PROFESSIONAL ENGINEERS ONTARIO
NATIONAL EXAMINATIONS –December 2010
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 three questions in SECTION A ....Total 40 marks
   All three questions in SECTION B.............Total 60 marks
5. The total exam value is 100 marks
6. One of two calculators can be used: Casio or Sharp approved models.
7. Drawing instruments are required.
8. All required charts and equations are provided at the back of the examination.
9. YOU MUST RETURN ALL EXAMINATION SHEETS.

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SECTION A
ANSWER ALL THREE QUESTIONS

Question 1: **(4 x 5 = 20 marks)**
State the correct answer. Also, provide reasons to justify the statement in your answer book along with the question number.

(i)	The degree of saturation of a compacted clayey sample at optimum moisture condition is always lower than 100% irrespective of the compaction energy used.	T	F
(ii)	The plastic limit of a bentonite can be greater than the liquid limit value	T	F
(iii)	The stresses associated with a structure in an elastic, homogeneous soil increases with depth.	T	F
(iv)	The shear strength an overconsolidated clay sample is higher when the pore-water pressure is negative.	T	F
(v)	The angle of internal friction of clayey soil (ϕ) measured from consolidated undrained conditions(without measuring the pore-water pressures) is always lower than the angle internal friction (ϕ') for the same measured under consolidated drained conditions.	T	F

Question 2: **(10 marks)**
A saturated soil (i.e., **S = 100%**) in a container that is subjected to a total stress, σ is shown in **Figure 1**. The level of water in a stand pipe represents the pore-water pressure of the soil (i.e. hydrostatic pore-water pressure). What will be the effective stress if an additional stress, $\Delta\sigma$ is applied on top of the total stress σ under **i) undrained** and **ii) drained condition**? Show the results using the symbols, σ, $\Delta\sigma$, u_s (static pore-water pressure, u_e (excess pore-water pressure) and provide comments on the results.

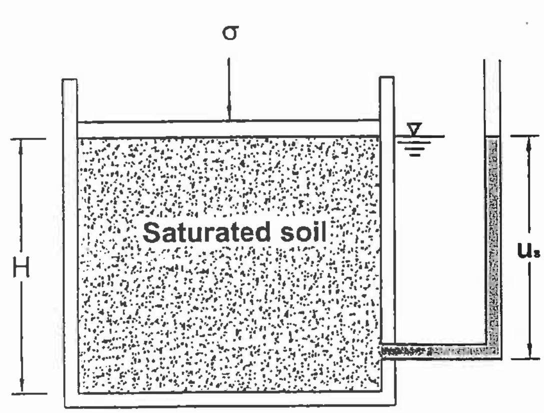


Figure 1

Question 3: **(10 marks)**
Explain possible reasons of soil liquefaction. Also, discuss why fine-grained soils are less susceptible to liquefaction in comparsion to sands.

SECTION B

ANSWER **ALL THREE** QUESTIONS

Question 4: **(Value: 20 marks)**
The following results (Table 1) were obtained from a standard compaction test on a soil ($G_s = 2.67$) in a laboratory.

Table. 1 Laboratory compaction test results

$w(\%)$	$\gamma_t (kN/m^3)$
6	15.70
8	18.80
9	20.20
11	21.00
12	20.70
14	19.30

(i) Plot the **dry unit weight against the water content** and determine the **maximum dry unit weight** and **optimum moisture content, OMC** (use the graph paper on page 5). **(8 Marks)**
(ii) Plot the zero-air-voids line and determine **air content (%)** at maximum dry density? **(7 Marks)**
(iii) A road is compacted a water content which is equal to the OMC using a roller. The γ_d estimated from balloon tests in field was 90 % of $\gamma_{d(max)}$ in comparison to the laboratory compaction test results. If this road was fully saturated by rain infiltration, what will be the amount of water percolated into the compacted road for $1 m^3$ of soil? (Neglect the volume change (i.e. void ratio) during infiltration). **(5Marks)**

Question 5: **(Value: 20 marks)**
For a cutoff wall shown in Figure 2
a. Establish the flow nets (i.e. flow and equipotential lines) following all the rules (Draw on Figure 2). **(10 marks)**
b. Determine the quantity of seepage (m^3/s per m) (coefficient of permeability, $k = 2.0 \times 10^{-5}$ m/s). **(5 marks)**
c. Calculate the effective stress point A (back of the piling) ($\gamma_{sat} = 20$ kN/m^3). **(5 marks)**

