PROFESSIONAL ENGINEERS ONTARIO
NATIONAL EXAMINATIONS –May 2011
07-Bld-A6 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 as to the interpretation of a question, you are encouraged to complete the question submitting a clear statement of your assumptions.
4. **You are required to answer:**
   All four questions in SECTION A...........Total 40 marks
   Three out of four questions SECTION B....Total 60 marks
5. The total exam value is 100 marks
6. For Section A answer all questions
7. For Section B only the first three questions answered will be graded.
8. One of two calculators can be used: Casio or Sharp approved models.
9. Drawing instruments are required.
10. All required charts and equations are provided at the back of the examination.
11. YOUR MUST RETURN ALL EXAMINATION SHEETS.

SECTION A
ANSWER ALL **FOUR** QUESTIONS

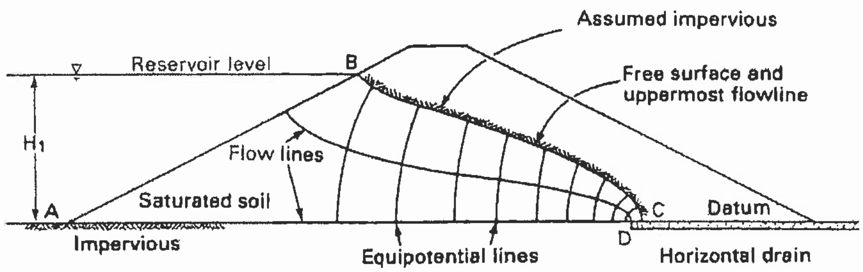
Question **10marks**

(a) Circle the correct answer.

1	Various densities such as ρ_{sat}, ρ_{sub}, ρ_{moist}, and ρ_{dry} are commonly used in geotechnical engineering practice. Of these density values, ρ_{sat} has the highest magnitude for all cases.	T	F
2	When the soil is fully saturated, the water content can be determined using the relationship: $w = \dfrac{n}{(1-n)G_s}$	T	F
3	Three soils; A, B, and C have liquid limit, w_L values equal to 44, 56, and 96. Note that the plastic limit, w_P values are 18, 22 and 24 respectively. The shear strength of all these soils at their respective liquid limit values is the same.	T	F
4	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 I_p value equal to 0 (i.e., Soil A) has the highest value of coefficient of permeability.	T	F
5	The soil structure of a fine-grained soil which is compacted dry of optimum has a large clod size and is flocculated in nature.	T	F
6	The effective cohesion of an over consolidated clay sample measured in the laboratory using triaxial tests is typically close to zero.	T	F
7	The direct shear test apparatus is only useful for reliably determining the effective shear strength parameters, c' and ϕ' of a saturated clay. This apparatus cannot be used for sandy soils because of its high coefficient of permeability.	T	F
8	A clayey soil with the mineral montmorrilonite has a lower coefficient of permeability in comparison to clays that have kaolinite or illite as clay minerals.	T	F
9	From a practical perspective, compaction curves (i.e., ρ_d versus water content {w} relationship) always fall below the zero-air voids line.	T	F
10	 **Figure 1** A well-graded soil has a good and equal representation of all particle sizes from the largest to smallest size of that particular group	T	F

Question 2: Choose the correct answer and justify it with a reasonable explanation.

(Value: 4 +3+3 = 10 marks)

<table>
<tr><td>(i)</td><td>Quick sand conditions occur only in sands and not in clays.</td><td>T</td><td>F</td></tr>
<tr><td>(ii)</td><td>


Boundary conditions:
AB: $h_w = H_1$
BC: free surface, it's location is unkown
CD: $h_w = 0$
DA: $q_w = 0$

Figure 2
The pore-water pressure along the upper-most flow line (i.e., phreatic surface) **(see Figure 2)** in a homogeneous earth dam is equal to atmospheric pressure (i.e., pore-water pressure is equal to zero)
</td><td>T</td><td>F</td></tr>
<tr><td>(iii)</td><td>


A) Large Clod Size (Dry of optimum)
B) Smaller Clod Size (Wet of optimum)
Figure 3

The water content of a compacted sample at dry of optimum conditions is lower than the sample compacted at wet of optimum conditions). The coefficient of permeability of a clay sample compacted at dry of optimum conditions is higher than the coefficient of permeability of the same clay compacted at wet of optimum conditions.
</td><td>T</td><td>F</td></tr>
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Question 3: **(Value: 10 marks)**

Figure 4 summarizes the grain size results of four different soils A, B, C and D.

