PROFESSIONAL ENGINEERS ONTARIO
NATIONAL EXAMINATIONS May 2017
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: **(4 x 5 = 20 marks)**

(i) **Figure 1** below shows compaction curves for a fine-grained soil generated using two different (low and high) compaction efforts. The engineering properties of the same soil at A, B and C will be different due to the influence of soil structure at different initial compaction water contents. At which of the points (i.e., A, B or C) will the soil have highest and lowest saturated coefficient of permeability? Explain providing reasons.

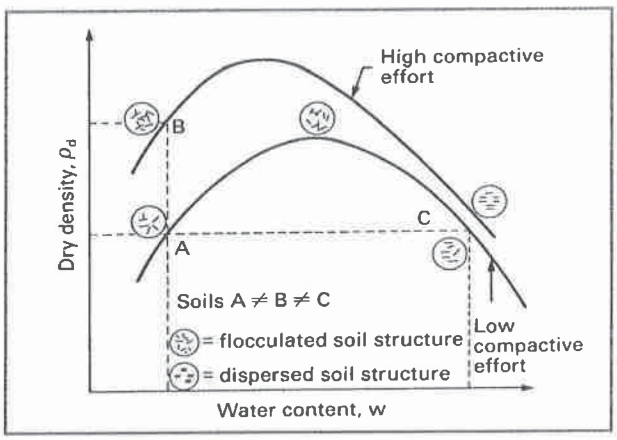


Figure 1

(ii) Draw typical compaction curves for the soils **(a)** GW and **(b)** CH. Also, provide approximate value of maximum dry density and optimum moisture content for both these soils along with their SI units.

(iii) Which one of the two soils: **(a)** GW or **(b)** CH would have a higher compression index, C_c? Give reasons. Suggest reasonable C_c values for both these soils. Also, which test do you suggest to determine C_c.?

(iv) Which one of the following sandy soils: **Sand A** with coefficient of curvature value equal 2 or **Sand B** with coefficient of curvature value equal1 would have the lower effective angle of internal friction, ϕ'? Provide reasons for your answer.

(v) What will be the approximate undrained angle of internal friction, ϕ_u determined from unconsolidated undrained triaxial tests for **Soil A:** Expansive clay; **Soil B:** Glacial till. Provide reasons for your answer.

Question 2: **(20 marks)**

Determine the effective stress at points A and B for the section through a dam spillway shown in **Figure 2**. Given that $\gamma_{sat} = 20$ kN/m^3.

