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SCEE, Geotechnical Engineering Chair

Examination paper for
CEng3143 Fundamentals of Geotechnical Engineering - III

Examination date:	13rd January 2020
Examination time (from-to):	13:30 - 16:30
Permitted exam support material:	No printed or handwritten material,
Number of pages enclosed:	**10 including cover page**

Instruction: -Write concise answers for theoretical questions.
-Show your steps clearly for problems involving calculations.

Examination paper set checked by: **Asrat Worku Setegn (Dr.-Ing.)**

Date Signature

Question #	Weight [%]	Score [%]
1	10	
2	10	
3	20	
4	30	
5	30	

Question 1: Soil Compressibility & Settlement Analysis [10%]

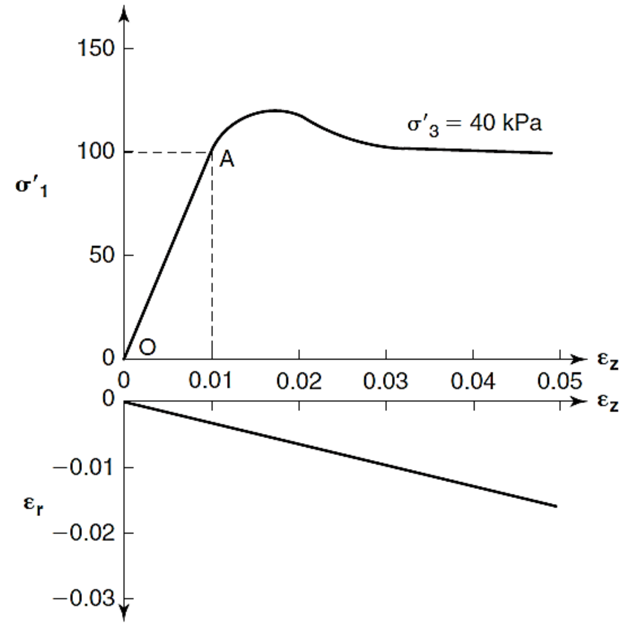
1.1 Explain the difference between the modulus and the modulus of subgrade reaction. Comment on which one is a true soil property and why. (6%)

1.2 Differentiate between bulk modulus and shear modulus of soil. Employ the use of diagrams to substantiate your answer. (4%)

Question 2: Shear Strength of Soils [10%]

2.1 Consider the stress-strain curve from a triaxial test shown in figure below:

a. Why is $\varepsilon_r < 0$ when $\varepsilon_z > 0$? (2%)



b. Calculate Poisson's ratio. (2%)

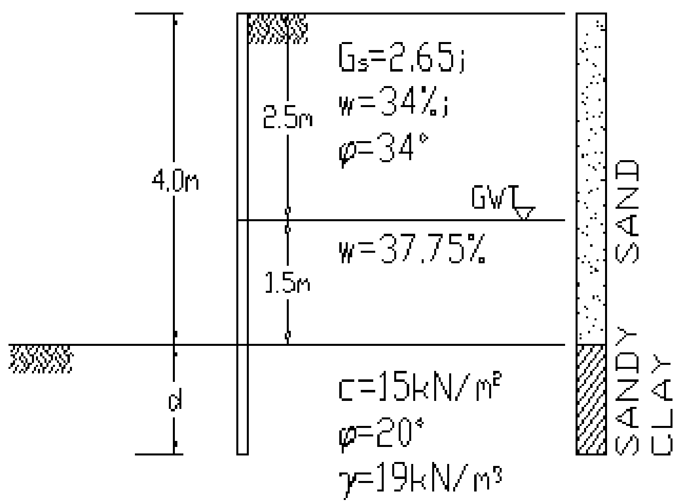
2.2 It is generally recommended not to use direct shear test for determination of shear strength parameters of fine-grained soils. Articulate the reason behind this recommendation. If you absolutely need to use direct shear test for fine-grained soil (for whatever reason), how would you go about doing that to achieve unbiased outputs? (4 %)

2.3 Imagine you are driving on a rural road constructed of predominantly fine-grained soil. You have come across a section logged with water. Should you drive fast or slowly to avoid getting stuck in the mud? Explain your answer from the perspective of loading conditions associated with soil shear strength. (2%)

Question 3: Lateral Earth Pressure [20%]

