THE UNIVERSITY OF BRITISH COLUMBIA

Department of Civil Engineering

FINAL EXAMINATION – DECEMBER 2003
SOIL MECHANICS II - CIVL 311
Instructor: Dr. D. Wijewickreme

Time: 3 hours

1. **Closed Book** Examination; a calculator and drawing instruments are 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 9.81 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.

Marks

Question 1

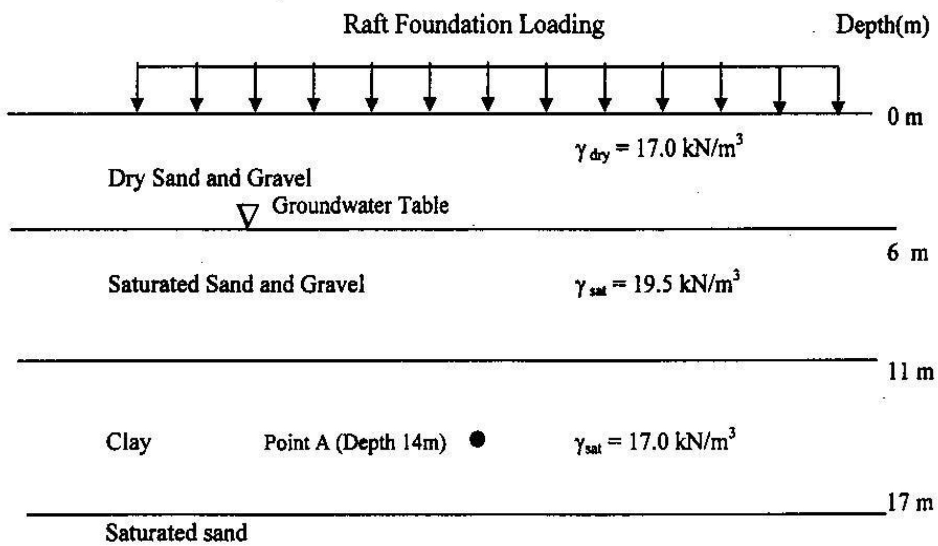
The soil stratigraphy at the site of a proposed raft foundation is shown below (Note: Schematic diagram only. Not to scale.) The estimated net increment of vertical stress at the centre depth of the clay layer below the centre of the raft foundation (i.e. at Point A) is 45 kPa. Laboratory consolidation test on a sample from the centre of the clay layer indicates that the deposit is normally consolidated and its field consolidation curve can be represented by: $e = 0.95 - 0.33 \log_{10}(\sigma_v'/150)$, where σ_v' = Vertical effective stress in kPa. Given that the average value of coefficient of consolidation (c_v) of the clay deposit is 5.2×10^{-4} cm^2/sec, and that stress conditions at Point A is considered applicable for the entire clay layer:

(6) (a) Compute the ultimate consolidation settlement of the clay layer as a result of the raft foundation;

(6) (b) After a period of 2 years since application of the foundation loading, what would be the degree of consolidation of the clay layer. Also compute the settlement incurred as a result of the consolidation process during this period;

(4) (c) What would be the settlement after 2 years if the clay layer was underlain by relatively impermeable bedrock instead of sand.

(4) (d) Redo the Question (a) above assuming that the site had its groundwater table located at a depth of 8 m at the time of loading (instead of 6 m as shown).



Question 2

A series of consolidated drained direct shear tests on saturated overconsolidated clay indicates that the shear strength of the soil could be characterized by the following parameters. $c' = 10.0$ kPa; $\phi' = 25$ deg; and Skempton pore pressure parameter at failure = $A_f = 0.60$. Assume that the consolidation stress levels used in all the tests given below are less than the preconsolidation stress (maximum past pressure) of this material.

(6) (a) What would be the shear strength 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 $\sigma'_{1c} = \sigma'_{3c} = 100$ kPa prior to shearing.

(9) (b) If another sample of this soil was consolidated to the same all round effective stress as above, estimate the deviator stress at failure if the sample was sheared in consolidated undrained (CU) triaxial compression. Compute the change in pore water pressure due to shearing of soil.

(5) (c) What would be the shear stress at failure in drained direct shear if the clay was initially consolidated to a vertical effective stress of 50 kPa.

(6) (d) One of the undisturbed samples of the above clay was obtained from a depth where the overburden effective stress is 60 kPa. Assuming perfect sampling, calculate the expected deviator stress at failure if the sample was sheared in an unconsolidated undrained (UU) loading mode.

(4) (e) If a sample of the above soil was consolidated to a stress level more than its preconsolidation stress, would the above failure envelope be still valid? Briefly explain the reasoning for your answer.

