OLLSCOIL NA hÉIREANN

NATIONAL UNIVERSITY OF IRELAND, GALWAY

SECOND SEMESTER EXAMINATIONS, 2001

B.E. CIVIL AND ENVIORNMENTAL ENGINEERING

SOIL MECHANICS

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Time allowed: *three hours.*

Answer *five* out of eight questions.

Question 1

(a) Describe with the aid of neat sketches how you would obtain the following parameters for a saturated soil:

i. the coefficient of primary consolidation;
ii. the coefficient of secondary consolidation; and
iii. the preconsolidation pressure.

Discuss the significance of the preconsolidation pressure in relation to embankment construction over lightly over consolidated soils. **(8 marks)**

(b) An embankment is to be constructed over a layer of saturated clay, 6 m thick, with an impermeable lower boundary. Construction of the embankment will increase the vertical stress throughout the clay layer by 80 kN/m^2. The coefficients of primary consolidation in the vertical and horizontal directions for the clay are c_v =1.0 m^2/year and c_h = 3.0 m^2/year respectively. The coefficient of volume change, m_v, is 0.45 m^2/MN. Determine the spacing, in a square pattern, of 200 mm diameter vertical drains if the design requirement is that all but 25 mm of the settlement due to primary consolidation will have

taken place in the first two years. Charts for radial and vertical consolidation are given in the appendix. **(12 marks)**

Question 2

a) Discuss briefly the following terms with respect to unsaturated soil mechanics: matric suction; osmotic suction and hysteresis. **(6 marks)**

b) Show that the matric suction in a tensiometer placed in the capillary fringe above the water table may be given by:

$$u_a - u_w = \frac{2T}{R}$$

where u_a is the pore air pressure, u_w is the pore water pressure, T is the surface tension between the air and water and R is the radius of the tensiometer tube. **(10 marks)**

c) A monometer is placed in unsaturated soil at a depth of 300 mm below ground surface. The difference in water levels between the two tubes is 100 mm. A piezometer indicates that the water table lies 1.0 m below the ground surface. Using the ground surface as a datum, determine the hydraulic potential at a depth of 300 mm below ground surface. Show how the hydraulic potential can vary from dry, warm summers to wet winters. **(4 marks)**

Question 3

a) Discuss briefly the formation of sinkholes in karstic regions in Ireland. Show with aid of a diagram how soil arching in sand or gravel above the cavity can make the final failure more serious. Describe what preventive measures may be taken to avoid catastrophic failure. **(8 marks)**

b) A soil stratum extends from ground surface to a depth of 10 m. A structure is to be founded on this soil at a depth of 1 m. The foundation width is 3 m. The structure applies a gross foundation pressure of 200 kN/m^2 to the soil. The unit weight of the soil is 15 kN/m^3 and the water table is located 4 m below ground level. Piezocone tests were carried out and the information from the tests is

given below. Estimate the settlement under the structure after a) the construction and b) after a period of 5 years has elapsed.

Depth below ground level (m)	0→2	2→4	4→6	6→8	8→10
Average end resistance (MN/m^2)	2.5	3.6	4.2	4.5	7.0

The following information may be useful:

$$\delta = C_1 \cdot C_2 \cdot \Delta p \cdot \sum_{0}^{2B} \left(\frac{I_z}{E} \cdot \Delta z \right)$$

$$C_1 = 1 - 0.5\left(\frac{p'_0}{\Delta p} \right)$$

$$C_2 = 1 + 0.2\log_{10}\left(\frac{t}{0.1} \right)$$

where δ is the settlement, p is pressure, t is time, Δz is the thickness of a soil layer, E is Young's modulus, I_z is a strain influence factor and 2B is the foundation width. **(12 marks)**

Question 4

a) Discuss how you would use the observation method for the design and construction of a geotechnical project. **(8 marks)**

b) A sheet pile wall is to be used to retain sand to a depth of 6 m. The sand has a bulk unit weight of 16 kN/m^3, an angle of internal resistance, ϕ', of 35°. The surface of the sand is level with the top of the piles. Design a suitable arrangement for an anchored sheet pile construction where the anchor tie-rods are located 1.4 m below the top sand surface and are spaced 2.5 m apart horizontally along the sheet pile wall.

List any assumptions made and calculate the proportion of the possible passive resistance that is mobilised on the embedded length of the sheet piling. Calculate the force in the tie rods. **(12 marks)**

Question 5

a) What material properties should be considered for geosynthetic reinforcement of embankments over soft soils? Describe the forces acting on the geosynthetic when placed at the base of an embankment. Use diagrams to illustrate your answer. **(6 marks)**

b) A constructed embankment is 6.0 m high. It has side slopes of 1 vertical to 1.5 horizontal. An assumed circular failure surface has a radius of 9 m; the circle centre of the failure surface is at a level of 9 m above the original horizontal ground surface and is 2.5 m horizontally in from the toe of the embankment on the embankment side. The unit weight of the soil is 20 kN/m^3 and the shear strength effective stress parameters are $c' = 12$ kN/m^2 and $\phi' = 30°$. The pore water pressure ratio for the soil can be taken as 0.5. Determine the factor of safety for the assumed failure surface using a method of slices. **(14 marks)**

