PROFESSIONAL ENGINEERS ONTARIO
NATIONAL EXAMINATIONS –December 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 DETAILED EXPLANATION IN YOUR ANSWER BOOK** along with the question number.

(i)	The shear strength of well graded sand is greater than uniform sand.	T	F
(ii)	The coefficient of permeability of normally consolidated clay is higher than that of an over consolidated clay.	T	F
(iii)	An earth dam of 10 m height will be inducing a higher stress in comparison to a 5 story condominium with a continuous footing of 1 m width at a depth of 2m ???	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, 25, and 50 respectively. The soil with the I_p value equal to 0 (i.e., Soil A) will consolidate more under an applied load of 200 kPa. (Note: all soils are normally consolidated	T	F

Question 2:   **(10 marks)**

A compacted soil sample of 12.5 kg has a volume of 0.006 m^3 and has a moisture content of 10%. Determine the unit weight, dry unit weight, degree of saturation, void ratio and porosity. Assume the specific gravity of soil solids of the soil is 2.67.

Question 3:   **(10 marks)**

Fine-grained soils can be compacted on the wet and on the dry side of optimum moisture content. Identify these with a typical Proctor's compaction curve. Explain the wet and dry side concept in a maximum of 30 words. Comment on the unconfined shear strength of soil samples compacted on dry and wet side.

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

(a) What are common assumptions and limitations of elastic theories with respect to estimation of the stress distribution in soils ? Draw the typical variation of vertical stress with depth and variation of vertical stress with horizontal distance at three different depths due to a point load. **(5 marks)**

(b) The footing shown in **Figure 1** is loaded to an intensity of 100 kPa. Determine the increase in vertical stress that occurs at a depth of 3 m below the point A. Use any two methods for determining the increase in vertical stresss; one of these methods must use Newmark's chart. Critique the results obtained from both methods you have used. **(15 marks)**
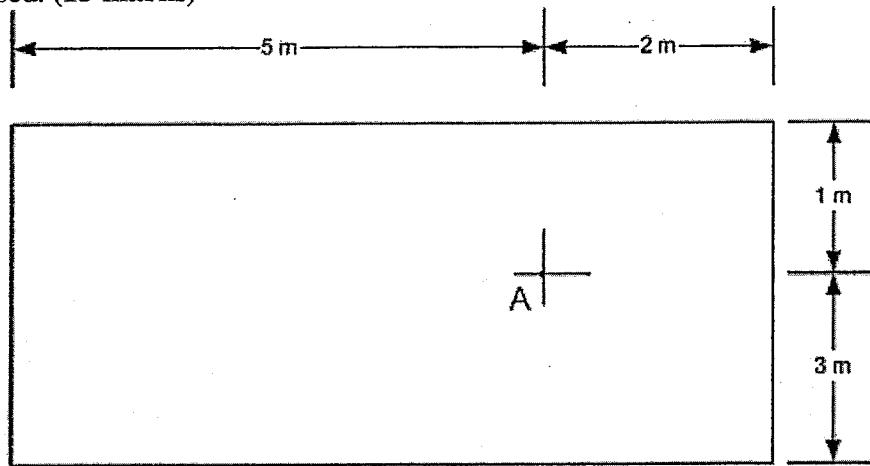

Figure 1

Question 5:   **(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 2** given below. **(5 marks)**
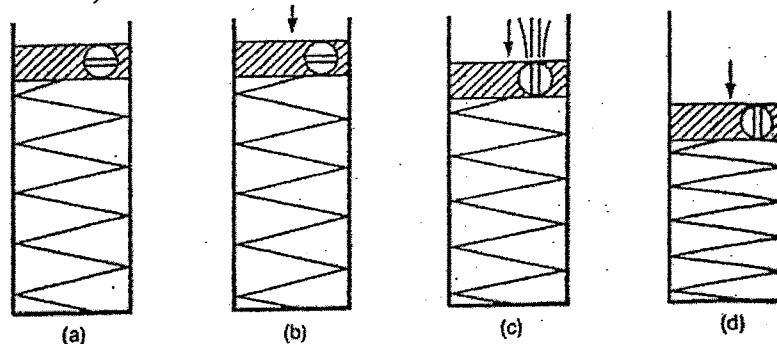

