PROFESSIONAL ENGINEERS ONTARIO
NATIONAL EXAMINATIONS –May 2013
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. 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.

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

State the correct answer. Also, provide reasons to **JUSTIFY THE STATEMENT PROVIDING YOUR JUSTIFICATION IN YOUR ANSWER BOOK** along with the question number.

(i)	The dry density of sandy soils at optimum moisture content (*OMC*) is typically higher than clayey soils; however, the *OMC* of sandy soils is lower.	T	F
(ii)	The plasticity index, I_p, value for bentonite is typically greater than for sandy clay.	T	F
(iii)	An earth dam of 5 m height placed over a normally-consolidated clay of 5 m thickness settles more in comparison to one on an over-consolidated clay of 5 m thickness.	T	F
(iv)	The angle of internal friction of a clayey soil (ϕ) measured under consolidated-undrained conditions (without measuring the pore-water pressures) is always greater than the angle of internal friction (ϕ') for the same soil measured under consolidated-drained conditions.	T	F
(v)	Three soils; A, B, and C have plasticity index, I_p values equal to 0, 100, and 200 respectively. Of these three soils, the soil with the I_p value equal to 0 (i.e., Soil A) has the highest value of coefficient of permeability	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 conditions**? 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.

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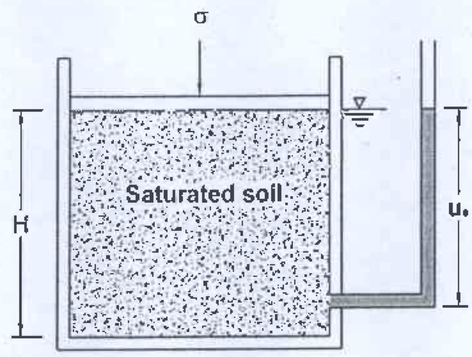

Figure 1

Question 3: **(10 marks)**

Figure 2 summarizes the grain size analysis results of four different soils A, B, C and D.

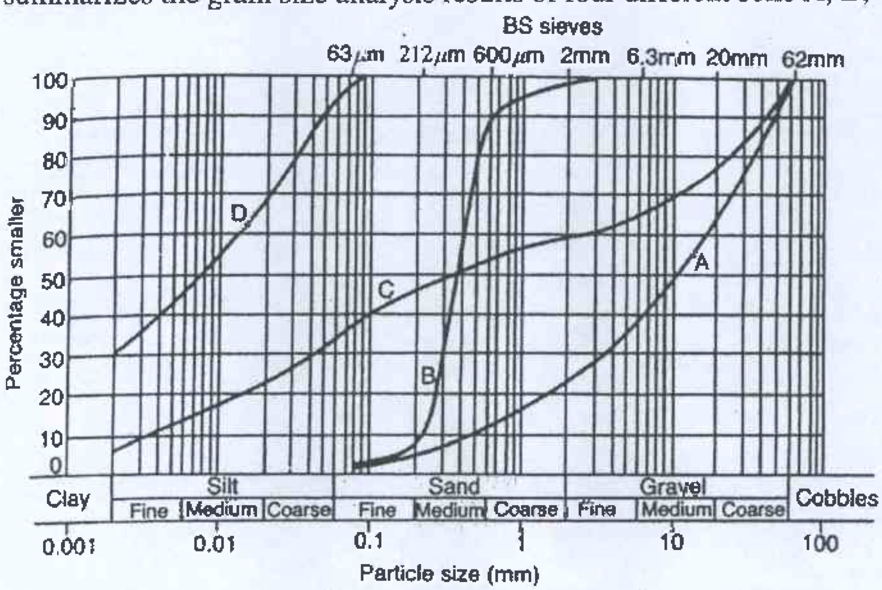

Figure 2

(i) Identify the uniform soil and explain its key features. Also, comment on the typical coefficient of uniformity, C_u values of a uniformly graded soil as per ASTM standards. What is the other name used in the literature for a uniform soil?

(3 marks)

(ii) Which of the soils; A, B, C or D shown in Figure 4 will have the highest shear strength under saturated conditions. Explain.

