

**PROFESSIONAL ENGINEERS ONTARIO**  
**NATIONAL EXAMINATIONS –December 2014**  
**GEOTECHNICAL MATERIALS AND ANALYSIS**

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**3 HOURS DURATION**

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- 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.**
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**ANSWER ALL QUESTIONS**

**Question 1:**

(4 x 5 = 20 marks)

State the correct answer for each of the questions below and **provide reasons** to **JUSTIFY THE STATEMENT IN YOUR ANSWER BOOK.**

|       |  |
|-------|--|
| (i)   | Which one of the following soils: (A) sand; (B) silt or (C) clay will have a higher optimum moisture content (OMC)?  |
| (ii)  | Which one of the following soils (A), sand (B) silt or (C) clay will have a higher coefficient of permeability?  |
| (iii) | A clay specimen was compacted at different compaction water contents (A) wet of optimum; (B) optimum; and (C) dry of optimum. Which one of these will give a higher unconfined compressive strength? |
| (iv)  | Which one of the soils (A) Normally Consolidated clay; (B) Over Consolidated clay will have a higher compression index, $C_c$ ? Provide your reasons.  |
| (v)   | Which one of the soils (A) Normally Consolidated clay or (B) Over Consolidated clay will have a higher effective cohesion value?   |

**Question 2:**

(10 marks)

Briefly explain the three different “limit” lateral earth pressures (i.e., at-rest, active, and passive conditions) that can act on a retaining wall. Also, show the Mohr circle for each condition (Note: You are expected to draw simple sketches of retaining walls and Mohr failure envelopes for the three cases; Figure 1 is shown below as an example without providing the key details).

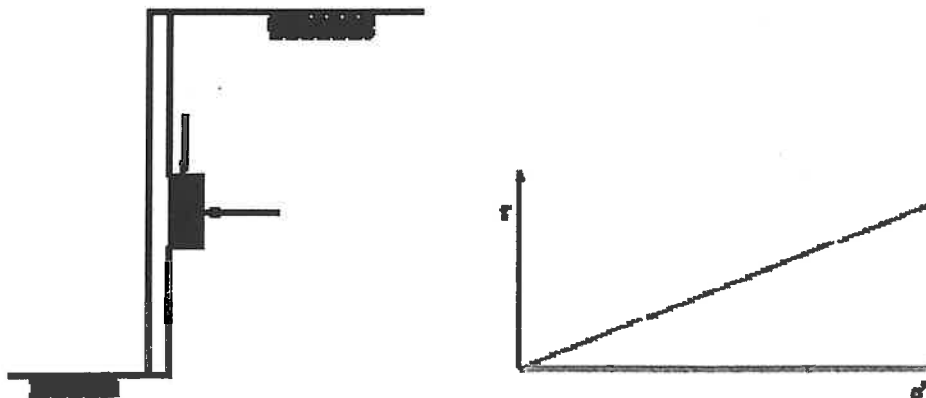


Figure 1

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**Question 3:**

(10 marks)

Clearly explain how seepage affects the stability of a homogeneous earth dam constructed with a silty sand. Describe any two measures you would recommend to improve the stability characteristics. Supplement your answer with a neat sketch.

*(Hint - The key words that can be used in answering this question: pore-water pressures, effective stress, seepage stress, critical hydraulic gradient, shear strength etc)*

**Question 4:**

(Value: 20 marks)

Figure 2 shows the plan view of a condominium structure. The foundation of the building (shaded area) will be loaded with a uniform stress of 50 kPa. Determine the increase in vertical stress  $\Delta\sigma_z$  due to the load, at depths of 2 and 5 m vertically below point A (Use superposition method). Comment on the stress values determined at different depths and how this information is useful for a geotechnical engineer.

