ENGINEERING TRIPOS PART IIB

Wednesday 22 April 2009 9 to 10.30

Module 4D14

CONTAMINATED LAND AND WASTE MANAGEMENT

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.*

Attachment: Special Datasheets (3 pages)

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

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) A clay liner was constructed to form the side slope of a 10 m deep landfill as shown in Fig. 1. A geomembrane of 6 mm thickness is to be used as a second line of defence against leachate leakage. The geomembrane has a mass of 24 kg/m^2. The friction angle between the underside of the geomembrane and the clay liner is 12° while that between the upper side of the geomembrane and the waste is 5°.

(i) Calculate the self-weight stress induced in the geomembrane. [15%]

(ii) The height of waste above the ground level is 15 m as shown in Fig.1. The waste has a unit weight of 7 kN/m^3. Making suitable assumptions, estimate the down-drag stress generated in the geomembrane. [25%]

(iii) A flat bed anchor is to be designed to anchor the geomembrane at the ground level as shown in Fig.1. The unit weight of the soil berm is 14 kN/m^3 and its height is 1 m. Calculate the anchor length L required. [20%]

(b) A chemical plant is pumping liquid waste into a suitable 'receptor' stratum deep below ground level as shown in Fig. 2. The injection flow rate into this well is Q m^3/s. The receptor stratum is well confined and has a thickness of 12 m and a porosity of 0.4.

(i) The liquid waste was known to reach a radial distance of 50 m after 5 hours of continuous pumping. Calculate the injection flow rate Q into this well. [20%]

(ii) The pumping was stopped after 5 hours. It was discovered that the waste had reached a radial distance of 80 m after a further period of 24 hours. Estimate the co-efficient of dispersion of the receptor stratum. [20%]

