PROFESSIONAL ENGINEERS ONTARIO
NATIONAL EXAMINATIONS –May 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 questions in SECTION A ....Total 40 marks
   Three out of four questions in 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. YOU MUST RETURN ALL EXAMINATION SHEETS.

SECTION A
ANSWER ALL 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 submerged density, γ_{sub} (or γ') can be lower than the unit weight of water, γ_w	T	F
(ii)	The liquid limit of a soil cannot be greater than 100%.	T	F
(iii)	A well graded soil has a higher coefficient of permeability than a poorly graded (or uniform) soil.	T	F
(iv)	The pore-water pressure in a normally consolidated clay sample is always positive.	T	F
(v)	The triaxial shear test apparatus is a versatile equipment and can be used for determining the shear strength of soils under different loading conditions for all soils including sands and clays (i.e., UU, CU and CD conditions).	T	F

Question 2: **(10 marks)**

A highly expansive clay was tested in the laboratory and found to have the following properties:(a) Bulk density, ρ = 1.28 Mg/m^3 (b) Void ratio, e = 9.0 (c) Density of soil solids, ρ_s = 2.75 Mg/m^3 (d) Degree of saturation, S = 95% and (e) water content, w = 311%.

In rechecking the above values, one was found to be inconsistent with the remainder of the data. Find the inconsistent value and report it correctly.

Question 3: **(10 marks)**

Define the critical hydraulic gradient. What is its significance in the design of soil structures that retain water. Suggest what design measures you would take to counter the negative effects of hydraulic gradient in soil structures. Supplement your answer with sketches if necessary.

SECTION B

ANSWER **ANY THREE** OF THE FOLLOWING FOUR QUESTIONS

Question 4: **(Value: 20 marks)**

The flow net for seepage through the foundation soil under a concrete dam is shown below in **Figure 1**.

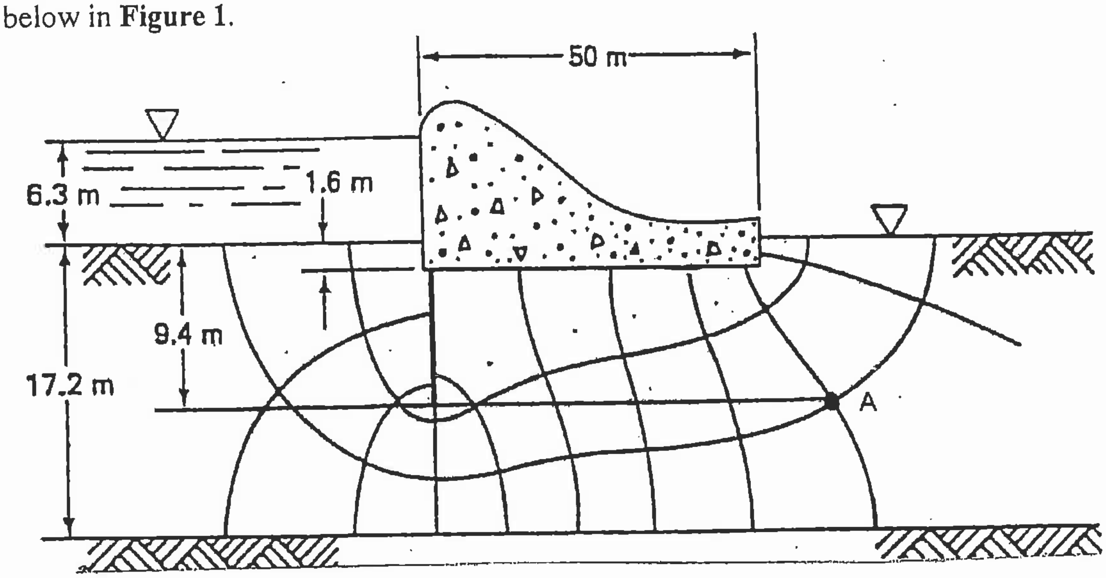


Figure 1

(i) Determine the total seepage through the foundation soil in cubic meters per day per meter of dam, if the coefficient of permeability for the foundation soil is 25 x 10^{-6} m/s

(ii) Calculate the effective stress at point *A* if the total unit weight of the soil is 20 kN/m^3.

(iii) Calculate the maximum exit gradient. If this gradient is assumed to be greater than the crtical hydraulic gradient, what effect could it have on the dam?

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

(i) What are common assumptions and limitations of elastic theories? Draw the typical variation of vertical stress with depth and variation of vertical stress with horizontal distance at three different depths due to a point load. **(6 marks)**

(ii) The foundation shown in **Figure 2** is loaded to an intensity of 100 kPa. Determine the increase in vertical stress that occurs at a depth of 4 m below point *A* in accordance with the Boussinesq elastic theory. Use any two methods, one of which must be a Newmark's chart method. Compare the results.