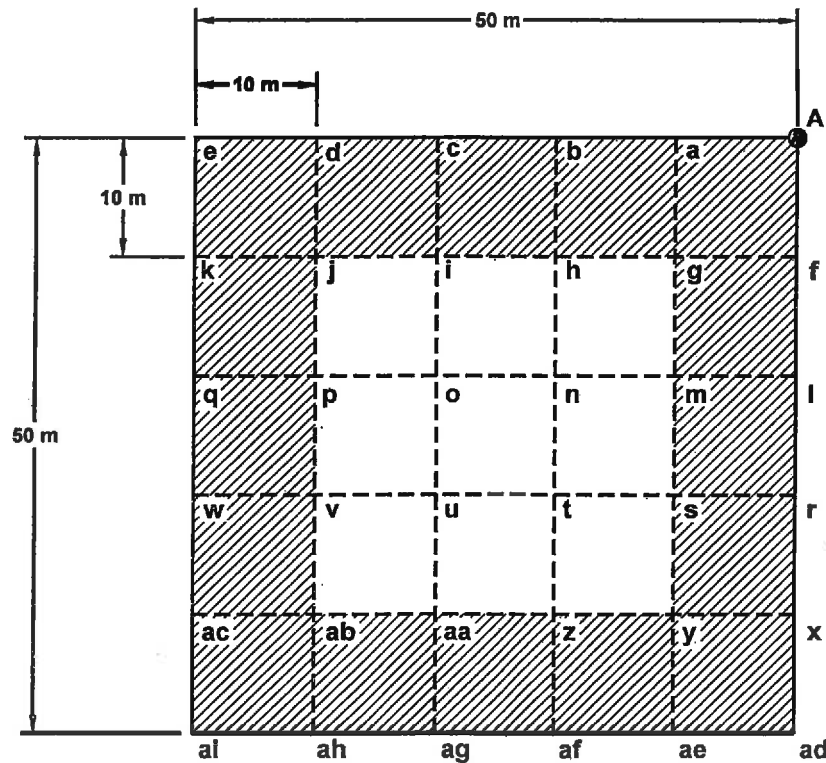


Figure 2

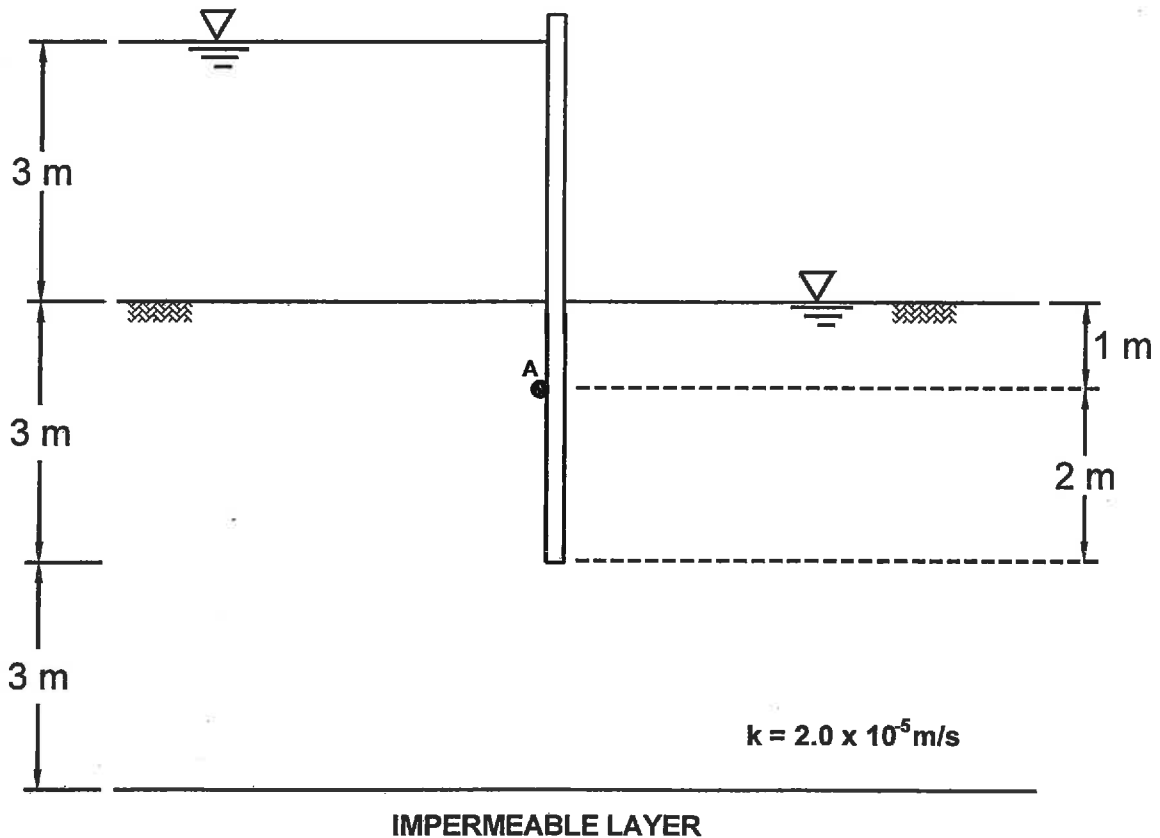
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**Question 5:**

