PROFESSIONAL ENGINEERS ONTARIO
NATIONAL EXAMINATIONS –December 2019
16-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 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.

ANSWER ALL QUESTIONS

Question 1:

(10 marks)

1	Which one of these soils has a higher optimum moisture content: (A) gravel (B) sand (C) silt (D) clay
2	The optimum moisture content of a soil is close to the soil's: (A) Shrinkage limit (B) Plastic limit (C) Liquid limit (D) Plasticity index
3	One of the following soil properties increases due to the compaction of soils (A) Shear strength (B) Coefficient of permeability (C) Consolidation (D) All of the above
4	Which one of these soils will have a maximum dry density at optimum moisture content determined from Proctors compaction test: (A) gravel (B) sand (C) silt (D) clay
5	The settlement in saturated clays are mainly attributed to (A) Deformation of soil grains (B) Compression of water within the voids (C) Expulsion of water from within the voids (D) Expulsion of soil grains
6	The stress versus strain behavior of a normally consolidated clay is similar to that of a loose sand. (A) True (B) False (C) There is no similarity between stress versus strain behavior of normally consolidated clay and loose sand

7	Which one of these soils will have a higher coefficient of permeability when it is compacted at optimum moisture content to achieve maximum dry density: (A) Gravel (B) Sand (C) Silt (D) Clay
8	Which of the following statements is / are INCORRECT: (A) Overconsolidated clay generally has an effective cohesion greater than zero (B) Pore-water pressure can be negative in an over consolidated clay when it is subjected to a loading lower than its preconsolidation pressure. (C) Volume change in a overconsolidated clay with a pre-consolidation pressure of 200 kPa is lower than in an normally consolidated when it is subjected to a loading of 100 kPa.is typically (D) Coefficient of permeability of an over consolidated clay is typically greater than that of normally consolidated clay.
9	Which of the below is / are NOT one of the assumption(s) in the 1-D consolidation theory proposed by Terzaghi? (A) Homogeneous and 100% saturation (B) The coefficient of volume change, m_v and coefficient of permeability, k vary with respect to the effective stress (C) Drainage at both the top and bottom of the compressible layer (D) Soil grains and water are incompressible (E) Unique relationship between the volume change and effective stress
10	Which one of the tests can be used to be determine the undrained shear strength of sandy soil? (A) Consolidated undrained triaxial test (B) Vane shear test (C) Unconfined compression test (D) None of the above

Question 2: **(10 marks)**

State the correct answer in your ANSWER BOOK along with the Question number and explain the reason **for your answer**. Have all your answers for **Question 2** at one place. No mark will be awarded if reason is not provided.

PS: Some questions are not multiple choice questions. You have to answer those questions providing a short discussion.

1	Which one of the following sandy soils (shown in **Figure 1** below); **Sand A or Sand B** will have a higher saturated coefficient of permeability. Give reasons.  Sand A  Sand B **Figure 1**
2	Which one of the two samples: **C** (normally consolidated clay) or **D** (over consolidated clay with an ***OCR*** of 2) will exhibit greater peak strength for consolidated undrained tests (i.e., ***CU***) test on saturated clay: (i) Sample **C** (normally consolidated clay) (ii) Sample **D** (over consolidated clay with an OCR of 2) (iii) Both of them will be the same
3	Samples **E** and **F** are collected from the same site (i.e., they are identical samples – sand) and tested under **CU** and **CD** conditions in a triaxial test. Which one of the statements below is true? Give your reasons. (i) Sample **E** has a higher shear strength (ii) Sample **F** has a higher shear strength (iii) Both of them have approximately the same shear strength
4	In a **CD** test on saturated dense sand the sample volume during shear (i) increases (ii) remains unchanged (iii) reduces
5	Assume you are swimming in a pool at an elevation of 1 m below from the top surface of water. One of the following statements is true. **Choose the correct statement and justify using effective stress equation.** (i) The total stress is equal to pore-water pressure (ii) The effective stress is equal to pore-water pressure (iii) There is no pore-water pressure as there are no pores in water. (iv) None of the above are correct

Question 3: **(Value: 20 marks)**

A building shown in **Figure 2** is subjected to a loading of 100 kPa. Determine the vertical stress increase, $\Delta\sigma$, at a depth z = 3m below the base of the foundation under:

(i) point **B** using m and n coefficients method, and
(ii) point **A** using Newmark's method
(iii) What are the advantages and disadvantages of these two methods?

