PROFESSIONAL ENGINEERS ONTARIO
NATIONAL EXAMINATIONS –May 2014
GEOTECHNICAL MATERIALS AND ANALYSIS

3 HOURS DURATION

NOTES:

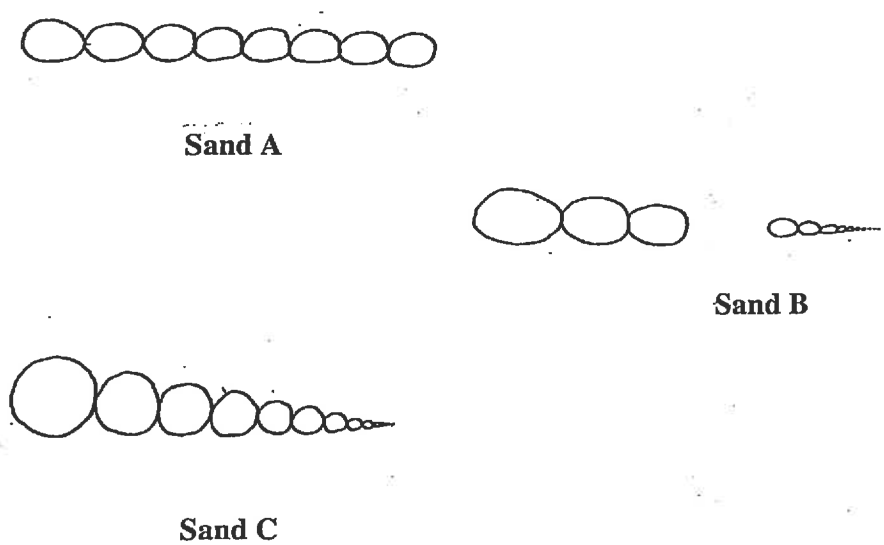
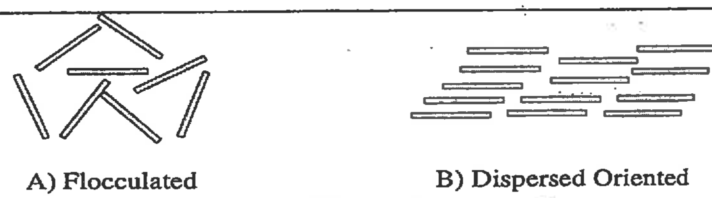
1. This is a **closed book** examination.
2. Read all questions carefully before you answer
3. Should you have any doubt regarding the interpretation of a question, you are encouraged to complete the question submitting a clear statement of your assumptions.
4. The total exam value is 100 marks
5. One of two calculators can be used: Casio or Sharp approved models.
6. Drawing instruments are required.
7. All required charts and equations are provided at the back of the examination.
8. YOU MUST RETURN ALL EXAMINATION SHEETS.

NATIONAL EXAMINATIONS –May 2014
GEOTECHNICAL MATERIALS AND ANALYSIS

ANSWER ALL QUESTIONS

Question 1: **(4 x 5 = 20 marks)**

State the correct answer for each of the questions below and provide reasons to **JUSTIFY THE STATEMENT IN YOUR ANSWER BOOK.**

(i)	Which one of the following sandy soils; **Sand A** with coefficient of uniformity, C_u = 4 or **Sand B** with C_u = 1 would have a greater shear strength.
(ii)	Which one of the following sandy soils (shown in **Figure 1** below); **Sand A, Sand B or Sand C** will have a lower coefficient of permeability.  **Figure 1**
(iii)	Which one of the soils GW, ML or CH will have a higher dry density and also a higher optimum moisture content?
(iv)	Which one of the following soils would have a higher effective angle of internal friction (ϕ') determined from consolidated drained triaxial shear tests: **Soil A:** Expansive clay; **Soil B:** Glacial till; **Soil C:** Silt; **Soil D:** Sand
(v)	 **Figure 2** A compacted fine-grained soil will typically have either a flocculated or dispersed structure as shown in Figure 2, based on the initial water content used for compaction. What type of soil structure will be created in fine-grained clay when it is compacted wet of optimum conditions?