**(Value: 20 marks)**

For a cutoff wall shown in Figure 3

- a. Establish the flow net (i.e. flow and equipotential lines) following all the rules (draw on Figure 4). (15 marks)
- b. Determine the quantity of seepage ( $\text{m}^3/\text{s}$  per m) (coefficient of permeability,  $k = 2.0 \times 10^{-5} \text{ m/s}$ ). (5 marks)



**Figure 3**

**Question 6:**

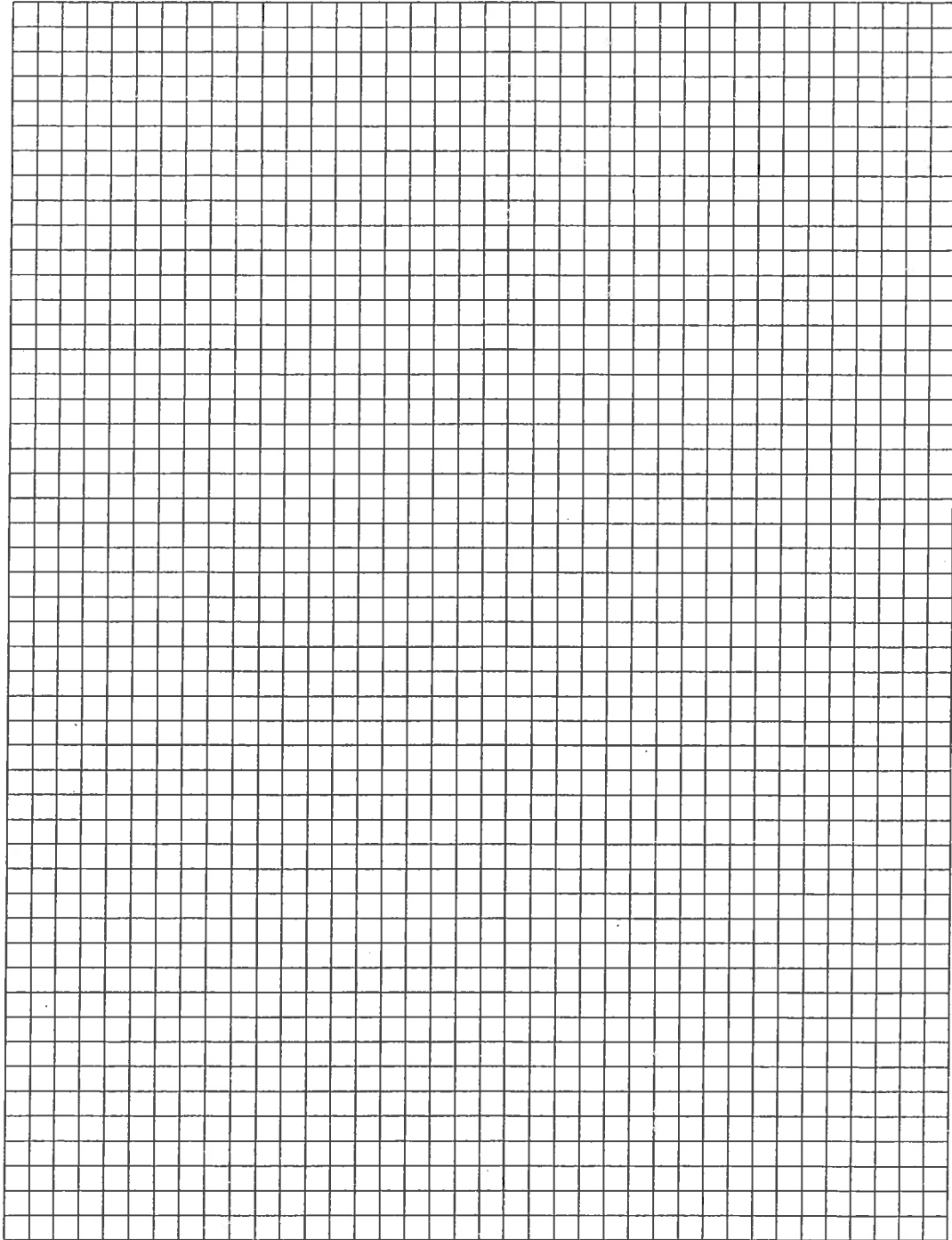
**(Value: 20 marks)**

Triaxial shear tests were conducted under CD conditions on saturated clay specimens and the effective shear strength parameters were determined as:  $c' = 10 \text{ kPa}$  and  $\phi' = 28^\circ$ . Another triaxial shear test was conducted on an identical saturated clay specimen under CU conditions. Determine the applied vertical total stress ( $\sigma_1$ ) that will be acting on the clay specimen at failure conditions, when the applied confining total stress,  $\sigma_3 = 100 \text{ kPa}$  and the measured pore-water pressure,  $u_w = 40 \text{ kPa}$ .

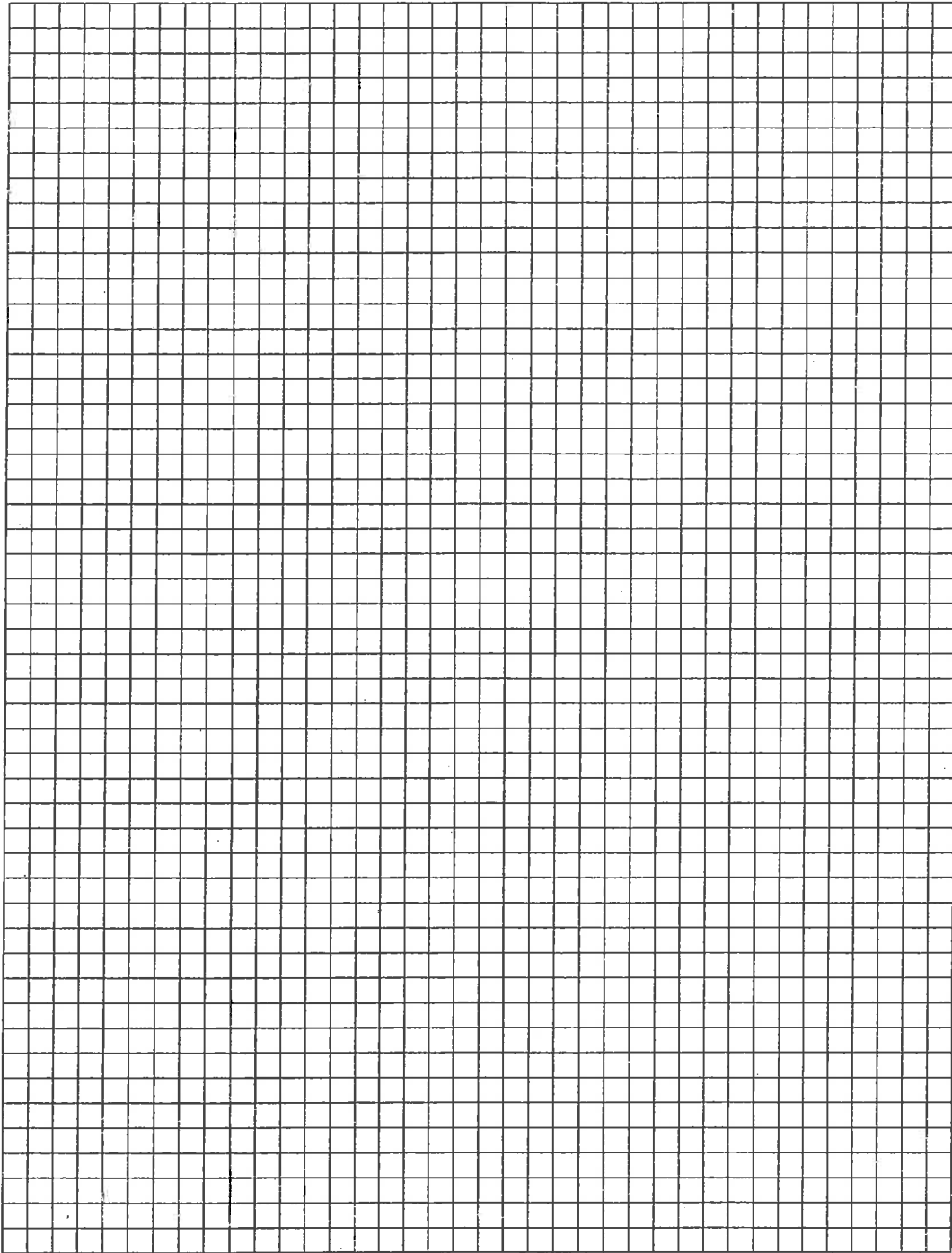
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- (i) The boss, senior geotechnical engineer has asked you, the junior geotechnical engineer to conduct the CU test (as stated in the problem above at a confining stress of  $\sigma_3 = 100$  kPa) to derive some practical information. Explain clearly the information that the senior geotechnical engineer has in mind that can be derived from this test.
- (ii) When do you recommend performing CD and CU tests? Give a practical example for both these tests, providing details.

