NATIONAL EXAMINATIONS –December 2018

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

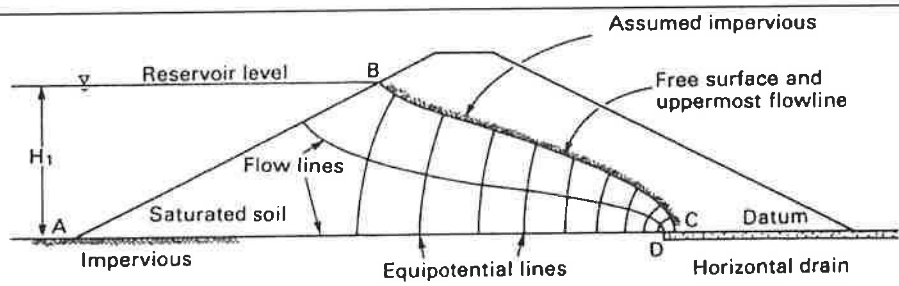
Question 1: **(10 marks)**

State the correct answer (**True or False**) in your ANSWER BOOK along with the **Question number**. Have all your answers for **Question 1** at one place.

1	Zero-air voids line (ZAVL) which is associated with the compaction curve (i.e., dry density versus water content relationship) is always above the compaction curve. In addition, typically ZAVL is parallel to wet-of-optimum portion of the compaction curve.	**T**	**F**
2	Effective cohesion value is typically larger in overconsolidated clays in comparison to the normally consolidated clays.	**T**	**F**
3	Plasticity index (I_p), plastic limit (PL) and liquid limit (LL) values for two soils; Soil **A** and Soil **B** are summarized below: Soil **A**: $I_p = 30$ %; $PL = 30$ %; $LL = 60$% Soil **B**: $I_p = 30$ %; $PL = 20$ %; $LL = 50$% Based on the above summarized information of soil properties, Soil **B** will have a lower Compression index, C_c	**T**	**F**
4	Two identical saturated soil specimens were tested in a triaxial shear apparatus for determining their shear strength under consolidated drained **(CD)** and consolidated undrained **(CU)** conditions. The soil specimens tested under **CD** conditions undergo more volume change in comparison to **CU** conditions in a triaxial test.	**T**	**F**
5	A soil specimen achieves 30% consolidation in 3 months at a site subjected to a load of 100 kN/m^2. If the site was loaded to 300 kN/m^2, 90% consolidation would occur in a period of 9 months.	**T**	**F**
6	Boussinesq's equation is typically used for estimating the variation of stress in soils due to a point load with respect to depth; however, this equation is not valid at a depth equal zero.	**T**	**F**
7	Knowledge of compression index, C_c is required for determination of settlement of sand.	**T**	**F**
8	The stress versus strain behavior of a normally consolidated clay is similar to that of a loose sand.	**T**	**F**
9	The plasticity index (I_p) of low compressible silt (**ML**) is typically lower than highly compressible clay (**CH**).	**T**	**F**
10	The amount of volume change that will occur when a soil is subjected to load depends on the coefficient of permeability, k, of the soil.	**T**	**F**

Question 2: **(2 x 5 = 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.

1	The angle of internal friction (i.e., ϕ') was measured from consolidated drained (i.e., ***CD***) tests on two soils; Soil **A** (well-graded sand) and Soil **B** (uniform sand). Which one these two soils will have a higher angle of internal friction. (i): Sample **A** (well-graded sand) (ii) Sample **B** (uniform sand)
2	Two identical soil samples **C** and **D** were consolidated to effective confining pressures of 100 and 300 kPa, respectively before undrained triaxial shear tests with pore-water pressure measurement. The pre-consolidation pressure of this soil was equal to 200 kPa. Which one of these samples, **C** or **D** will have higher pore-water pressure at failure? (i): Sample **C** (tested with a confining pressure 100 kPa) (ii) Sample **D** (tested with a confining pressure 300 kPa)
4	In a **CD** test on saturated normally consolidated clay, the sample volume during shear (i) increases (ii) remains unchanged (iii) is reduced
5	 **Figure 1** The pore-water pressure below the flow line BC (i.e., phreatic surface) in a homogeneous earth dam is equal to (i) negative value (ii) atmospheric pressure (i.e., pore-water pressure is equal to zero) (iii) positive value

Question 3: **(Value: 15 marks)**

(a) If sands in **Figure 2** (i.e., sand A and sand B) are liquefied under the impact of an earthquake, which one of the statements below is true? Justify the answer that you have chosen.