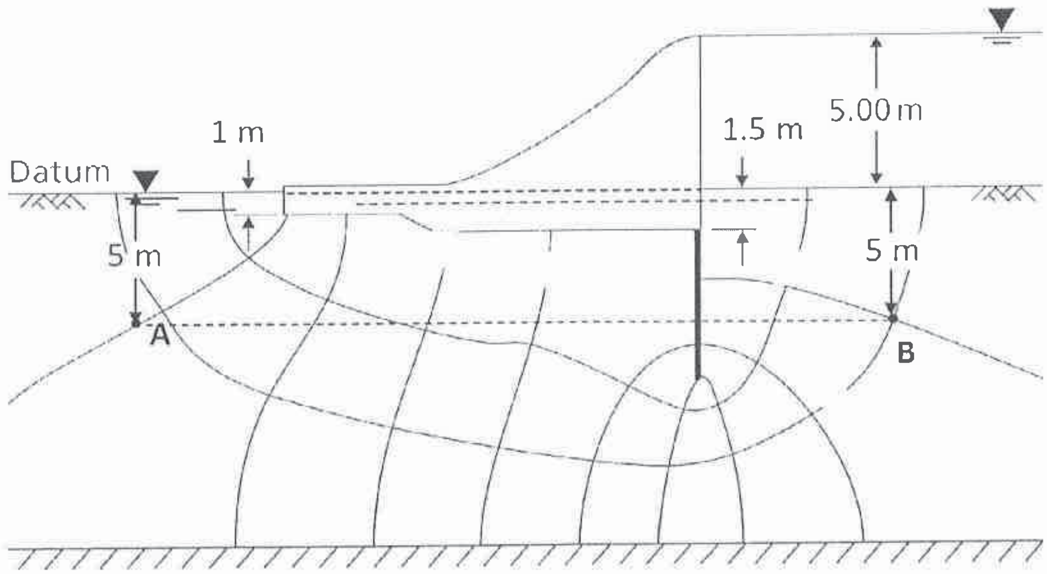


Figure 2

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

The results in **Table 2** given below were obtained at failure conditions from a series of Consolidated-Undrained triaxial tests with pore-water pressure measurements on fully saturated clay specimens ($u_o = 0$).

Table 2

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

i) Determine the effective shear strength parameters for the tested soil (i.e., c' and ϕ'). Also, calculate the Skempton's A_f value for this clay. Is the clay normally consolidated or over consolidated? Give reasons. Note: **Figure 3** will be useful for answering this question

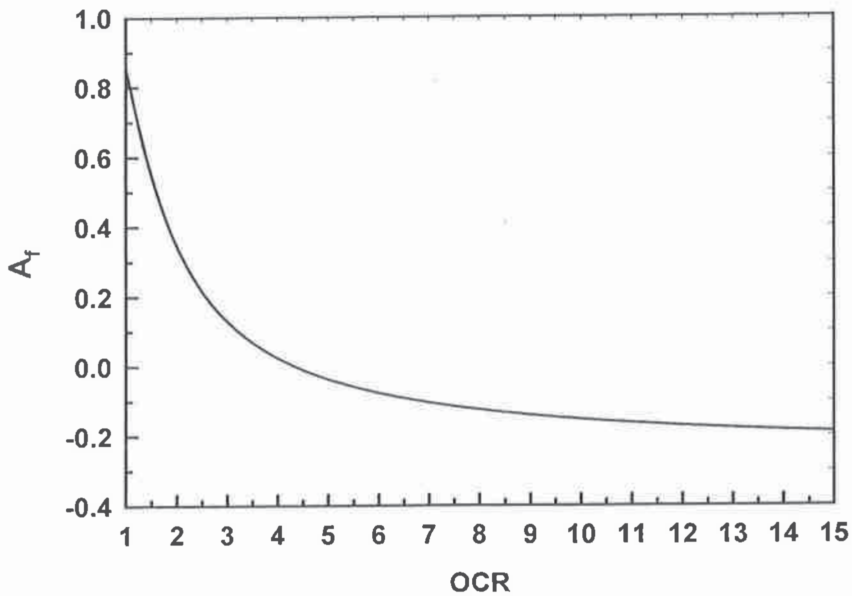


Figure 3. OCR versus A_f relationship

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

Assume that the void ratio variation with respect to pressure relationship shown in **Figure 4(a)** is representative of the clay shown in **Figure 4(b)**. Determine the settlement in the clay layer under the centre of footing. Assume, specific gravity $G = 2.7$.

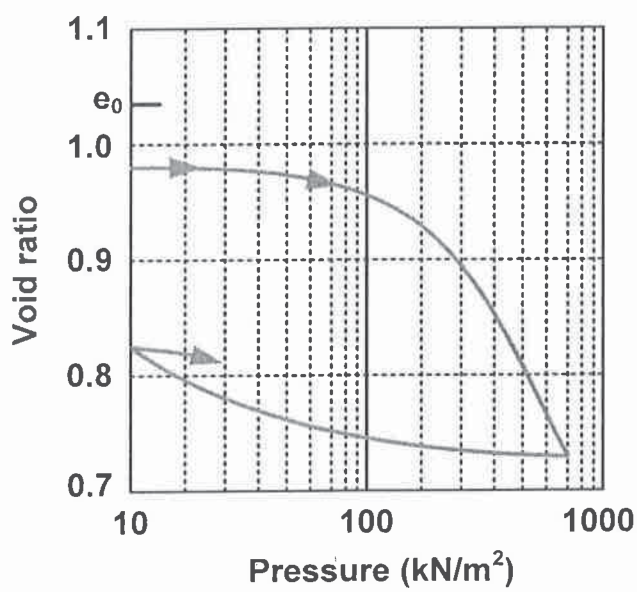


Figure 4(a)

