ENGINEERING TRIPOS   PART IIA

Tuesday 29 April 2008   9 to 10.30

Module 3D6

ENVIRONMENTAL GEOTECHNICS

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

Attachments: Data Book (10 pages)
Working sheet for Q2 (Should be handed in with your script)

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed
Extra copy of Fig. 2 (Question 2)

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1 (a) Derive an expression for the capillary rise of water with surface tension T in a tube of diameter d. [20%]

(b) Table 1 shows the properties of two soils, silt and sand. Estimate the capillary rise of water in the silt if the surface tension of water T is 7.3×10^{-5} kN/m. [10%]

(c) Calculate the dry and saturated unit weights of the silt and sand taking the unit weight of water as 10 kN/m^3. [20%]

(d) Figure 1 shows a cross section of soil strata at a site in which 2 m of silt layer overlies 5 m of sand layer which in turn overlies bed rock. Both the soil layers remain fully saturated. Two standpipes were inserted through the silt into the sand layer at locations A and B separated by a horizontal distance of 50 m. The base of standpipe at A and B is 2.5 m above the bedrock. The Darcy's flow velocity for ground water flow from A to B in the sand layer is given as 0.05 cm/s. If the height to which water rises in standpipe A is 0.5 m below the surface of the silt layer, determine the height to which water would rise at location B with respect to the surface of the silt layer. [20%]

(e) Assuming that all the ground water flow is through the sand layer only, sketch the pore pressure, total and effective stress distributions with depth at a cross-section xx shown in Fig. 1. State any additional assumptions you had to make. [30%]

Table 1 Soil properties

Soil layer	Specific gravity of grains G_s	Void ratio e	Particle sizes			Hydraulic conductivity K (m/s)
			D_{10} (mm)	D_{20} (mm)	D_{50} (mm)	
Silt	2.63	0.73	0.01	0.03	0.08	4.5×10^{-5}
Sand	2.65	0.62	0.2	0.3	1.0	2.5×10^{-2}

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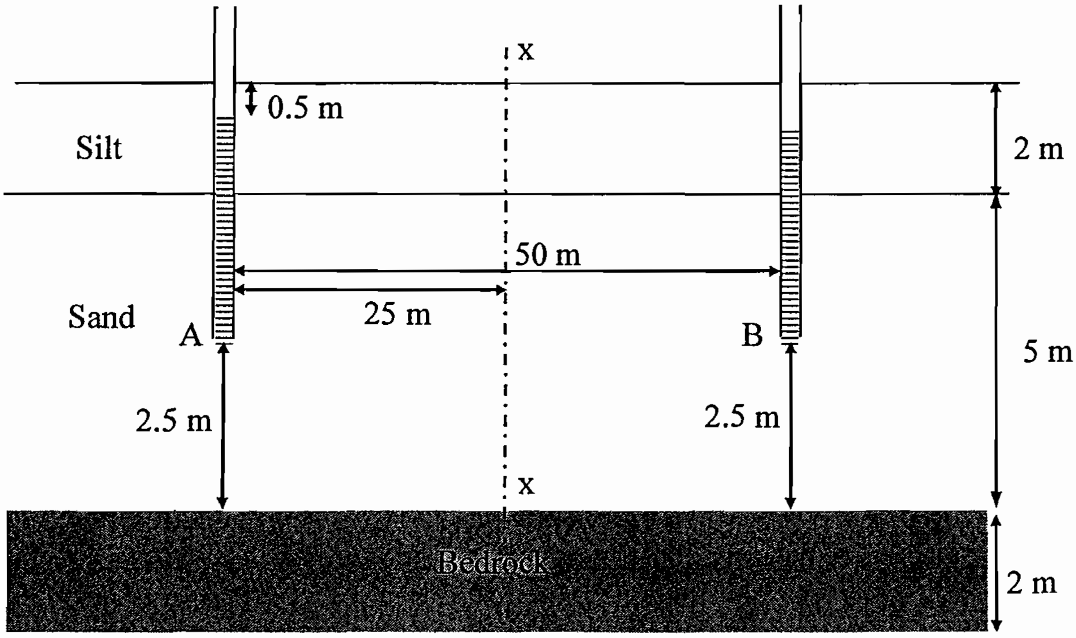

Fig. 1

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2 (a) Assuming Darcy's law for steady state seepage through porous media is valid and that such seepage flow can be described by a *curvilinear square* flownet, derive an expression for the volumetric rate of water flow through a soil of hydraulic conductivity K with potential head difference $\Delta \bar{h}$. You should use the number of potential drops as N_h and the number of flownet tubes as N_f. [20%]

(b) An earth dam is to be constructed across a river using locally available silty clay. The earth dam is expected to remain fully saturated with no air entry. A 4 m thick silty clay layer overlies a 4 m thick impermeable shale as shown in Fig. 2. The upstream and downstream water levels are expected to be maintained at 12 m and 0 m with respect to the surface of the virgin silty clay layer. Laboratory tests revealed that the hydraulic conductivity of the silty clay to be 6.8×10^{-6} m/s. A blanket drain is to be constructed on the downstream side of the dam as shown in Fig. 2.

