

**PROFESSIONAL ENGINEERS ONTARIO**  
**NATIONAL EXAMINATIONS –December 2008**  
**98-CIV-A4 GEOTECHNICAL MATERIALS AND ANALYSIS**

**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 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.**
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**NATIONAL EXAMINATIONS –December 2008**  
**98-CIV-A4 GEOTECHNICAL MATERIALS AND ANALYSIS**

**SECTION A**  
**ANSWER ALL FOUR QUESTIONS**

**Question 1:**

**(Value: 10 marks)**

State the correct answer in your answer book along with the question number.

(i)	The vertical stress in a uniform sandy deposit due to the construction of a ten storey structure increases with the depth.	T	F
(ii)	The effective cohesion in a normally consolidated clay slurry sample measured in the laboratory using triaxial tests is typically close to zero.	T	F
(iii)	At the liquid limit value, the shear strength of an expansive clay (liquid limit = 82%) is the same as the shear strength of a silty clay (liquid limit = 35.5%).	T	F
(iv)	The pore-water pressures are likely to be negative in a typical overconsolidated clay sample when they are subjected to loading in a triaxial test apparatus with a confining pressure lower than its pre-consolidation pressure	T	F
(v)	The pore-water pressure is always positive in a normally consolidated clay sample tested in a triaxial test apparatus irrespective of the applied confining pressure.	T	F
(vi)	The zero-air voids line plotted on a compaction curve for fine-grained soil is typically parallel to the wet of optimum moisture content line (or curve) and is always above it.	T	F
(vii)	Well graded sand has a higher coefficient of permeability in comparison to uniform sand.	T	F
(viii)	Vane shear tests can be used to determine the shear strength of saturated clays under drained loading conditions.	T	F
(ix)	The direct shear test apparatus is useful for determining the undrained cohesive strength, $c_u$ of a soft clay sample.	T	F
(x)	The strength parameters have to be determined under consolidated drained loading conditions to estimate the short term stability of a homogenous earth dam constructed using homogeneous clay.	T	F

**NATIONAL EXAMINATIONS –December 2008**  
**98-CIV-A4 GEOTECHNICAL MATERIALS AND ANALYSIS**

**Question 2:**

**(Value: 10 marks)**

**(i) Which particle shape offers the least shear resistance during loading?**

- (a) angular    (b) sub-angular    (c) sub-rounded    (d) rounded

**(ii) From among the ranges of numerical values given for the degree of saturation, select the valid range for a typical soil sample collected from the field.**

- (a)  $S \leq 0$                       (b)  $0 < S < 100$                       (c)  $0 \leq S \leq 100$                       (d)  $0 \leq S$

**(iii) Fine-grained expansive soils can be classified as per ASTM standards using the following information**

- (a) Using liquid limit and shrinkage limit; (b) Using sieve analysis and hydrometer analysis data; (c) Using plastic limit and liquid limit values (d) None of the above – need more information.

**(iv) One of the symbols listed below is not correct. Circle it.**

- (a) SW                      (b) PS                      (c) GW                      (d) GP

**(v) Which of the following cannot have a value greater than 100%. Note: it is likely that there is more than one correct answer. You will loose marks if your answer is incorrect for this question.**

- (a) Degree of saturation,  $S$     (b) Water content,  $w$     (c) Liquid limit,  $w_L$     (d) Void ratio,  $e$

**Determine whether the following statements below are true or false. Justify your answer with just one or two sentences only if the answer is FALSE.**

**(vi)** Individual sand particles are visible to the naked eye.

**(vii)** Under drained loading conditions on a sand layer, the entire load is borne by the soil particles.

**(viii)** A sample of sand and a sample of clay have the same void ratio value equal to 0.75. Both sand and clay samples will have the same coefficient of permeability as it is dependent on the void ratio.

**(ix)** Effective stresses in a clay layer do not change when water is flowing in a horizontal direction.

NATIONAL EXAMINATIONS –December 2008  
98-CIV-A4 GEOTECHNICAL MATERIALS AND ANALYSIS

(x) Consolidation settlements are typically higher in clayey soils that are finer by nature compared to relatively coarser soils such as silts.

