OCD36

UNIVERSITY OF BOLTON

WESTERN INTERNATIONAL COLLEGE FZE

BENG (HONS) IN CIVIL ENGINEERING

SEMESTER ONE EXAMINATION 2019/2020

GEOTECHNICAL ENGINEERING AND GROUND IMPROVEMENT

MODULE NO: CIE6003

Date: Saturday 11th January 2020 **Time: 10.00 AM - 1.00 PM**

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) **Figure Q1a** shows a 6.0 m high gravity retaining wall with relevant material properties. (Assume that the wall has a smooth back). Ground water level is at 2.0m below the ground level.

Soil 1	Bulk Unit weight	17.0 kN/m^3
	Saturated Unit Weight	18.5 kN/m^3
	Effective friction angle ϕ'	24°
Soil 2	Bulk Unit weight	19.0 kN/m^3
	Saturated Unit Weight	20.5 kN/m^3
	Effective friction angle ϕ'	28°

Reinforced concrete: Unit weight 24 kN/m^3

i. Sketch the earth pressure diagram for the retained soil, labelling all relevant values. You may assume the soil and the wall to be free-draining (so that there is no pore water), and that movement of the wall is sufficient for active conditions to develop in the soil.

(8 marks)

ii. Determine the total force (F) and moment (M) acting about the level of the base of the wall due to earth pressure.

(5 marks)

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

(5 marks)

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

(7 marks)

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Question 1 continued over the page

Question 1 continued

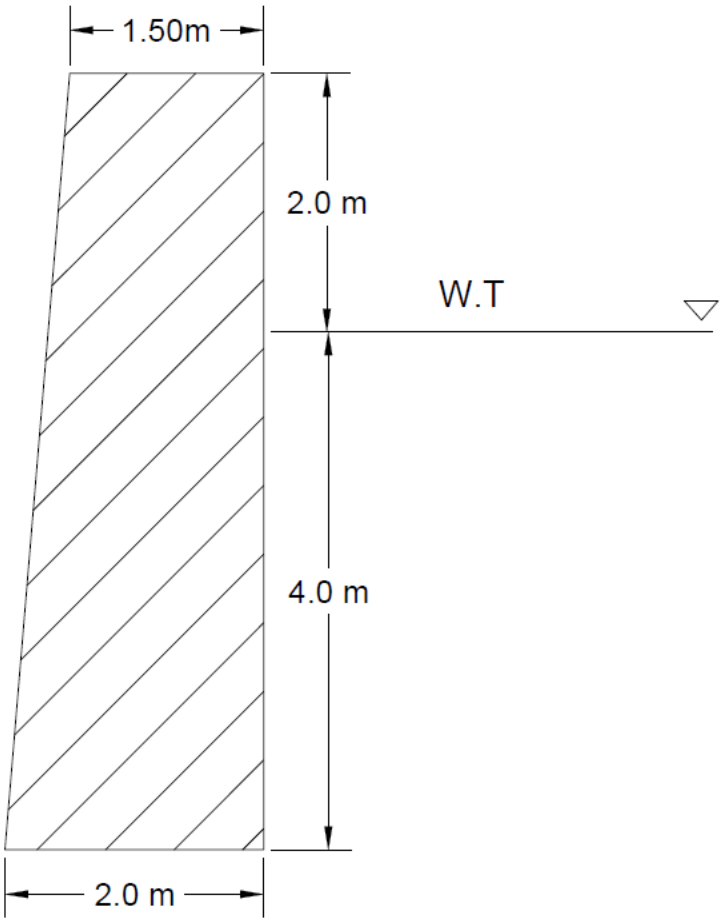

Figure Q1a.

Total 25 marks

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Question 2

(a) Standard Penetration test gives a measure of the bearing capacity or the strength of the soil. Results in the form of SPT (N) value -predicts the approximate density, bearing capacity and settlement characteristics of the soil. The number of blows, N, or each 75mm of penetration is recorded as it is very useful in predicting the approximate relative density, bearing capacity, shear strength and settlement characteristics of the soil. Table Q2(a) shows the relation between N-value and relative density of soil.