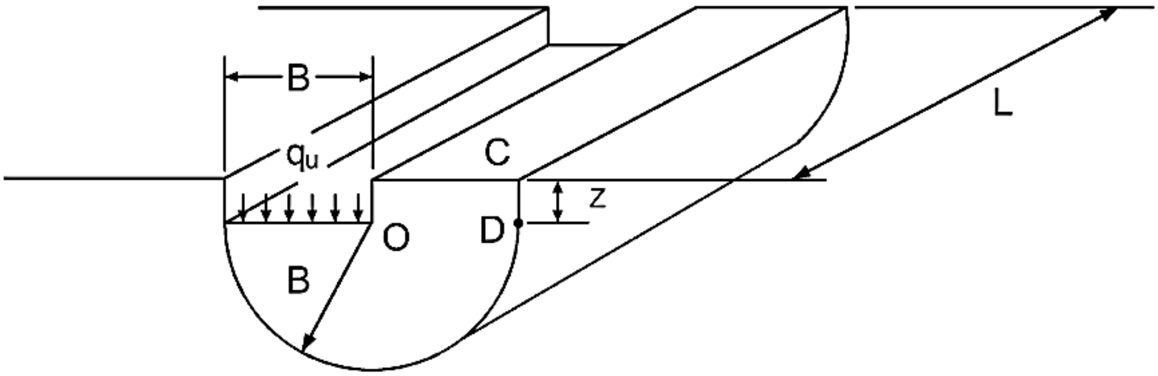
3.1 Explain the conditions at which Rankine's earth pressure theory and Coulomb's earth pressure theory become equal. (5%)

3.2 Find the minimum depth of embedment, d_{min}, of the thin rigid wall shown in figure below so that it will not fail by sliding. Use Rankine's theory for lateral earth pressure distribution and neglect the sliding resistance at the base of the wall. (15 %)



Question 4: Bearing Capacity of Soils [30%]

4.1 Consider a foundation failing by rotation about one edge and founded at a depth z below the surface of a saturated clay of unit weight γ and undrained strength c_u as depicted in the figure below.



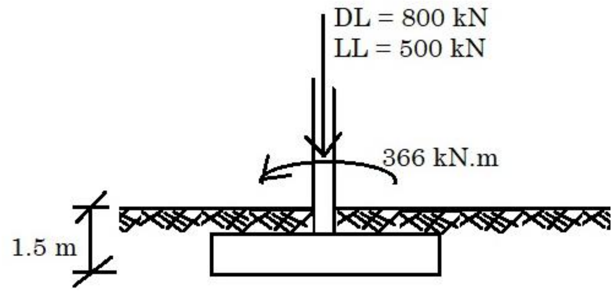
Derive the following bearing capacity formula for a strip footing by considering disturbing and resisting moments about Point O.

$$q_u = 6.28c_u\left(1 + 0.32\frac{z}{B} + 0.16\frac{\gamma z}{c_u}\right)$$

(10%)

4.2 Check whether or not overall stability (ULS) requirement is satisfied for the drained bearing resistance for the isolated foundation shown in the figure. A column exerts an unfactored 800 kN of deadload, 500 kN of unfactored live loads, and 366 kN.m of uniaxial moment.

- Use DA 2 (A1+M1+R2) for load combination
- Ignore self-weight of the foundation
- Foundation Area = 3m x 3m
- Effective unit weight of the soil (silty sand)– $\gamma' = 16$ kN/m³
- Other parameters – c' = 10 kPa, Ø' = 20⁰



Partial factors on actions (γ_F) or the effects of actions (γ_E)				
Action		Symbol	Set	
			A1	**A2**
Permanent	Unfavourable	γ_G	1.35	1.0
	Favourable		1.0	1.0
Variable	Unfavourable	γ_Q	1.5	1.3
	Favourable		0	0

$$s_q = 1 + \sin \emptyset'$$
$$s_c = \frac{s_q N_q - 1}{N_q - 1}$$
$$s_\gamma = 1 - 0.3\frac{B'}{L'}$$

Partial factors for soil parameters (γ_M)			
Soil parameter	Symbol	Value	
		M1	**M2**
Shearing resistance	$\gamma_\varphi{}^1$	1.0	1.25
Effective cohesion	γ_c	1.0	1.25
Undrained strength	γ_{cu}	1.0	1.4
Unconfined strength	γ_{qu}	1.0	1.4
Weight density	γ_γ	1.0	1.0
¹ This factor is applied to tan φ'			