**Question 3:**

(Value: 10 marks)

Figure 1 below shows a sheet pile and its flownet. There are a couple of errors in the flownet shown below. Identify at least four different errors (Label them as 1, 2, 3 and 4) and clearly explain what is wrong.

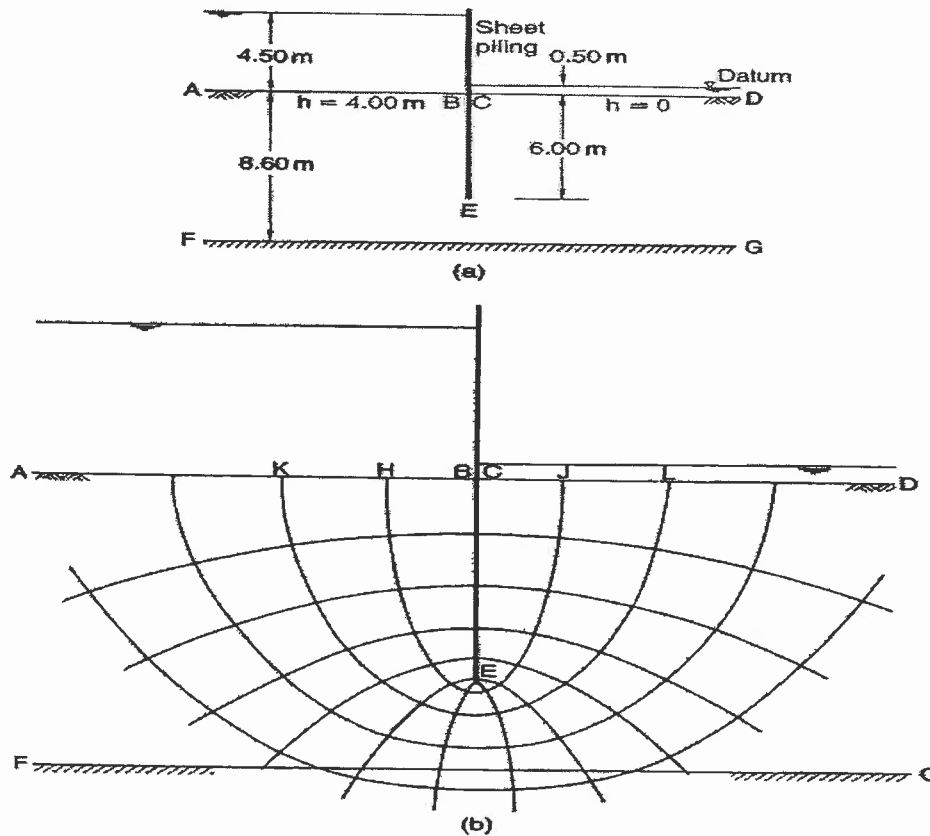


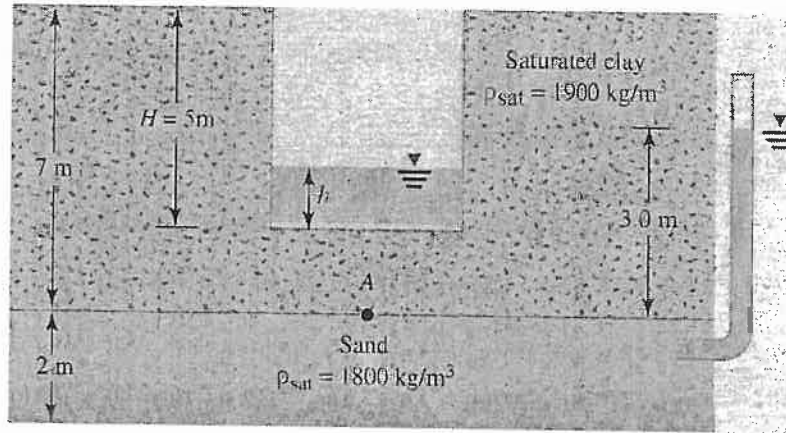
Figure 1

**Question 4:**

(Value: 10 marks)

A cut is made in a stiff saturated clay that is underlain by a layer of sand as shown in Figure 2. What should be the height of the water,  $h$ , in the cut so that the short-term stability of the saturated clay is not lost?

