THE UNIVERSITY OF BRITISH COLUMBIA

Department of Civil Engineering

FINAL EXAMINATION – DECEMBER 2004
SOIL MECHANICS II - CIVL 311
Instructor: Dr. D. Wijewickreme

Time: 3 hours

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1. **Closed Book** Examination; a calculator only is permitted.
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.
11. Make any reasonable assumptions (where appropriate and if required) to answer the questions.

Marks **Question 1**

The soil stratigraphy at a site for a proposed cylindrical storage tank is shown in the figure below (Note: Schematic diagram only. Not to scale.) The following 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: $e = 1.00 - 0.30 \log (\sigma_v'/100)$ where σ_v' = Vertical Effective Stress in kPa.

It has been suggested that foundation loading of 100 kPa over a 12-m diameter circular area as shown in the figure be considered for design purposes. Dividing the clay deposit into two sub-layers of equal thickness, and assuming that the stress conditions at the mid-depth of each sub-layer are representative of that sub-layer:

(16) (a) estimate expected ultimate consolidation settlement within the clay deposit due to the applied load from the circular foundation [Note: (i) compute separate initial void ratios (e_o) for mid-depth of each sub-layer before the settlement calculations are undertaken; (ii) ignore settlements within the upper sand zones; (iii) see table below for calculation of applied stresses];

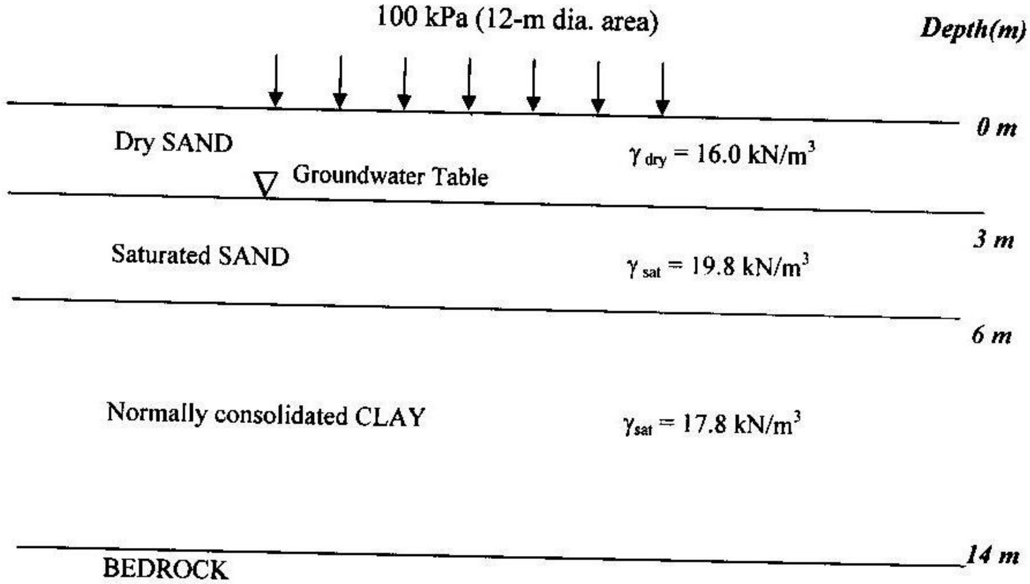
(5) (b) estimate the time required for completion of 90% of the total consolidation settlement within the clay deposit due to the placement of the load (assume that the load is placed is relatively quickly). C_v of the clay deposit is 5.0×10^{-4} cm^2/sec;

(4) (c) If the anticipated settlements are considered not acceptable to the owner, preloading can be considered as a means of reducing settlements. Using a sketched plot of e vs. log σ_v' explain/illustrate how the process of preloading would assist in reducing consolidation settlements. With the aid of the same diagram, provide the definition of preconsolidation pressure and over-consolidation ratio (no calculations are necessary).