Figure 2

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(b) For **Figure 3** shown below, plot the distribution of pressure, total head and elevation head versus height, and give the values at the entrance and exit ends and at point A. (7 marks)
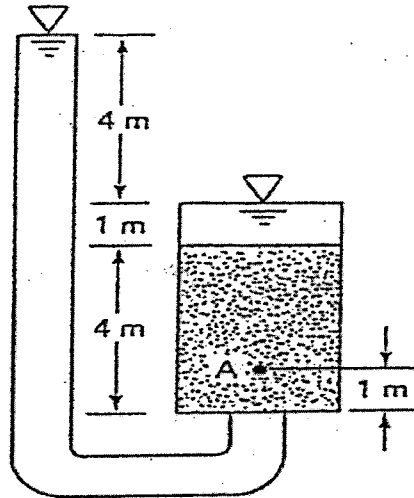

Figure 3

(c) A layer of clay 4 m thick lies between two layers of sand each 4 m thick, with 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 sand is 19 kN/m^3: the unit weight of sand above the water table is 16.5 kN/m^3. Calculate the effective vertical stresses at the top and bottom of the clay layer. (7 marks)

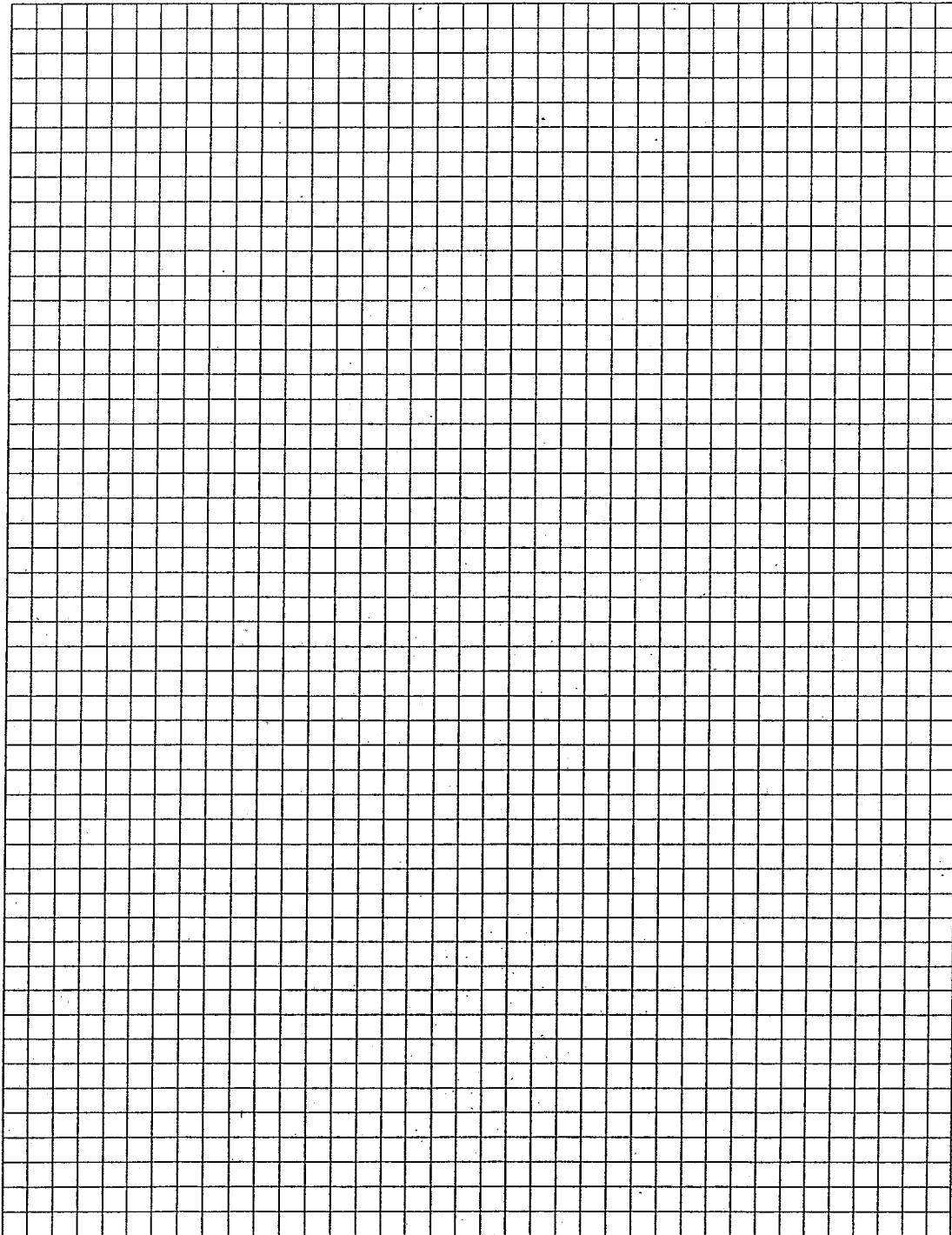**Question 6:**   **(Value: 20 marks)**