(3 marks)

(iii) Arrange the soils in an ascending order (lower to higher) based on their coefficient of permeability values. Give your reasons for choosing the order.

(4 marks)

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

Figure 3 shows the plan view of two multiplex buildings, M1 and M2. The foundations of M1 and M2 are loaded with uniform stresses of 50 kPa (q_1) and 60 kPa (q_2), respectively. Determine the increase in vertical stress $\Delta\sigma_z$ due to q_1 and q_2 at the depth of **5 m** vertically below **point A** (Use superposition method).

- Use **m and n coefficients** for estimating $\Delta\sigma_{z1}$ due to q_1. **(10 marks)**
- Use the **Newmark chart** for estimating $\Delta\sigma_{z2}$ due to q_2. **(10 marks)**

➢ m and n coefficients: $m = B/z$, $n = L/z$, $\Delta\sigma_z = q \cdot I$

➢ Newmark chart: $\Delta\sigma_z = I_N \cdot N \cdot q$

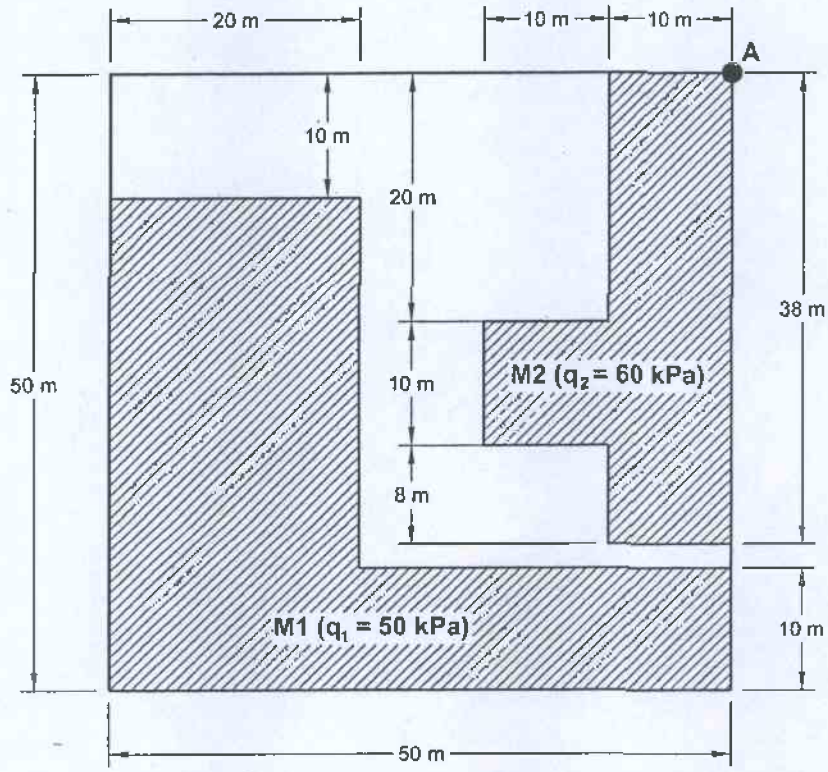

Figure 3

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

For a cutoff wall shown in **Figure 4**

a. Establish the flow nets (i.e. flow and equipotential lines) following all the rules (Draw directly on Figure 4).
b. Determine the quantity of seepage (m^3/s per m) (coefficient of permeability, $k = 2.0 \times 10^{-5}$ m/s).
c. Calculate the effective stress at point A (back of the piling) ($\gamma_{sat} = 20$ kN/m^3).
d. Estimate the stability of the cutoff wall using the Factor of Safety, FS.