(14 marks)

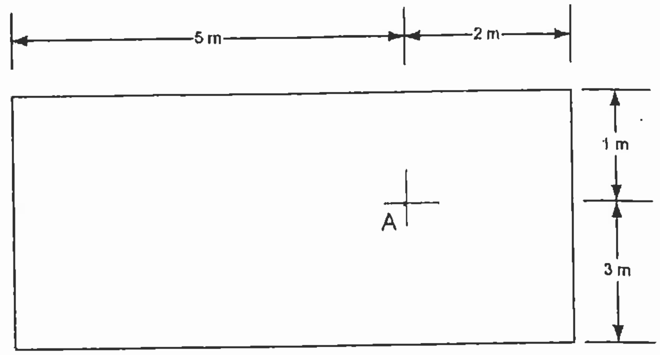


Figure 2

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

The results in **Table 1** given below were obtained at failure conditions in a series of consolidated-undrained triaxial tests with pore water pressure measurements on fully saturated clay specimens. Determine the effective shear strength parameters for the tested soil. If a specimen of the same soil were consolidated under a confining stress of 250 kPa, what would be the expected value of the principal stress difference at failure?

Table 1

Confining stress, σ_3 (kPa)	Deviator stress, $(\sigma_1 - \sigma_3)$ kPa	Pore-water stress, u (kPa)
150	103	82
300	202	169
450	305	252

Answer the questions given below based on the results you have obtained:

(i) Is the clay normally consolidated or over consolidated? Give reasons.

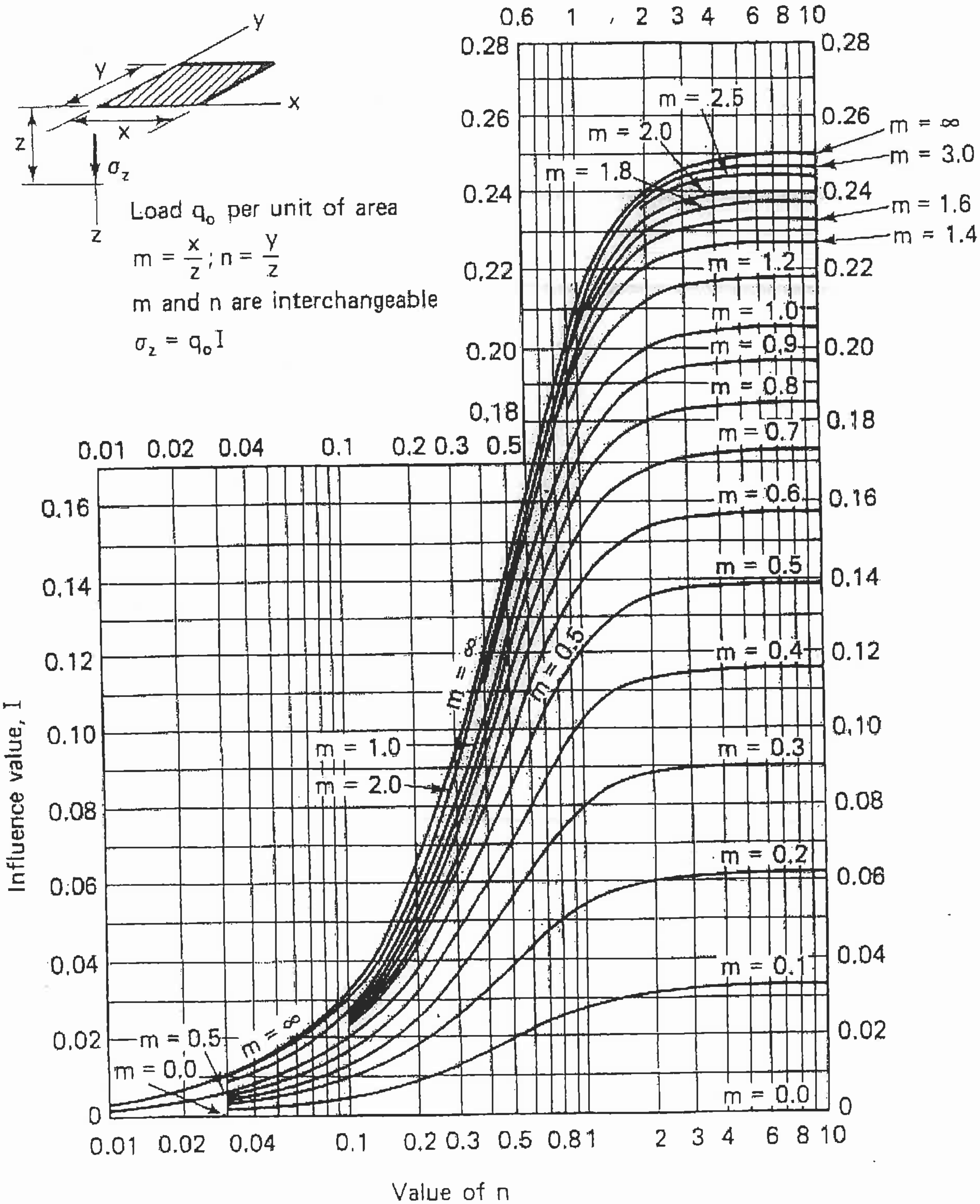
(ii) If an earth dam is constructed using this clay, can you use the above shear strength parameters to determine the long term stability of the structure. Give reasons.