NOTE:

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

D/z Ratio	Stress Influence Factor I_z
1.0	0.30
1.5	0.50
2.0	0.65
3.0	0.83



Question 2

A series of triaxial tests carried out on undisturbed samples of saturated clay indicated that the shear strength and pore water pressure response of a soil could be characterized by the following parameters:

$c' = 5$ kPa; $\phi' = 27$ deg; and Skempton pore pressure parameter at failure = $A_f = 0.80$

(6) (a) What would be the deviator stress at failure in a consolidated drained (CD) triaxial compression test if an undisturbed sample of this clay was consolidated to an effective all round stress of $\sigma'_{1c} = \sigma'_{3c} = 150$ kPa prior to shearing.

(9) (b) If another sample of this soil was consolidated to $\sigma'_{3c} = 200$ kPa, estimate the deviator stress at failure if the sample was sheared in consolidated undrained (CU) triaxial compression.

(4) (c) One of the undisturbed samples of the above clay was obtained from a depth where the overburden effective stress is 185 kPa. Assuming perfect sampling, calculate the expected deviator stress at failure if the sample was sheared in an unconsolidated undrained (UU) loading mode with a hydrostatic cell pressure of 200 kPa. Would the deviator stress at failure be different if the sample was tested using another cell pressure? Briefly indicate the reasoning for your answer.

(d) What would be the shear stress at failure in <u>drained direct shear</u> if the clay were initially consolidated under a vertical effective stress of 450 kPa.

(4) (e) The deviator stress at failure (σ_{df}) of a heavily OC clay in CU compression can be larger than the value of σ_{df} obtained from a CD test if both the tests were started from an identical σ'_{3c} state. Explain the reasoning for this using a sketch of effective stress Mohr circles at failure for the two tests.

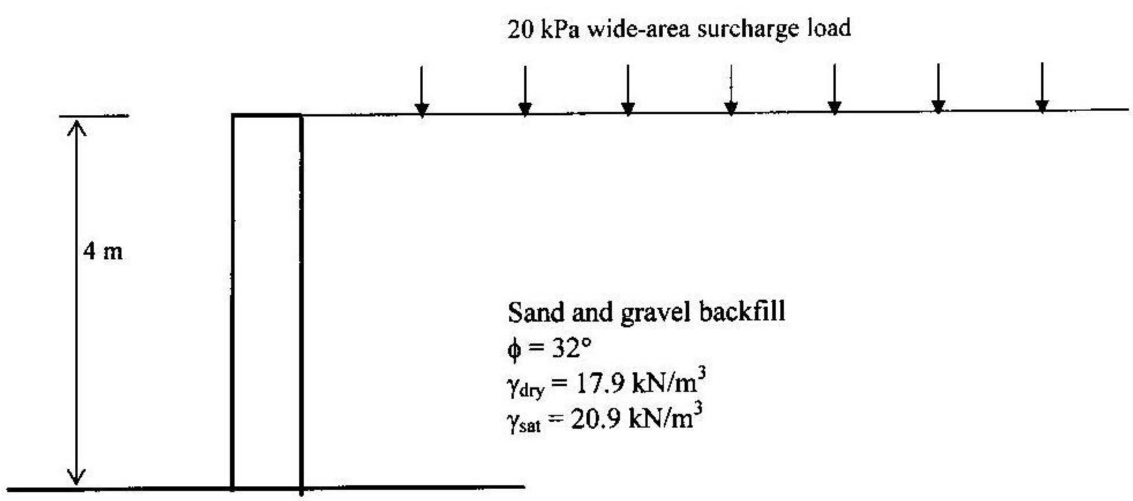
Question 3

A schematic cross section of a retaining wall is illustrated below. It is given that the sand backfill is dry, and it supports a 20 kPa wide-area surcharge load as shown under operating conditions.

(9) (a) Calculate the coefficients of active earth pressure and passive earth pressure for the backfill soil. Illustrate, with magnitudes, the active earth pressure distribution on the wall from the backfill. Calculate the total force (per metre length of wall) arising from this active earth pressure distribution (Use Rankine theory).