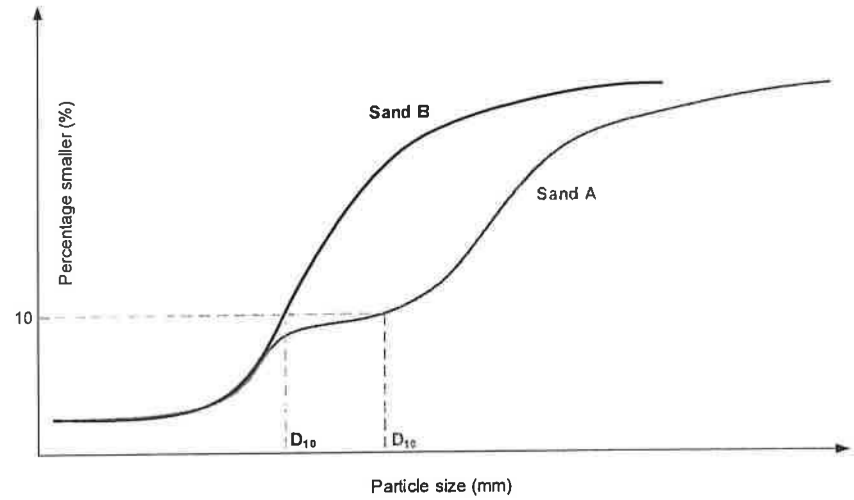


Figure 2

(i) Sand A has a higher shear strength than sand B.
(ii) Sand B has a higher shear strength than sand A.
(iii) Both sand A and sand B will have approximately the same shear strength.
(iv) Both sand A and sand B will have no shear strength.

(b) Also, which one of the sands in **Figure 2** (i.e., sand A and sand B) will have a higher saturated coefficient of permeability? Give reasons.

Question 4: **(Value: 25 marks)**

The following results were obtained from an oedometer test (i.e., consolidation test) on a specimen of saturated clay:

Pressure (kN/m^2)	27	54	107	214	429	214	107	54
Void ratio	1.243	1.217	1.144	1.068	0.994	1.001	1.012	1.024

A layer of this clay, 6m thick, lies below a 4m layer of sand and the water table is at the surface. The saturated unit weight for both soils is 18 kN/m^3. A 4m depth of fill of unit weight 20 kN/m^3 is placed on the sand over an extensive area.

a. Determine the settlement due to consolidation of the clay.

b. If the fill was removed some time after the completion of consolidation, calculate the heave or consolidation rebound of the clay that would eventually take place.

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

Calculate the hydraulic head, h along with the pore-water pressure, u at points 2, 4 and 6, after determining the number of potential drops, N_d and the head loss for each drop, Δh, for the dam shown in **Figure 3**.

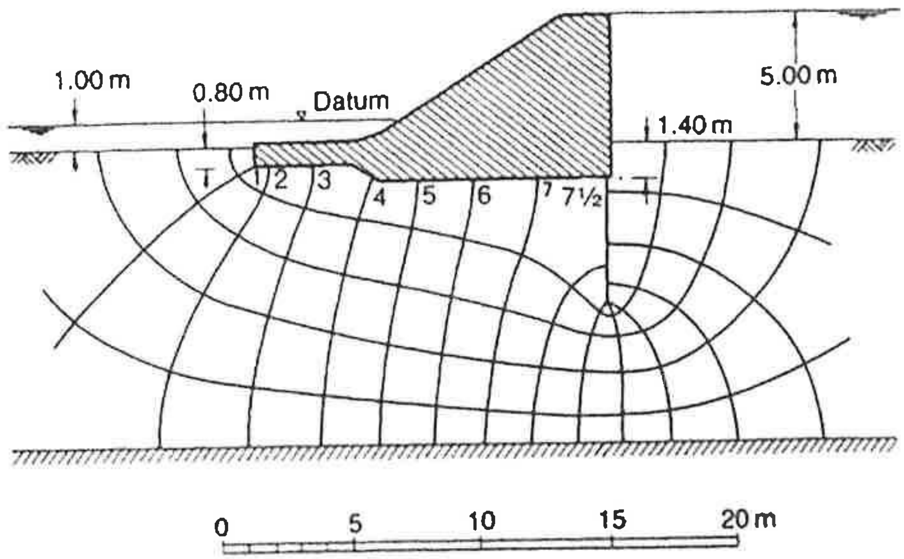


Figure 3.