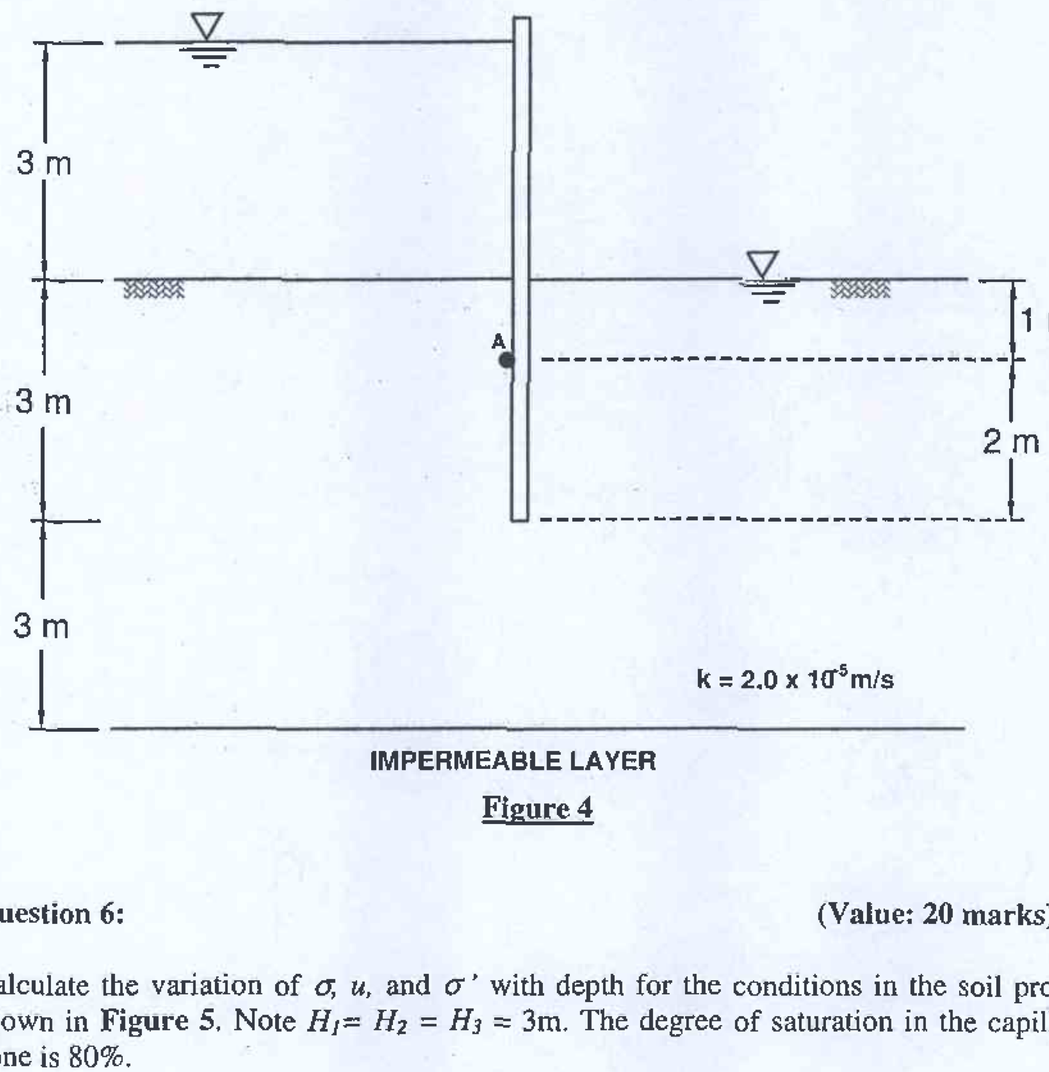

Figure 4

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

Calculate the variation of σ, u, and σ' with depth for the conditions in the soil profile shown in **Figure 5**. Note $H_1 = H_2 = H_3 = 3$m. The degree of saturation in the capillary zone is 80%.