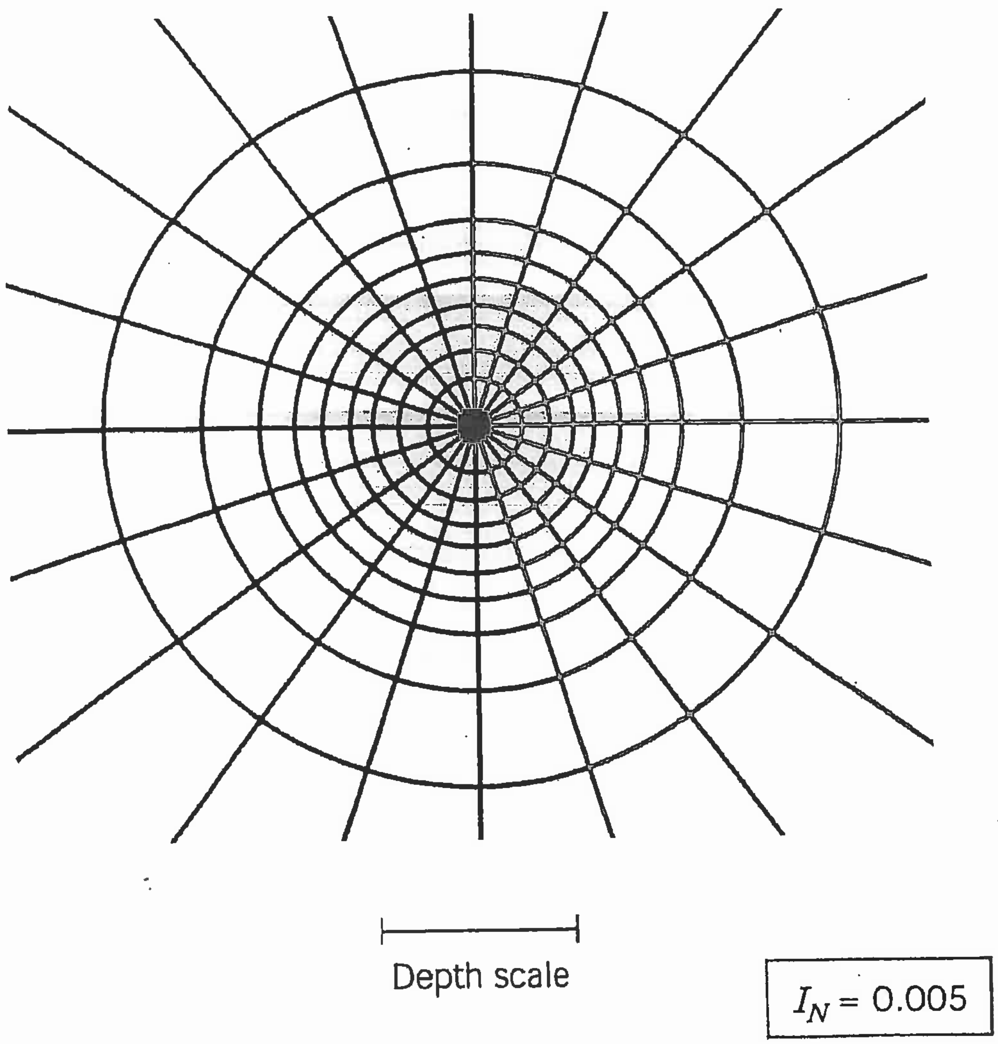
Question 7: **(Value: 20 marks)**

A site investigation for a large excavation revealed that 10 m of uniform clay overlay 3 m of sand resting on bedrock. The water level in the clay was at ground level and the piezometric head for the sand was 2 m above the top of the clay. The unit weights of the clay and sand were 20 kN/m^3 and 21 kN/m^3 respectively.

(i) Cacluate the hydraulic gradient across the clay and draw the profile of total and effective stresses and pore water pressure down to the bedrock.

(ii) Calculate the depth to which an excavation can be taken before ground heave failure occurs.


Load q_o per unit of area
$m = \frac{x}{z}$; $n = \frac{y}{z}$
m and n are interchangeable
$\sigma_z = q_o I$
Influence value, I
Value of n
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


Depth scale
$I_N = 0.005$

Formula Sheet

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

$\sigma = \gamma D$

$P = \sum N' + uA$

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

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

$\sigma' = \sigma - u$

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

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

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

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

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

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

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

$T_v = \frac{c_v t}{d^2}$; $T_v = \frac{\pi}{4} U^2$ (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, $C_c = 0.009(LL - 10)$;