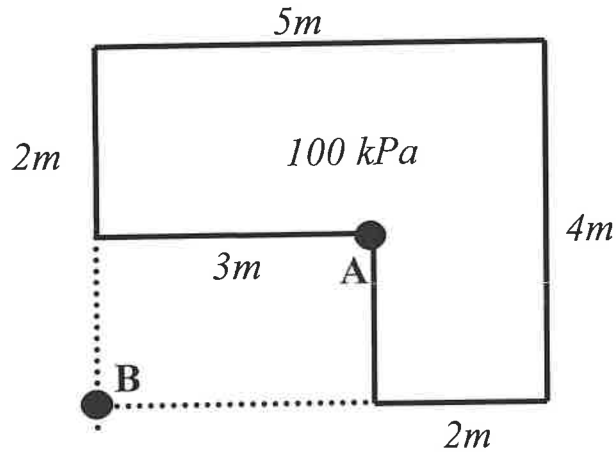


Figure 2

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

(a) Explain one-dimensional consolidation behavior with particular reference to the effective stress principle using the spring analogy model shown in **Figure 3** given below. **(5 marks)**

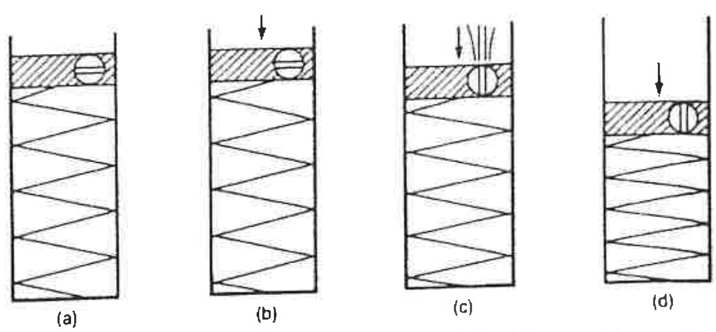


Figure 3: Consolidation analogy model

(b) What type of tests and equipment do you recommend to determine the shear strength parameters for loading shown in **Figure 3** for **(b)**? You may assume the spring in the **Figure 3** represents a normally consolidated clay. Note that the valve is closed in **(b)** and open in **(d)**. Also, **draw** typical **shear strength envelope** for the loading in **(b)**.

Question 5: **(Value: 15 marks)**

The coordinates of two points on a virgin compression curve (i.e., results obtained from a consolidation test) are as follows:

$e_1 = 0.8,\ \sigma'_1 = 200\ kN/m^2$

$e_2 = 0.5,\ \sigma'_2 = 400\ kN/m^2$

(i) Determine the coefficient of volume compressibility, m_v for the pressure range stated above.

(ii) Given the coefficient of consolidation, $c_v = 0.003\ cm^2/sec$, determine the coefficient of permeability, k in cm/sec corresponding to the average void ratio.

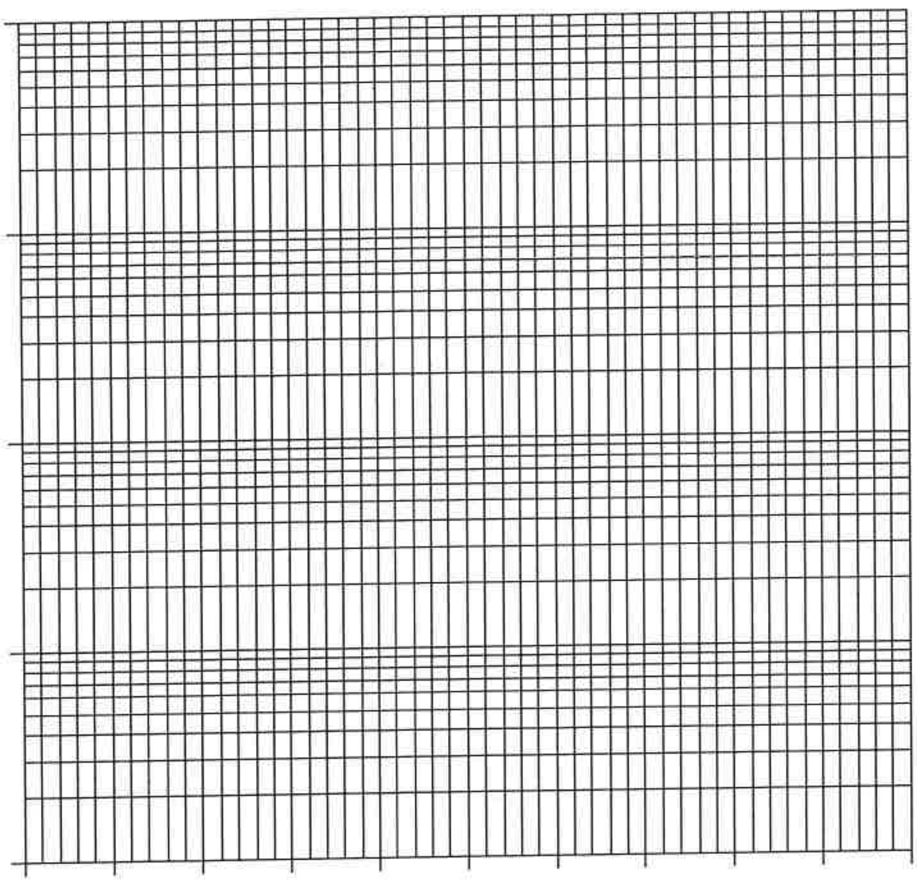
(iii) What would be the effective pressure, σ' corresponding to e = 0.65?