(4) (b) Considering the above case, illustrate the relative magnitudes of active, passive, and "at-rest" earth pressure coefficients using a sketch that shows the variation of effective lateral earth pressure coefficient with horizontal wall movement (provide schematic diagram only; no need to draw to scale).

(7) (c) It has been suggested that the above wall should be designed to withstand lateral forces under "at-rest" (K_o) earth pressure conditions with the backfill fully saturated over full height of the wall. Compute and illustrate the anticipated earth pressure and groundwater pressure distributions on the wall under this loading condition (no need to calculate resultant forces).



Question 4

Answer the following questions making liberal use of illustrations, or tables, wherever possible (Note: If the answer can be given exclusively using illustrations, or tables, you do not have to provide written text explaining your answer).

(6) (a) Using plots of shear stress (τ) vs. normal stress (σ), illustrate the following:

(i) total and effective stress Mohr circles [identify the major and minor principal stresses of an arbitrary stress condition where effective 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].

(ii) typical failure envelopes for normally consolidated clay and overconsolidated clay.

(iii) the definition of maximum shear stress obliquity.

(3) (b) Depending on the permitted drainage conditions during the testing process, there are 3 main types of conventional triaxial shear tests on soils. [Namely, Consolidated Drained (CD), Consolidated Undrained (CU), and Unconsolidated Undrained (UU)]. Using "Yes" or "No" answers, and employing a tabular format as shown below, indicate the applied drainage conditions and need for pore water pressure measurement during the two testing stages for the above three test types.

	Consolidation Stage		Shearing Stage	
Test Type	Drainage allowed?	Pore water pressure measurement required?	Drainage allowed?	Pore water pressure measurement required?
UU Test	*	*	*	*
CU Test	*	*	*	*
CD Test	*	*	*	*

*Copy the above table to your answer script, and complete the empty cells of the table, as appropriate. (Note: "Yes" = Drainage open and "No" = Drainage closed).

(3) (c) From the three types of tests given in (b) above, identify the suitable test type (or types, if applicable) for deriving strength parameters to analyse the following geotechnical problems:

(i.) Evaluation of the stability of a proposed rapid excavation in a clayey soil mass;
(ii.) The stability of an earth dam with steady state seepage; and
(iii.) The long-term stability of a foundation supported on a heavily over-consolidated soil deposit.

(3) (d) Using a plot of shear stress (τ) vs. normal stress (σ), and considering an arbitrary stress condition in the field, schematically illustrate the definition of "pole" in relation to Mohr circle of stress.

Question 5

(8) (a) Given the following information, compute the ultimate bearing capacity of a 2.0 m square footing founded on a soil deposit.

(i) Shear strength parameters: ϕ' = 34 deg and c'= 10 kPa.
(ii) Depth of footing base below ground surface = D = 1.0 m;
(iii) Groundwater table is located 0.5 m below base of footing;
(iv) Total unit weight of soil above groundwater level = 17.8 kN/m^3.
(v) Total unit weight of soil below groundwater level = 19.8 kN/m^3.

(7) (b) A strip (continuous) footing, 1 m in width, is to be founded on a clay deposit. Deviator stress at failure of 40 kPa was obtained for the clay based on unconfined compression testing. The depth of footing embedment (D) is 0.75 m, and the soil has a total unit weight of 18 kN/m^3. Determine the ultimate bearing capacity of the foundation.

