ENGINEERING TRIPOS PART IIA

Wednesday 7 May 2003 2.30 to 4

Module 3D6

ENVIRONMENTAL ENGINEERING II

*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.*

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

(TURN OVER

1 (a) As climate change causes surface temperatures to increase, the UK is predicted to experience increased annual average rainfall. In terms of integrated water resources management in the UK, describe the effect that this will have on existing infrastructure and what can be done to minimise the resultant problems. [30%]

(b) An integrated water resources model may have several elements. Describe the information that may be included in each of the following model components:

(i) urban drainage; [15%]

(ii) river. [15%]

Describe also how the interactions between these two elements would be modelled. [15%]

(c) The role of engineering needs to change to accommodate the concepts of sustainable development that will allow the needs of today to be met while also having consideration for future needs. Discuss how the new engineering professional can progress from applying engineering science to considering broader aspects more holistically. (Holistically means considering complete systems rather than parts). [25%]

2 (a) Use Darcy's law for steady state seepage to derive an expression for the volume of water flow through soil where seepage flow can be described by a 'curvilinear square' flownet. [20%]

(b) Figure 1 shows a cross-section through a reservoir embankment. The embankment is constructed of homogeneous silty clay resting on a 2 m thick layer of similar material, overlying impermeable rock. The depth of water in the reservoir is 10 m. The embankment is provided with a downstream drainage blanket designed to prevent clogging. The hydraulic conductivity of the silty clay is 3×10^{-8} m s^{-1}. Assume that the embankment is completely saturated.

(i) Construct a flownet through the embankment clearly stating any assumptions made, in particular those related to boundary conditions. Use the enlarged copy of Fig. 1 provided on a separate sheet at the end of the paper. This sheet must be handed in with your answer. [40%]

(ii) What is the leakage rate through the embankment? [10%]

(iii) Construct the phreatic surface through the embankment explaining your procedure. [20%]

(iv) Find the potential and pore pressure at a point under the centreline of the embankment at a depth of 2 m below the crest. [10%]

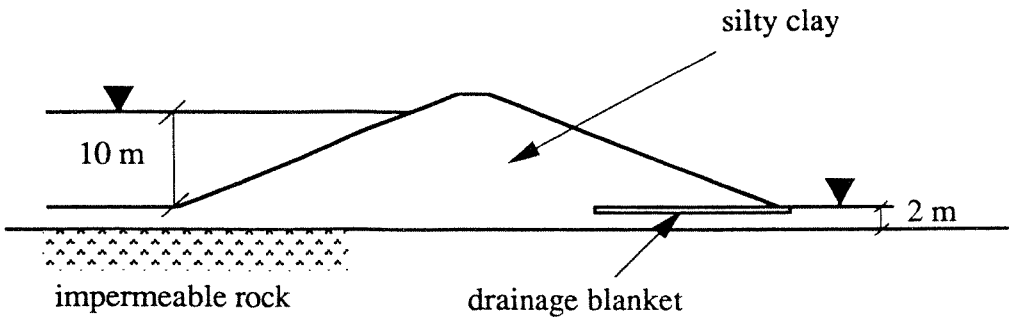

Fig. 1

3 (a) Derive the expression for the effective vertical hydraulic conductivity of a soil deposit consisting of two horizontal layers of different thicknesses and with different hydraulic conductivities. [25%]

(b) At a chemical works site the ground conditions consist of 2 m of fine sand overlying 6 m of clayey silt which in turn overlies an aquifer. The hydraulic conductivities of the fine sand and clayey silt are 0.8×10^{-5} m s^{-1} and 0.3×10^{-7} m s^{-1} respectively. There is a surface pond 0.5 m deep while the level to which water rises in a standpipe driven into the aquifer is 5 m below the top surface of the soil. For convenience assume that both soils have the following properties: porosity n of 0.45, longitudinal dispersivity α of 0.4 m and tortuosity τ of 0.5.

(i) What is the effective vertical hydraulic conductivity of the soil deposit? [10%]

(ii) An accident contaminates the surface pond with a chemical. Assuming dispersive vertical flow, how long will it take for the chemical to reach the aquifer? Assume that the concentration of the chemical is constant in the surface pond. The aqueous diffusion coefficient for the chemical is 1.6×10^{-9} m^2 s^{-1}. [30%]

(iii) Assuming only vertical advective flow, how long will it take for the chemical to reach the aquifer in this case? [20%]

(iv) Comment on the results from parts (ii) and (iii) above. [15%]

Assume that when dispersion is the dominant contaminant transport mechanism, the expression for the chemical concentration, c, in a soil is given by:

$$\frac{c}{c_o} = \frac{1}{2}\,\mathrm{erfc}\left[\frac{z - v_f\, t}{\sqrt{4\, D_\ell\, t}}\right]$$

where c_o is the initial constant chemical concentration in the surface pond, erfc is the complementary error function, z is the depth below the top surface of the soil, v_f is the mean vertical water velocity, t is time and D_ℓ is the longitudinal dispersion coefficient of the chemical.

4 Write brief notes on the following:

(a) Sorption as a contaminant transport mechanism in porous media. [20%]

(b) The functions of landfill cover systems. [20%]

(c) Immobilisation as a technique for the treatment of contaminated materials. [20%]

(d) Electro-kinetic land remediation. [20%]

(e) Hydraulic measures used in contaminated land clean-up schemes. [20%]

END OF PAPER

Engineering Tripos Part IIA, Module 3D6 Environmental Engineering II

Answers

1.

2. (b) (ii) 1.33×10^{-7} m^3/s.
   (iv) -33.3 kPa.

3. (b) (i) 4×10^{-8} m/s
   (ii) 1.16 years
   (iii) 4.15 years

4.