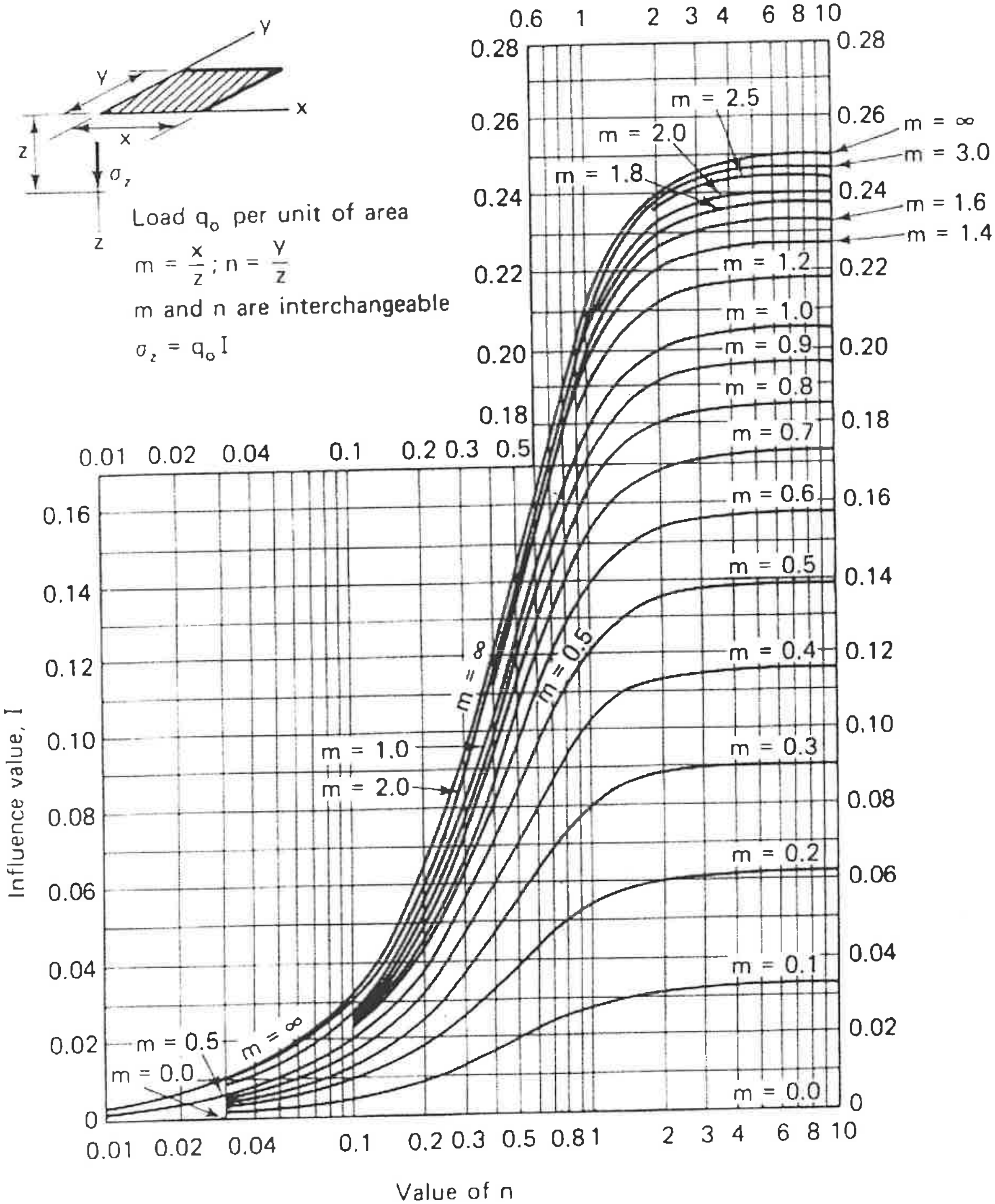
(20 marks)