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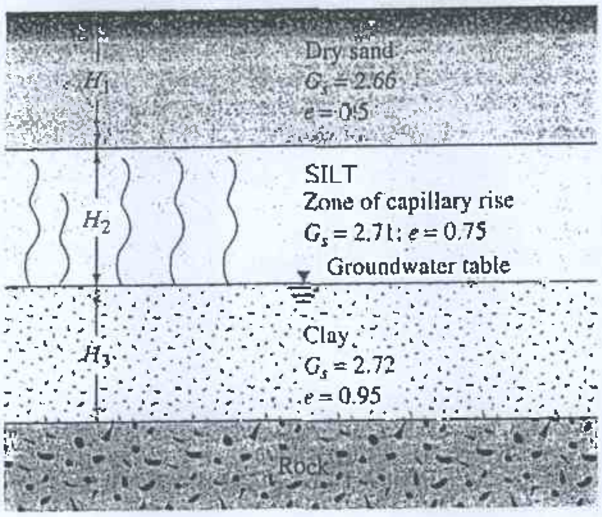

Figure 5

A laboratory *consolidation test* on a clay sample obtained from the clay layer (in the depth zone of H_3) gave the following results:

Pressure (kN/m^2)	**Void ratio**
100	0.900
200	0.815

Determine the consolidation settlement in the clay layer if the average effective stress in the clay layer is increased by 150 kPa due to the construction of a structure. Assume the clay layer to be normally-consolidated.

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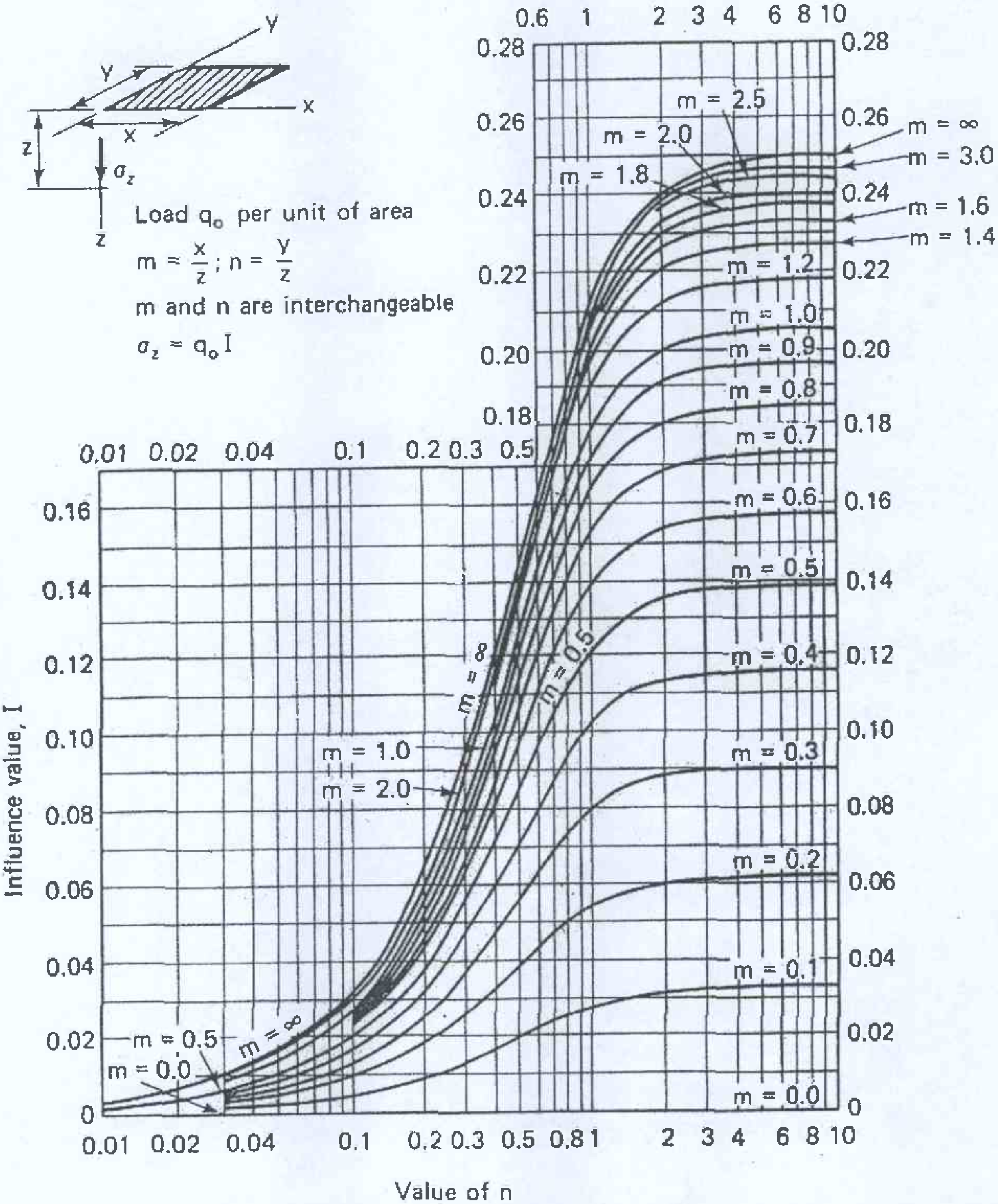

