PROFESSIONAL ENGINEERS ONTARIO
NATIONAL EXAMINATIONS –May 2008
98-CIV-A4 GEOTECHNICAL MATERIALS AND ANALYSIS

3 HOURS DURATION

NOTES:

1. This is a closed book examination.

2. Read all questions carefully before you answer

3. Should you have any doubt to the interpretation of a question, you are encouraged to complete the question submitting a clear statement of your assumptions.

4. **You are required to answer:**
   All four questions in SECTION A ....Total 40 marks
   Three out of four questions SECTION B....Total 60 marks

5. The total exam value is 100 marks

6. For Section A answer all questions

7. For Section B only the first three questions answered will be graded.

8. One of two calculators can be used: Casio or Sharp approved models.

9. Drawing instruments are required.

10. All required charts and equations are provided at the back of the examination.

11. YOUR MUST RETURN ALL EXAMINATION SHEETS.

SECTION A
ANSWER ALL **FOUR** QUESTIONS

Question 1: **(Value: 10 marks)**

State the correct answer in your answer book along with the question number.
Circle the correct answer.

(i)	A soil with a higher liquid limit settles more than a soil with a lower liquid limit.	T	F
(ii)	A direct shear test can be used for determining the effective shear strength parameters of both sandy soils and clayey soils by conducting consolidated drained tests.	T	F
(iii)	The rate of consolidation of a normally consolidated clay is typically higher than that of an over-consolidated clay.	T	F
(iv)	The pore-water pressures are negative in an over-consolidated clay sample when they are subjected to loading lower than the preconsolidation pressure.	T	F
(v)	A non-plastic silty sand can be classified using the particles size data from sieve analysis and hydrometer analysis.	T	F
(vi)	The maximum dry density values of coarse-grained soils are typically higher than that of fine-grained soils. However, the optimum moisture content for coarse-grained soils is always lower than for fine-grained soils.	T	F
(vii)	The critical state shear strength parameters are independent of the void ratio of a sandy soil. In other words, the internal friction angle, ϕ will be the same at both the low and high void ratio for a sandy soil.	T	F
(viii)	In the case of a slope constructed with a clayey soil, it is recommended to have a higher factor of safety in the short term than in the long term.	T	F
(ix)	The volume change behavior of dense sands is similar to that of overconsolidated clays.	T	F
(x)	The field coefficient of permeability is typically higher than the coefficient of permeability determined from laboratory tests.	T	F

Question 2: Multiple choice questions: state the correct answer in your answer book along with the question number. **(Value: 10 marks)**

(i)	Three clayey soils were classified as (a) CH (b) CL (c) CL-MH as per the Unified Soil Classification System. Which one of these soils would likely have the lowest saturated coefficient of permeability?	
(ii)	Which one of the soils (a) SW (b) CL (c) CH classified as per the Unified Soil Classification System would be a suitable soil for use as pavement base material to withstand the frost action more favorably?	
(iii)	The shear deformation-related positive pore-water pressures are typically higher in (a) Normally consolidated clays (b) Over-consolidated clays (c) Sandy soils	
(iv)	The friction angle of a clayey soil was determined using three different triaxial tests (a) UU tests (b) CU tests and (c) CD tests using identical samples. Which one of these tests would provide the highest internal friction angle.	
(v)	The saturated coefficient of permeability of a clayey soil compacted at three different water contents reflecting (a) Dry of optimum (b) Optimum (c) Wet of Optimum conditions, would be significantly different. Which water content (i.e., a, b or c) would you recommend to compact the soil to achieve the highest saturated coefficient of permeability.	
(vi)	Which one of the soils (a) Sands (b) Normally Consolidated Clay (c) Over-Consolidated Clay will predominantly have elastic settlements?	
(vii)	The pore-water pressures below the ground water table increases with depth for (a) Sands (b) Silts (c) Clays (d) All the soils	
(viii)	The degree of saturation of a clayey soil will be equal to 100% when it is compacted at a water content equal to (a) Dry of optimum conditions (b) Optimum (c) Wet of optimum conditions (d) None of the above	
(ix)	The shear strength equation proposed by Terzaghi extending the Mohr-Coulomb failure criterion, $\tau = c' + (\sigma - u_w)\tan\phi'$ is valid for (a) Normally consolidated clays (b) Over consolidated clays (c) both Normally and over consolidated clays (d) none of the above	
(x)	The Vane shear test is useful to determine the in situ shear strength of (a) stiff clay soils (b) sands and gravels (c) soft clayey and sensitive soils (d) none of the above	

Question 3: **(Value: 10 marks)**

Explain with practical examples when you use Terzaghi's and Skempton's approach for determining the bearing capacity of soils. What are the limitations of each of these approaches in engineering practice.