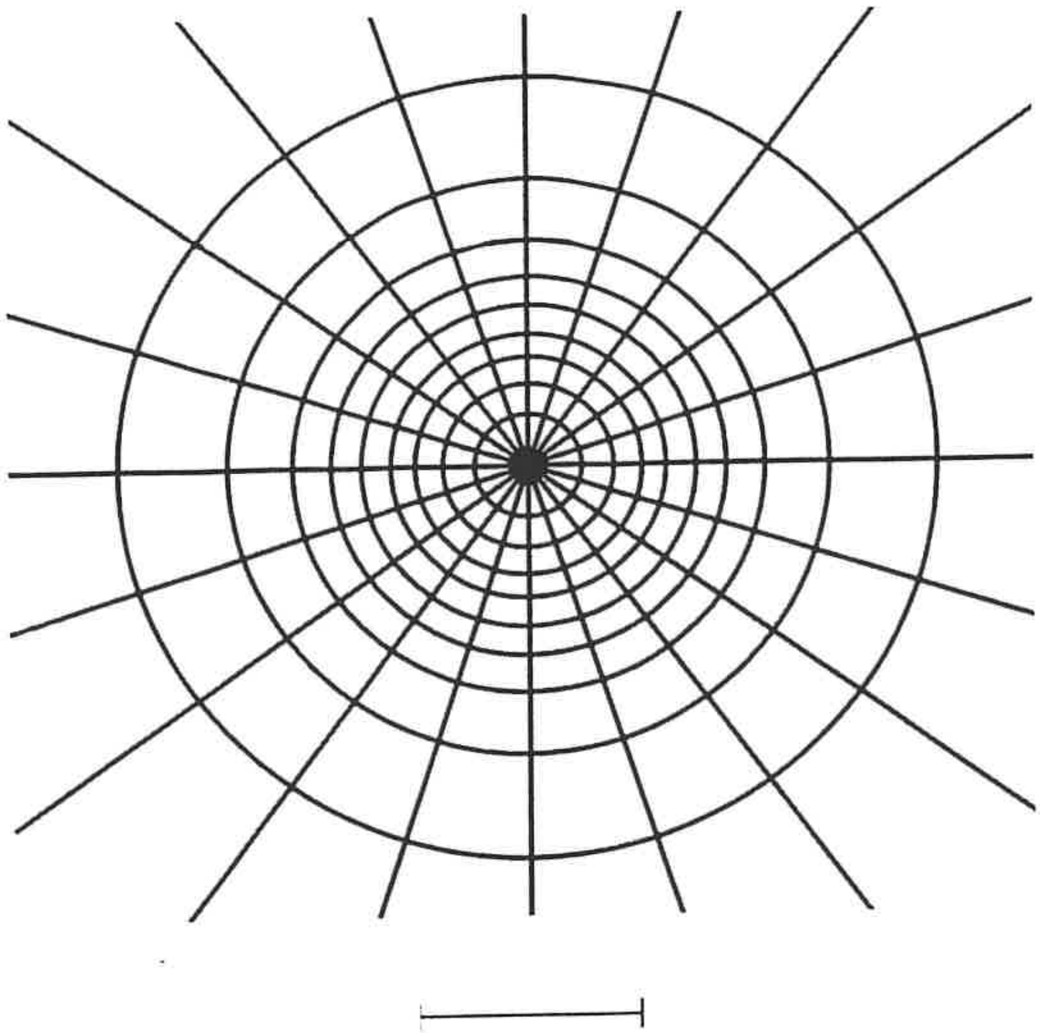
Question 6: **(Value: 30 marks)**

The results presented in the table on the right were obtained from two drained triaxial tests on a saturated clay at failure. Calculate the shear strength parameters of the soil analytically. Also, draw Mohr's circles to verify your results.

	Specimen 1	Specimen 2
Chamber confining Pressure (kN/m^2)	100	200
Deviator stress at failure (kN/m^2)	269	469




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

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

$\sigma = \gamma D$

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

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

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

$\sigma' = \sigma - u$

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

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

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

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

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

$\tau_f = c' + (\sigma - u_w)\tan\phi'$; $\quad \sigma_1' = \sigma_3' \tan^2\left(45^o + \dfrac{\phi'}{2}\right) + 2c'\tan\left(45^o + \dfrac{\phi'}{2}\right)$

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

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

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

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

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

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