THIS EXAMINATION CONSISTS OF 9 PAGES. PLEASE CHECK THAT IT IS COMPLETE.

THE UNIVERSITY OF BRITISH COLUMBIA

Department of Civil Engineering

FINAL EXAMINATION – DECEMBER 2006
SOIL MECHANICS II - CIVL 311
Instructor: Dr. D. Wijewickreme

646

Time: 3 hours

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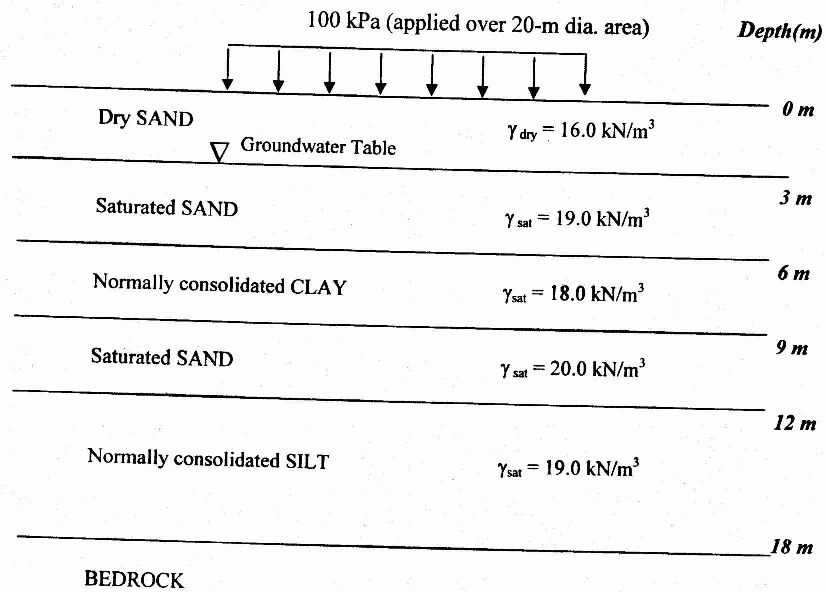
1. **Closed Book** Examination; Permitted: calculator, drawing instruments (optional).
2. Please ensure that you write your name and student number on the first page of all answer books.
3. Answer all 5 questions.
4. The formula sheet is attached.
5. Assume the unit weight of water to be 9.8 kN/m^3.
6. Make any reasonable assumptions (where appropriate and if required) to answer the questions.
7. Use sketches whenever possible.
8. Write clearly. Be neat and brief. Marks will be deducted for poor presentation.
9. Show all steps of your calculation to receive full marks.
10. Note the mark value distribution for each question.

Question 1

The soil stratigraphy (and associated physical parameters) at a site for a proposed cylindrical storage tank is shown in the figure below (Note: Schematic diagram only. Not to scale.). It has been suggested that foundation loading of 100 kPa over a 20-m diameter circular area as shown in the figure be considered for design purposes.



The following average field relationship between void ratio and vertical effective stress σ_v' was obtained based on data from 1-D consolidation tests on representative undisturbed samples of the NC clay: $e = 1.00 - 0.25 \log(\sigma_v'/100)$ where σ_v' = Vertical Effective Stress in kPa. For the considered stress level, assume that the average coefficient of consolidation C_v for the layer is 2.0×10^{-4} cm^2/sec .

Similarly, the average field relationship between void ratio and vertical effective stress σ_v' for the NC silt is: $e = 1.00 - 0.15 \log(\sigma_v'/100)$ where σ_v' = Vertical Effective Stress in kPa, average coefficient of consolidation for the layer $C_v = 3.0 \times 10^{-3}$ cm^2/sec.

<u>*Marks*</u> Assume that the stress conditions at the mid-depth of clay and silt layers are representative of the stress conditions in those layers. Ignoring settlements within the sand zones and using Table below for the calculation of stress increases due to applied loading:

(15) (a) estimate expected ultimate consolidation settlement at the foundation level due to the applied load from the circular foundation;

(7) (b) estimate the time required for completion of 50% of the total consolidation settlement within the clay layer due to the placement of the load (assume that the load is placed is relatively quickly);

(7) (c) what is the average degree of consolidation within the silt deposit when the clay layer has reached an average degree of consolidation of 90%;

(7) (d) what is the anticipated settlement of the foundation 3 years after placement of load;

(4) (e) comment on the impact of increasing the bearing pressure to 120 kPa (without changing the footing size) on: (i) the anticipated settlements; and (ii) time for completing primary consolidation settlements;

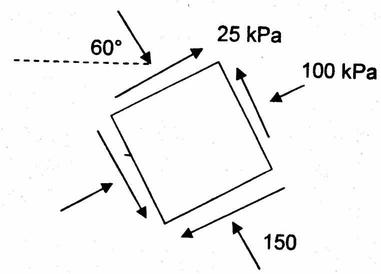
<u>TABLE 1</u>:

The vertical stress increase $\Delta\sigma_z$ at depth z under the centre of a circular area of <u>radius</u> R carrying uniform pressure q is given by $\Delta\sigma_z = q\ I_z$. The values of I_z at several R/z ratios have been computed using elastic theory as below:

R/z Ratio	Stress Influence Factor I_z
2.00	0.91
1.67	0.86
1.33	0.78
1.00	0.65
0.67	0.42
0.33	0.15
0.1	0.01

Marks **Question 2**

(8) (a) At a given point in a sand deposit the state of stress is as shown.