The following results were obtained at failure in a series of consolidated drained triaxial shear strength tests on fully saturated clay specimens originally 38 mm diameter by 76 mm long. Determine the values of the shear strength parameters c' and ϕ' plotting a **modified failure shear strength envelope (K_f envelope)**. What is the advantage of plotting a modified failure shear strength envelope to determine the shear strength parameters?

| All round pressure (kN/m^2)	200	400	600
Axial compression (mm)	7.22	8.36	9.41
Axial load (N)	480	895	1300
Volume change (ml)	5.25	7.40	9.30

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

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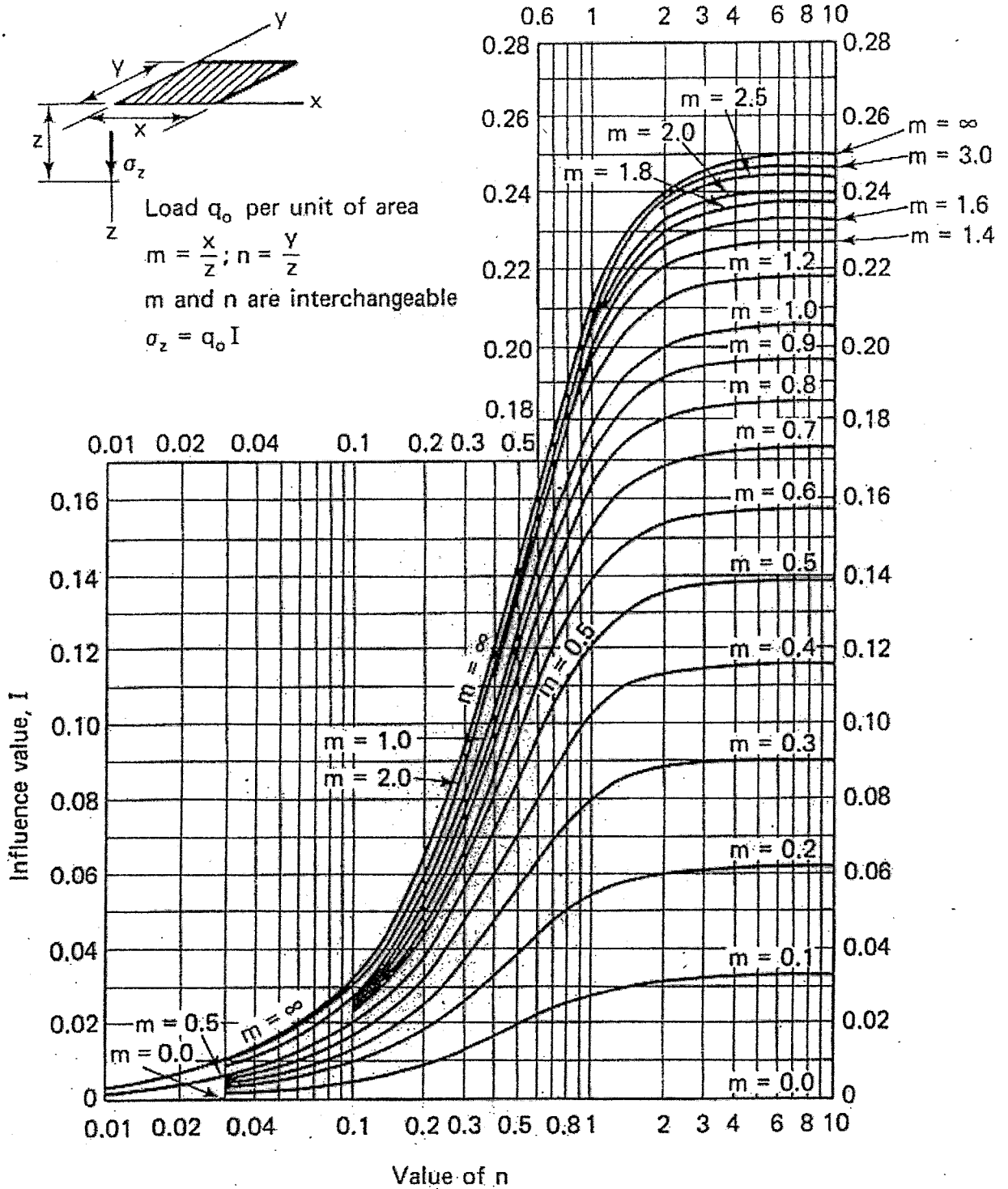## GEOTECHNICAL MATERIALS AND ANALYSIS