Partial resistance factors for spread foundations (γ_R)				
Resistance	Symbol	Set		
		R1	**R2**	**R3**
Bearing	γ_{Rv}	1.0	1.4	1.0
Sliding	γ_{Rh}	1.0	1.1	1.0

Drained Bearing Capacity Equation

$$q = c'N_c b_c s_c i_c + q'N_q b_q s_q i_q + 1/2\gamma' B' N_\gamma b_\gamma s_\gamma i_\gamma$$

$$N_q = e^{\pi \times \tan\varphi'} \tan^2(45° + \varphi'/2)$$
$$N_c = (N_q - 1)\cot\varphi'$$
$$N_\gamma = 2(N_q - 1)\tan\varphi'$$

$$i_q = (1 - 0.70 \times H / (V + A' \times c' \times \cot\phi'))^m$$
$$m = m_B = [2 + (B'/L')]/[1 + (B'/L')]$$
$$m = m_L = [2 + (L'/B')]/[1 + (L'/B')]$$
$$m = m_\theta = m_L \cos^2\theta + m_B \sin^2\theta$$

$$i_c = (i_q \times N_q - 1) / (N_q - 1)$$
$$i_\gamma = (1 - H / (V + A' \times c' \times \cot\phi'))^3$$

$$b_c = b_q - (1 - b_q) / (N_c \tan\phi')$$
$$b_q = b_\gamma = (1 - \alpha \tan\phi')^2$$

(20 %)

Question 5: Soil Slope Stability [30%]

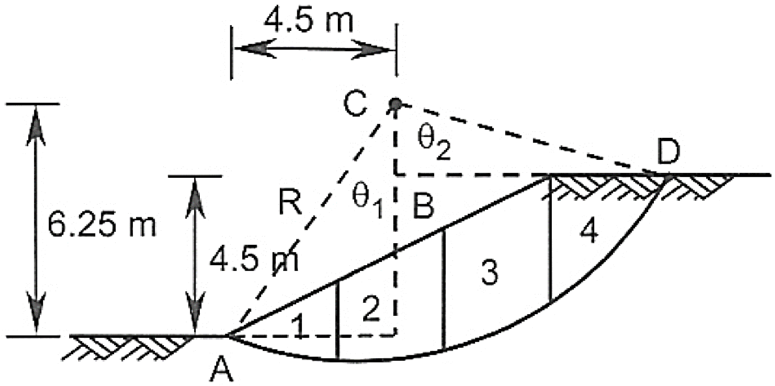
5.1 Investigation of the stability of finite slopes generally involves three steps according to the commonly adopted procedure. List these steps. (3 %)

5.2 An infinite slope is made of sand with a friction angle of 32° and a unit weight of 20 kN/m^3 as part of the currently under-construction Modjo-Hawassa express route. The slope angle is 2.5 horizontal to 1 vertical.
Calculate the factor of safety

a. in the "spring/በጋ/birraa" when the slope has no water,
b. in the "summer/ክረምት/bona" when the slope is filled with water,
c. for the same slope on the moon. (The acceleration due to gravity on the surface of the Moon is about 1.625 m/s^2 i.e. 16.6% of that on Earth's surface. Assume that there is no water on the moon:) (7%)

5.3 Using Fellenius' method, determine the factor of safety for a slope of 1 vertical to 2 horizontal and height H=4.5 m using a trial toe circle for which $x_c = 4.5$ m and $y_c = 6.25$ m. The soil mass is divided into 4 slices all having identical width of b = 3 m, whose average height and angle α are tabulated below. (Show a sample calculation for one of the slices)
The soil properties are as follows: c'= 6.75 kPa, ϕ'= 17° and ρ = 1.96 Mg/m³

(20 %)



$$F = \frac{\sum_{i=1}^{i=4}\left[c'l + (w\cos\alpha\tan\phi')\right]_i}{\sum_{i=1}^{i=4}(w\sin\alpha)_i}$$

Slice	h (m)	α (deg.)	w (kN)	wcosα (kN)	wsinα (kN)
1	1.6	-23			
2	3.7	0			
3	4.6	23			
4	3.0	51			
Total					