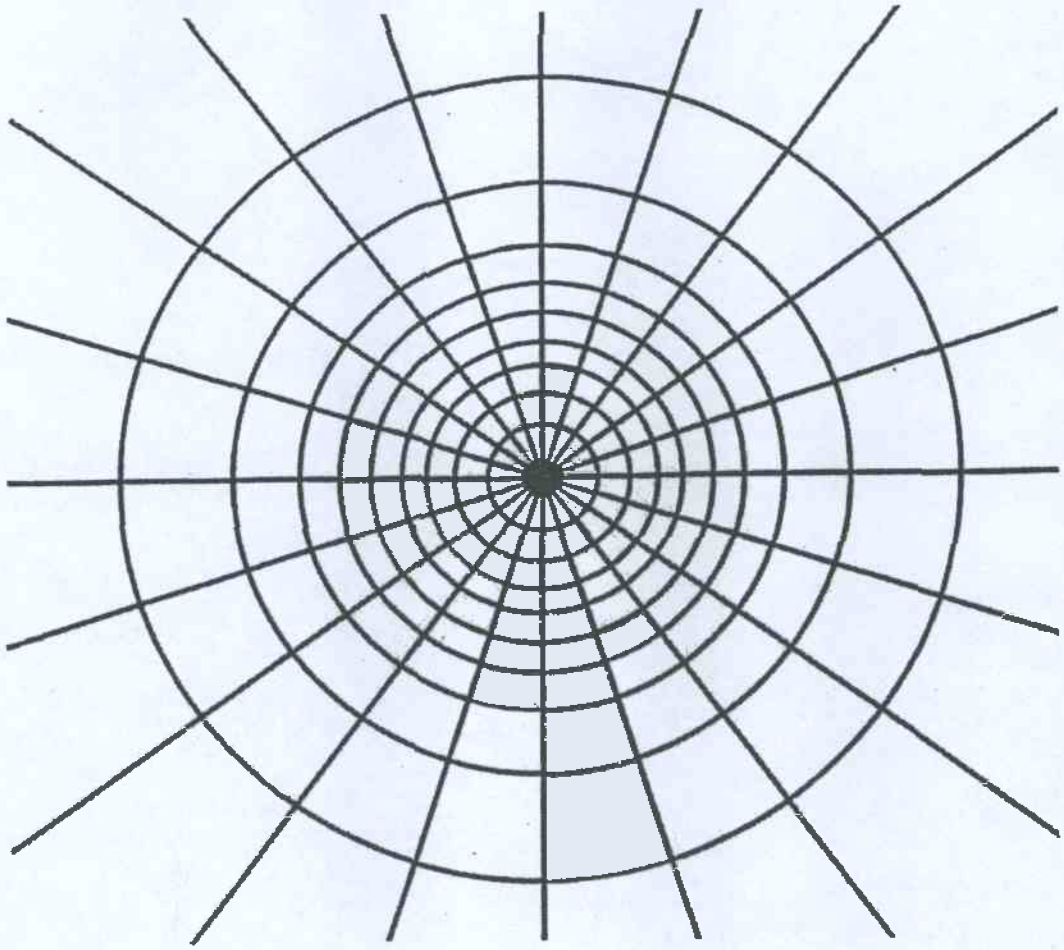

Depth scale

$I_N = 0.005$

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

Equation for determination of vertical stress change 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* $c' = \dfrac{a}{\cos\phi'}$

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

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

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

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

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