

THIS EXAMINATION CONSISTS OF 8 PAGES. PLEASE CHECK THAT IT IS COMPLETE.

THE UNIVERSITY OF BRITISH COLUMBIA

Department of Civil Engineering

FINAL EXAMINATION – DECEMBER 2005

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. Unit weight of water = 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 may 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.
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Marks

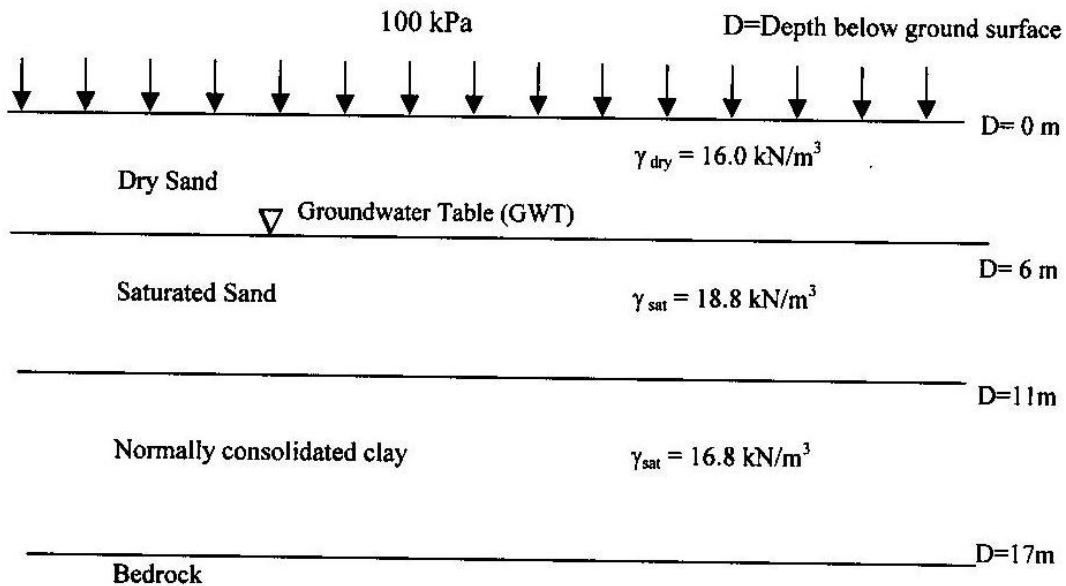
Question 1

The soil stratigraphy at a site for a proposed material storage yard is shown in the figure below (Note: This is a schematic diagram only. Not to scale.) One-dimensional consolidation test on an undisturbed sample of the clay retrieved from the centre of the clay deposit yielded the following data for its field compressibility.

$$\begin{aligned} \text{Initial void ratio} &= e_0 = 0.920 \\ C_c &= 0.36 \\ C_r &= 0.04 \\ \text{average } C_v &= 3.3 \times 10^{-3} \text{ cm}^2/\text{sec.} \end{aligned}$$

A permanent wide-area load of 80 kPa as shown in the figure has been proposed at the site (assume that wide-area load is placed over a relatively short period of time). Assuming that the stress conditions at the mid-depth of the clay deposit are representative of the entire clay layer:

- (9) (a) compute the expected ultimate consolidation settlement of the clay deposit due to the 100 kPa wide-area load (ignore settlements within sand);
- (4) (b) estimate the time required for completion of 90% of the above total consolidation settlement;
- (9) (c) compute the additional consolidation settlement within the clay deposit if the groundwater level is anticipated to be lowered by 2 m from the present level. Assume that the lowering of the GWT occurs after placement of the wide-area load.
- (3) (d) If the above anticipated settlements are considered not acceptable to the owner, very briefly indicate the remedial options that you would propose as a part of site preparation (no calculations necessary). Comment on the methods available for expediting the occurrence of settlements.



