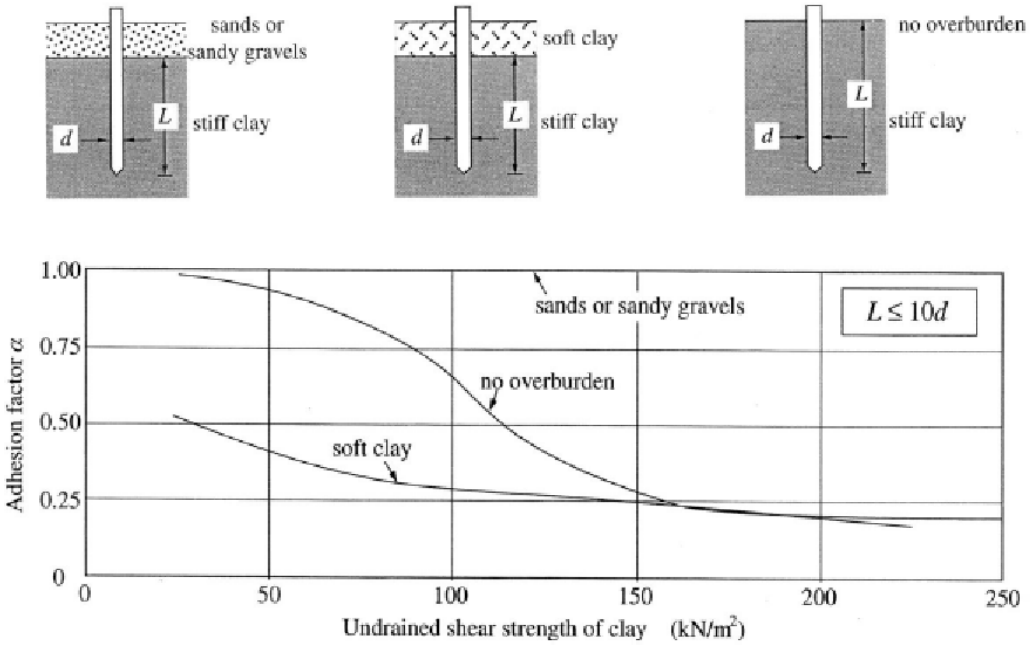
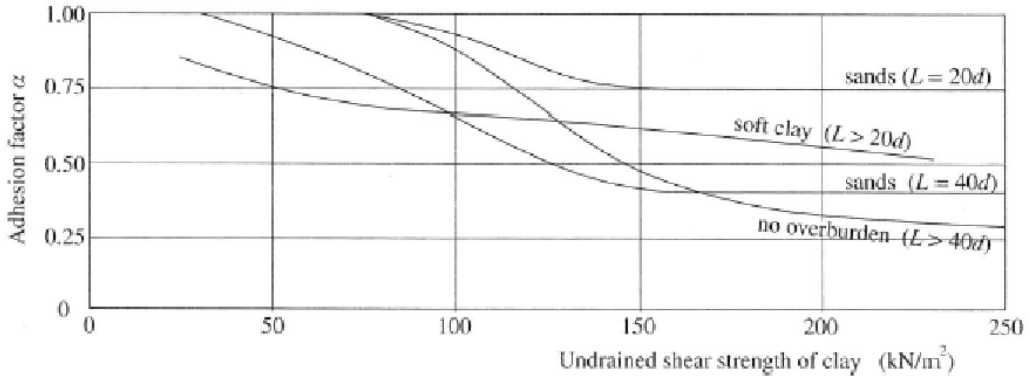
Question 1 continued…



Adhesion factors for short piles(L<10d) driven into stiff clay



Adhesion factors for long piles(L>20 to 40d) driven into stiff clay (Tomlinson, 1987)

Figure Q1-4

[TOTAL 25 MARKS]

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QUESTION 2

a)