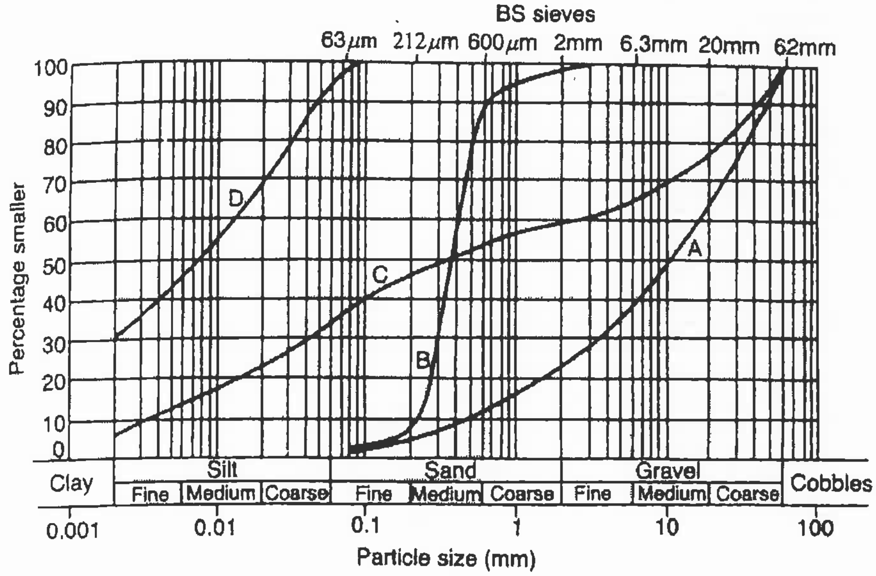


Figure 4

(i) Identify the uniform soil and explain its key features. Also, comment on 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 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)

Question 4: **(Value: 10 marks)**

An embankment for a highway 30 m wide and 1.5 m in compacted thickness is to be constructed from a sand soil trucked from a borrow pit. The water content of the sandy soil in the borrow pit is 15% and its void ratio is 0.69. The specification requires the embankment be compacted to a dry unit weight of 18 kN/m^3. Determine, for 1 km length of embankment, the following:

(i) The weight of sandy soil from the borrow pit required to construct the embankment.

(3 marks)

(ii) The number of 10 m^3 truckloads of sandy soil required for the construction

(3 marks)

(iii) The weight of water per truckload of sandy soil.

(3 marks)

(iv) The degree of saturation of the sandy soil *in situ*.

(2 marks)

SECTION B

ANSWER **THREE** OF THE FOLLOWING **FOUR** QUESTIONS

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

The following results were obtained at failure conditions in a series of consolidated undrained triaxial shear strength tests with pore water pressure measurements on fully saturated clay specimens. Determine the cohesion, c' and the angle of internal friction, ϕ' using two different methods. One of these methods should be an analytical method (i.e., using mathematical equations) and the other should be a graphical solution.

Confining pressure, σ_3 (kPa)	Deviator stress, $(\sigma_1 - \sigma_3)$ (kPa)	Pore-water pressure, u (kPa)
150	100	80
300	200	170

If an earth dam is constructed using this clay, can you use the shear strength parameters determined from these tests for evaluating the short term stability of the structure. Give reasons.

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

Figure 4 shows the plan view of two multiplex buildings, M1 and M2. The foundations of M1 and M2 are loaded with a uniform stress 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 **25 m** vertically below **point A** (Use superposition method).

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

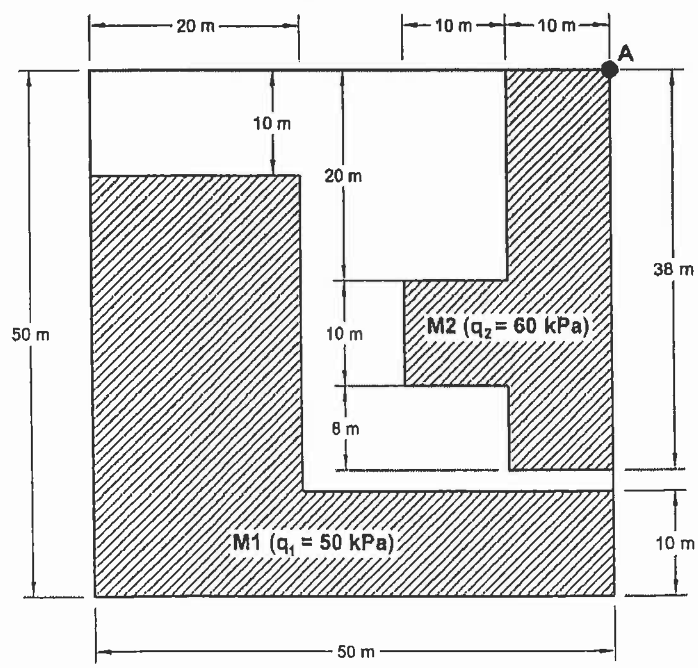


Figure 4

Question 7: **(Value: 20 marks)**

The hydraulic structure and the flow net for the structure are shown in the **Figure 5a** and **Figure 5b** respectively. The coefficient of permeability of the soil is 5×10^{-5} m/s. Determine the quantity of seepage and the uplift force on the base of the structure.