(i) Draw a flownet for seepage on the additional copy of Fig. 2 provided, which must be handed in with your answer. Draw attention to any shortcomings in your solution. [20%]

(ii) Estimate the rate of leakage rate from the reservoir. [20%]

(iii) Sketch the phreatic surface on your flownet. [20%]

(c) Explain how the performance and stability of the earth dam may be influenced by the length of the blanket drain. [20%]

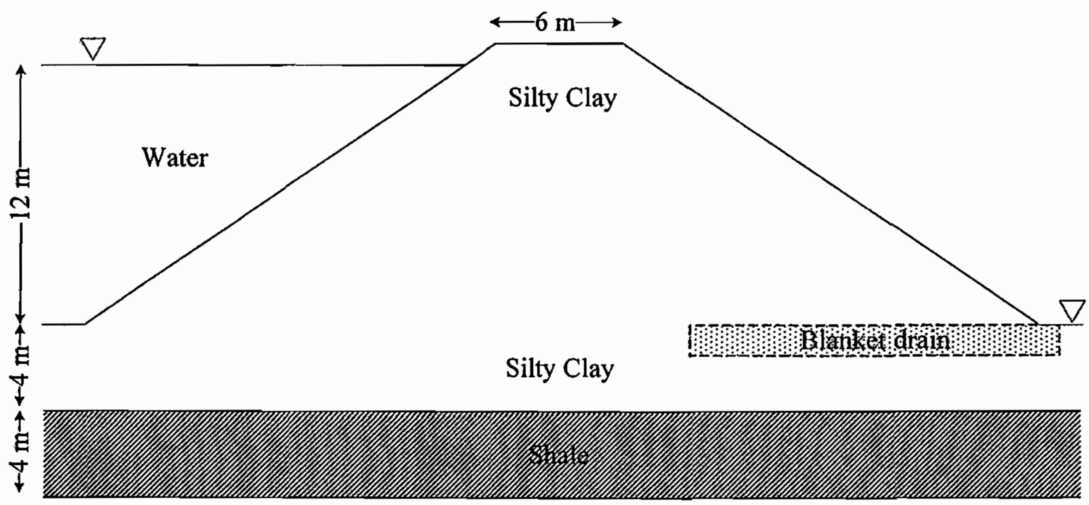

Fig. 2

3 (a) A pumping well was driven into an aquifer 6 m in thickness that is embedded between two layers of stiff clay. The radius of the well is 100 mm. The aquifer is a sandy layer with a hydraulic conductivity K of 5×10^{-3} m/s. If the hydraulic potential heads are 7.0 m and 7.1 m at horizontal distances of 20 m and 30 m from the centre of the well, calculate the water yield from the well. [30%]

(b) The radius of influence R of the pumping well in part (a) above is 200 m. Calculate the maximum drawdown in the water table due to pumping. [20%]

(c) Due to construction activity in the neighbouring area a sheet pile wall is to be driven through the aquifer. This sheet pile wall is driven in a straight line in plan view and is 10 m from the centre of the well at its closest point. Using image theory for wells, estimate the change in drawdown at the closest point after the sheet pile wall is driven. [20%]

(d) The advective-dispersive equation for contaminant transport can be written as;

$$\frac{\partial c}{\partial t} = D_l \frac{\partial^2 c}{\partial z^2} - v_f \frac{\partial c}{\partial z}$$

where D_l and v_f are the longitudinal hydrodynamic dispersion coefficient and the vertical ground water flow velocity respectively. Consider the case of a contaminated site with a constant concentration c_o of contamination at the surface of a clay layer of thickness L that overlies an aquifer as shown in Fig. 3. Under steady state conditions that are established in the long term, show that the contaminant concentration changes linearly with depth if v_f can be assumed to be small. [30%]

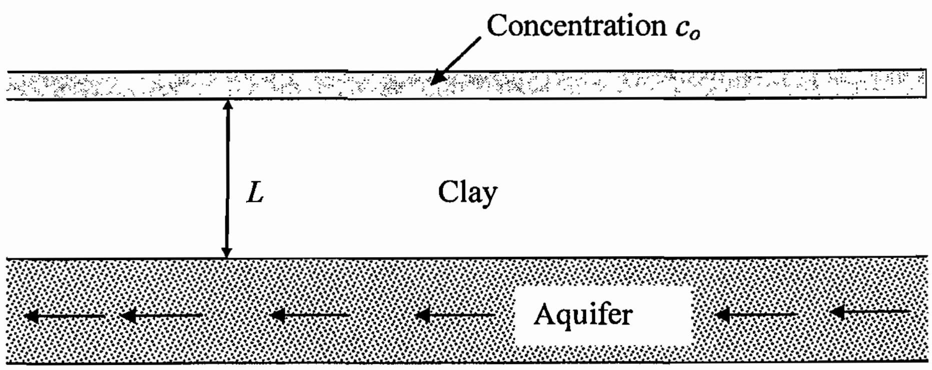

Fig. 3

4 (a) What are DNAPLs and LNAPLs? How do they tend to migrate in the subsurface? Which contaminants are more difficult to find in the subsurface? Discuss in relation to their physical properties. [20%]

(b) What does a cancer risk of 10^{-6} mean? How does this value relate to the maximum contamination level in drinking water? [15%]

(c) A former industrial site is to be redeveloped for new residential houses. During the site investigation, it was found that hydrocarbons had leaked from an abandoned underground storage tank. The tank is located above the water table and the spill contaminated the vadose (unsaturated) zone. The subsurface temperature is 20 °C. The bulk density of the soil is 1800 kg/m^3 and the soil contained 1% of organic carbon.