Question 2

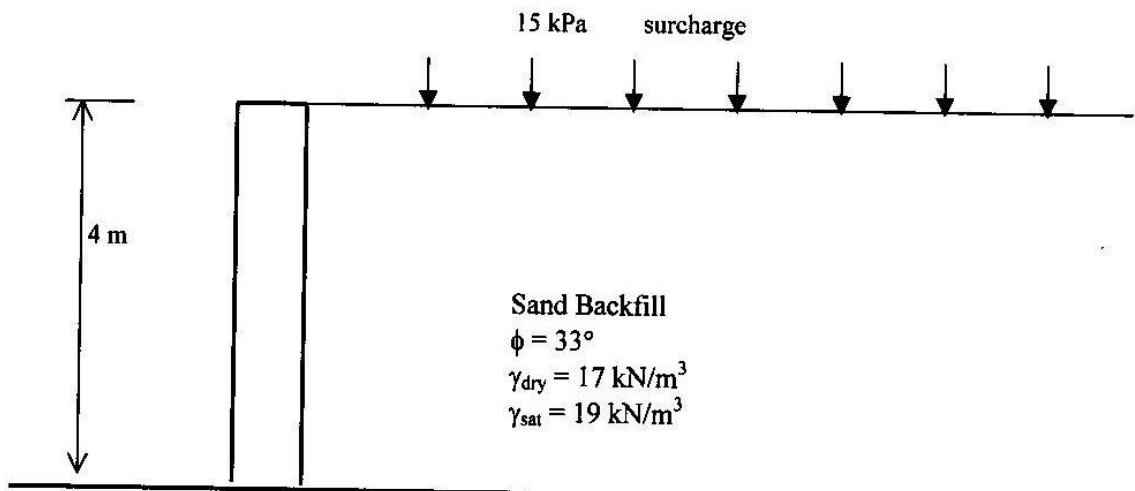
A series of triaxial tests carried out on undisturbed samples of saturated clay indicated that the shear strength and pore water pressure response of the soil could be characterized by the following parameters: $c' = 8$ kPa; $\phi' = 27$ deg; and Skempton pore pressure parameter at failure = $A_f = 0.8$.

- (6) (a) What would be the deviator stress at failure in a consolidated drained (CD) triaxial compression test if a sample of this clay was consolidated to an effective all round stress of $\sigma'_{1c} = \sigma'_{3c} = 350$ kPa prior to shearing.
- (9) (b) If another sample of this soil was consolidated to the same all round stress as above, estimate the deviator stress at failure if the sample was sheared in consolidated undrained (CU) triaxial compression.
- (4) (c) What would be the shear stress at failure in drained direct shear if the clay were initially consolidated under a vertical effective stress of 300 kPa.
- (6) (d) One of the undisturbed samples of the above clay was obtained from a depth where the overburden effective stress is 200 kPa. Assuming perfect sampling, calculate the expected deviator stress at failure if the sample was sheared in an unconsolidated undrained (UU) loading mode.

Question 3

A schematic cross section of a retaining wall, including relevant soil parameters, is illustrated below. It is anticipated that the sand backfill will be saturated with the groundwater table at the surface and that the backfill will be loaded with a 15 kPa wide-area surcharge load as shown in the figure.

- (10) (a) Calculate the coefficient of active earth pressure for the backfill soil. Illustrate with magnitudes, using Rankine theory, the active earth pressure distribution from the backfill and groundwater pressure distribution on the wall. Calculate the total force (per metre length of wall) arising from these pressure distributions.
- (5) (b) If the backfill was dry and the wall has to be designed to withstand "at rest" earth pressure conditions, illustrate the anticipated earth pressure distribution on the wall. (assume $K_0 = 1 - \sin \phi$)
- (10) (c) Instead of sand, if the backfill is a fully saturated clayey soil having an average undrained shear strength $S_u = 15$ kPa and a total unit weight of 19 kN/m³, illustrate, with magnitudes, the anticipated total lateral pressure distribution on the wall under active soil conditions. Clearly show the depth of tension cracking.



Question 4

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

- (8) (a) In a laboratory one-dimensional consolidation test, a specimen of saturated clay 20 mm thick reaches 50% consolidation in 20 min. How long would it take a layer of this clay 5 m thick to reach the same degree of consolidation under the same stress and drainage conditions? How long would it take the layer to reach 30% consolidation?
- (4) (b) Using a plot of void ratio (e) vs. log effective stress (σ'), sketch the typical consolidation characteristics of a clay. Identify the normally consolidated (NC) and overconsolidated (OC) regions of the e -log σ' response. Also provide the definition of the term overconsolidation ratio (OCR).
- (3) (c) Using a plot of shear stress (τ) vs. normal stress (σ), illustrate the concepts of 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].
- (6) (d) 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.

Test Type	Consolidation Stage		Shearing Stage	
	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) (e) From the three types of tests given in (d) 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 excavation in a clayey soil mass, given that consolidation of the clay deposit should be anticipated from some additional loading prior to the proposed excavation work;
 - (ii.) The short-term stability of a footing supported on a fine-grained soil; and
 - (iii.) The long-term stability of a foundation supported on an over-consolidated soil deposit.
- (6) (f) Very briefly explain the reasoning for the following statements:
- (a) "The consolidated undrained (CU) and unconsolidated undrained (UU) tests can be argued to be similar from a fundamental point of view".
 - (b) "unconfined compression test is a special case of unconsolidated undrained (UU) tests".