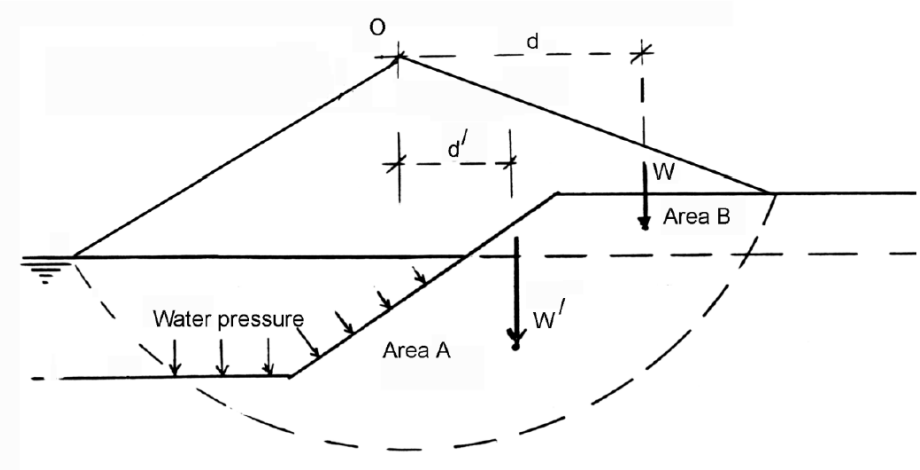

Figure Q2-1: Partially Submerged Slope

(i) An earthen reservoir with side slope is partially submerged throughout the year as shown in **Figure Q2-1**. Discuss how this will affect the stability of the slope.

(5 marks)

(ii) Critically discuss the effect of a rapid drawdown on the above slope, if the retained water is quickly lowered.

(5 marks)

Use appropriate equations to support your findings.

Question 2 continued over the page…

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Question 2 continued…

b) A cutting, 7.8m in vertical height, has a side slope of 28^o from the horizontal and is excavated in a thick stratum of firm saturated clay with the following properties.

The radius of the slip circle, R = 14.5 m
Sector Angle, $\theta_C = 56^0$
Saturated Unit weight, $\gamma_{sat} = 18.8$ kN/m^3
Unit weight of Water, $\gamma_w = 9.8$ kN/m^3

Shear strength parameters for the clay are.

$c' = 6$ kN/m^2
$\Phi' = 18^o$

(i) Complete the table shown in **Table Q2 on Page 8** and hence determine the long-term factor of safety, F, of the trial slip surface using Bishop's Method.

(12 marks)

(ii) Comment on the engineering significance of the value of factor of safety obtained.

(3 marks)

[TOTAL 25 MARKS]

Question 2 continued over the page…

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Question 2 continued…

Candidate Number …….

Table Q2.

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	
Slice No:	b	h	h_w	α	sinα	cosα	W	l	C'l	u	r_u	r_u.secα	c'.l+W(cosα-r_u.secα).tan φ	Wsinα
	(m)	(m)	(m)	(deg)			kN	(b/cosα)		kN/m^2	(u/rz)			
1	2.1	0.68	0.68	-5.78										
2	2.1	2.04	2.04	0.00										
3	2.1	3.16	3.16	8.26										
4	2.1	3.83	3.83	15.8										
5	2.1	4.19	4.19	23.3										
6	2.1	4.01	4.01	32.1										
												Σ		

Please turn the page

QUESTION 3

a) **Figure Q3-1** shows the subsoil profile, where sand extends from the ground level to a depth of 1 m, with the water table located at this level. From a depth of 1 m to 2 m, the sand layer has a void ratio of 0.4 and a specific gravity of 2.65. Below 3 m depth, the profile consists of a saturated clay layer with a unit weight of 20 kN/m³. Consider the unit weight of water γ_w = 9.81 kN/m³.

Figure Q3-1

(i) Calculate the Total Stress, Effective Stress and Neutral Stress at depths of 1 m, 3 m, and 6 m below the ground level.

(7 marks)

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

(5 marks)

b) For a laboratory consolidation test on a soil specimen that is drained on both sides, the following data was obtained:

Thickness of the clay specimen = 25 mm

P_1 = 50 kN/m^2; e_1 = 0.92

P_2 = 120 kN/m^2; e_2 = 0.78

Question 3 continued over the page…

Question 3 continued…

Time for 50% consolidation = 2.5 min

Take $T_V = 0.197$ and γ_w = 9.81 kN/m³.