Question 4: **(Value: 10 marks)**

Explain the consolidation behavior of clays using **Figure 1** below:

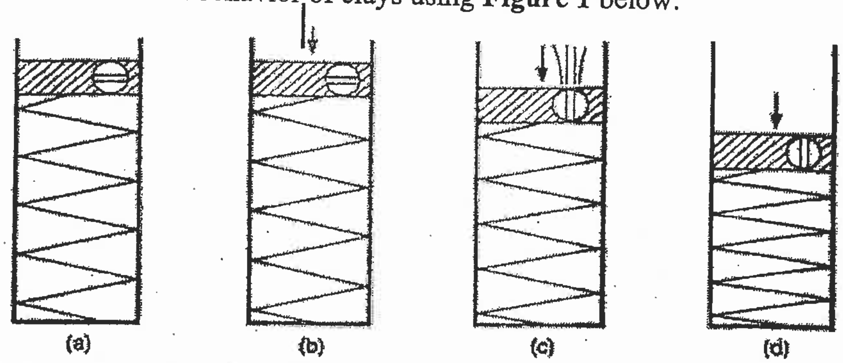


Figure 1: Consolidation analogy model

SECTION B

ANSWER ANY THREE OF THE FOLLOWING FOUR QUESTIONS

Question 5: **(Value: 20 marks)**

A cut is made in a stiff saturated clay that is underlain by a layer of sand as shown in **Figure 2**. What should be the height of the water, *h*, in the cut so that **the stability of the saturated clay is not lost?** Also, check the stability against uplift due to the differential water pressure if the width of the excavation at the base is equal to 5 m.

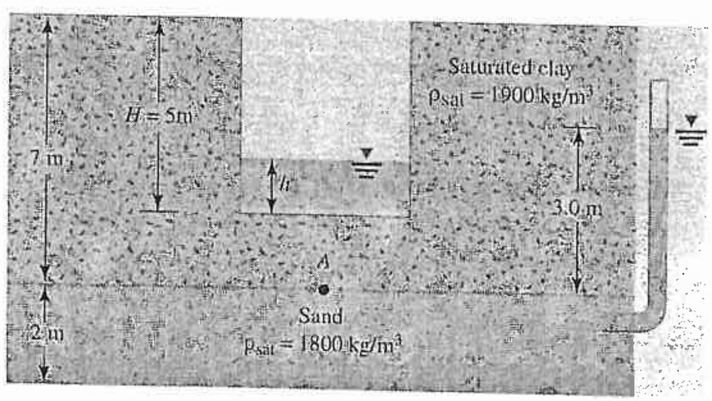


Figure 2

Question 6: **(Value: 20 marks)**

For a given soil profile in **Figure 3**, the building will impose a vertical stress increase of 150 kPa at the middle of the clay layer. Estimate the primary consolidation settlement of the clay. Assume the soil above the water table to be saturated. The specific gravity of the sand, $G_s = 2.7$. The specific gravity of the clay, $G_s = 2.7$, natural water content, $w = 45\%$, plasticity index, $I_p = 23\%$, and plastic limit, $w_p = 10\%$ and its initial void ratio, $e_0 = 0.8$.

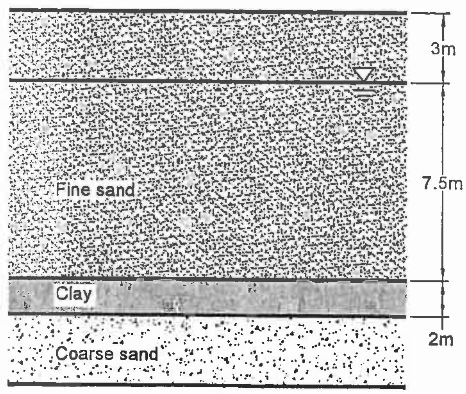


Figure 3

Question 7: **(Value: 20 marks)**

For a square footing of *4m x 4 m*, determine the average increase in stress at the centre of the area and at a depth of *5 m* due to a uniform loading of *100 kPa*. Use any three of the different procedures (i.e., point load method, use *m* and *n* coefficients, Newmark's chart, and trapezoidal rule) and compare the results.

