ENGINEERING TRIPOS PART IIB

Wednesday 9 May 2007 9 to 10.30

Module 4D14

CONTAMINATED LAND AND WASTE CONTAINMENT

*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) Describe the type of reactions that can take place within Municipal Solid Waste that has been deposited in a landfill. [10%]

(b) Explain briefly the interaction between waste deposited in a landfill and the clay liner forming the base and side walls of the landfill. What effect will the presence of hydrocarbons in the waste have on the performance of the clay liner? [10%]

(c) A new waste disposal facility is being planned near Cambourne village. As part of this facility, a new landfill is to be constructed. The landfill will have a side slope consisting of a single clay liner overlain by a HDPE geomembrane that is 4 mm thick. The weight of this geomembrane will be 16 kgm^{-2}. The depth of the landfill will be 12 m and the side slope of the landfill is to be constructed at 60^o to the horizontal as shown in Fig. 1. The height of the waste deposited above ground level will be 12 m and will have a slope angle of 60^o as shown in Fig. 1. The friction angle between the underside of the geomembrane and the clay liner is estimated to be 9^o. Estimate the self-weight stress induced in the geomembrane. [20%]

(d) Extensive laboratory experiments were carried out on the geomembrane. Based on these experiments it was determined that the yield stress of the geomembrane was 13.9 MPa and the friction angle between the upper side of the geomembrane and the waste is 6^o. The waste is expected to be compacted poorly and as a result will have a unit weight of 6 kNm^{-3}. The shear strength of the waste can be assumed to be negligible. Estimate the down-drag stress induced in the geomembrane lining of the side slope due to the settlement of the waste. Using this and your result in part (c) above, comment on the suitability of the geomembrane. Without any calculations explain what will be the effect of considering the shear strength of the waste on the estimated down-drag stress. [30%]

(e) Design a suitable flat bed anchor for the geomembrane that could sustain the mechanical stresses calculated in parts (c) and (d) above. You may assume a soil cover depth of 1 m above the anchor. The unit weight of this soil is 15 kNm^{-3}. [30%]

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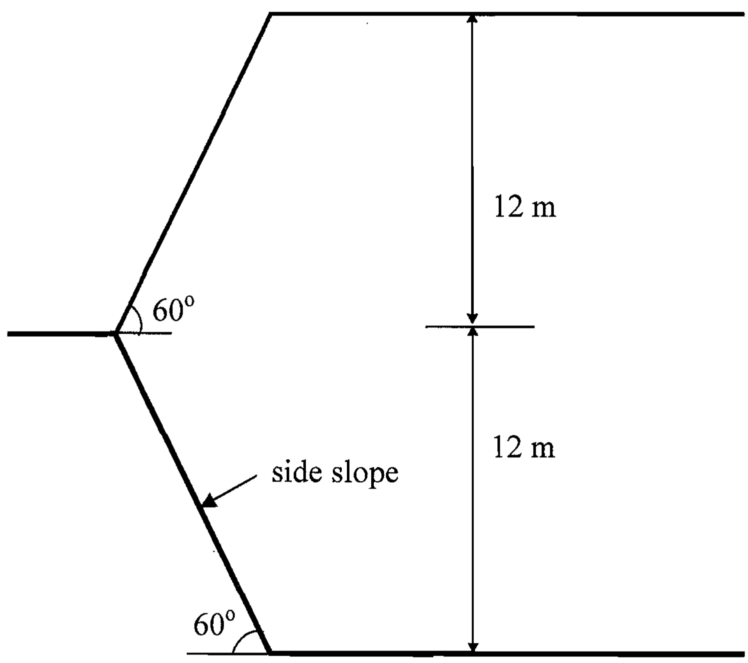

Fig. 1

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2. (a) A landfill with a plan area of 400 m × 500 m is to be constructed near London. The rainfall in London is approximately 1300 mm $year^{-1}$ and 20 % of this is expected to be infiltrated through the top cover of the landfill. You may assume that an equal amount of leachate will be produced due to the reactions within the waste.