(i) Benzene is the major component of the spilled contaminants. A soil vapour survey was conducted at the site and the gas contained 2000 ppmV of benzene. Estimate the benzene concentration (in mg/L) in the soil moisture, using Henry's law. [15%]

(ii) From the aqueous concentration evaluated in part (i), estimate the sorbed soil concentration. Use the linear adsorption isotherm model. [15%]

(iii) A child inhales 2 m^3 of the contaminated air and ingests a mouthful (10 cm^3) of the contaminated soil daily. Which of these (inhalation or ingestion) exposes the child to more benzene? [15%]

(iv) Identify a remediation technology to remove the nonaqueous phase hydrocarbons. Describe how it works using a diagram. [20%]

END OF PAPER

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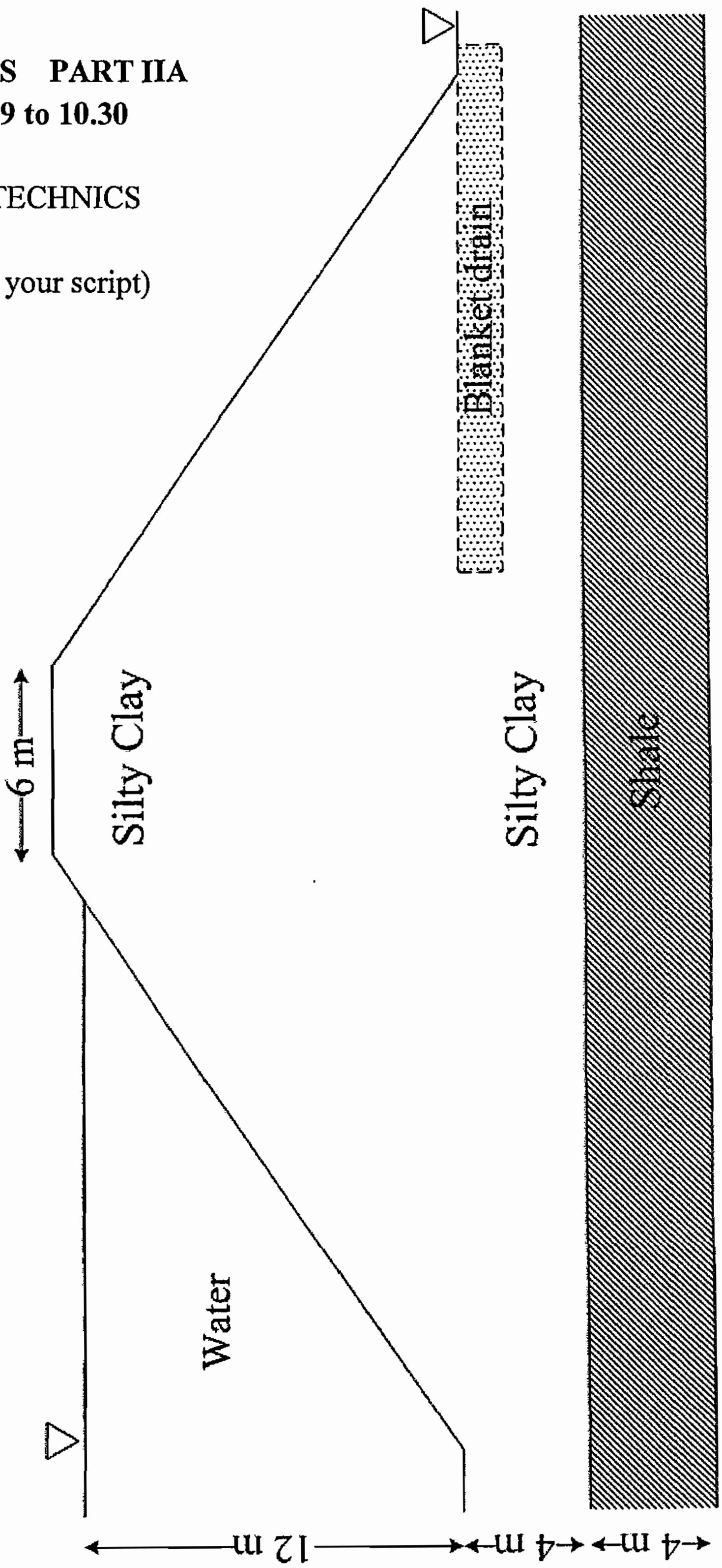

Extra copy of Fig. 2