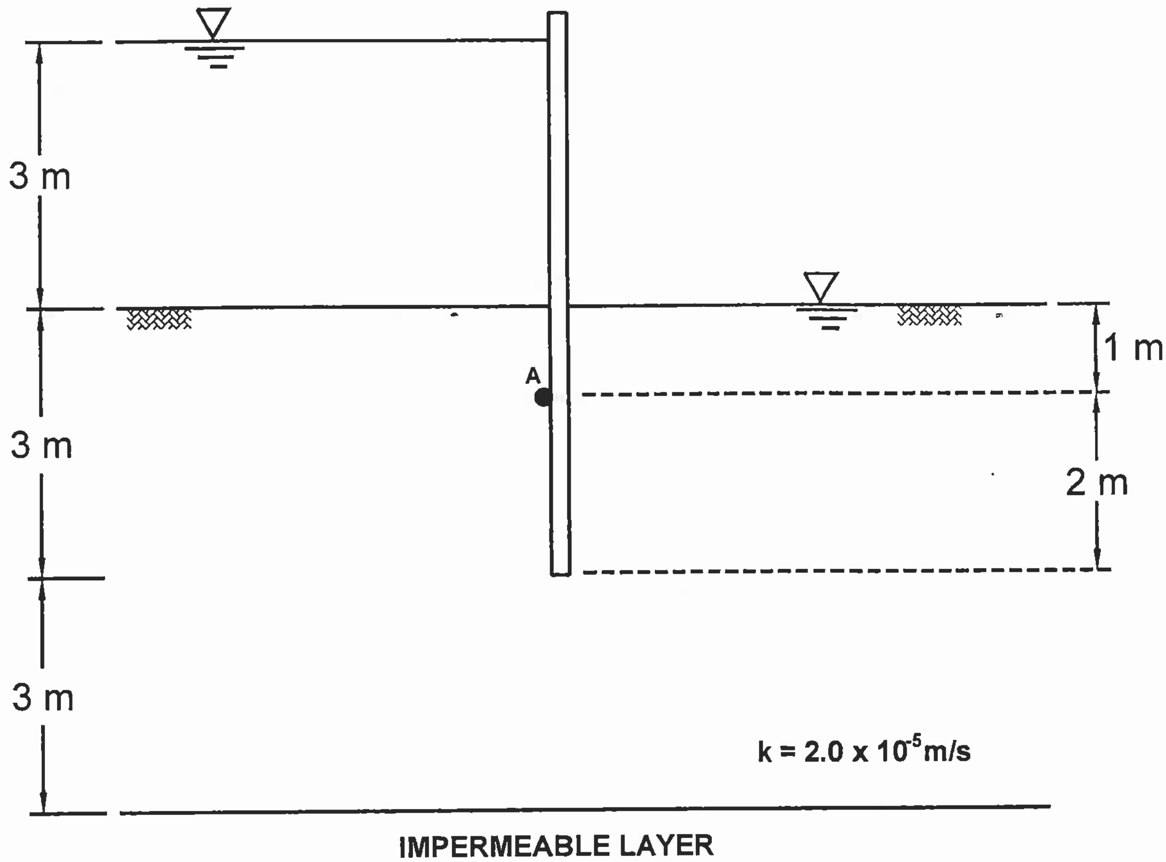


Figure 2

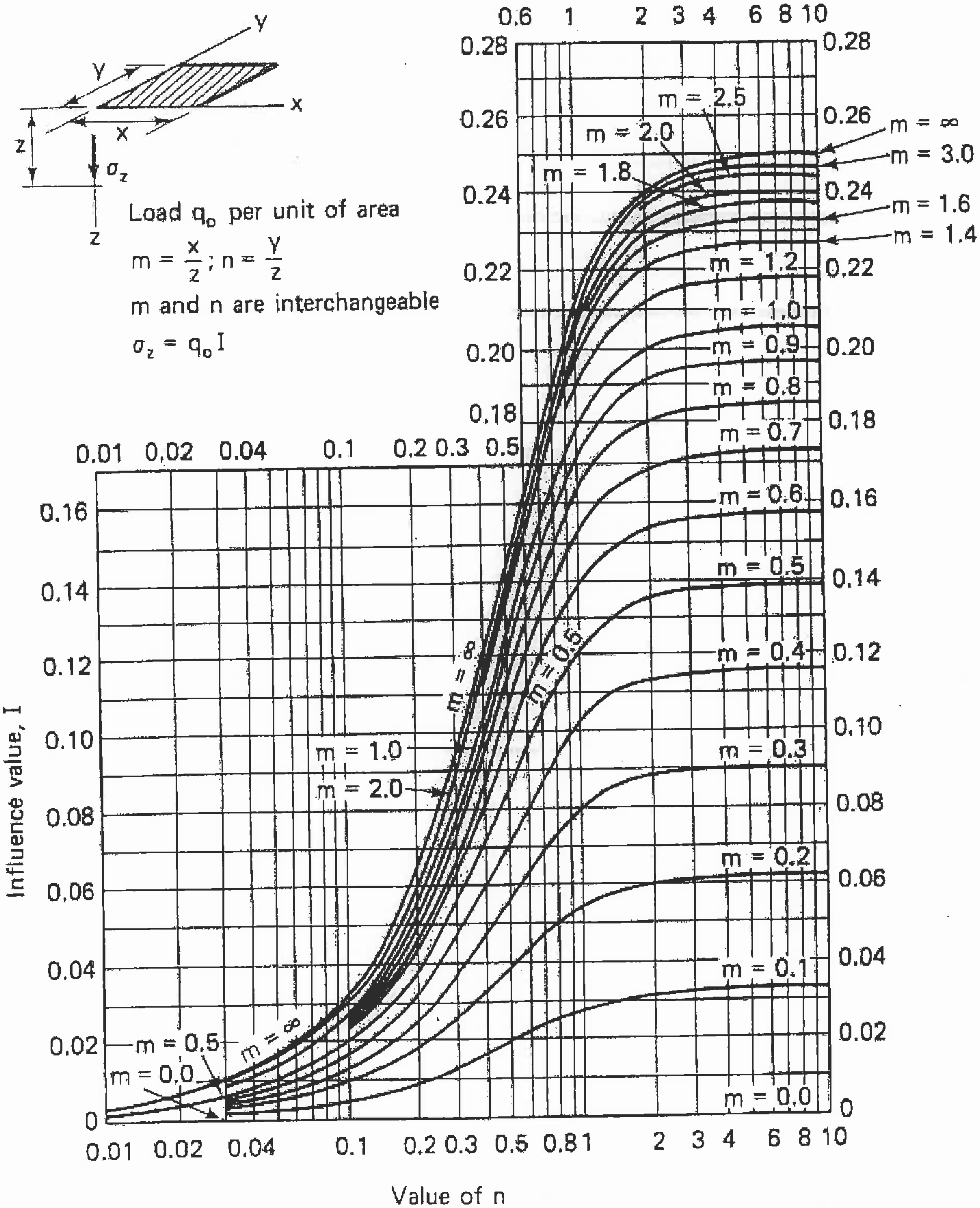
Question 6: **(Value: 20 marks)**

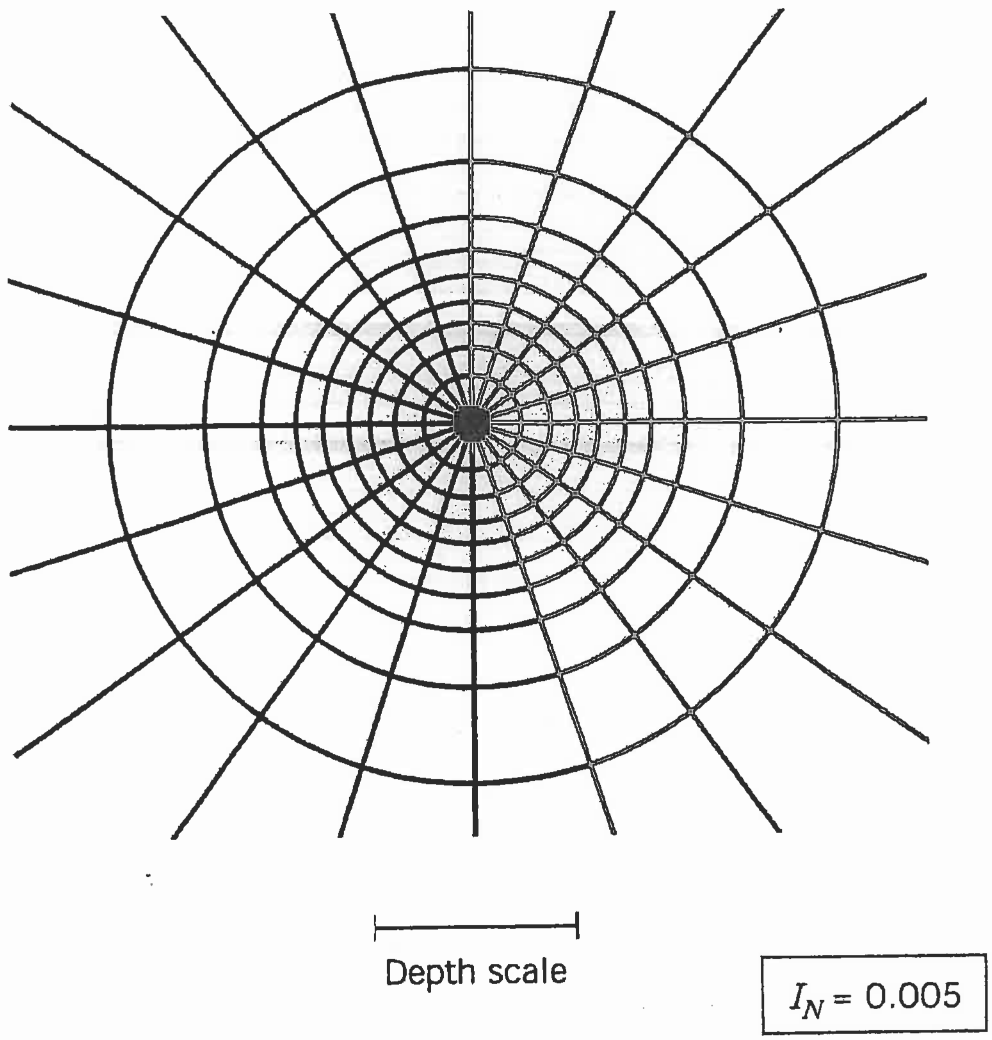
The following results were obtained at failure conditions in a series of **consolidated undrained** triaxial shear strength tests with pore water pressure measurements on fully saturated clay specimens. Determine cohesion, c' and angle of internal friction, ϕ' using two different methods, of which one should be an analytical method (i.e., using mathematical equations only and **NOT** a graphical solution).