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

The results in Table 1 given below were obtained at failure conditions in a series of consolidated-undrained triaxial tests with pore water pressure measurements on fully saturated clay specimens. Determine the effective shear strength parameters (i.e., c' and ϕ') for the tested soil. If a specimen of the same soil were consolidated under a confining stress, σ_3 of 250 kPa, what would be the expected value of the principal stress difference at failure?

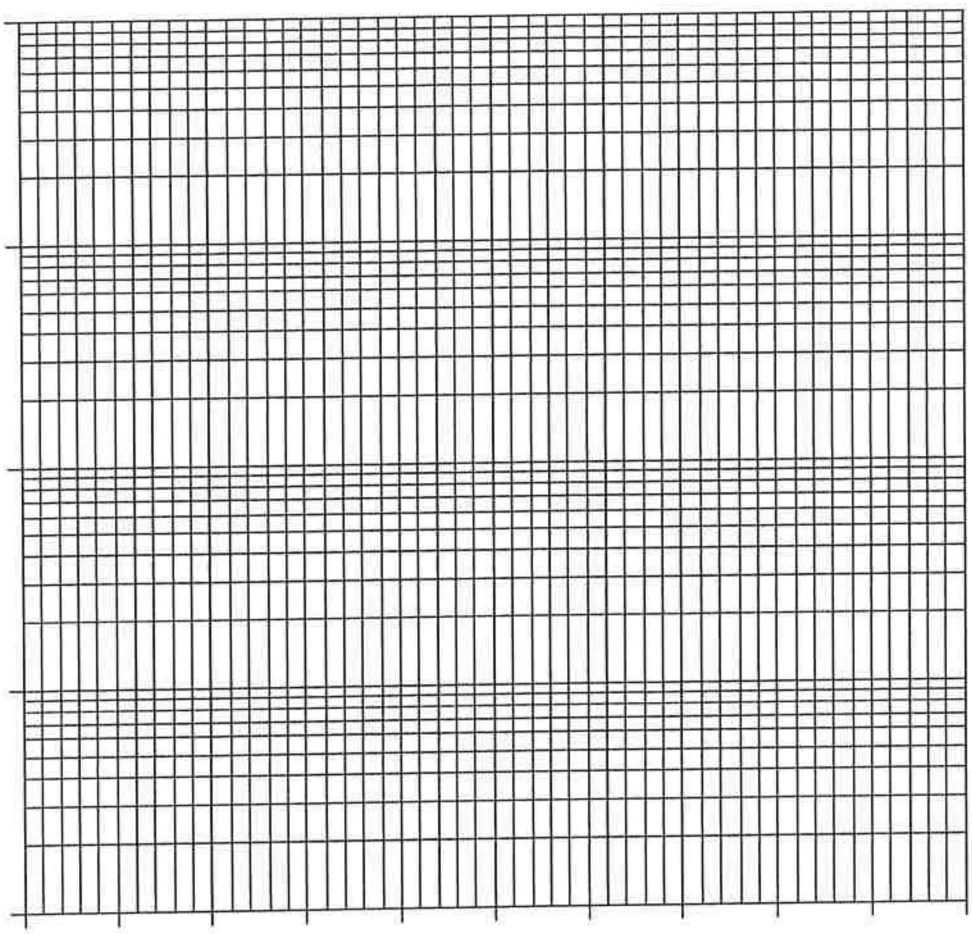
Table 1

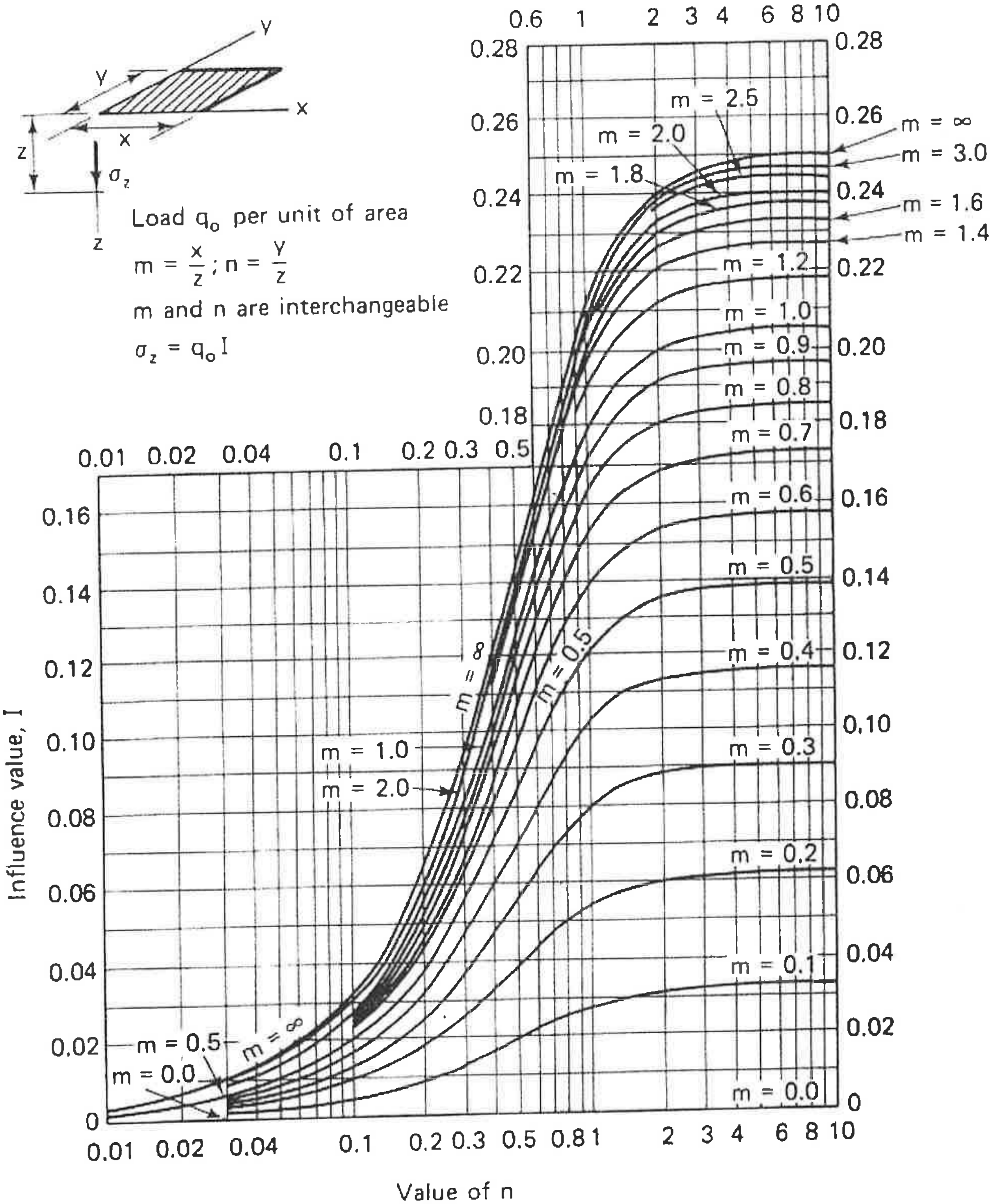
Confining stress, σ_3 (kPa)	Deviator stress, $(\sigma_1 - \sigma_3)$ kPa	Pore-water stress, u (kPa)
150	103	82
300	202	169
450	305	252