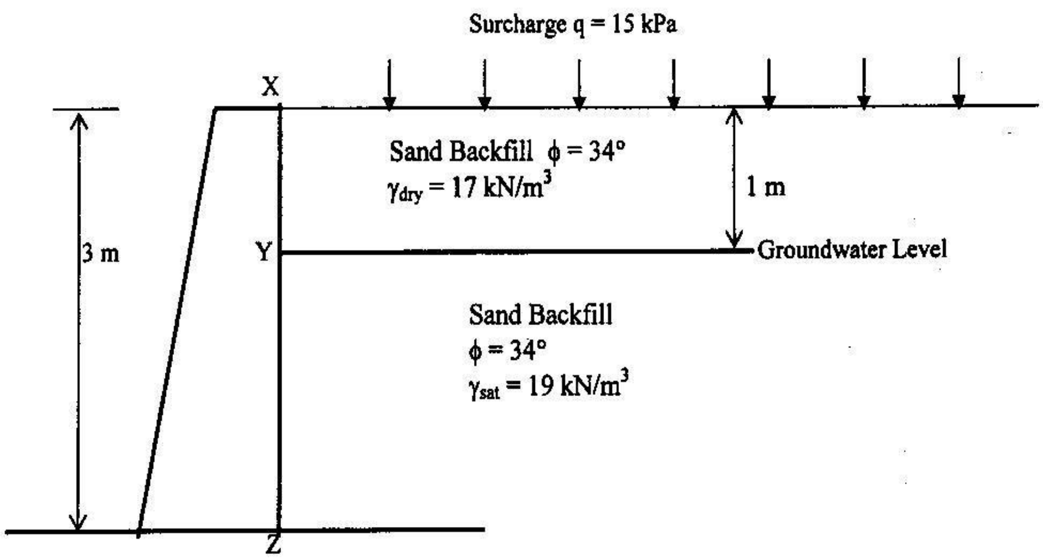
Question 3

A schematic cross section through a retaining wall is illustrated below. Sand backfill is essentially in a dry condition above the groundwater level, and it supports a 15 kPa surcharge load as shown.

(a) Calculate the coefficients of active earth pressure and passive earth pressure for the backfill soil. Sketch the distributions of Rankine's active earth pressure and groundwater pressure on the wall. Also calculate the total force (per metre length of wall) arising from this pressure distribution.

(b) 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/m^3, illustrate, with magnitudes, the anticipated total lateral pressure distribution on the wall under active soil conditions. Clearly show the depth of tension cracking.

(c) If the angle of interface friction between the backfill and wall (ϕ_w) is 24°, and the backfill is sloped at 15° to the horizontal, find the coefficient of active earth pressure using Coulomb theory Assume a completely dry sand backfill condition (again ϕ= 34°), for this case.



Question 4

Answer the following questions making liberal use of clear hand-sketched 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) Briefly describe your understanding of the following: (a) normally consolidated (NC) clay; (b) overconsolidated clay; and (c) undrained shear strength.

(4) (b) Illustrate the concepts of total and effective stress Mohr's 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]. Also illustrate the definition of the term "pole" considering the stress state in an arbitrary element of soil.

(6) (c) Describe the imposed drainage conditions during: (a) Consolidated Drained (CD); (b) Consolidated Undrained (CU); and (c) Unconsolidated Undrained (UU) triaxial tests.

(3) (d) When subjected to shear, a dense sand typically would exhibit a peak friction angle higher than that displayed by the same soil when tested under loose conditions. Explain the reasons for this difference.

(6) (c) From the three types of triaxial tests given in (c) 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 relatively rapid excavation in a normally consolidated clayey soil mass;

(ii.) Short-term and long-term stability of an earth dyke constructed on a saturated normally consolidated clayey soil; and

(iii.) Stability of a foundation supported on an over-consolidated soil deposit.

Question 5

(8) (a) Do you agree, or disagree, with the statement "*Low factors of safety might be used in computing the allowable bearing capacity for non-critical structures founded on sandy soils with good site characterization*"? Explain the rationale for your answer.

(9) (b) Given the following information, compute the ultimate bearing capacity of a 1.5 m square footing founded on a soil deposit.

(i) Shear strength parameters: $\phi' = 32$ deg; and $c' = 10$ kPa.
(ii) Depth of footing below ground surface = D = 1.0 m;
(iii) Depth of groundwater table = 2.0 m;
(iv) Dry Unit weight of soil = 16 kN/m^3.
(v) Saturated Unit weight of soil = 19 kN/m^3.