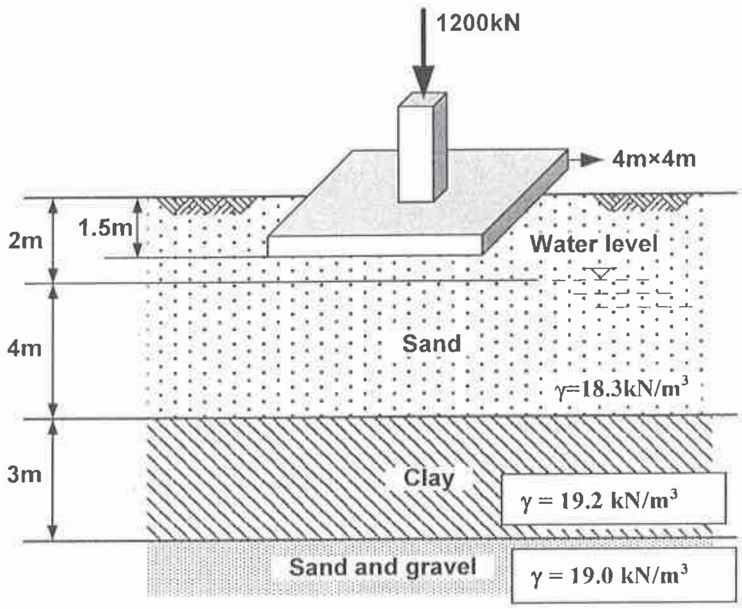


Figure 4(b)

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

Figure 5 summarizes the loading on two footings. What will be the increase in the vertical stress ($\Delta\sigma_v$) at point A which is located in the middle of two foundations and is 2 meters deep from the ground surface? Calculation should be performed using two different methods.