If an earth dam is constructed using this clay, can you use the above shear strength parameters to determine the long term stability of the structure. Give reasons.
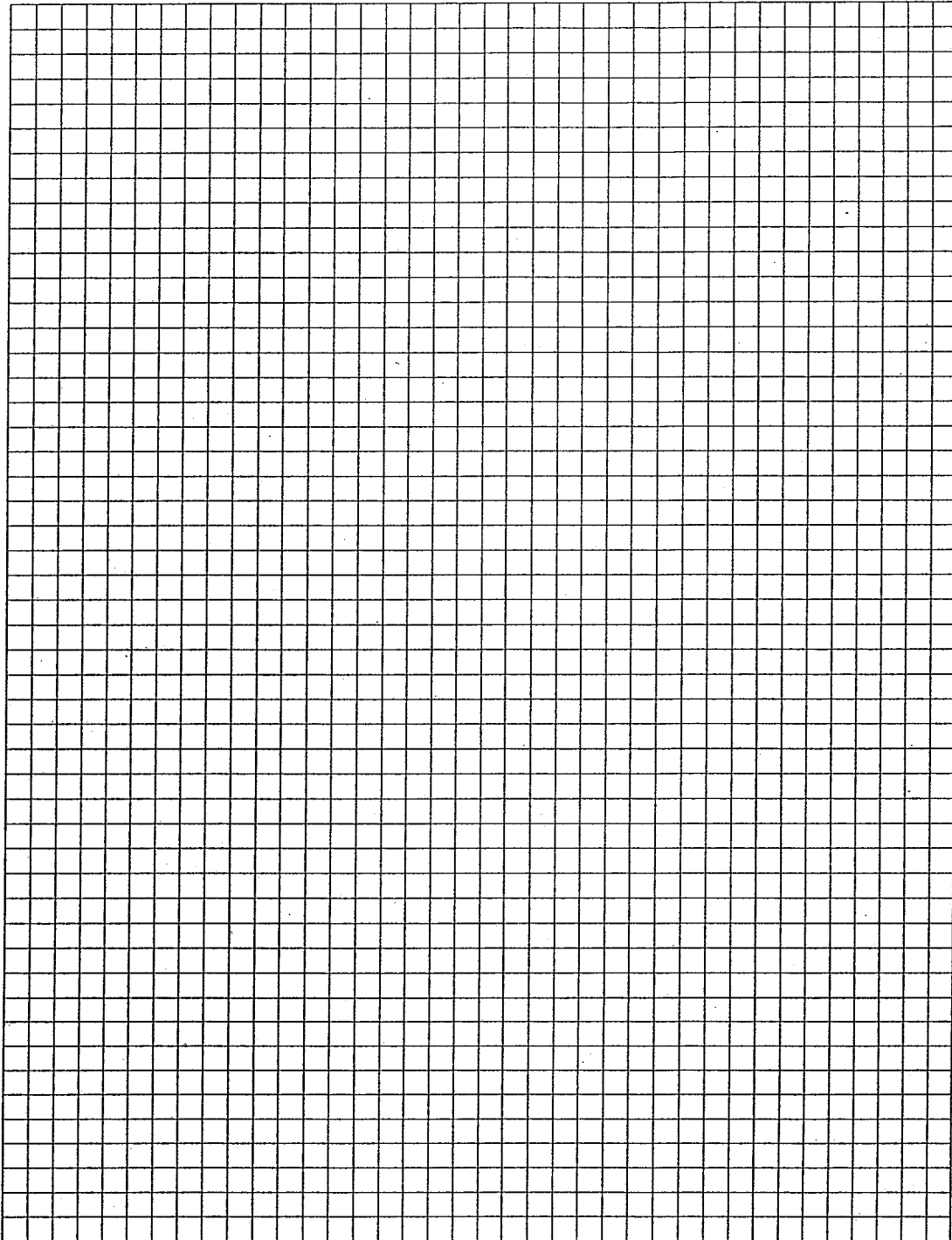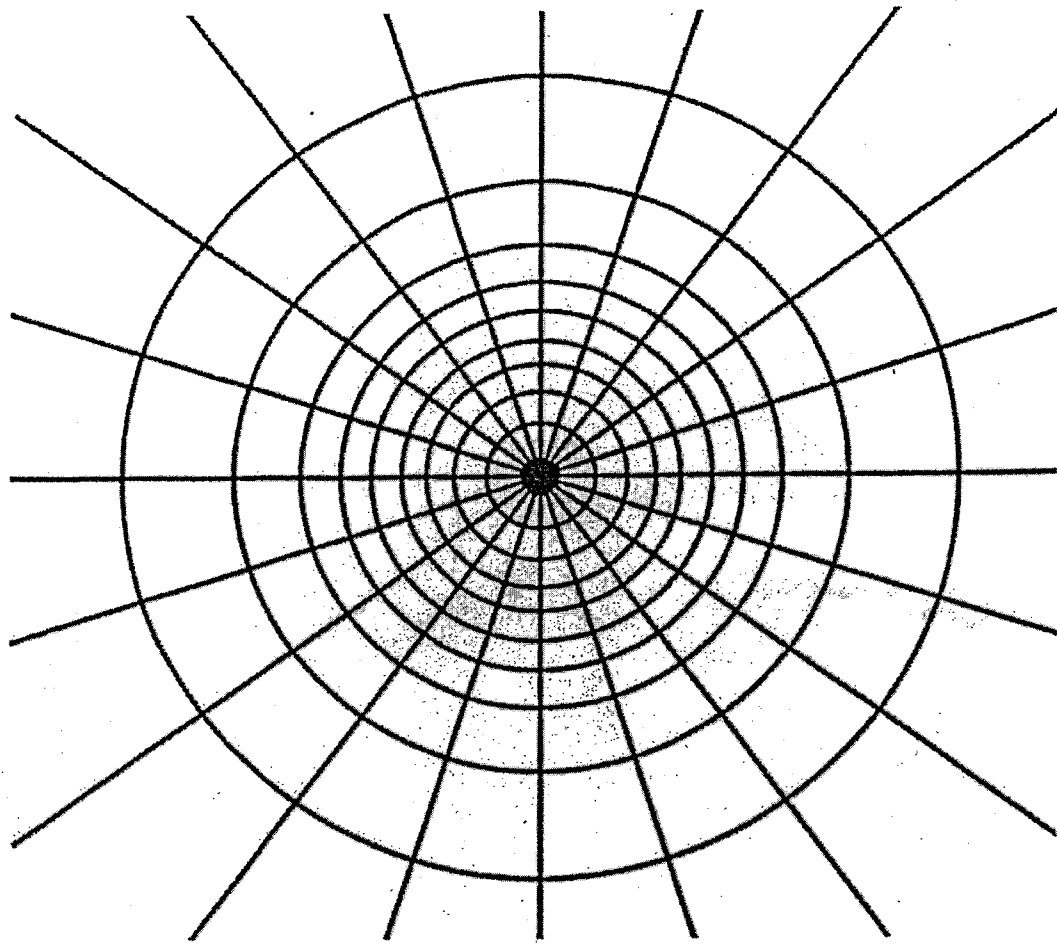
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Load q_o per unit of area

$$m = \frac{x}{z}; n = \frac{y}{z}$$

m and n are interchangeable

$$\sigma_z = q_o I$$

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Depth scale

$$I_N = 0.005$$

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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 $\sigma' = \gamma' D$

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

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

Boussinesq's equation for determining vertical stress change due to a point load

$$\sigma_z = \frac{3Q}{2\pi z^2}\left\{\frac{1}{1 + \left(\dfrac{r}{z}\right)^2}\right\}^{5/2}$$

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

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

Mohr's circles can be represented as stress points by plotting the data $\dfrac{1}{2}\left(\sigma_1' - \sigma_3'\right)$

against $\dfrac{1}{2}\left(\sigma_1' + \sigma_3'\right)$; $\phi' = \sin^{-1}(\tan\alpha')$ *and* $c' = \dfrac{a}{\cos\phi'}$

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

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

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

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

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