Transfer this diagram to your answer script by hand-sketching. Describe this stress state using a Mohr Circle. Sketch the orientation of the planes of major principal stress and maximum shear stress after locating the "Pole" (use of an approximate scale is acceptable; use of drawing instruments is optional; sign convention: Compressive stresses → + ve and counterclockwise shear → + ve)

(10) (b) Using a plot of shear stress $(\sigma_1' - \sigma_3')/2$ vs. $(\sigma_1' + \sigma_3')/2$, schematically illustrate the typical total stress paths and effective stress paths during Consolidated Drained (CD) and Consolidated Undrained (CU) triaxial testing of normally consolidated clay. Assume initial hydrostatic consolidation to σ_{3c}' and then shearing up to failure [major and minor principal stresses are denoted by the symbols σ_1' and σ_3', total stresses by σ_1 and σ_3, and pore water pressure by u].

(c) Consolidation and triaxial testing carried out on undisturbed tube samples of saturated clay obtained from an average effective overburden stress of 100 kPa indicated the following: (i) pre-consolidation stress = 200 kPa; (ii) strength and pore-water pressure parameters for the overconsolidated region: c' = 39 kPa; ϕ' = 21° deg; Skempton pore pressure parameter at failure = A_f = 0.70 (ii) strength and pore-water pressure parameters for the normally consolidated region: c' = 0 kPa; ϕ' = 30°; A_f = 1.0.

(7) (c.1) What would be the deviator stress at failure in a <u>consolidated undrained (CU)</u> triaxial compression test if a sample of this clay was consolidated to an all round effective stress of $\sigma'_{1c} = \sigma'_{3c}$ = 125 kPa prior to shearing.

(7) (c.2) If another sample of this soil was consolidated to an all round effective stress of $\sigma'_{1c} = \sigma'_{3c}$ = 500 kPa, estimate the maximum shear stress at failure if the sample was sheared in <u>consolidated undrained (CU)</u> triaxial compression.

(9) (c.3) What would be the normal stress on the plane of failure in <u>consolidated drained (CD)</u> shear if the clay was initially consolidated to a vertical effective stress of 400 kPa.

(9) (c.4) One of the undisturbed samples was obtained from the same deposit of clay from a depth where the overburden effective stress is 110 kPa. Assuming perfect sampling, calculate the expected undrained shear strength (S_u) at failure if the sample was sheared in an <u>unconsolidated undrained (UU)</u> loading mode.

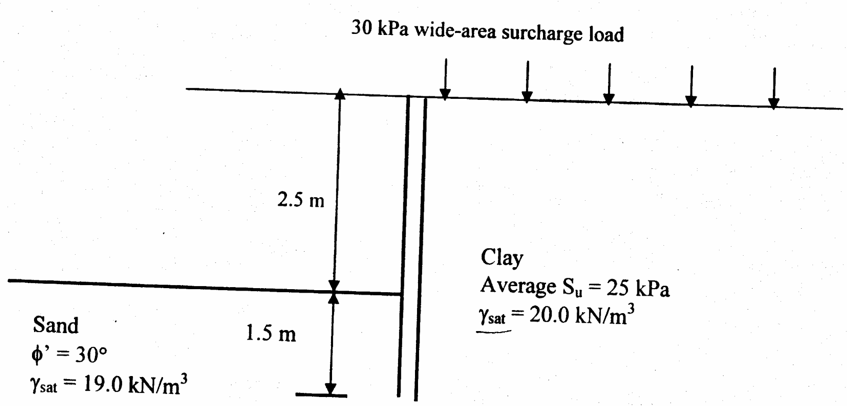
Marks **Question 3**

A conceptual cross section of a structure retaining a clay deposit is illustrated below. It is given that the soil behind the wall is saturated (and located in a zone of wet weather), and it supports a 30 kPa wide-area surcharge load as shown under operating conditions. The soil in front of the retaining structure is saturated sand.

(9) (a) Illustrate, with magnitudes, the lateral earth/groundwater pressure distribution on the wall from the saturated clay deposit considering active conditions. Calculate the total force (per metre length of wall) arising from these pressures (Use Rankine theory; consider total stress approach).