(8) (b) A square footing, 1 m in width, is founded in a clay with an undrained shear strength $S_u = 30$ kPa. The depth of footing embedment (D) is 0.6 m, and the soil has a total unit weight of 17 kN/m^3. Compute the allowable bearing capacity of the foundation. Also calculate the maximum allowable column load on the footing using a factor of safety of 2.5. Assume that the bearing pressure from the weight of the footing is given by γ_{con} D, where γ_{con} = Unit weight of concrete = 23.6 kN/m^3.

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

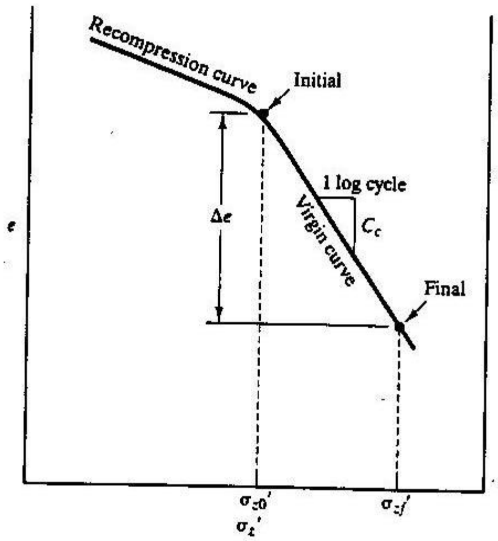
EQUATION SHEET

$\sigma' = \sigma - u;\ u = \gamma_w z$

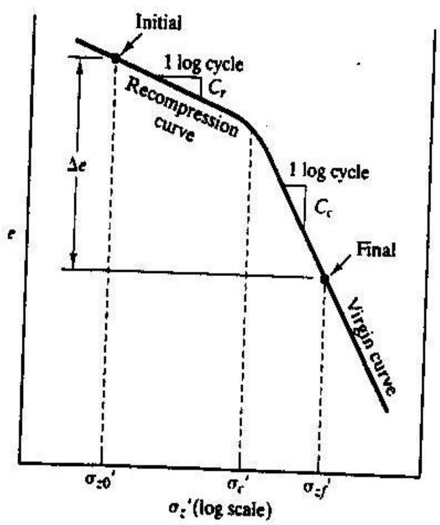
$T_v = [C_v \cdot t / (H_{dr})^2]$

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

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



$$(\delta_c)_{ult} = \sum \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_{zf}}{\sigma'_{z0}}\right)$$



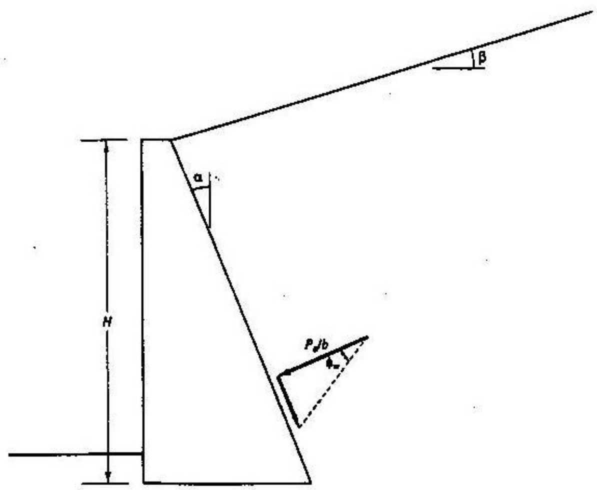
$$(\delta_c)_{ult} = \sum\left[\frac{C_r}{1+e_0} H \log\left(\frac{\sigma'_c}{\sigma'_{z0}}\right) + \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_{zf}}{\sigma'_c}\right)\right]$$

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:
$p_a = K_a \sigma_v' - 2c' (N_\phi)^{0.5}$
$K_a = 1/N_\phi$ $\quad$ $K_p = N_\phi$
σ_v' = Effective vertical stress at a given depth

Lateral earth pressure - Total stress analysis:
$p_a = \sigma_v - 2 S_u$
σ_v = Total vertical stress at a given depth
Note: At tension crack depth level, Z_c, $p_a = 0$.



$$K_a = \frac{\cos^2(\phi - \alpha)}{\cos^2\alpha \cos(\phi_w + \alpha)\left[1 + \sqrt{\dfrac{\sin(\phi + \phi_w)\sin(\phi - \beta)}{\cos(\phi_w + \alpha)\cos(\alpha - \beta)}}\right]^2} \qquad (16.1$$

where: K_a = coefficient of active earth pressure
σ_z' = vertical effective stress
α = inclination of wall from vertical
β = inclination of ground surface above the wall
ϕ_w = wall–soil interface friction angle