Table Q2(a)

SPT Resistance Value (N)	**Relative Density (%)**	**Classification**
0-4	<15	Very loose
4-10	15-35	Loose
10-30	35-65	Medium dense
30-50	65-85	Dense
>50	85-100	Very dense

Analyse how the bearing capacity determination of granular soils is determined with respect to the standard penetration test. (8 marks)

(b) A pad foundation, 3m square is to be located at a depth of 1.5m in a uniform bearing stratum of firm clay in the proposed land in order to construct a Public Library. The water table level is at an assumed depth of 1.0m below ground level (from a recent and reliable site investigation).

The clay soil properties are shown in Table Q2(b) as follows

Table Q2(b)

Bulk unit weight	γ = 20.0 kN/m^3
Saturated unit weight	γ_{sat} = 21.5 kN/m^3
Effective Stress Shear Strength Parameters	c^{l} = 25 kN/m^2
	Φ^{l} = 28^0

(i) Determine the net safe bearing capacity of the footing (5 marks)

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Question 2 continued over the page

Question 2 continued

Determine the percentage of variation in 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 1.5m from the ground level (6 marks)

(ii) The water table is 5 m below the base of foundation (6 marks)

NOTE: Clearly state any assumptions made in your calculations to determine the safe bearing capacity. Refer to the **Tables Q2(c), (d) and (e)** and the formulae provided on Page 13

Total 25 marks

Table Q2c: 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 Q2d: 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

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Question 2 continued over the page

Question 2 continued

Table Q2e: 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

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Question 3

(a) Briefly discuss the significance of the assumptions made for total stress analysis. Explain how slip circle analysis is adopted when developing slope stability assessments. Ensure that your answer illustrates the concept of a critical centre of rotation for a given slope and explain how that critical circle position would be determined.

(7 marks)

(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;

Saturated unit weight, γ_{sat} = 18.8 kN/m^3
Unit weight of Water, γ_w = 9.8 kN/m^3

Shear strength parameters for the clay are;
c' = 6 kN/m^2
Φ' = 18^o

A trial slip surface of radius, R = 14.5m and sector angle, θ = 56^o, allows the sector to be divided into 6 slices, each 2.1m wide, where slice number 1 is adjacent to the toe.

(i) Complete the table shown in Table Q3 and hence determine the long term factor of safety, F, of the trial slip surface using the Bishop's Method analysis.

(15 marks)

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

(3 marks)

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Question 3 continued

Candidate Number ……

Table Q3.

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)		(j)	(k)	(l)
Slice No:	b	H	α	hw	$\sin\alpha$	$\cos\alpha$	l	c'.l	W	r_u	$r_u \sec\alpha$	c'.l+ W($\cos\alpha$- $r_u \sec\alpha$).tan ϕ'	W$\sin\alpha$
	(m)	(m)	(deg)	(m)			(b/$\cos\alpha$)		kN	u/γ.h			
1	2.1	0.68	-5.78										
2	2.1	2.04	0.00										
3	2.1	3.16	8.26										
4	2.1	3.83	15.8										
5	2.1	4.19	23.3										
6	2.1	4.01	32.1										
												Σ	

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Question 4

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 G=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/m^3 and its bulk unit weight above water table is (γ_b) 18.68 kN/m^3.

(a) Determine the distribution of Effective stress, Pore Water Pressure and Total Stress at each soil strata. Hence plot the stress diagrams 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) The following results shown in **Table Q4** were obtained from an oedometer test on a specimen of saturated clay from the clay layer above. The load is being held constant for 24 hours before the addition of the next increment.

Table Q4

Applied stress σ (kN/m²)	0	25	50	100	200	400	800
Void ratio (e)	1.016	0.980	0.952	0.914	0.866	0.819	0.774

At the end of the last load period the load was removed, and the sample allowed to expand for 24hours. The thickness of the specimen was 17.92mm and its water content was found to be 31.8 %.