**NATIONAL EXAMINATIONS –December 2008**  
**98-CIV-A4 GEOTECHNICAL MATERIALS AND ANALYSIS**



**Figure 2**

**SECTION B**

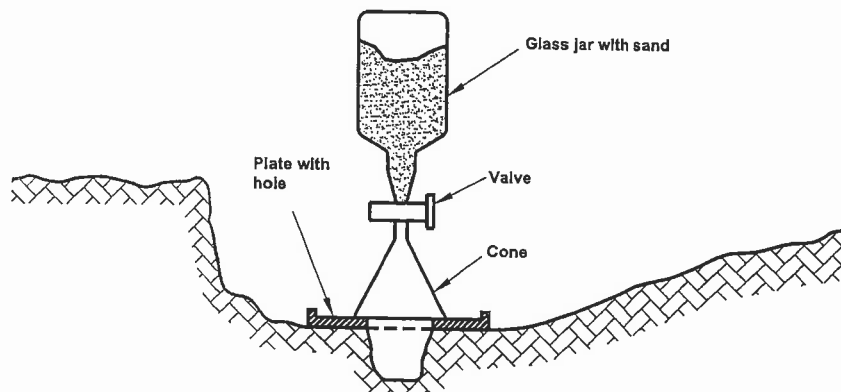
**ANSWER ANY THREE OF THE FOLLOWING  
FOUR QUESTIONS**

**Question 5:**

**(Value: 20 marks)**

Preliminary field compaction tests were carried out during the construction of an embankment. The field unit weight was measured using the sand cone method (see Fig. 3) to check whether the proposed design value of the unit weight was achieved. The following results were obtained.

- Dry unit weight of sand in the jar =  $1570 \text{ kg/m}^3$
- Weight of sand to fill the cone = 0.545 kg
- Weight of jar + cone + sand (before use) = 7.59 kg
- Weight of jar + cone + sand (after use) = 4.78 kg
- Weight of moist soil from hole = 3.007 kg
- Water content of moist soil = 10.2 %



**Figure 3**

**NATIONAL EXAMINATIONS –December 2008**  
**98-CIV-A4 GEOTECHNICAL MATERIALS AND ANALYSIS**

- a. Determine the dry unit weight of compacted soil in the field ( $\text{kN/m}^3$ ).
- b. The laboratory compaction test results for the same soil are shown in Table 1. The contractor has to achieve a value equal or higher than 95% of the maximum dry unit weight determined from the laboratory compaction test results. Provide your comments whether or not the contractor achieved the desired dry unit weight for the construction of the embankment.

Table. 1 Laboratory compaction test results

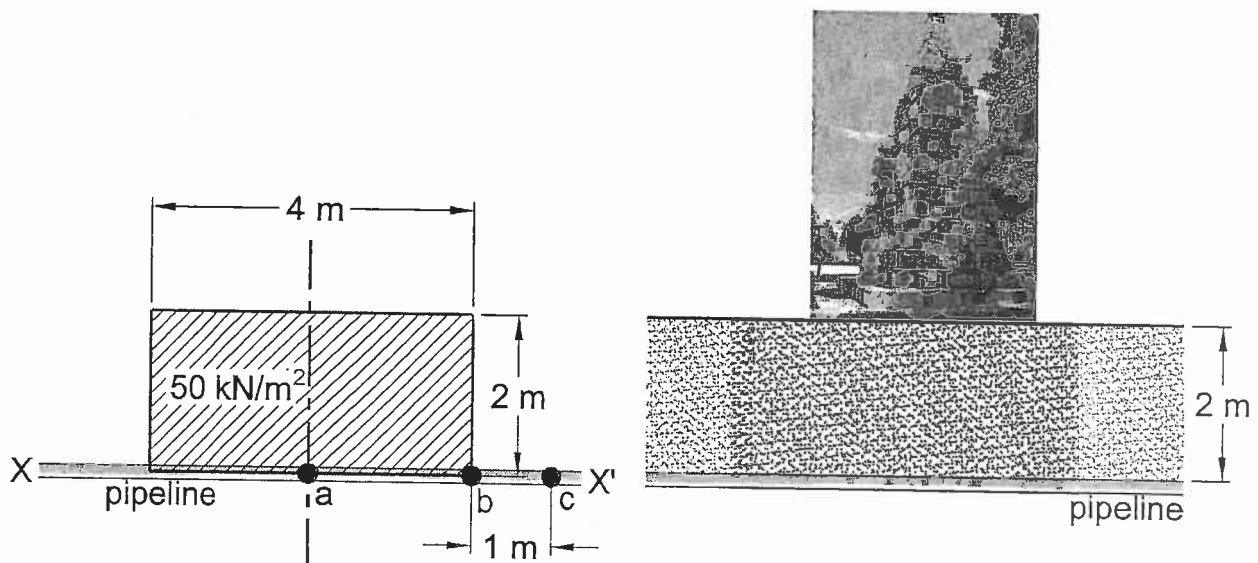
$w(\%)$	$\gamma_d(\text{kN} / \text{m}^3)$
6	14.80
8	17.45
9	18.52
11	18.90
12	18.50
14	16.90