Question 6

a) Using a critical state model, show that the incremental elastic volumetric and shear strains for a soil can be given by the following equations:

$$\Delta\varepsilon_p = -\frac{\kappa \cdot \Delta p'}{V \cdot p'}$$

$$\Delta e_q = \frac{2}{9}\frac{(1+V)}{(1-2V)}\frac{\kappa \cdot \Delta q}{v \cdot p'}$$

where $\Delta\varepsilon_p$ and $\Delta\varepsilon_q$ are the incremental elastic volumetric and shear strains respectively, p' is the mean effective normal stress, q is the deviator stress, v is the specific volume, V is Poisson's ratio and κ is the slope of the unloading line on the plane of v and ln p'. **(12 marks)**

b) A soil element with a specific volume of 2.10 had a mean normal effective stress of 120 kPa and a deviator stress of 60 kPa. The critical state parameters of the soil were: M = 0.95; N = 3.10; $\kappa = 0.05$; $\lambda = 0.25$; $H = 0.75$; $V = 0.3$ and $\Gamma = 3.10$. The element was then subjected to increments of mean normal effective and deviator stresses of 5 kPa and 10 kPa respectively. Find the resulting shear and volumetric strains.

Use should be made of the following equation for the Hvorslev surface in a critical state model:

$$q = (M - H)\exp^{\left(\frac{\Gamma - v}{\lambda}\right)} + Hp'$$

where M is the slope of the critical state line and H is the slope of the Hvorslev surface on the plane of q and p', and λ is the slope of the normal consolidation line on the plane of v and ln p'. **(8 marks)**

Question 7

a) Describe how the isotropic consolidated test is performed. What use is made of the pore water pressure parameter B? Describe briefly how the pore water pressure ratio A can be negative for positive increases in total stress in heavily over consolidated clays. **(8 marks)**

b) A saturated clay specimen was placed in a triaxial cell with a cell pressure of 200 kPa. The specimen was loaded axially in compression in an isotropic consolidated undrained test and the maximum observed deviator stress was 60 kPa. If the effective stress shear parameters of the clay are $c' = 10$ kPa and $\phi' = 30°$, find the values of excess pore water pressure generated. If the initial pore water pressure was 110 kPa, what was the magnitude of the pore water pressure ratio A and what was the stress history of the clay? **(12 marks)**

Question 8

A vertical sheet pile wall is driven 4 m into a horizontal surface stratum of permeable material 8 m thick overlying impermeable bedrock. The surface of the water is 6 m above the stratum surface at the back of the wall and is at the stratum surface at the front of the wall. The soil is isotropic and has a permeability coefficient of $k = 5 \times 10^{-8}$ m/s. From the flow net establish a set of potentials on a one metre grid. Using a relaxation process improve the set of potentials obtained from the flow net. Assume suitable locations for upstream and downstream vertical boundaries. Estimate the steady state seepage under the sheet pile and calculate the pore water pressures at the front and back of the sheet pile. **(20 marks)**