NATIONAL EXAMINATIONS –May 2014
GEOTECHNICAL MATERIALS AND ANALYSIS

Question 2: **(10 marks)**

Briefly explain the three different "limit" lateral earth pressures (i.e., at-rest, active, and passive conditions) that can act on a retaining wall. Also, show the Mohr circle for each condition (Note: You are expected to draw simple sketches of retaining walls and Mohr failure envelopes for the three cases; **Figure 3** is shown below as an example without providing the key details).

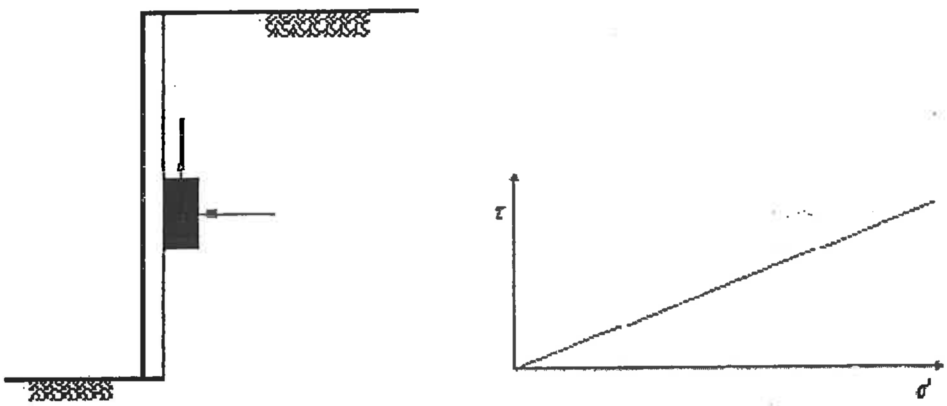


Figure 3

Question 3: **(10 marks)**

Laboratory tests on a 40-mm-thick clay specimen drained at the top only shows that 50% consolidation takes place in 18 min.

(i) How long will it take for a layer of the same clay in the field, 4 m thick and drained at the top and bottom, to undergo 50 % consolidation?

(ii) Find the time required for the clay layer in the field, as described in part (i), to reach 80 % consolidation.

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

A footing as shown in **Figure 4** (shaded area only) is loaded to a uniform intensity of 100 kPa. Determine the increase in vertical stress that occurs at a depth of 2.0 m below point *A* using Newmark's chart. Also, determine the increase in vertical stress using any another suitable method. Comment on the results that you have obtained using these two methods.

NATIONAL EXAMINATIONS –May 2014
GEOTECHNICAL MATERIALS AND ANALYSIS

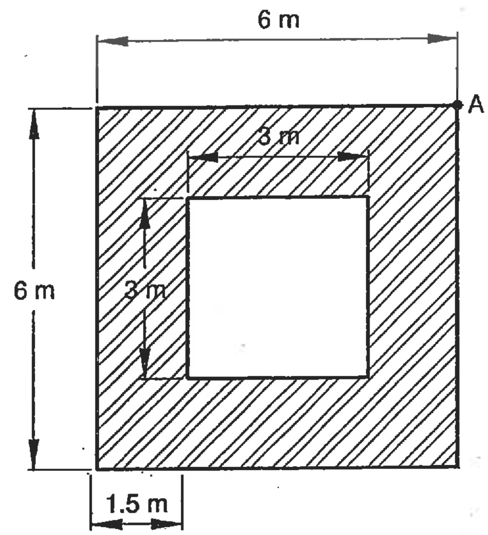


Figure 4

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

A dam, shown in **Figure 5** retains 10 m of water. A sheet pile wall (cutoff curtain) on the upstream side, which is used to reduce seepage under the dam, penetrates 7 m into a 20 m thick silty sand stratum. Below the silty sand is a thick deposit of clay. The average coefficient of permeability of the silty sand is 2.0 x 10^{-4} cm/sec. Assume that the silty sand is homogeneous and isotropic.