The thickness of the drainage layer at the base will be 1.2 m and its permeability will be 2.4×10^{-2} ms^{-1}. You may assume that the level of leachate will be kept just below the top surface of the drainage layer. Large PVC pipes with an outer diameter of 560 mm and wall thickness of 50 mm are available at this site. The natural slope at the site is 1:1500 in the width direction as shown in Fig. 2. 8

Design a suitable Leachate Collection and Removal (LCR) system for this landfill. Sketch the plan and sectional views of the landfill showing the LCR system. [50%]

(b) Liquid waste from an oil refining plant has been injected into the ground using a Class II well. A well was located into a 6 m thick porous soil layer and unlimited lateral extent. The soil layer formation is sandwiched between the impermeable strata. The porosity n and the coefficient of diffusion D_d of the porous layer are 0.3 and 0.8 m^2s^{-1} respectively. The radial distance to which the liquid waste extended immediately after pumping is 200 m. Estimate the volume of liquid waste injected initially and the radial distance to which the liquid waste would extend after a long period of time. 4 [30%]

(c) Describe briefly how waste can be disposed of into underground caverns formed by solution mining if the waste is:

(i) lighter than brine solution; 3

(ii) heavier than brine solution. [20%]

$\frac{108}{120} \times 104$

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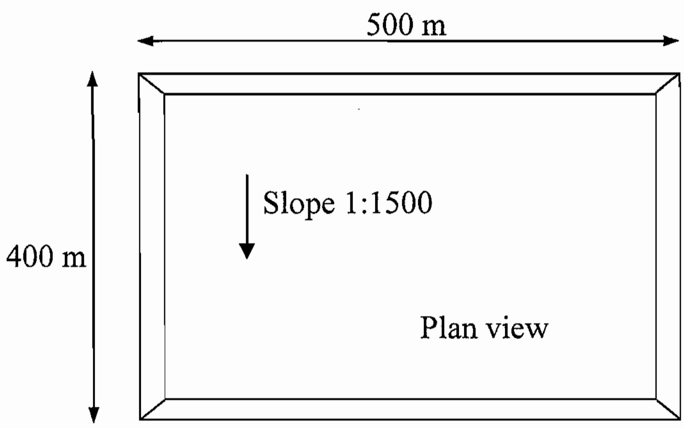

Fig. 2

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3 (a) In a chemical site investigation, it is not practical to sample an entire soil mass. Hence a limited number of representative samples are usually taken. There are two approaches to this:

(i) Targeted sampling and

(ii) Systematic sampling.

Define each approach and explain the circumstances when they are likely to be used. [20%]

(b) Consider the following sample of results for Toluene concentration from a defined area on a contaminated site detailed in Table 1. The relevant Contaminated Land Exposure Assessment (CLEA) soil guideline value for Toluene is 250 $mgkg^{-1}$.

Sample no.	1	2	3	4	5	6	7	8
Concentration of Toluene ($mgkg^{-1}$)	80	130	210	350	160	90	120	150

Table 1

For the calculation of the 'mean' concentration of a contaminant present at a site, the CLEA model recommends the use of the 'mean value test'. The upper bound value, US_{95}, is calculated using:

$$US_{95} = \bar{x} + \frac{t\,s}{\sqrt{n}}$$

where $\bar{x}$ is the arithmetic sample mean, s is the standard deviation of the sample, n is the sample size and t is the confidence level, for 95th percentile, for the sample size n, obtained from Table 2.

Calculate the upper bound value US_{95} and comment on your results. Discuss what further analysis of the results would be necessary, if any. [40%]

(cont.

(c) Define the following terms used in the CLEA model:

(i) Mean daily intake;

(ii) Tolerable daily intake;

(iii) Tolerable soil daily intake.

Explain how these three quantities are related to one another giving examples of different possible scenarios. [40%]

n	t	n	t	n	t
-	-	11	1.812	21	1.725
2	6.314	12	1.796	22	1.721
3	2.920	13	1.782	23	1.717
4	2.353	14	1.771	24	1.714
5	2.132	15	1.761	25	1.711
6	2.015	16	1.753	26	1.708
7	1.943	17	1.746	27	1.706
8	1.895	18	1.740	28	1.703
9	1.860	19	1.734	29	1.701
10	1.833	20	1.729	30	1.699

Table 2

(TURN OVER

4 (a) List five of the properties which control the environmental impact of pollutants? [10%]

(b) Name three of the individual chemical contaminants likely to be found in the groundwater near an underground petroleum storage tank of a service station which has developed a leak. [15%]

(c) Which of these chemical contaminants identified in Part (b) is likely to be found furthest from the tank? Give reasons. [15%]

(d) Phytoremediation is being considered for the remediation of the site described in Part (b). Phytoremediation is an innovative remediation technique that involves a range of mechanisms including:

(i) Phytostabilisation;

(ii) Rhizodegradation;

(iii) Phytoaccumulation.

Discuss how each of the above mechanisms work and indicate which of those mechanisms is appropriate for the group of contaminants present at the site. [60%]

END OF PAPER

Engineering Tripos Part IIB/EIST Part II
FOURTH YEAR

Module 4D14: Contaminated Land and Waste Containment

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

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Michaelmas 2006