Question 8: **(Value: 20 marks)**

An embankment is being constructed of soil whose effective shear strength parameters are $c' = 50\ kN/m^2$, $\phi' = 21^0$ and $\rho = 1.6\ Mg/m^3$. The pore pressure parameters as found from triaxial tests are $A = 0.5$ and $B = 0.9$. Find the shear strength of the soil below the center of the embankment just after the height of fill has been raised from *3 m to 6 m*. Assume that the dissipation of pore pressure during the stages of construction is negligible, and that the lateral pressure at any point is one half of the vertical pressure.

Hint: $\Delta u = B[\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)]$ and $\Delta\sigma_3 = \dfrac{\Delta\sigma_1}{2}$

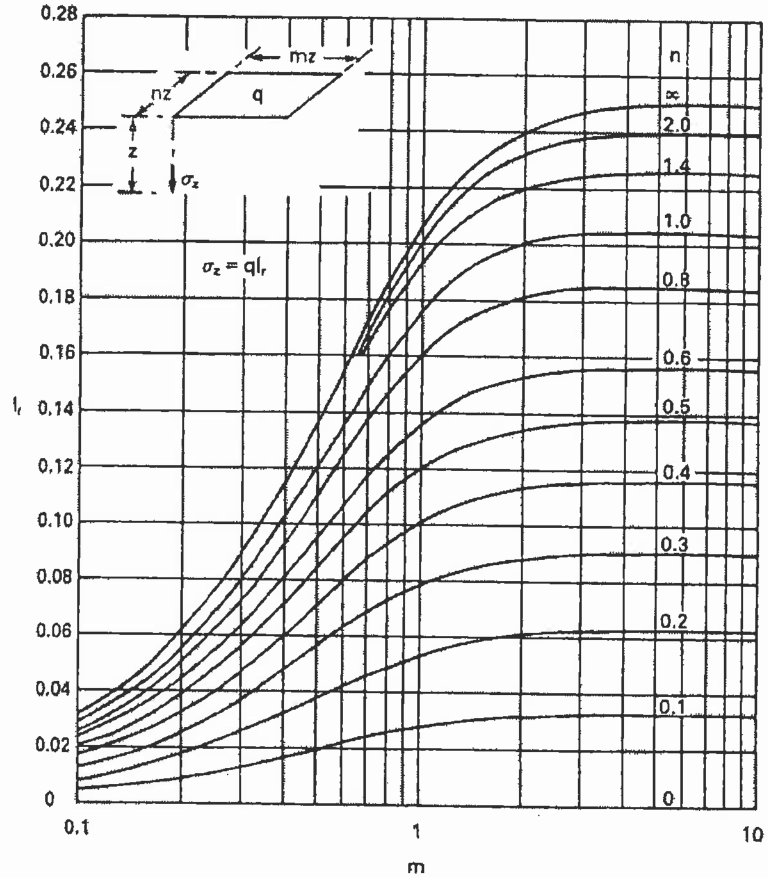
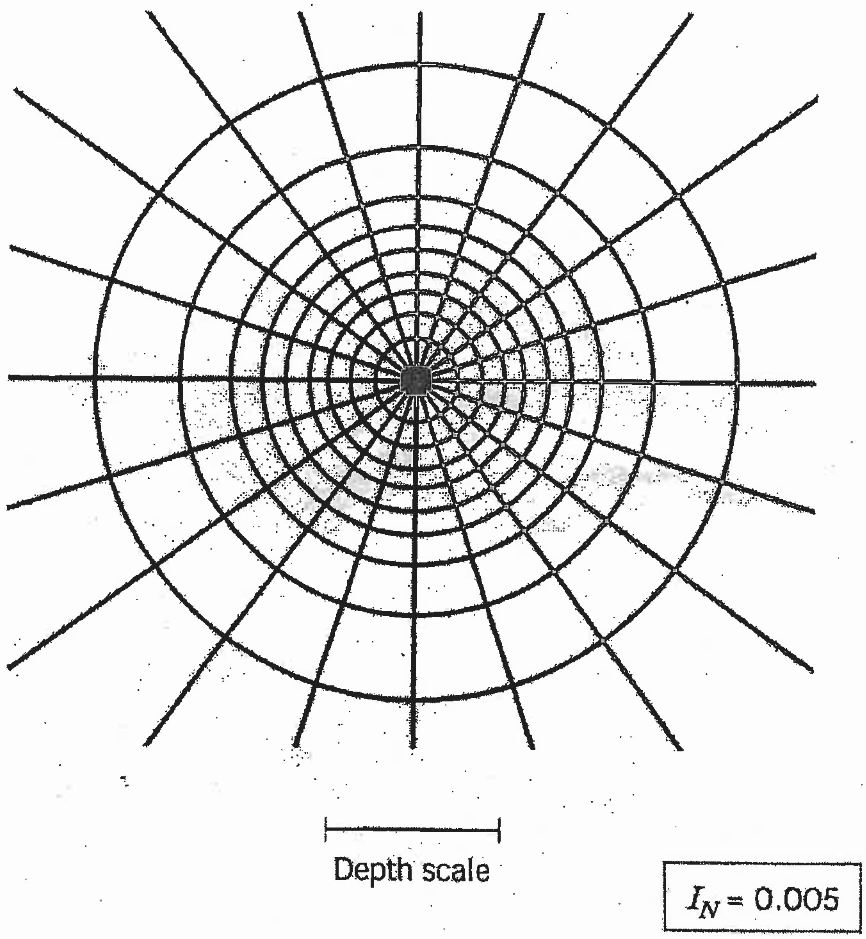