Note : for ϕ' = 34 deg $\Rightarrow$ Use $N_c = 42$; $N_q = 29$; $N_\gamma = 29$
for ϕ' = 0 deg $\Rightarrow$ Use $N_c = 5.14$; $N_q = 1.0$; $N_\gamma = 0$

EQUATION SHEET

$\sigma' = \sigma - u; \; u = \gamma_w z$ $\qquad T_v = (C_v t) / (H_{dr})^2$

$T_v = -0.933 \log(1-U) - 0.085$ - for Degree of Consolidation (U) > 0.53

$T_v = (\pi/4) * (U)^2$ - for Degree of Consolidation (U) < 0.53

Strip footings : $q_{ult} = c'N_c + \sigma_D' N_q + 0.5\, \gamma' B N_\gamma$
Square footings: $q_{ult} = 1.3\, c'N_c + \sigma_D' N_q + 0.4\, \gamma' B N_\gamma$

Correction to account for the depth of water table:

- Case 1: $D_w \le D$
- Case 2: $D < D_w < D+B$
- Case 3: $D+B \le D_w$

All three cases are shown in Figure 17.6.

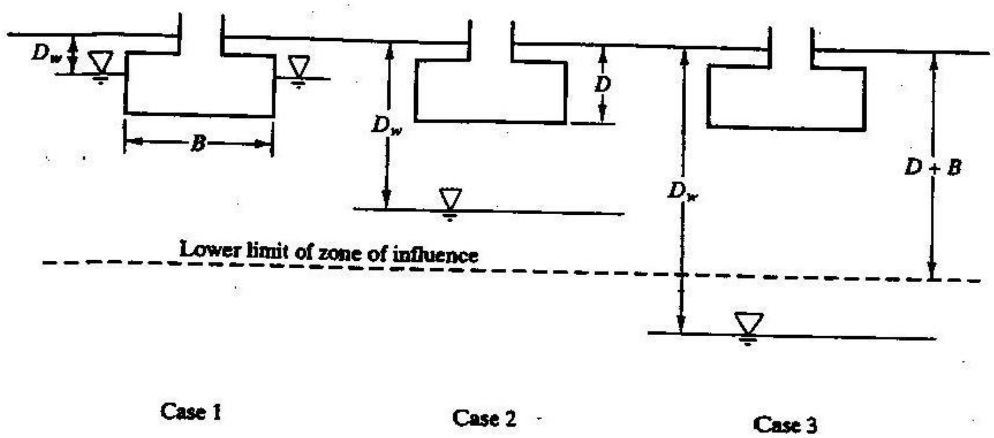


Figure 17.6 Three groundwater cases for bearing capacity analyses.

For case 1 ($D_w \le D$):

$$\gamma' = \gamma_b = \gamma - \gamma_w$$

For case 2 ($D < D_w < D+B$):

$$\gamma' = \gamma - \gamma_w\left(1 - \left(\frac{D_w - D}{B}\right)\right)$$

For case 3 ($D+B \le D_w$; no groundwater correction is necessary):

$$\gamma' = \gamma$$

Mohr Coulomb Failure Criterion $\Rightarrow$ Shear strength at failure = s = c' + σ' tan φ'

$\sigma_{df} = \sigma'_{3f} (N_\phi - 1) + 2c' (N_\phi)^{0.5}$

$\sigma'_{3f} = (\sigma'_{3c} - \Delta u_f)$

$\Delta u_f = A_f \sigma_{df}$

$N_\phi = (1+\sin\phi')/(1-\sin\phi')$

$K_a = 1/N_\phi$; $K_p = N_\phi$; $K_o = (1-\sin\phi')$

Lateral earth pressure - Effective stress analysis (when c'=0):

σ_v' = Effective vertical stress at a given depth

$\sigma_h' = K \sigma_v'$ where K = one of K_a (active), K_o (at-rest), or K_p (passive) depending on the case analyzed.

Lateral earth pressure - Effective stress analysis (with c' and φ'):

$p_a = K_a \sigma_v' - 2c' (K_a)^{0.5}$ - Active

$p_p = K_p \sigma_v' + 2c' (K_p)^{0.5}$ - Passive

Lateral earth pressure - Total stress analysis:

$p_a = \sigma_v - 2 S_u$;

$p_p = \sigma_v + 2 S_u$

σ_v = Total vertical stress at a given depth; Note: At tension crack depth level, Z_c, $p_a = 0$.