**Question 6:**

**(Value: 20 marks)**

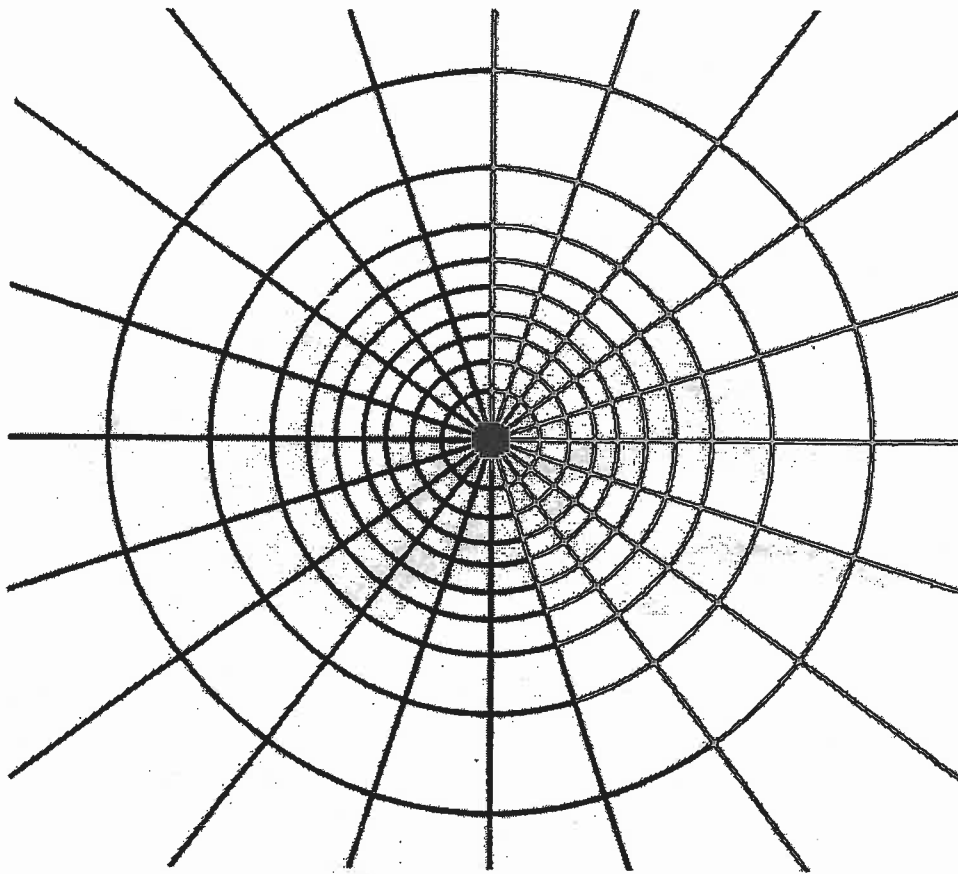
The City of Toronto is planning to construct a monument structure as shown in Figure 4 below close to the downtown area. A vertical stress equal to 50 kPa acts on the footing ( $2 \text{ m} \times 2 \text{ m}$ ) due to the construction of one of the columns for the proposed structure. From the investigation studies, it was found that a pipeline XX' runs along the edge of the building at a depth of 2 m below the foundation level. Estimate the increase in vertical stress at **point b** (as shown in Fig. 4) along the pipeline XX' using Newmark's chart.

