THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING
2022

END - TERM EXAMINATION

CE411: Geotechnical Engineering

Student Name: ______________________________

ID: ______________________________

Date:	Monday, June 6th 2022
Time:	08:30 – 11:30 AM
Venue:	SLT
Faculty:	Dr. Shiva Prashanth Kumar Kodicherla

Examination Notes:

1) Maximum Marks: 100; Time allowed: 3hrs
2) Answer all questions.
3) Marks of all questions are indicated at the end of each question.

Q1. What are basic types of shear failures of foundations? Explain them in detail with neat sketches along with their significance?

[10 Marks]

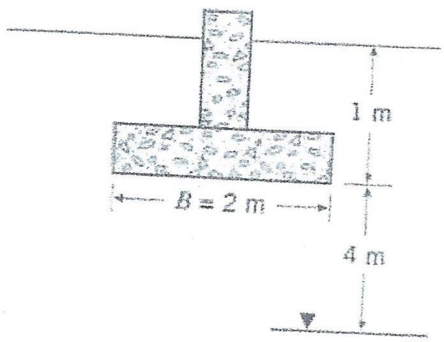
Q2. List the remedial/corrective measures for failing slopes and explain any one of them in detail?

[10 Marks]

Q3. Figure shows the details of an embankment made of cohesive soil with $\varphi = 0$ and $c = 30$ kN/m^2. The unit weight of the soil is 18.9 kN/m^3. Determine the factor of safety against sliding along the trial circle as shown in figure. The weight of the sliding mass is 360 kN acting at an eccentricity of 5.0 m from the centre of rotation. Assume that no tension crack develops. The central angle is 70°.

[10 Marks]

Q4. A footing 2 m square, subjected to a centric vertical load, is located at a depth of 1.0 m below the ground surface in a deep deposit of compacted sand ($\phi_p' = 35°$, $\phi_{cs}' = 30°$, and $\gamma_{sat} = 18kN/m^3$). The groundwater level is 5 m below the ground surface, but you should assume that the soil above the groundwater is saturated. The friction angles were obtained from plain strain tests. Determine the allowable bearing capacity for a factor of safety of 3.



[15 Marks]

Q5. A trapezoidal masonry retaining wall 1 m wide at top and 3 m wide at its bottom is 4 m high. The vertical face is retaining soil ($\varphi = 30°$) at a surcharge angle of 20° with the horizontal. Determine the maximum and minimum intensities of pressure at the base of the retaining wall. Unit weights of soil and masonary are 20 kN/m^3 and 24 kN/m^3 respectively. Assuming the coefficient of friction at the base of the wall as 0.45, determine the factor of safety against sliding. Also determine the factor of safety against overturning (Use Rankine's earth pressure theory).

[20 Marks]

Q6. Compute the safe bearing capacity of a continuous footing 1.8 m wide, and located at a depth of 1.2 m below ground level in a soil with unit weight $\gamma = 20$ kN/m^3, c =20 kN/m^2, and $\varphi = 20°$. Assume a factor of safety of 2.5. Terzaghi's bearing capacity factors for $\varphi = 20°$ are $N_c = 17.7$, $N_q = 7.4$, and $N_\gamma = 5.0$, what is the permissible load per metre run of the footing?

[15 Marks]

Q7. A concrete pile 458 mm × 458 mm in cross section is embedded in a saturated clay. The length of embedment is 16 m. The undrained cohesion, c_u, of clay is 60 kN/m^2, and the unit weight of clay is 18 kN/m^3. Use a factor of safety of 5 to determine the allowable load the pile can carry. (a). Use the α method. (b). Use the β method.

[10 Marks]

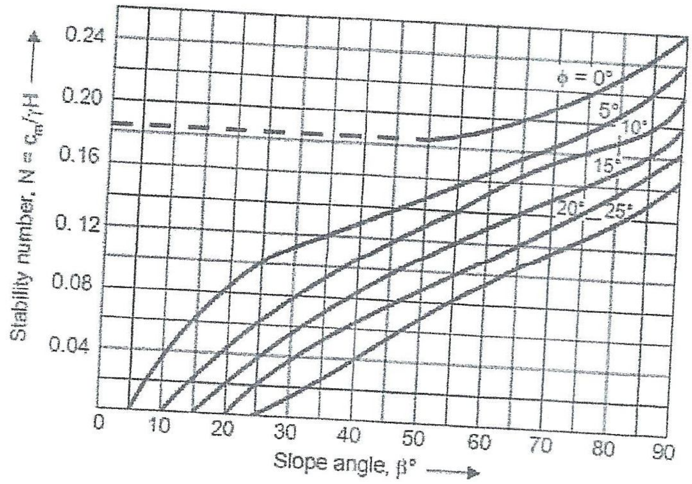
Q8. A line load of 100 kN/metre run extends to a long distance. Determine the intensity of vertical stress at a point, 2 m below the surface and (i) directly under the line load, and (ii) at a distance of 2 m perpendicular to the line. Use Boussinesq's theory.