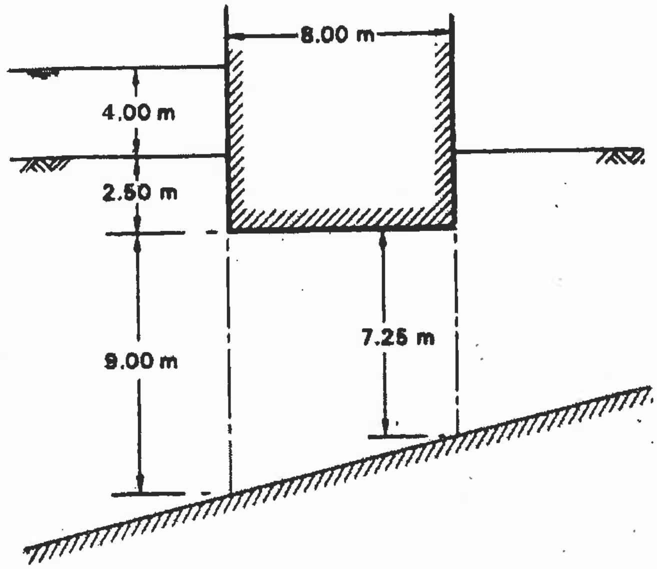


Figure 5a

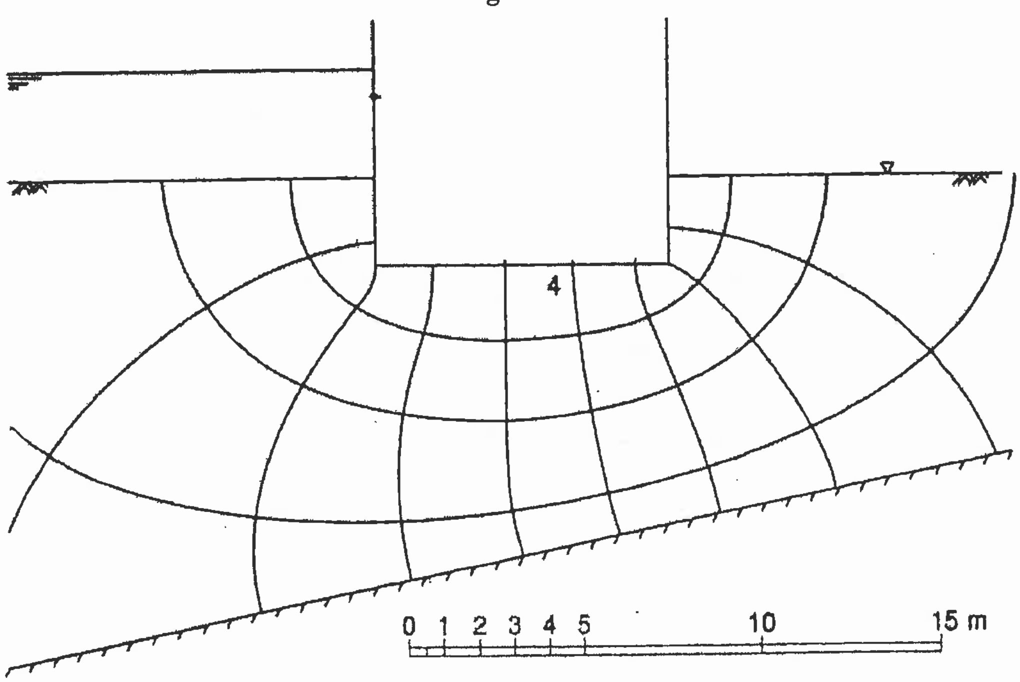


Figure 5b

Question 8: **(Value: 20 marks)**

A vertical retaining wall in Figure 6 has a height, H= 5 m . The backfill has the following properties: $H_1 = 3$m, $H_2 = 2$ m, $q = 20$ kN/m^3, $\gamma_1 = 18$ kN/m^3, $\phi_1 = 30°$, $c_1' = 20$ kN/m^3, $\gamma_2 = 18.5$ kN/m^3, $\phi'_2 = 25°$, and $c_2' = 25$ kN/m^3, $\gamma_{2sat} = 20$ kN/m^3. The water table is located at a depth of 4 m.

a. Determine the Rankine active earth pressure distribution diagram behind the wall.
b. Estimate the Rankine active force per meter length of wall after tensile cracks appear.

