PROFESSIONAL ENGINEERS ONTARIO
NATIONAL EXAMINATIONS December 2015
98-CIV-A4 GEOTECHNICAL MATERIALS AND ANALYSIS

3 HOURS DURATION

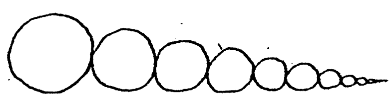
NOTES:

1. This is a **closed book** examination.
2. Read all questions carefully before you answer
3. Should you have any doubt 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: **(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**. You will NOT receive any marks unless you provide your justification.

(i)	The zero-air voids line is: (a) Typically above the compaction curve and can be plotted without conducting any compaction tests. (b) Can be above or below the compaction curve and has to determined conducting compaction tests
(ii)	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**
(iii)	Which one of the soils **(a)** GW; **(b)** CH will typically have a higher angle of internal friction?
(iv)	Which one of the following soils would have a higher swelling index, C_s: **Soil A:** Silty clay; **Soil B:** Expansive clay
(v)	The shear deformation-related positive pore-water pressures are typically higher in (a) Normally consolidated clays (b) Over-consolidated clays.

Question 2: **(10 marks)**

An earth dam of 10 m high is to be constructed on a saturated normally consolidated clay deposit which extends to a great depth. What type of tests do you propose to conduct for determining the reliable shear strength parameters for design of the dam? Also, what type of samples would you suggest be collected for conducting these tests? Give reasons.

Question 3: **(10 marks)**

A layer of clay 4 m thick lies between two layers of sand each 4 m thick, the top of the upper layer of sand being ground level. The water table is 2 m below ground level but the lower layer of sand is under artesian pressure, the piezometric surface being 4 m above ground level. The saturated unit weight of the clay is 20 kN/m^3 and that of the sand is 19 kN/m^3: above the water table the unit weight of the sand is 16.5 kN/m^3. Calculate the effective vertical stresses at the top and bottom of the clay layer.

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

A footing as shown in **Figure 2** (shaded area only) is loaded to a uniform intensity of 100 kPa.

(i) 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.

(ii) Will the vertical stress increase or decrease at 4.0 and 6.00 depth for the same loading? Provide your answer as a discussion without any calculations.

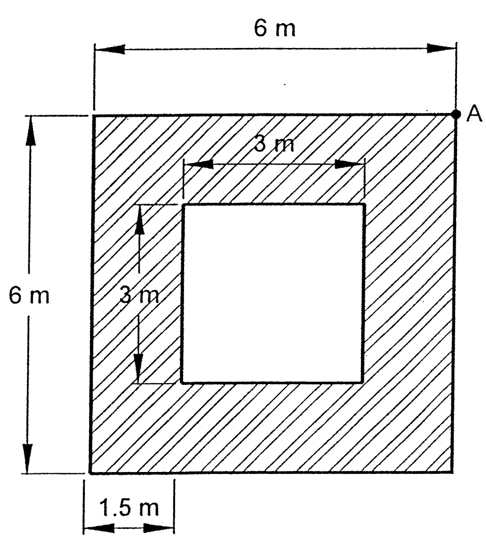


Figure 2

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 3. What should be the height of the water, *h*, in the cut so that **the stability of the saturated clay is not lost?**