(7) (b) Illustrate, with magnitudes, the earth and groundwater pressure distribution from saturated soil in front of the wall considering passive conditions. (Use Rankine theory; consider ~~total~~ effective stress approach; No need to calculate forces).

(4) (c) Considering a horizontal semi-infinite sandy soil mass, illustrate the typical variation of lateral pressure with respect to wall movement identifying the active, passive and "at-rest" (K_o) earth pressure conditions. Use this diagram to reason why it is not practical to rely on the development of the full amount of available passive pressure as a resisting force in the design of retaining walls.



Marks **Question 4**

(15) A site investigation determined that a subject site to be developed is underlain by relatively clean (less than 5% fines content) medium to coarse sand. The water table was at the ground surface. The total unit weight of the sand is 20 kN/m^3. The normalized Standard Penetration Test values $(N_1)_{60}$, representing the density, at four depth locations within the deposit are given below:

Depth (m)	$(N_1)_{60}$
3	24
6	15
9	5
12	6

$$\left(\frac{\tau_{cyc}}{\sigma'_{z0}}\right)_{eqk} = 0.65\,\frac{a_{max}}{g}\,\frac{\sigma_{z0}}{\sigma'_{z0}}\,r_d$$

where:

$(\tau_{cyc}/\sigma_{z0}')_{eqk}$ = cyclic stress ratio produced by an earthquake

a_{max}/g = peak horizontal ground acceleration divided by acceleration of gravity

σ_{z0} = initial vertical total stress

σ_{z0}' = initial vertical effective stress

r_d = stress reduction factor

The estimated peak horizontal ground acceleration at the ground surface (a_{max}) on site is 0.2 g from a magnitude 7.5 design earthquake. Using the above equation and chart next page calculate the variation of factor of safety against liquefaction at the four depth locations using the Seed simplified method. For the stress reduction factor, r_d, you can use the following equations:

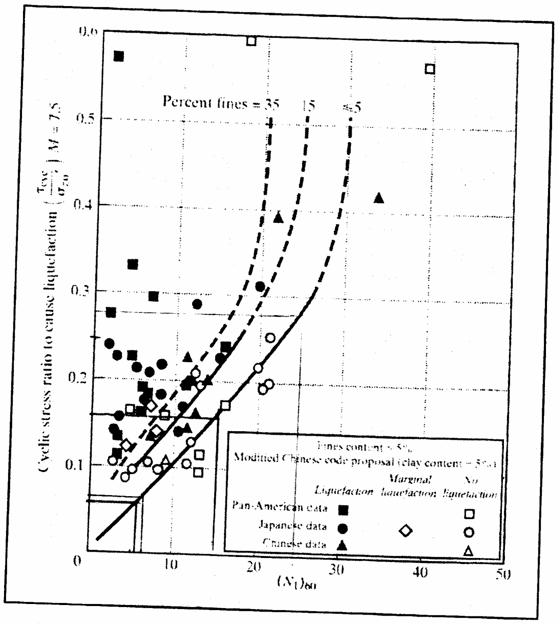
$r_d = 1.0 - 0.00765z$ for $z < 9.15$ m, or

$r_d = 1.174 - 0.0267z$ for $z > 9.15$ m

(5) Very briefly describe two "dynamic" methods of ground improvement available to densify relatively clean sandy soils.

→ vibrates

→ weights from large height



for determining liquefaction Resistance (in terms of cyclic stress ratio) with respect to $(N_1)_{60}$ at a given depth. (for M=7.5 earthquake).

Marks **Question 5**

(10) (a) Given the following information, compute the ultimate bearing capacity of a 2 m square footing founded on a soil deposit.

- (i) Shear strength parameters: $c' = 5$ kPa; $\phi' = 30$ deg.
- (ii) Depth of footing below ground surface = D = 1.0 m;
- (iii) Depth of groundwater table = $D_w = 2.5$ m;
- (iv) Total unit weight of soil above groundwater table = 18 kN/m^3.
- (v) Total unit weight of soil below groundwater table = 20 kN/m^3.

(10) (b) A strip (continuous) footing, 1 m in width, is founded in a clay with an undrained shear strength $S_u = 60$ kPa. The depth of footing embedment (D) is 0.5 m, and the soil has a total unit weight of 19 kN/m^3. Using a factor of safety of 3.0, compute the allowable bearing capacity of the foundation. Assume that the bearing pressure from the weight of the footing is given by γ_{con} *D, where γ_{con} = Unit weight of concrete = 24 kN/m^3.

Note : for $\phi' = 30$ deg $\Rightarrow$ Use $N_c = 30$; $N_q = 18$; $N_\gamma = 15$
for $\phi' = 0$ deg $\Rightarrow$ Use $N_c = 5.14$; $N_q = 1.0$; $N_\gamma = 0$