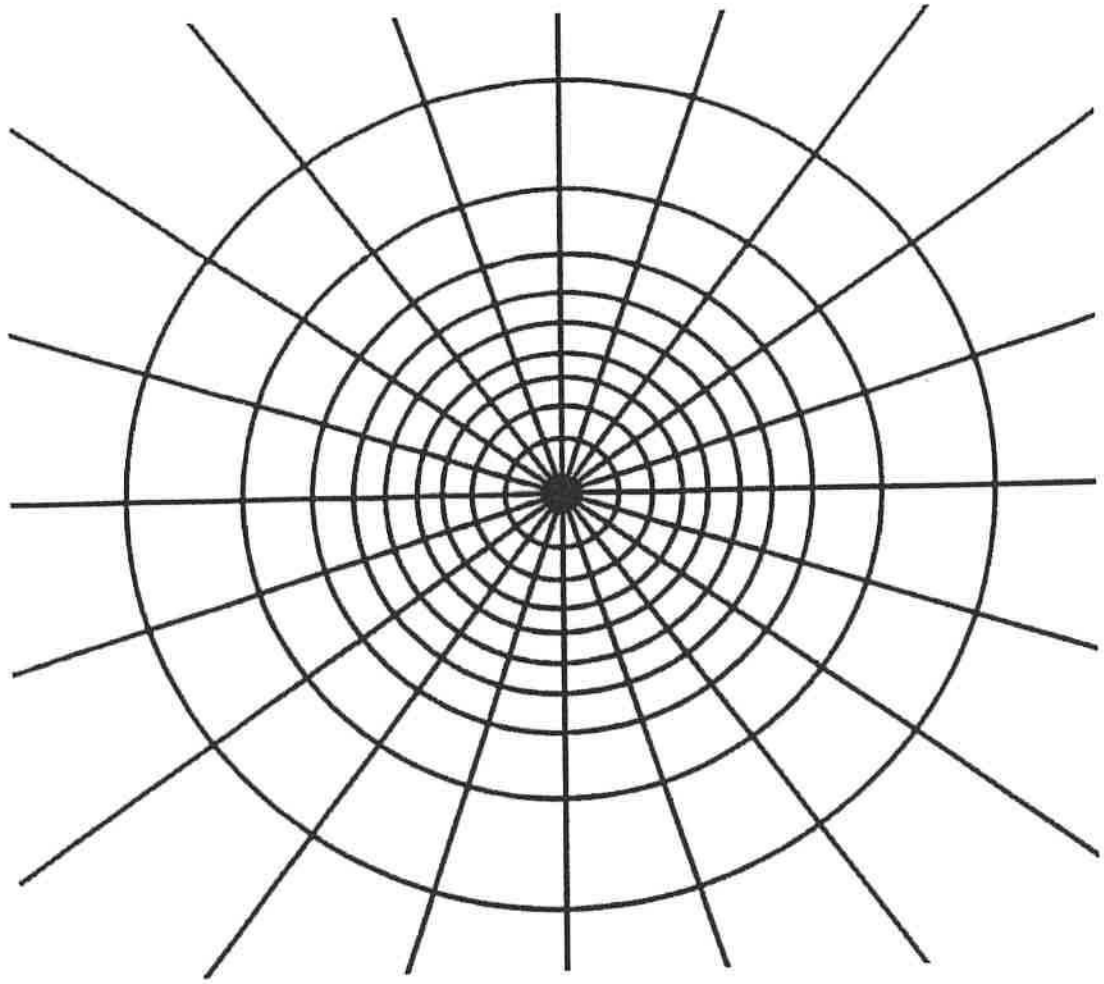
Answer the questions given below based on the results you have obtained:

(i) Is the clay normally consolidated or over consolidated? Give reasons.

(ii) If an earth dam is constructed using this clay, can you use the above shear strength parameters to determine the short term stability of the structure. Give 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
$\sigma_z = q_o I$
0.6 1 2 3 4 6 8 10
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
m = 2.5
m = 2.0
m = 1.8
m = ∞
m = 3.0
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
Influence value, I
m = ∞
m = 0.5
m = 1.0
m = 2.0
m = 0.5
m = 0.0
m = ∞
0.01 0.02 0.04 0.1 0.2 0.3 0.5 0.8 1 2 3 4 6 8 10
Value of n



Depth scale

$I_N = 0.005$

Formula Sheet

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

$\sigma = \gamma D$

$P = \sum N' + uA$

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

$\sigma = \sigma' + u$ (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: $\sigma_z = 0.005Nq$

$\tau_f = c' + (\sigma - u_w)\tan\phi'$; $\sigma_1' = \sigma'_3 \tan^2\left(45^o + \frac{\phi'}{2}\right) + 2c'\tan\left(45^o + \frac{\phi'}{2}\right)$

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

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

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

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

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

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