Determine the soil permeability for the loading range.

(6 marks)

c) Consider a clay deposit that has undergone significant historical loading and unloading due to natural and man-made processes. Explain the role of the coefficient of recompression (Cr) and the swelling index (Cs) in determining the soil's response to unloading and reloading. How do these values differ in their implications for over-consolidated and normally consolidated soils?

(7 marks)

[TOTAL 25 MARKS]

QUESTION 4

a) Explain how the presence of a well-defined wedge and the associated soil displacement affect the behaviour of the foundation during general shear failure. What observations can be made about the tilting of the foundation?

(8 marks)

b) A square foundation measuring 3.5 m x 3.5 m is found at a depth of 3 m in a soil with the following properties:

Unit weight of soil (γ) = 18.5 kN/m³

Saturated unit weight of soil (γ_{sat}) = 21.0 kN/m³

Cohesion (c) = 25.0 kN/m²

Angle of internal friction (φ) = 30°

Unit weight of water γ_w = 9.81 kN/m³

Question 4 continued over the page…

Question 4 continued…

i) Calculate the net allowable or safe bearing capacity in kN/m² when the water table is located at the foundation base level, using a factor of safety of 3 against bearing capacity failure.

(9 marks)

ii) Determine the change in the net allowable bearing capacity when the water table rises to 1 m below ground level. Also, calculate the percentage reduction in bearing capacity.

(8 marks)

NOTE: Clearly state any assumptions made in your calculations to determine the safe bearing capacity. Use **Table Q4** and the formulae provided on **page 12.**

[TOTAL 25 MARKS]

Question 4 continued over the page…

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Question 4 continued…

Table Q4

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

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QUESTION 5

Figure Q5-1 shows a 5.0 m high gravity retaining wall with relevant material properties.

a) Sketch the earth pressure diagram for the retained soil, labelling all relevant values. State any assumption you have made according to the Rankine theory of earth pressure and comment on the validity of each.

(9 marks)

b) Determine the active pressure on the concrete retaining wall and the height of the resultant thrust above the base of the retaining wall. Comment on the engineering significance of the value of the factor of safety obtained.

(16 marks)

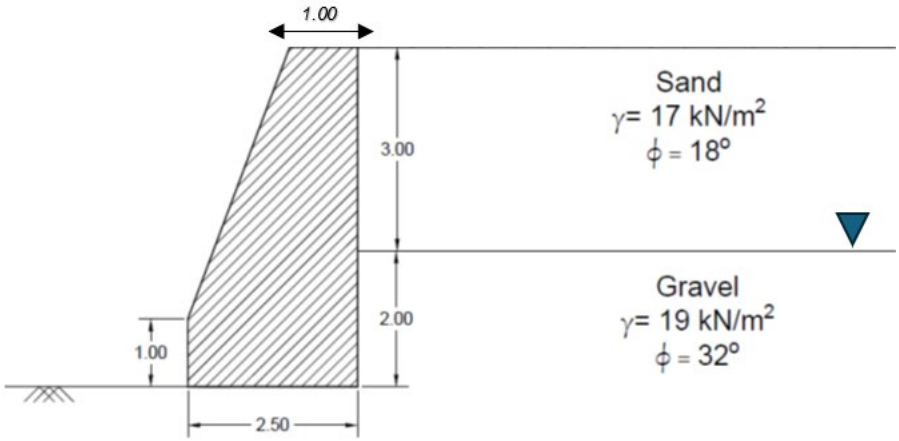

Figure Q5-1: Retaining Wall

[TOTAL 25 MARKS]

END OF QUESTIONS
PLEASE TURN THE PAGE FOR SUPPLEMENTARY GEOTECHNICAL INFORMATION

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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

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

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

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

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

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

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

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

C,φ soils:

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	S_C	S_q	Sr
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

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

Pile Foundations,

$$Q_u = Q_s + Q_b$$

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

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

$$\sigma_v = \gamma.D$$

Slope Stability,

$$F = \frac{1}{\sum\ Wsinsin\,\alpha}.\sum\quad [c'l + W(cos\ cos\ \alpha\ - r_u.sec\alpha)\ tan\ tan\ \emptyset']$$

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