(i) Plot the e / σ_v' curve using the values provided in **Table Q4** on the **graph paper provided.**

(4 marks)

(ii) Plot the e / logσ_v' curve on another **graph paper provided** and determine the compressibility index(Cc) and the pre-consolidation pressure from it.

(6 marks)

(iii) Determine the coefficient of compressibility, mv for the effective stress range of 220kN/m² and 360kN/m² with respect to the soil conditions.

(3 marks)

(iv) Calculate the consolidation settlement for the layer of clay having a layer thickness of 8m.

(2 marks)

Total 25 marks

Question 5

(a) A large diameter under-reamed bored pile is to be installed in stiff clay with an undrained shear strength value of 215 kN/m^2. The main shaft of the pile is 1.2 m diameter and the base of the under ream is 3.5m diameter with a height of 2.5m. The total length of pile from the ground level to the base of the under-ream is 15 m.

Determine the working load of the pile in MN, assuming the following factors for adhesion, α = 0.3 and end bearing Nc = 9.0. Apply a factor of safety of 3.0 to the base load. Full mobilisation of shaft adhesion can be assumed.

(8 marks)

NOTE: Clearly state any assumptions made in your calculations

(b) A concrete pile of 450mm diameter was driven into a thick deposit of dense sand to a depth of 15m, with an SPT N value of 25 blows/300mm. The water table is at 4m from ground level. Unit weights of sand above and below water table are 17kN/m^3 and 18.5 kN/m^3 respectively. Estimate the working load supported by this length of pipe assuming an overall factor of safety of 2.5.

i. Estimate the working load this length of pile will support assuming an overall factor of safety of 2.5. Use **Figures Q5-1, Q5-2,** and **Q5-3** provided.

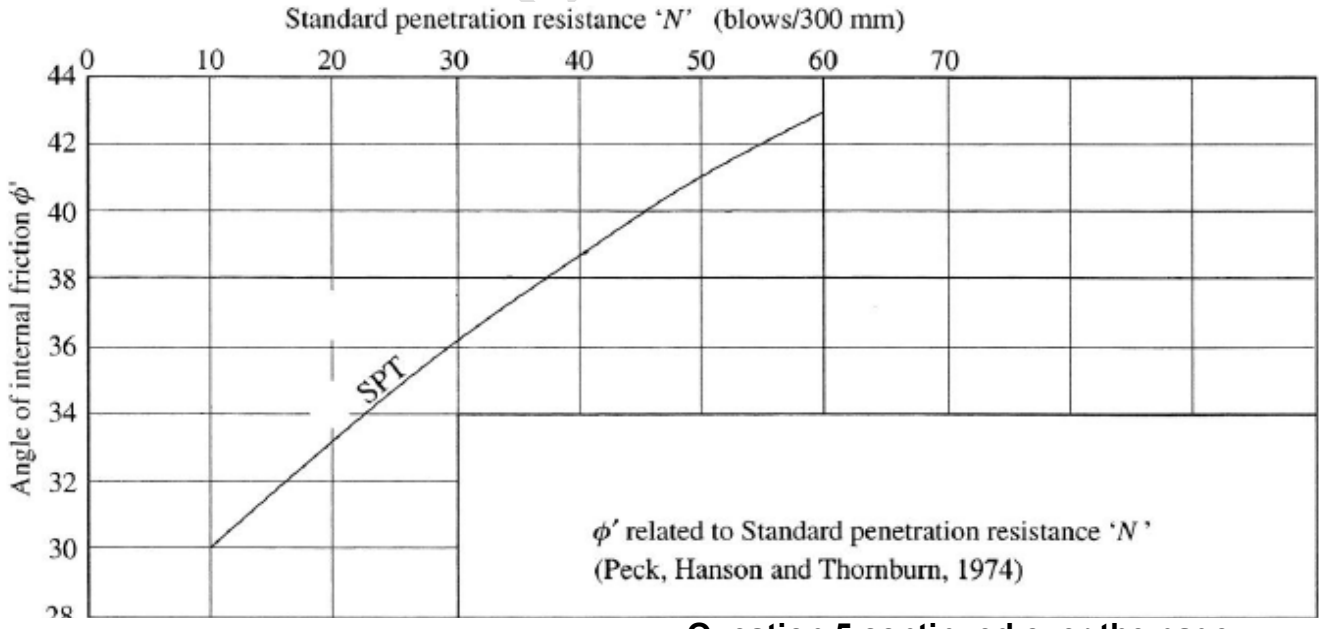
(12 marks)