Comment on the qualitative difference in the stress values between point **b** and the other two points **a** and **c**. Do not calculate the stresses at points **a** and **c**.



**Figure 4**

NATIONAL EXAMINATIONS –December 2008  
98-CIV-A4 GEOTECHNICAL MATERIALS AND ANALYSIS



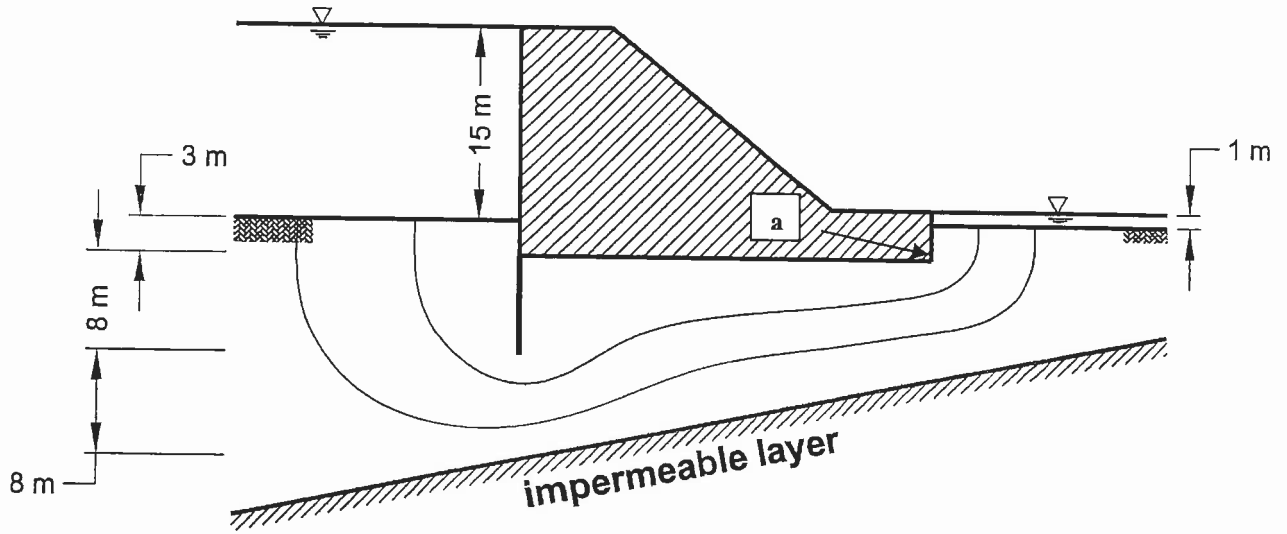
|-----|  
Depth scale

$I_N = 0.005$
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**Question 7:**

(Value: 20 marks)

The dam shown in Fig. 5 is located on an isotropic soil. The coefficient of permeability is  $5.0 \times 10^{-7}$  m/s. Complete the flow net and determine the quantity of seepage under the dam ( $\text{m}^3/\text{s}$  per m). Also, determine the pressure at point a.



**Figure 5**

**Question 8:**

**(Value: 20 marks)**

The effective stress parameters for a fully saturated clay are known to be  $c' = 20 \text{ kN/m}^2$  and  $\phi' = 30^\circ$ . In an unconsolidated-undrained triaxial test on a specimen of the same clay the all-round pressure was  $100 \text{ kN/m}^2$  and the principal stress difference at failure was  $180 \text{ kN/m}^2$ . What was the value of the pore water pressure in the specimen at failure?



**NATIONAL EXAMINATIONS –December 2008**  
**98-CIV-A4 GEOTECHNICAL MATERIALS AND ANALYSIS**

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

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

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