(i) Draw the **flow net** under the dam.

(ii) Calculate the **seepage rate,** ***q*** per meter length of the sheet pile.

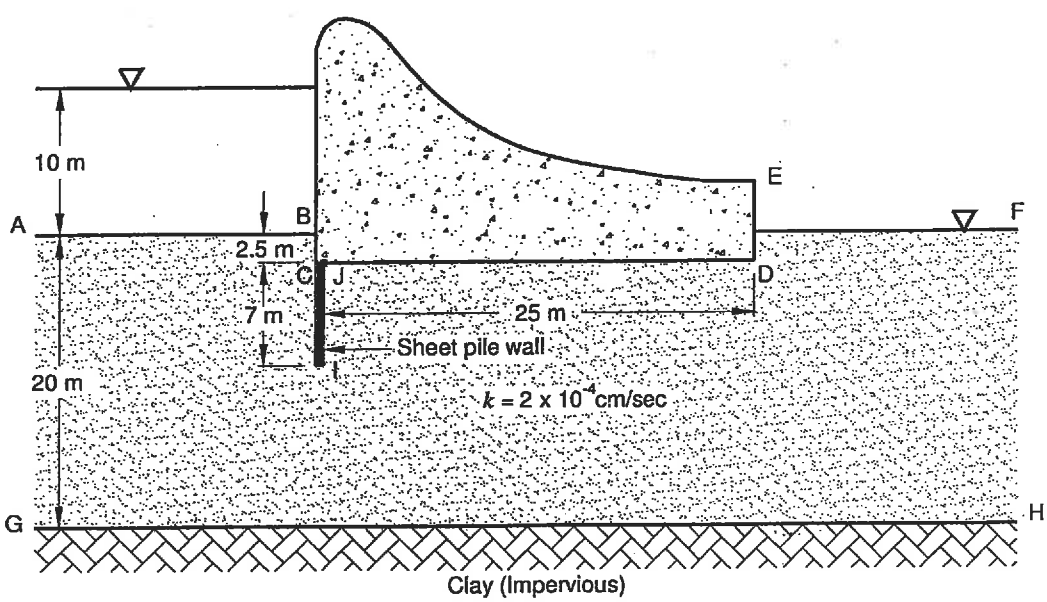


Figure 5

NATIONAL EXAMINATIONS –May 2014
GEOTECHNICAL MATERIALS AND ANALYSIS

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

(a) The following results were obtained at failure conditions in a series of **consolidated undrained** (*CU*) triaxial shear strength tests with pore water pressure measurements on fully saturated clay specimens. Determine the values of the shear strength parameters *c'* and ϕ' by plotting a **modified failure envelope**.

Confining pressure, σ_3 (kPa)	Deviator stress, $(\sigma_1 - \sigma_3)$ (kPa)	Pore-water pressure, u (kPa)
150	100	80
300	200	160
600	400	320