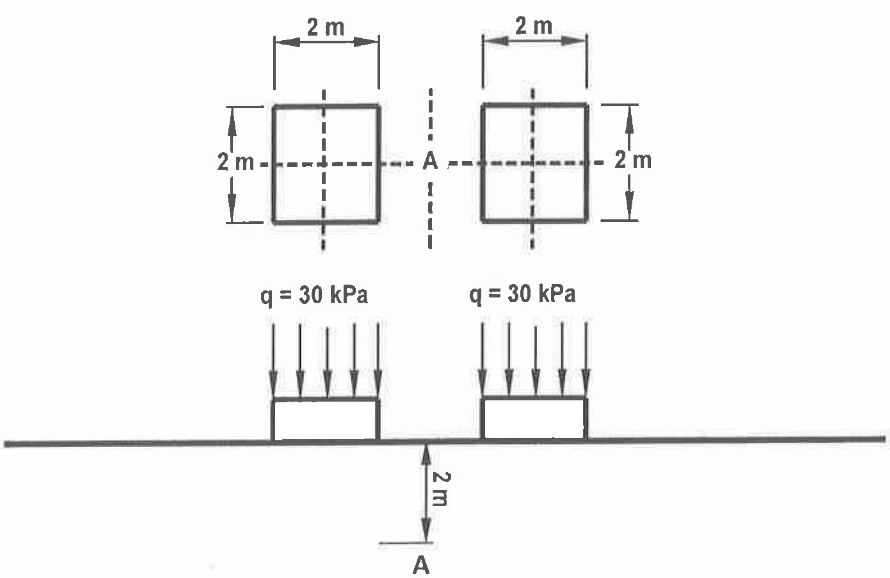
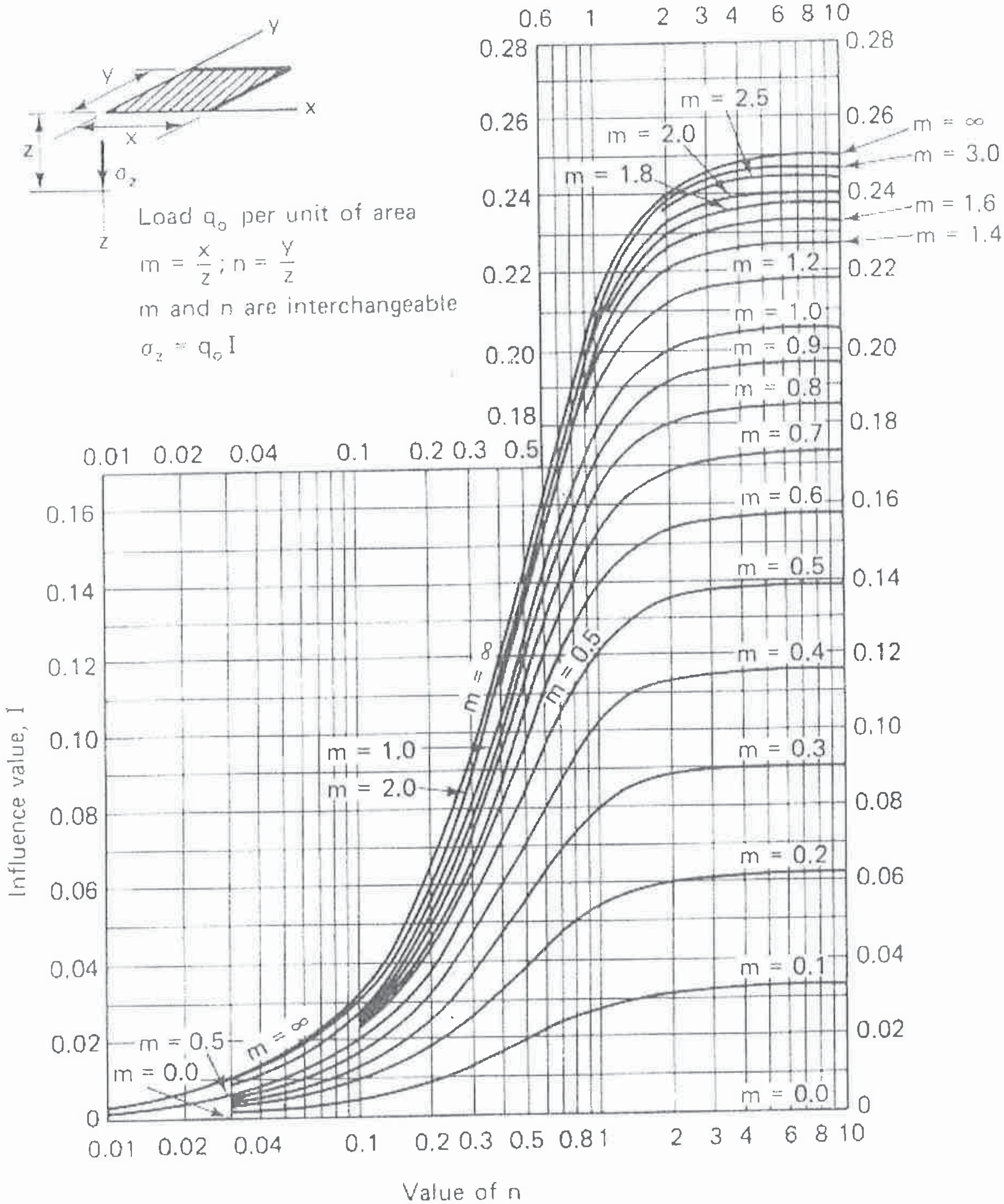
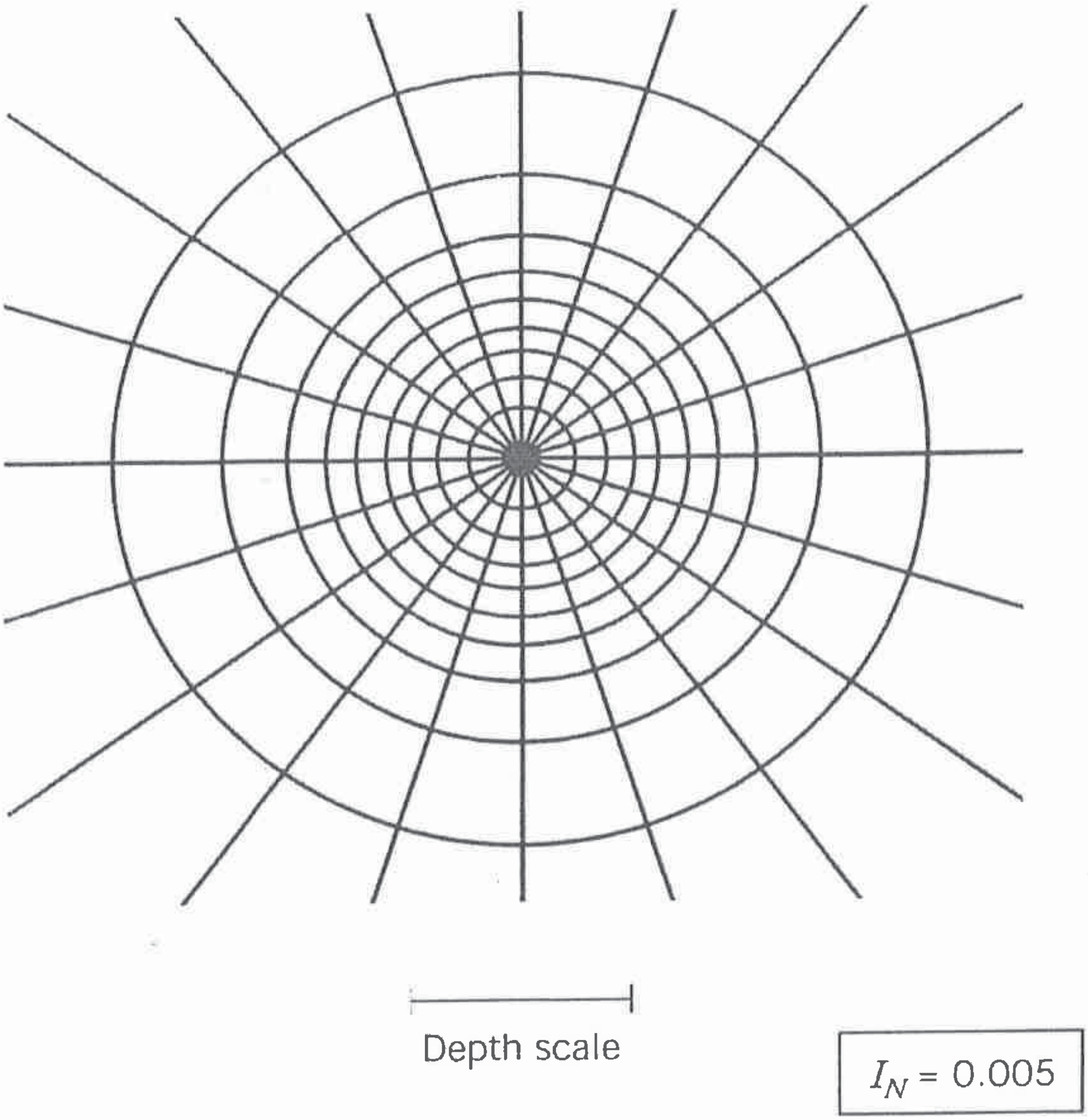


Figure 5


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

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

$\sigma = \gamma D$

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

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

$\sigma = \sigma' + u$ (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, $\sigma_z = \frac{q\,B\,L}{(B+z)(L+z)}$

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

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

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

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

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

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