Fig. 5.10 Vertical stress under corner of rectangular area carrying a uniform pressure. (Reproduced from R.E. Fadum (1948) *Proceedings 2nd International Conference SMFE*, Rotterdam, Vol. 3, by permission of Professor Fadum.)


Depth scale
$I_N = 0.005$

Formula Sheet

$$G_s = \frac{\rho_s}{\rho_w} \qquad \rho = \frac{(Se+G_s)\rho_w}{1+e} \qquad \gamma = \frac{(Se+G_s)\gamma_w}{1+e}$$

$$wG = Se$$

$$\sigma = \gamma D$$

$$P = \sum N' + uA$$

$$\frac{P}{A} = \frac{\sum N'}{A} + u$$

$$\sigma = \sigma' + u \ (or)$$

$$\sigma' = \sigma - u$$

For a fully submerged soil $\sigma' = \gamma' D$

$v = ki$; where $i = h/L$

Boussinesq's equation for determining vertical stress due to a point load

$$\sigma_z = \frac{3Q}{2\pi z^2}\left\{\frac{1}{1+\left(\frac{r}{z}\right)^2}\right\}^{5/2}$$

Determination of vertical stress due to a rectangular loading: $\sigma_z = q I_c$ (Charts also available)

$m = B/z$ *and* $n = L/z$ (both m and n are interchangeable)

Approximate method to determine vertical stress, $\sigma_z = \frac{qBL}{(B+z)(L+z)}$

Equation for determination vertical stress using Newmark's chart: $\sigma_z = 0.005Nq$

$$\tau_f = c' + (\sigma - u_w)\tan\phi'$$

$$\sigma_1' = \sigma_3' \tan^2\left(45^o + \frac{\phi'}{2}\right) + 2c'\tan\left(45^o + \frac{\phi'}{2}\right)$$

Mohr's circles can be represented as stress points by plotting the data $\frac{1}{2}(\sigma_1' - \sigma_3')$ against $\frac{1}{2}(\sigma_1' + \sigma_3')$; $\phi' = \sin^{-1}(\tan\alpha')$ *and* $c' = \frac{a}{\cos\phi'}$

$$\frac{\Delta e}{\Delta H} = \frac{1+e_o}{H_o}; \quad s_c = H\frac{C_c}{1+e_o}\log\frac{\sigma_1'}{\sigma_o'}; \quad s_c = \mu s_{od}; \quad m_v = \frac{\Delta e}{1+e}\left(\frac{1}{\Delta\sigma'}\right) = \frac{1}{1+e_o}\left(\frac{e_o - e_1}{\sigma_1' - \sigma_0'}\right)$$

$C_c = \dfrac{e_o - e_1}{\log\left(\frac{\sigma_1'}{\sigma_0}\right)}$; also, $C_c = 0.009(\text{Liquid limit\%} - 10)$