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

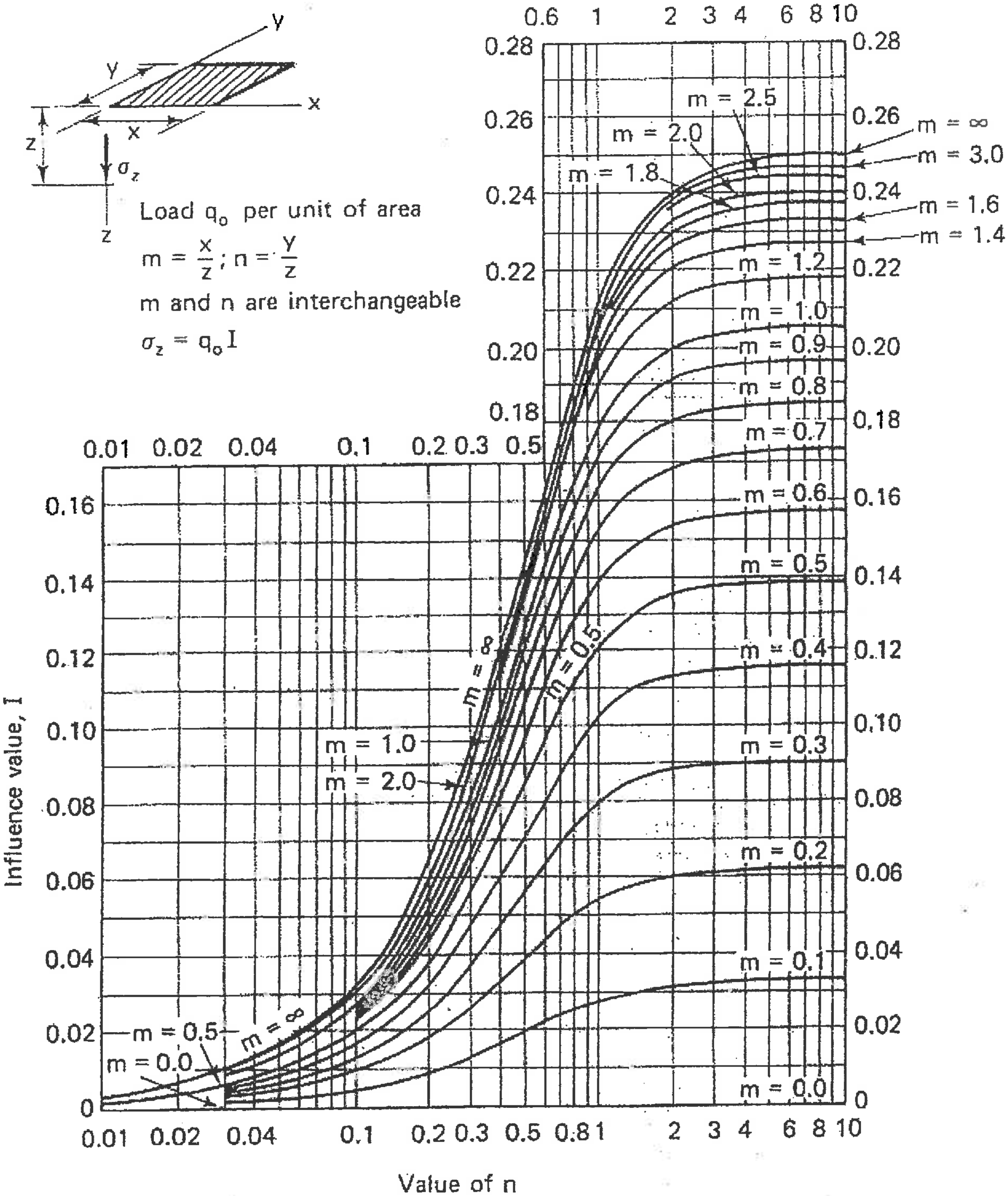
(i) What is the **advantage** of plotting the **modified failure envelope** instead of **Mohr's envelope** to determine the shear strength parameters?