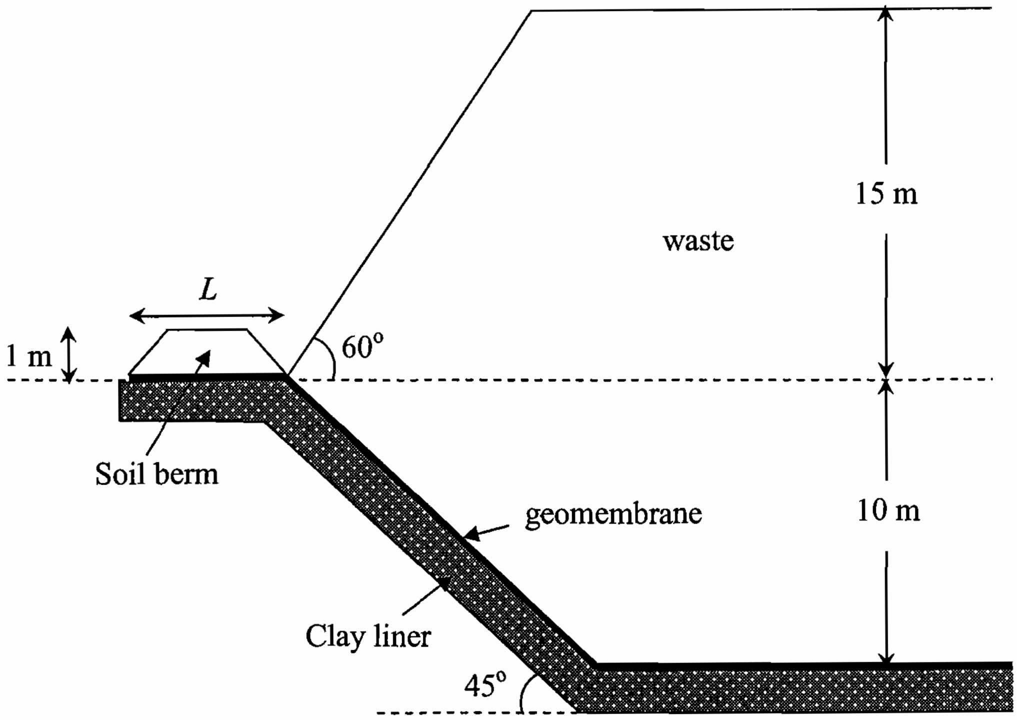

Fig. 1

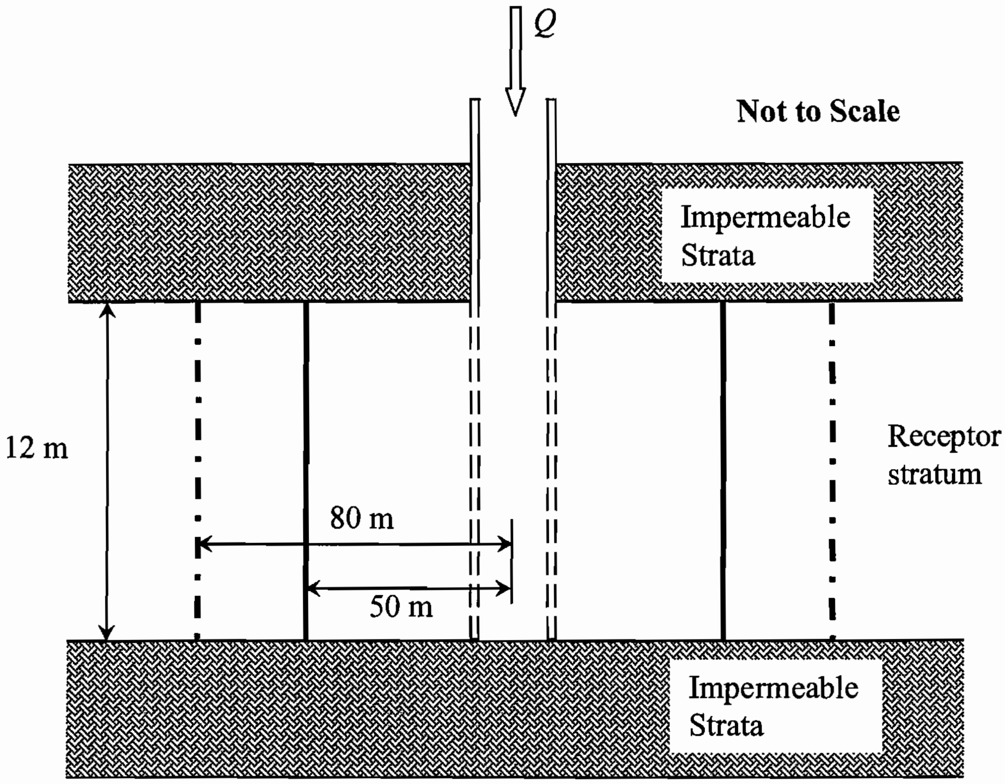

Fig. 2

(TURN OVER

2 (a) How do you classify the waste generated in a residential community? [10%]

(b) Give examples of hazardous waste generated in a residential community? [10%]

(c) Explain briefly the types of reactions that can take place in the following cases:

(i) within a landfill that has been closed by placing a well-designed top cover layer;

(ii) between the clay liner of the landfill and the waste. [30%]

(d) The population of a new township being planned is expected to be 25,000 in the year 2012 and is expected to grow at an annual rate of 6% for the next 5 years i.e. 2013 to 2017. The average solid waste generated per person is expected to be 30 kg per week for the first 3 years and then drop to 20 kg per week thereafter, due to increased recycling facilities. In both periods the ratio by weight of non-hazardous to hazardous waste is expected to be 8:1.

(i) Estimate the size of the landfill that can receive non-hazardous waste from the township up to the end of the year 2017. You may assume that the waste will be moderately compacted to a unit weight of 7.5 kN/m^3.

(ii) Calculate the revenue generated by the landfill operator up to the end of the year 2017, if they charge £28 per tonne for non-hazardous waste and £62 per tonne for hazardous waste.

(iii) Calculate the revenue generated for the local government up to the end of the year 2017, if the landfill tax for non-hazardous waste is £5 per tonne and for hazardous waste is £15 per tonne. [50%]

3 In-ground barriers are widely used for the remediation of contaminated land. They range from cut-off low permeability walls to permeable reactive barriers. Compare and contrast those two barrier systems in terms of the following:

(a) their function, illustrated with a sketch as appropriate; [20%]

(b) the type of materials used and their performance mechanisms; [20%]

(c) their design requirements; [20%]

(d) the techniques employed for their construction; [20%]

(e) their long-term effectiveness including potential failure mechanisms. [20%]

4 (a) Briefly describe two laboratory-based analytical techniques, one suitable for organic contaminants and the other for heavy metal contaminants. [30%]

(b) On what type of sites are you likely to find each of the above two groups of contaminants? [20%]

(c) The above two contaminated groups are amenable to remediation by a range of thermally-based treatment methods which include: (1) vitrification; (2) incineration; (3) thermal desorption.

(i) Explain the main differences between these three techniques. [30%]

(ii) State which contaminant groups can be treated by each method. [20%]

END OF PAPER

Engineering Tripos Part IIB FOURTH YEAR

Module 4D14: Contaminated Land and Waste Management

Data Sheets - WASTE CONTAINMENT

Population rise:

$$P_{new} = P_{current} \cdot \left[1 + \frac{r}{100}\right]^{n}$$

where r is percentage rate of increase of population, n is the number of years.

Darcy's Law:

$$v = k.i$$

where k is the permeability and i is the hydraulic gradient.

Manning's formula for flow velocity in Open Channels:

$$V = \frac{1.486}{n} R_h^{2/3} . S^{1/2}$$

where R_h is the hydraulic radius defined as Area divided by Wetted Perimeter, n is the Manning's constant and S is the slope.

Values of Manning's constant:

Material of pipes	n
PVC	0.01
HDPE	0.009
Concrete	0.016 ~ 0.017
Steel	0.016

Flow through pipes:

$$Q = A.V$$

where A is the cross-sectional area and V is the velocity of flow.

Allowable deflection of HDPE pipes:

$$\Delta y = 0.0025.\frac{D^2}{t}$$

where D is the diameter of the pipe in m and t is the wall thickness of the pipe in m.

LCRS analysis:

Assuming leachate will distribute equally between the pipes under gravity flow; we have following relations;

$$Q = q.\frac{L}{2}$$

$$Q = 2k.\frac{h_{max}^2}{L}$$

$$L = 2h_{max}\sqrt{\frac{k}{q}}$$

Q - flow into the drainage layer
q - flow rate into the drainage layer
k - permeability of the drainage layer
L - spacing between the drainage pipes
h_{max} - maximum height to which leachate is allowed to raise in the drainage layer (usually taken as the thickness of the drainage layer so that at worst location the leachate is just at the interface between the waste and the drainage layer)

Injection well radius – Empirical correction for diffusion:

$$r' = r + 2.3\sqrt{(D_d r)}$$

where

r is the radius of influence obtained by volumetric method
r' is the corrected radius of influence
D_d is the diffusion coefficient

SP Gopal Madabhushi
Michaelmas 2006