Confining pressure, σ_3 (kPa)	Deviator stress, $(\sigma_1 - \sigma_3)$ (kPa)	Pore-water pressure, u (kPa)
150	100	80
300	200	170

If an earth dam is constructed using this clay, **can you use the shear strength parameters determined from these tests for evaluating the short term stability** of the structure. Give reasons.

(8+8+4 = 20 marks)


y
y
x
x
z
σ_z
z
Load q_o per unit of area
$m = \frac{x}{z}$; $n = \frac{y}{z}$
m and n are interchangeable
$\sigma_z = q_o I$
m = ∞
m = 3.0
m = 2.5
m = 2.0
m = 1.8
m = 1.6
m = 1.4
m = 1.2
m = 1.0
m = 0.9
m = 0.8
m = 0.7
m = 0.6
m = 0.5
m = 0.4
m = 0.3
m = 0.2
m = 0.1
m = 0.0
Influence value, I
Value of n


Depth scale
I_N = 0.005

Formula Sheet

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

$\sigma = \gamma D$

$P = \sum N' + u\,A$

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

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

$\sigma' = \sigma - u$

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

$v = ki$; where $i = h/L$; $q = kiA$; $\Delta h = \frac{h_w}{N_d}$

$q = k \cdot h_w \cdot \frac{N_f}{N_d}(width)$; $h_p = \frac{n_d}{N_d} h_w$

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, $\sigma_z = \frac{q\,B\,L}{(B+z)(L+z)}$

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

$\tau_f = c' + (\sigma - u_w)\tan\phi'$; $\sigma'_1 = \sigma'_3 \tan^2\left(45^o + \frac{\phi'}{2}\right) + 2c'\tan\left(45^o + \frac{\phi'}{2}\right)$

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* $c' = \frac{a}{\cos\phi'}$

$\frac{\Delta e}{\Delta H} = \frac{1+e_o}{H_o}$; $s_c = H\frac{C_c}{1+e_o}\log\frac{\sigma'_1}{\sigma'_o}$; $s_c = \mu\, s_{od}$; $m_v = \frac{\Delta e}{1+e}\left(\frac{1}{\Delta\sigma'}\right) = \frac{1}{1+e_o}\left(\frac{e_o - e_1}{\sigma'_1 - \sigma'_0}\right)$

$\frac{t_{lab}}{d_{lab}^2} = \frac{t_{field}}{(H_{field}/2)^2}$

$T_v = \frac{c_v t}{d^2}$; $T_v = \frac{\pi}{4} U^2$ (for U < 60%)

$T_v = -0.933 \log(1 - U) - 0.085$ (for U > 60%)

$C_c = \frac{e_o - e_1}{\log\left(\frac{\sigma_1'}{\sigma_0}\right)}$; also, $C_c = 0.009(LL - 10)$;