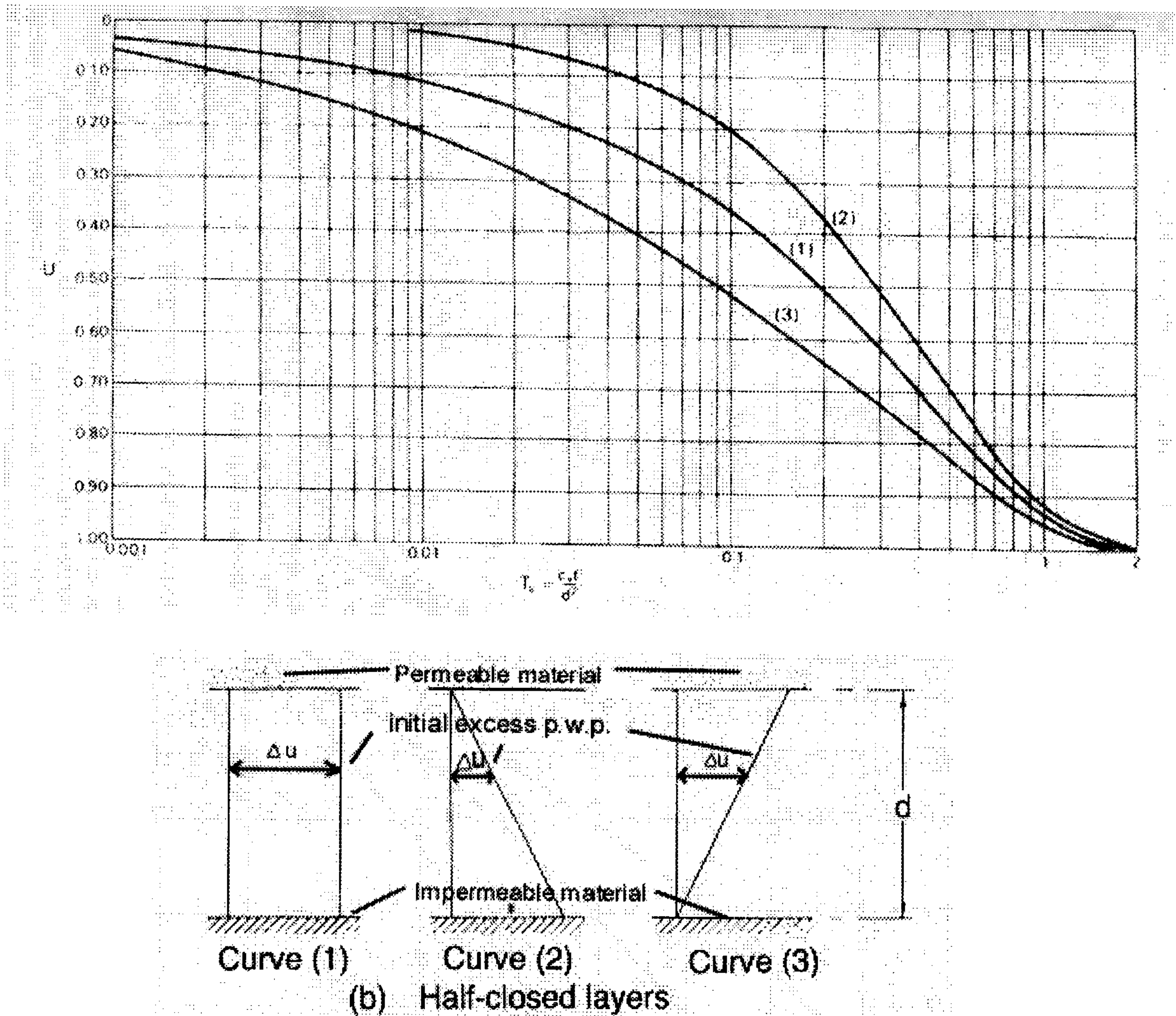

Figure 1. Solutions for vertical consolidation

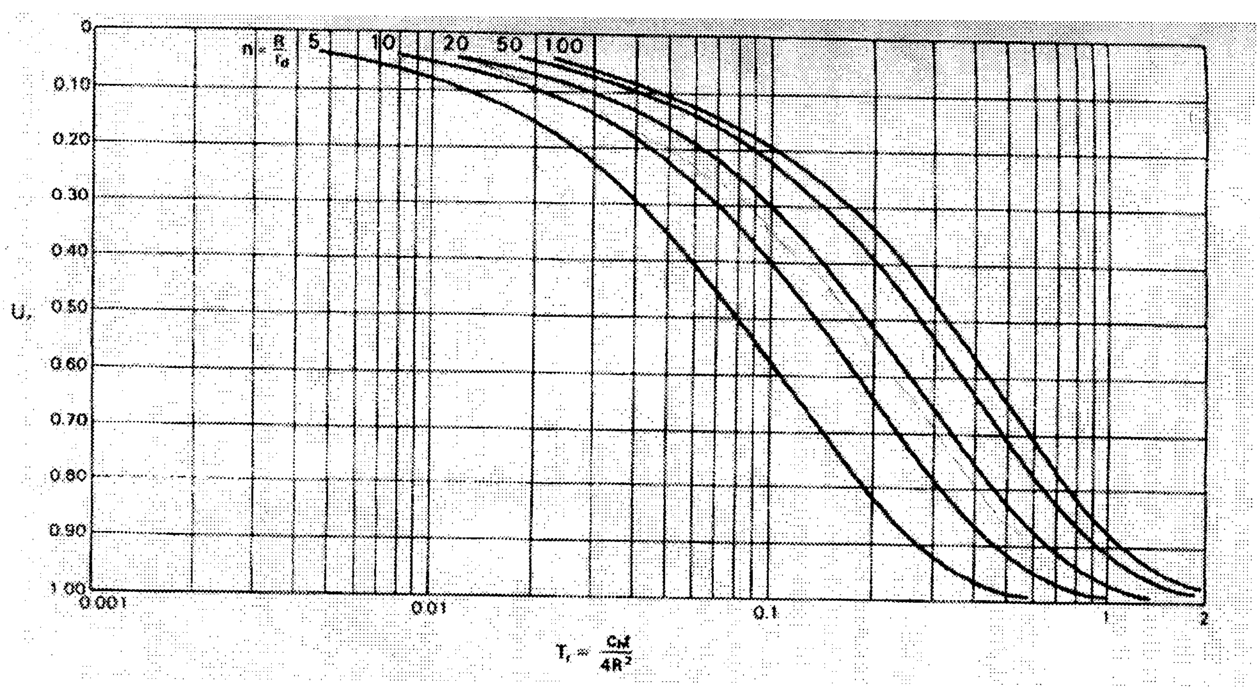

Figure 2. Solution for radial consolidation.