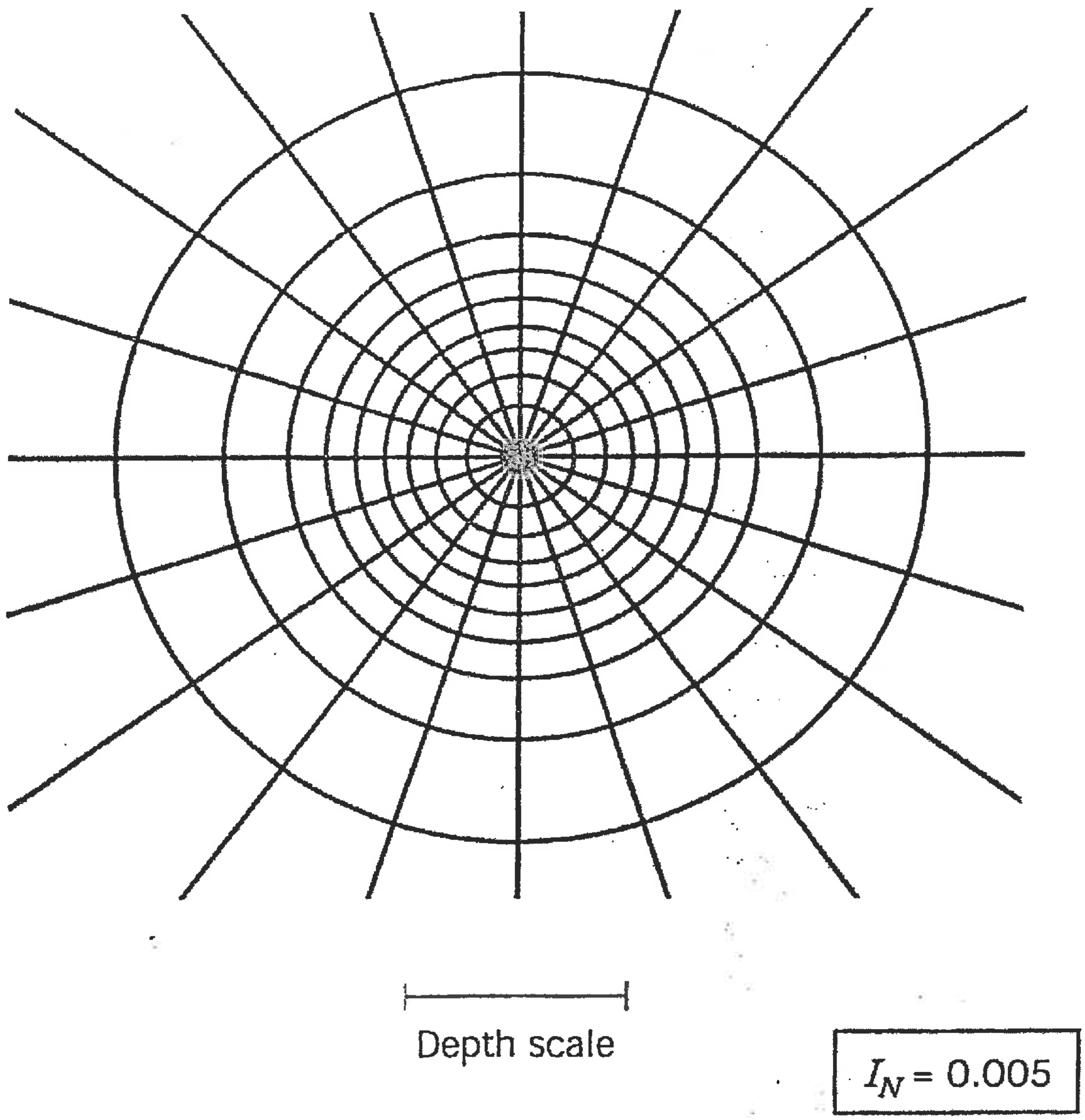
(ii) Is the tested clay **normally consolidated or over consolidated**? Give reasons.

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

(8+8+4 = 20 marks)

NATIONAL EXAMINATIONS –May 2014
GEOTECHNICAL MATERIALS AND ANALYSIS




Depth scale
$I_N = 0.005$

NATIONAL EXAMINATIONS –May 2014
GEOTECHNICAL MATERIALS AND ANALYSIS

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

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

$\frac{\Delta e}{\Delta H} = \frac{1+e_o}{H_o}$; $s_c = H\frac{C_c}{1+e_o}\log\frac{\sigma'_1}{\sigma_o}$; $s_c = \mu s_{od}$; $m_v = \frac{\Delta e}{1+e}\left(\frac{1}{\Delta\sigma'}\right) = \frac{1}{1+e_o}\left(\frac{e_o - e_1}{\sigma_1' - \sigma_0'}\right)$

NATIONAL EXAMINATIONS –May 2014
GEOTECHNICAL MATERIALS AND ANALYSIS

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

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

$$T_v = -0.933\log\left(1-U\right) - 0.085 \text{ (for U > 60\%)}$$

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