ii. In the above scenario, analyse the load carrying capacity of the pile if the pile penetration is increased. **Calculations are not required for this answer.**

(5 marks)

Total 25 marks

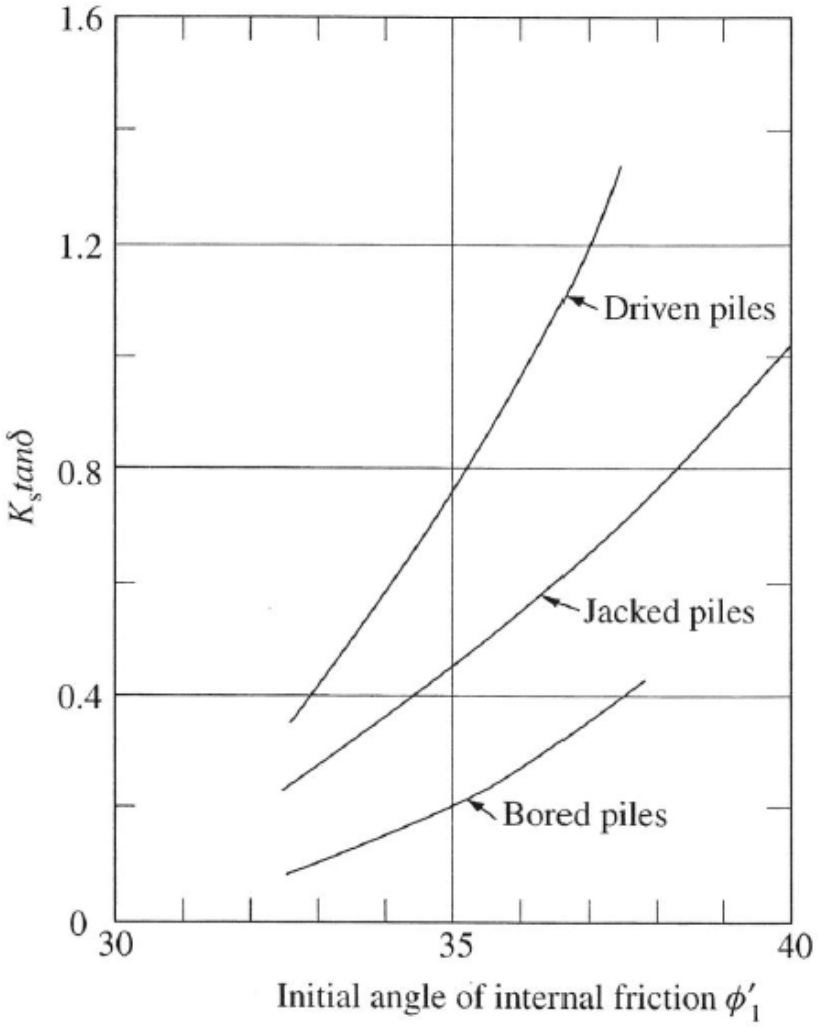
Figure Q5-1



Question 5 continued over the page

Question 5 continued

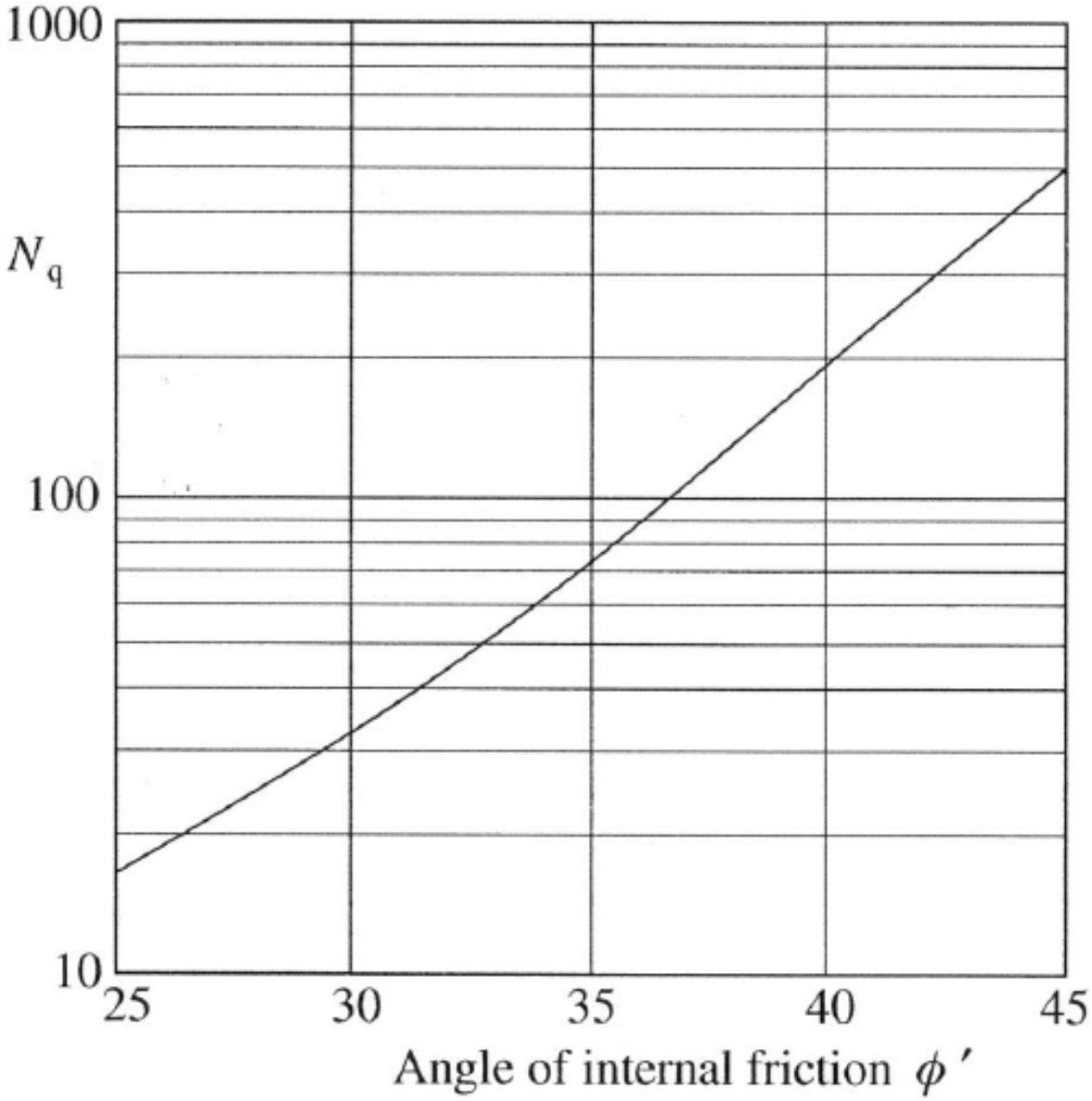
Figure Q5-2



Question 5 continued over the page

Question 5 continued

Figure Q5-3



(From Berezantsev et al 1961)

END OF QUESTIONS

Please turn the Page for Supplementary Information

Supplementary Geotechnical Information

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

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

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

$\sigma_v = \gamma . D$

Slope Stability,

$$F = \frac{1}{\sum W \sin\alpha} . \sum \left[c' l + W(\cos\alpha - r_u . \sec\alpha) \tan\phi' \right]$$

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