Question 5

- (8) (a) Given the following information, compute the ultimate bearing capacity of a 1.2 m wide strip (continuous) footing founded on a soil deposit.
- (i) Shear strength parameters: $\phi' = 32$ deg and $c' = 12$ kPa.
 - (ii) Depth of footing below ground surface = $D = 0.6$ m;
 - (iii) Depth of groundwater table = 1.5 m;
 - (iv) Unit weight of soil above groundwater table = 19 kN/m³.
 - (v) Saturated unit weight of soil below groundwater table = 19.8 kN/m³.
- (7) (b) A square footing, 1.5 m in width, is founded in a clay with an undrained shear strength $S_u = 50$ kPa. The depth of footing embedment (D) is 0.6 m, and the soil has a total unit weight of 18.5 kN/m³. Using a factor of safety of 3.0, compute the allowable column load on the foundation. Assume that the equivalent bearing pressure from the weight of the footing (and the soil above) is 15 kPa.

Note : for $\phi' = 32$ deg \Rightarrow Use $N_c = 35$; $N_q = 23$; $N_\gamma = 21$
for $\phi' = 0$ deg \Rightarrow Use $N_c = 5.14$; $N_q = 1.0$; $N_\gamma = 0$

EQUATION SHEET

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

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

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

$$S_{ult} = \epsilon_z \cdot H \quad \text{where } \epsilon_z = [\Delta e / (1+e_o)] \text{ and } \Delta e = e_o - e_f = C_c \cdot \log_{10} [(\sigma'_{z0} + \Delta\sigma'_z) / \sigma'_{z0}]$$

H = thickness of consolidation layer considered for the calculation

e_o = initial void ratio; e_f = final void ratio; σ'_{z0} = initial stress; $\Delta\sigma'_z$ = increase in stress

C_c = compression index

General formula for the computation of vertical effective stress = $\sigma'_z = \sum \gamma_i h_i$,

where, γ_i = submerged (or dry) unit weight of a given layer of soil, and

h_i = thickness of the same layer. Submerged unit weight = $\gamma' = \gamma_{sat} - \gamma_{water}$

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

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

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

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

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

Lateral earth pressure - Effective stress analysis:

$$(\sigma_h)_{active} = p_a = K_a \sigma'_v - 2c' (K_a)^{0.5}$$

$$K_a = (1/N_\phi)$$

σ'_v = Effective vertical stress at a given depth

Lateral earth pressure - Total stress analysis:

$$(\sigma_h)_{active} = p_a = \sigma_v - 2 S_u$$

σ_v = Total vertical stress at a given depth

Note: At tension crack depth level, Z_c , $p_a = 0$.

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

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

Note: $\sigma_D' =$ Vertical effective stress at the base level of footing;

Correction to account for the depth of water table:

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

All three cases are shown in Figure 17.6.

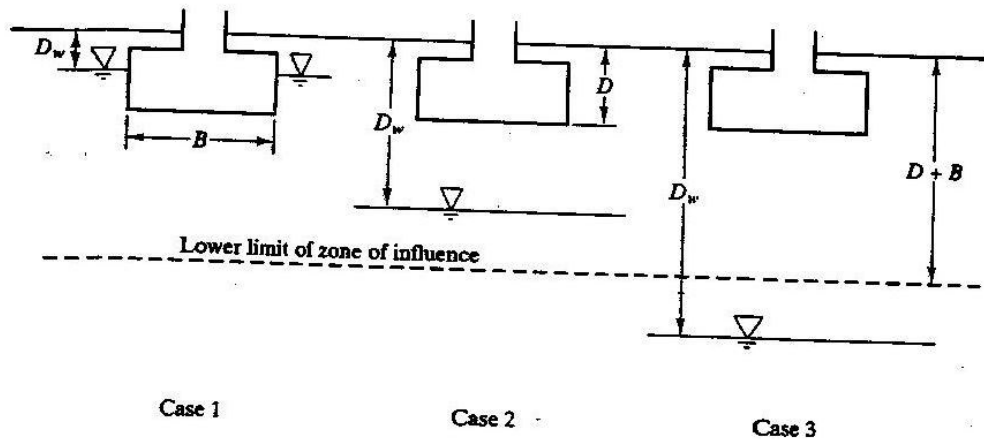


Figure 17.6 Three groundwater cases for bearing capacity analyses.

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

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

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 ($D+B \leq D_w$; no groundwater correction is necessary):

$$\gamma' = \gamma$$