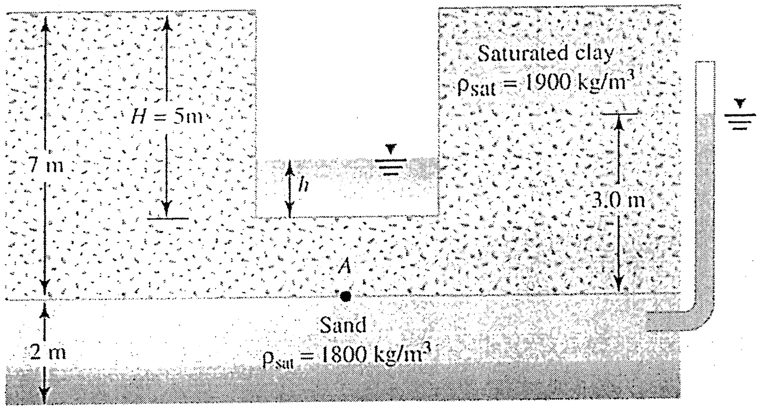


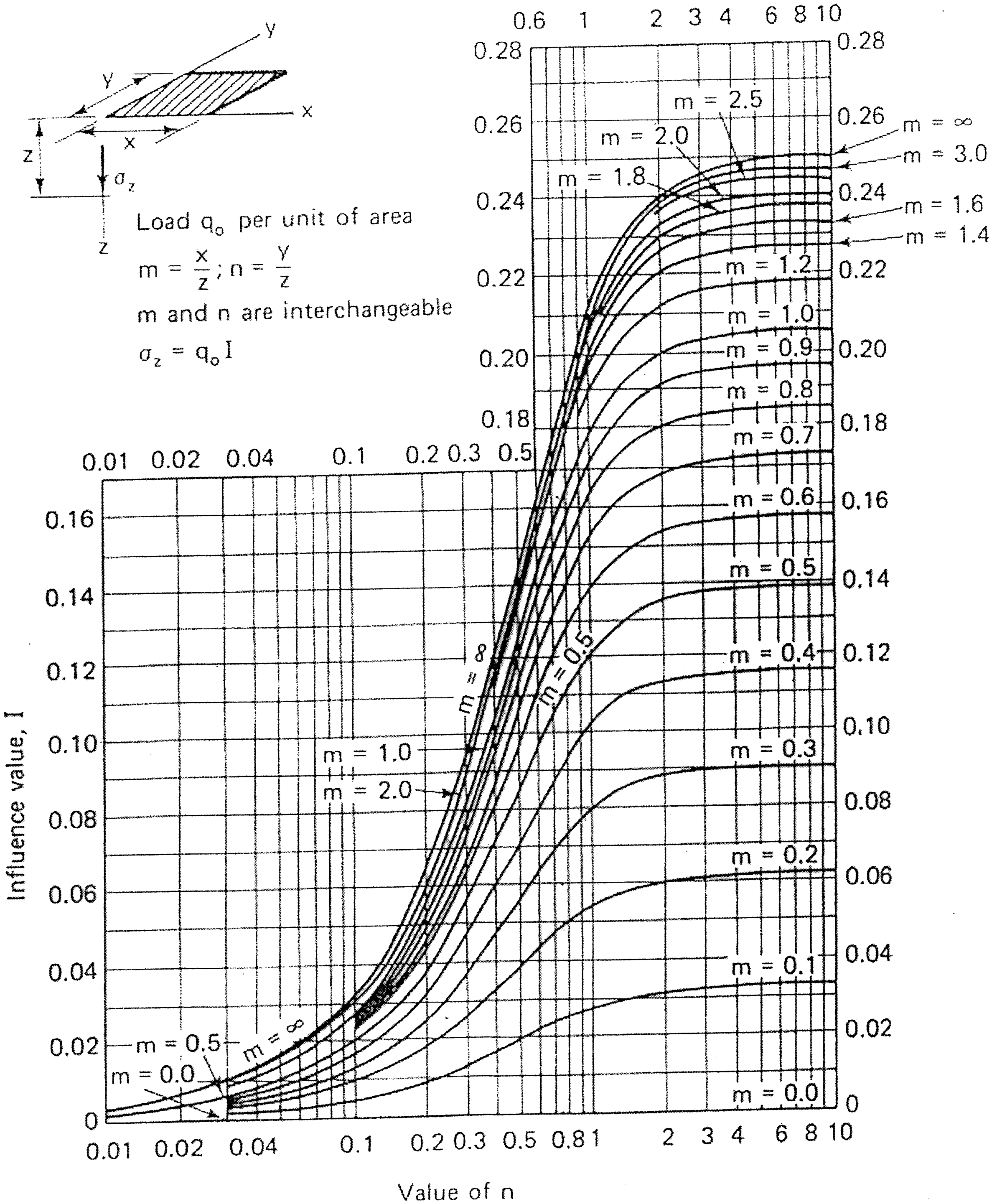
Figure 2

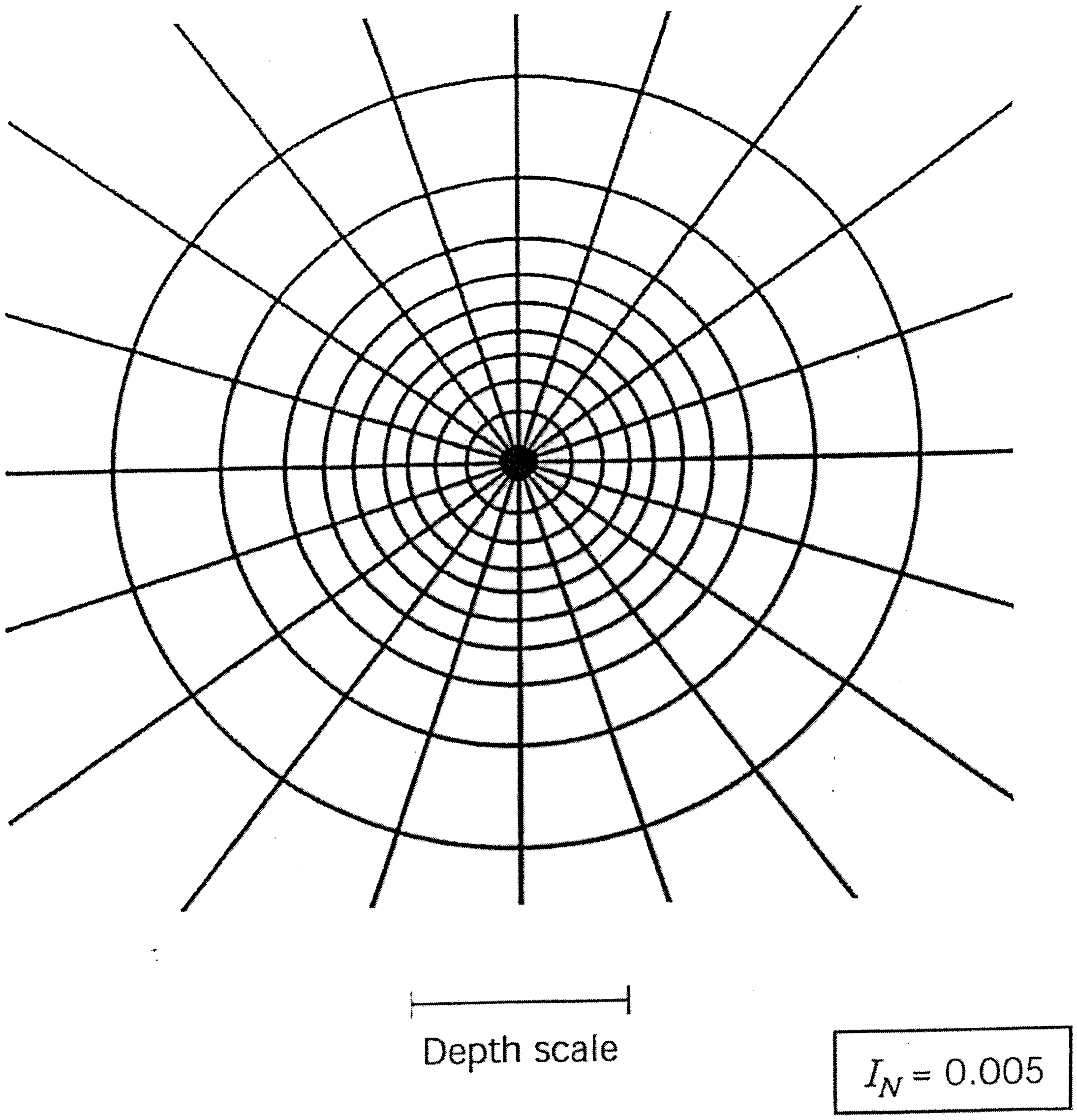
Question 6: **(Value: 20 marks)**

An embankment (ρ = *1.7 Mg/m³*) is being constructed on 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 $A = 0.2$ and $B = 0.98$. Find the undrained 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 increase at any point is one half of the vertical pressure increase.

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

Is this soil normally consolidated or over consolidate? Provide your reasons.


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
$\sigma_z = q_o I$
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
0.01 0.02 0.04 0.1 0.2 0.3 0.5 0.8 1 2 3 4 6 8 10
0.6 1 2 3 4 6 8 10
0 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28


Depth scale
$I_N = 0.005$

Formula Sheet

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

$\sigma = \gamma D$

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

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

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

$\sigma' = \sigma - u$

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

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

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

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: $\sigma_z = 0.005\,N\,q$

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

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

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

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

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

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

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