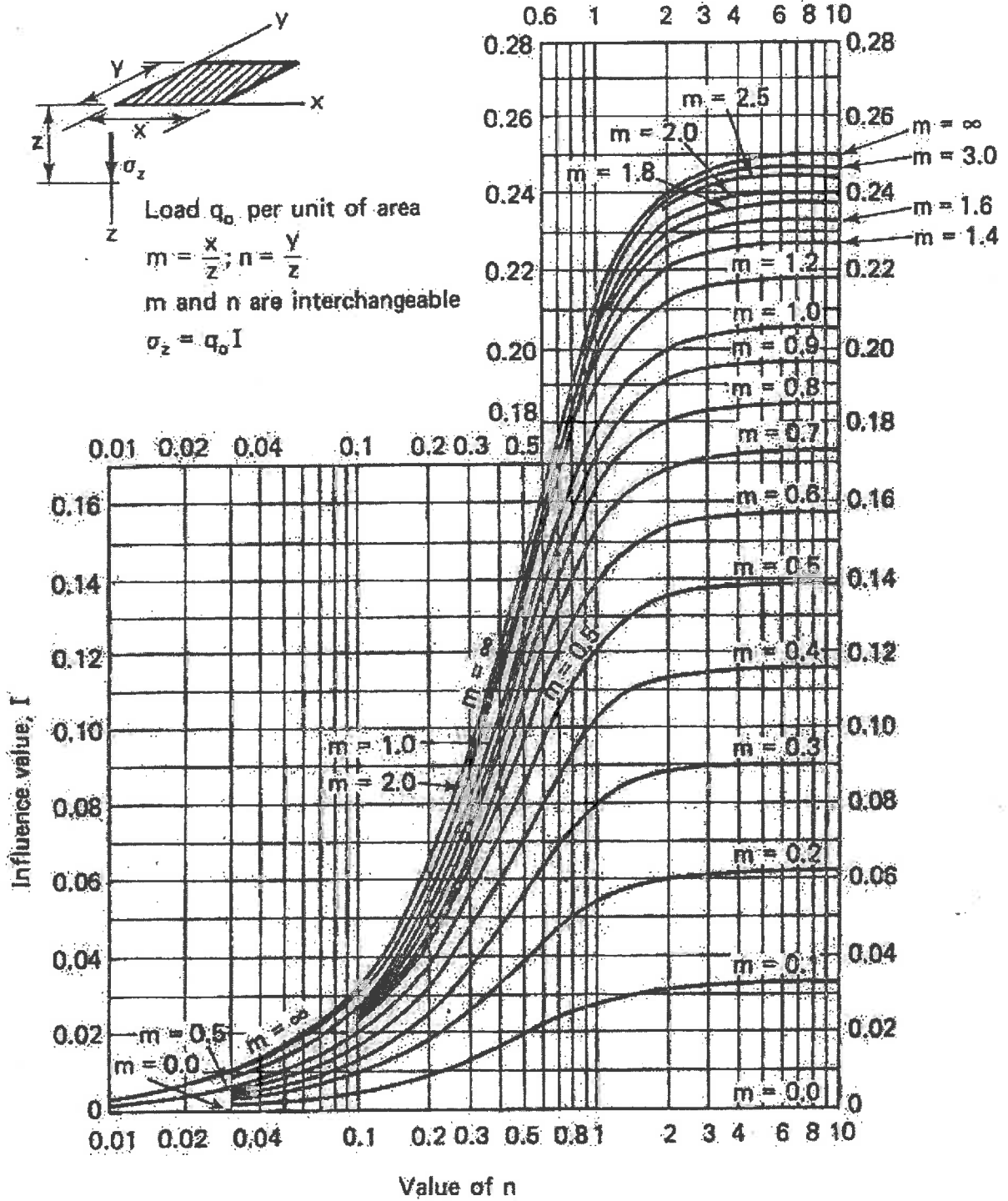
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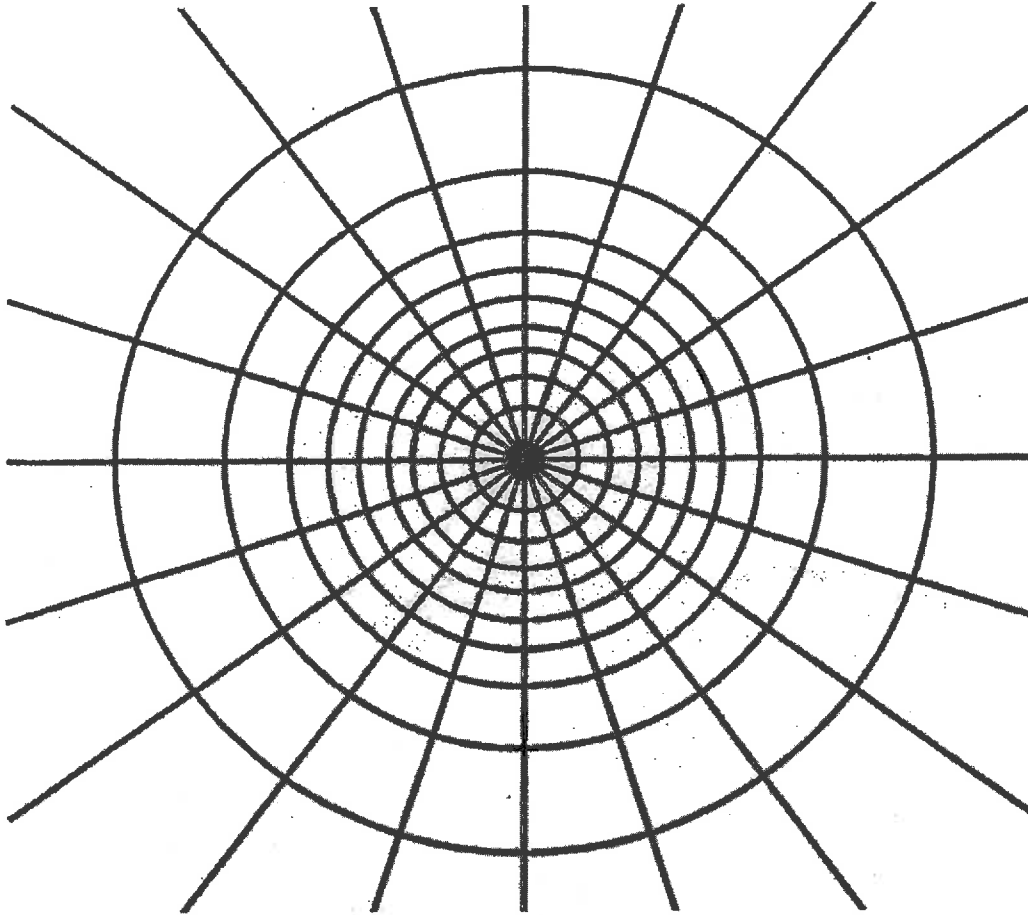


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Depth scale

$$I_N = 0.005$$

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**Formula Sheet**

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

$$\sigma = \gamma D$$

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

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

$$\sigma = \sigma' + u \text{ (or)}$$

$$\sigma' = \sigma - u$$

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

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

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

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)

$$\text{Approximate method to determine vertical stress, } \sigma_z = \frac{qBL}{(B+z)(L+z)}$$

Equation for determination vertical stress using Newmark's chart:  $\sigma_z = 0.005 N q$

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

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

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

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

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

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

$$C_c = \frac{e_0 - e_1}{\log\left(\frac{\sigma_1'}{\sigma_0}\right)}; \text{ also, } C_c = 0.009(LL - 10);$$