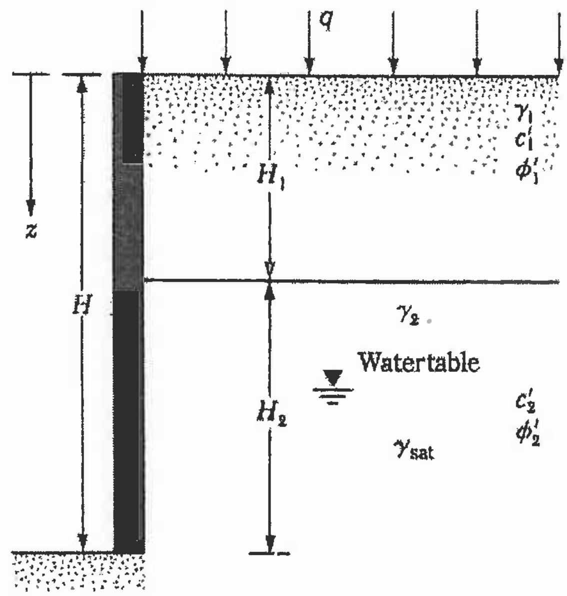
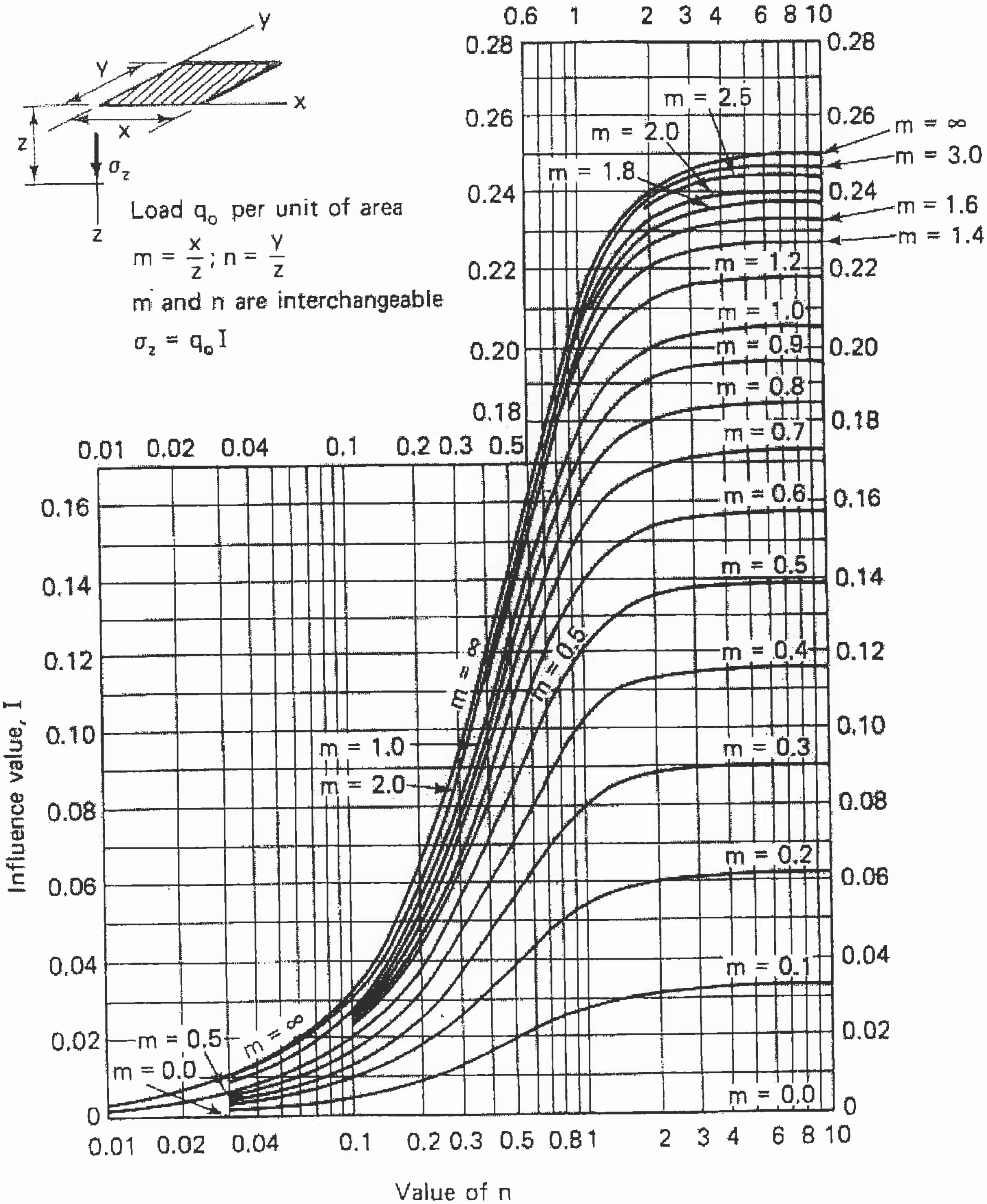
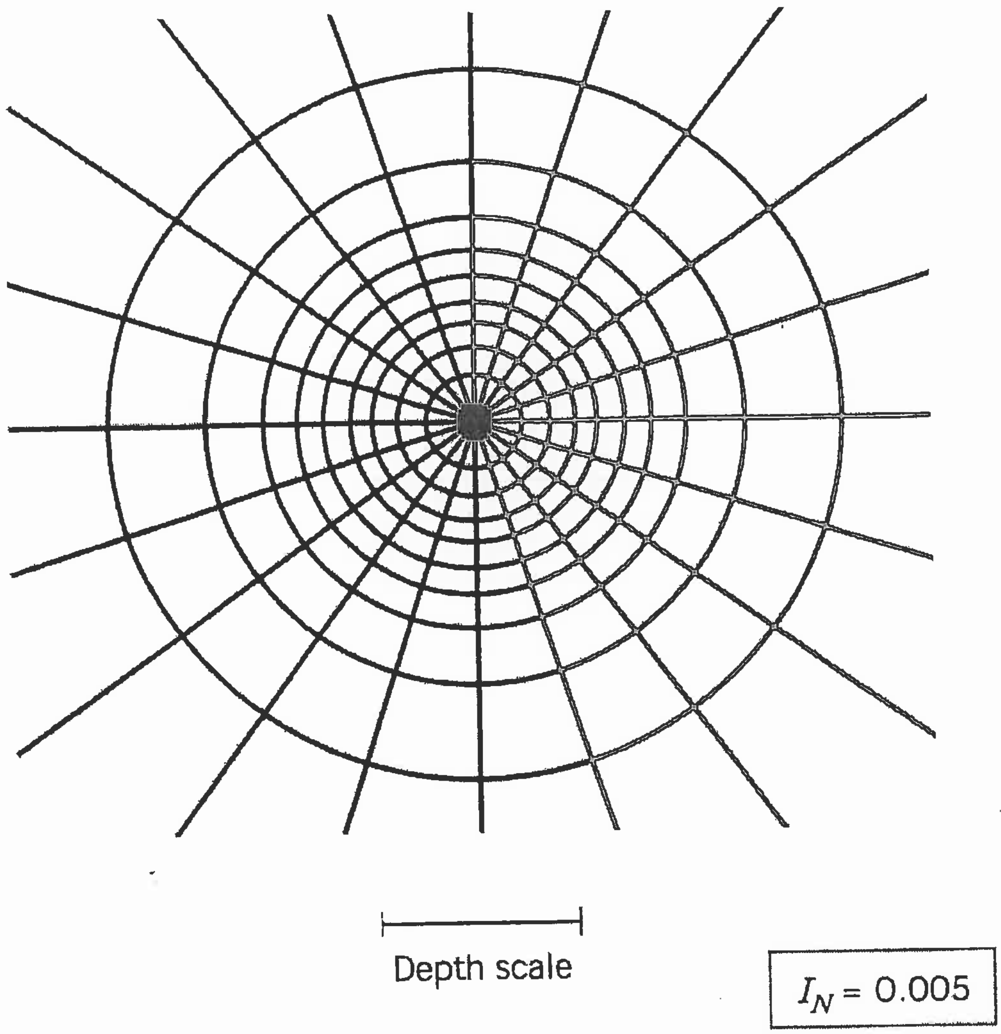


Figure 7


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

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Formula Sheet

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

$\sigma = \gamma D$

$P = \sum N' + u A$

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

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

$\sigma' = \sigma - u$

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

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

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

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: $\sigma_z = 0.005 N q$

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

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

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

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

$T_v = \frac{c_v t}{d^2}$; $T_v = \frac{\pi}{4} U^2$ (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, $C_c = 0.009(LL - 10)$;