[10 Marks]

-End of Exam-

APPENDIX – A

Taylor's method:



Stability number $N = c_m / \gamma H$

Factor of safety (FS) $= cr^2\theta / We$

The depth of tension crack $h_c = 2c / \gamma$

Bearing Capacity Factors The bearing capacity factor N_q is

$$N_q = e^{\pi \tan \phi_p'} \tan^2\left(45^\circ + \frac{\phi_p'}{2}\right); \quad \phi_p' \text{ in degrees}$$

Various equations have been proposed for N_γ in the literature. Among the popular equations ar

Vesic (1973): $N_\gamma = 2(N_q + 1)\tan \phi_p'$; ϕ_p' in degrees

Meyerhof (1976): $N_\gamma = (N_q - 1)\tan(1.4\phi_p')$; ϕ_p' in degrees

Davis and Booker (1971): $N_\gamma = 0.1054 \exp(9.6\phi_p')$ for rough footing; ϕ_p' in radians

$N_\gamma = 0.0663 \exp(9.3\phi_p')$ for smooth footing; ϕ_p' in radians

The ultimate net bearing capacity equations for general failure are

TSA: $q_u = 5.14 s_u s_c d_c i_c b_c g_c$

ESA: $q_u = \gamma D_f (N_q - 1) s_q d_q i_q b_q g_q + 0.5\gamma B' N_\gamma s_\gamma d_\gamma b_\gamma g_\gamma$

TABLE 12.2 Geometric Factors for Use in Theoretical Bearing Capacity Equations

Geometric parameters for TSA				
s_c	d_c	i_c	b_c	g_c
$1 + 0.2\frac{B'}{L'}$	$1 + 0.33\tan^{-1}\frac{D_f}{B'}$ See note 1	$1 - \frac{nH}{5.14 s_u B'L'}$ See note 2	$1 - \frac{\eta^\circ}{147}$ $\beta < \phi'_p;\ \eta^\circ + \beta^\circ < 90^\circ$ See Figure 12.9	$1 - \frac{\beta^\circ}{147}$ $\beta < \phi'_p;\ \eta^\circ + \beta^\circ < 90^\circ$ See Figure 12.9
Geometric parameters for ESA				
s_q	d_q	i_q	b_q	g_q
$1 + \frac{B'}{L'}\tan\phi'_p$	$1 + 2\tan\phi'_p(1 - \sin\phi'_p)^2\tan^{-1}\left(\frac{D_f}{B'}\right)$	$\left(1 - \frac{H}{V_n}\right)^n$ See note 2	$(1 - \eta\tan\phi'_p)^2$ η is in radians	$(1 - \tan\beta)^2$
s_γ	d_γ	i_γ	b_γ	g_γ
$1 - 0.4\frac{B'}{L'}$	1	$\left(1 - \frac{H}{V_n}\right)^{n+1}$ See note 2	$b_\gamma = b_q$	$g_\gamma = g_q$

Note 1: If the shear strength of the soil above the footing is low compared with that of the soil below the footing, you should set all depth factors to 1. The term $\tan^{-1}\left(\frac{D_f}{B'}\right)$ is in radians.

Note 2: The depth and shape factors for inclined loads should be set to 1. For loading inclined in the direction of the width, B, $\theta = 90^\circ$ in Figure 12.10d, $n = n_B = \left(2 + \frac{B'}{L'}\right)\Big/\left(1 + \frac{B'}{L'}\right)$. For loading inclined in the direction of the length, L, $\theta = 0^\circ$ in Figure 12.10d, $n = n_L = \left(2 + \frac{L'}{B'}\right)\Big/\left(1 + \frac{L'}{B'}\right)$. For other loading conditions, $n = n_L\cos^2\theta + n_B\sin^2\theta$.

For pure clays, $\phi = 0°$.

$$q_{ult} = cN_c + \gamma D_f = 5.7c + \gamma D_f$$

$\therefore$ $q_{net\ ult} = 5.7c$, for continuous footings.

$$q_{net\ ult} = 1.3 \times 5.7c = 7.4\,c \qquad \text{...(Eq. 14.127)}$$

(for square or circular footings, c being the cohesion.)

$$q_{net,ult} = [q_{ult} - \gamma D_f]$$
$$q_{net,safe} = [q_{net,safe} / FOS]$$
$$q_{Safe} = [q_{net,safe} + \gamma D_f]$$

Rankines earth pressure theory:

$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \tan^2\left(45° - \frac{\phi}{2}\right) \qquad K_p = \frac{1+\sin\phi}{1-\sin\phi} = \tan^2\left(45° + \frac{\phi}{2}\right)$$

$$K_a = \cos\beta\left(\frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}\right) \qquad K_p = \cos\beta\left(\frac{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}\right)$$

$$\sigma_{max} = \frac{N}{b}\left(1+\frac{6e}{b}\right)$$

$$\sigma_{min} = \frac{N}{b}\left(1-\frac{6e}{b}\right)$$

Equations for estimation of Pile capacity:

$$Q_u = Q_p + Q_s$$

$$Q_p = A_p q_p = A_p(c'N_c^* + q'N_q^*)$$

For piles in saturated clays in undrained condition (φ=0)

$$Q_p = N_c^* c_u A_p = 9c_u A_p \qquad Q_s = \sum p\,\Delta L f \qquad f = K\sigma_o' \tan\delta'$$

$$Q_s = pLf_{av} \qquad f_{av} = \lambda(\overline{\sigma}_o' + 2c_u)$$

$$f = \alpha c_u$$

Table 14.4 Variation of λ with *L* [Eq. (14.25)]

L (m)	λ	*L* (m)	λ
0	0.5	35	0.136
5	0.318	40	0.127
10	0.255	50	0.123
15	0.205	60	0.118
20	0.177	70	0.117
25	0.155	80	0.117
30	0.145	90	0.117

Boussinesq's solution:

$$\sigma_z = K_B \cdot \frac{Q}{z^2} \qquad K_B = \frac{(3/2\pi)}{[1+(r/z)^2]^{5/2}}$$

$$\sigma_z = \frac{2q'z^3}{\pi(x^2+z^2)^2} = \frac{2q'}{\pi z}\cdot\frac{1}{[1+(x/z)^2]^2} \qquad \sigma_z = \frac{2}{\pi}\cdot\frac{q'}{z}$$

$$z = q\left[1-\frac{1}{\{1+(a/z)^2\}^{3/2}}\right]$$