ENGINEERING TRIPOS PART IIB

Wednesday 25 April 2012 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) Which groundwater contaminants might you expect to find on an inner city development site whose previous use had been:

(i) a garage (refuelling and repair shop);
(ii) a clothes dry-cleaning business;
(iii) a rifle shooting range. [20%]

(b) Suggest which of these is likely to have contamination below 10 m depth, giving reasons for your answer. [10%]

(c) Describe the stages of the process you would undertake in assessing the risk to human health from the contaminants present on one of those development sites using the Contaminated Land Exposure Assessment (CLEA) model. [70%]

2 (a) The side slope of a landfill liner is shown in Fig. 1. Due to site conditions and restrictions on construction, the angle of the clay liner changes from 45° to 60° as shown in Fig. 1. The clay liner is overlain by an 8 mm thick geomembrane which has a mass of 22 kg m^{-2}. The friction angle between the underside of the geomembrane and the clay liner is 18°. Determine the maximum self-weight induced stress in the geomembrane. [30%]

(b) The landfill will have waste deposited at an angle of 45° above the ground surface as shown in Fig. 1. The density of the waste is 650 kg m^{-3}. The friction angle between the upper surface of the geomembrane and the waste is 5°. Estimate the maximum down-drag stress that might be induced in the geomembrane due to settlement of the waste. The shear strength of the waste may be considered negligible. [30%]

(c) Calculate the anchor force T (see Fig. 1) that is required to support the geomembrane at the ground surface. Describe briefly two methods by which this anchor force may be provided to the geomembrane. No further calculations are required. [20%]

(d) Describe how hazardous waste can be disposed of into solution-mined caverns using the brine balance method. [20%]

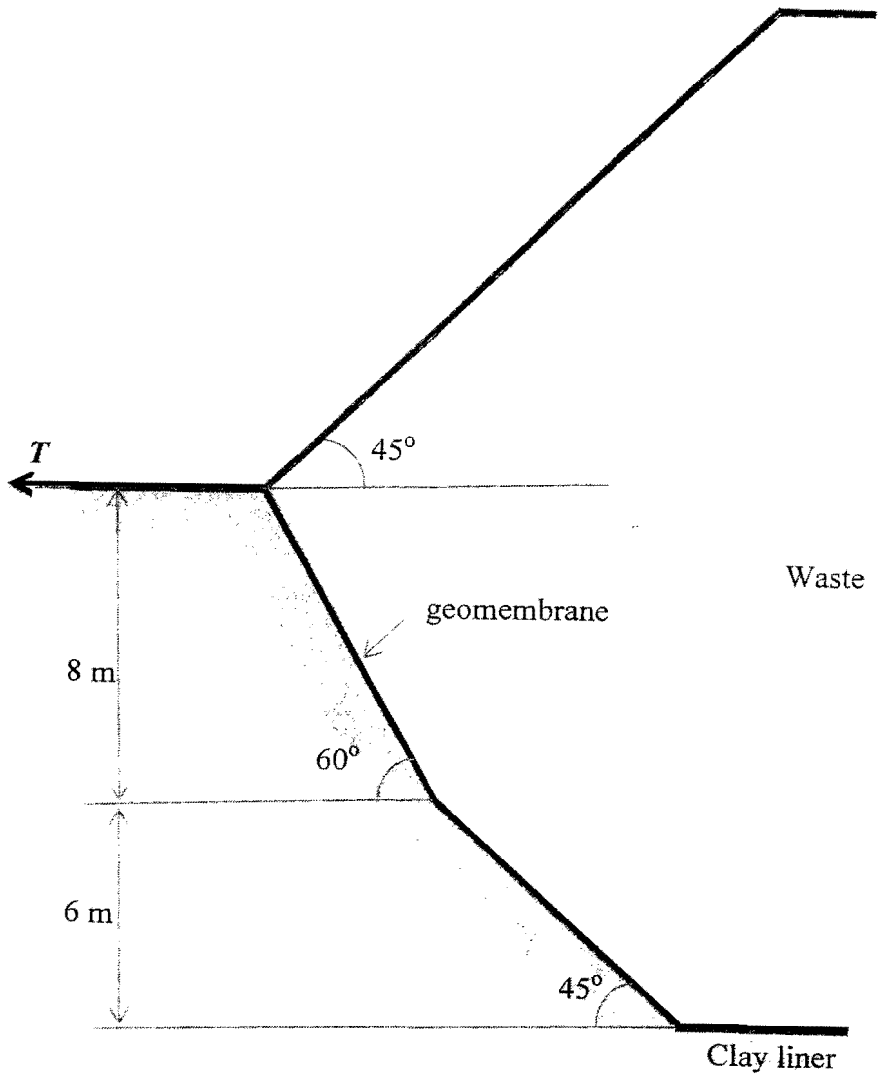

Fig. 1

3 (a) Describe some of the hazardous substances found in the Municipal Solid Waste (MSW). [20%]

(b) What types of reaction can take place within the MSW placed in a landfill:

(i) soon after the top cover of the landfill is placed;
(ii) a long time after the top cover is placed. [20%]

(c) A site 300 m × 200 m was identified for construction of a landfill in a semi-rural area and will service several villages and a town in the area. The water table at the site is 25 m below ground level, restricting the maximum depth of the landfill to 20 m. Waste can be deposited to a height of 25 m above ground level. The waste is expected to be compacted to a density of 825 kg m^{-3} when placed in this landfill. The number of households in the area is 140000. Each household produces 30 kg of waste per week. The construction time for the landfill may be taken as 2 years before operations can begin. The number of households in this area is expected to grow by 5% for first 5 years including the construction period of the landfill and by 3% after that.

(i) Calculate the number of years the landfill can continue to receive waste. [20%]

(ii) If the operator charges £15 per tonne of waste, how much profit will be generated by the landfill? The construction cost of the landfill is £ 3 million and the operational costs are £ 1 million per year. [15%]

(iii) If the landfill tax is £6.50 per tonne of waste, how much revenue will the Local Authority make? [10%]

(iv) It is expected that on average 0.1% of the waste by weight is converted into methane gas in the first 5 years of operations. Calculate the energy output in this period, if 0.001 kg of methane produces 55.7 kJ of energy. [15%]

4 A contaminated site at a location in the north of the UK is being considered for remediation. The site is around 4 ha in size and is approximately square in area. A river runs along one side of the site and there has been no sign of contamination in the river water to date. The ground conditions consist of 3-4 m of made ground, overlying 3-4 m of natural sand & gravel deposits which in turn are underlain by bedrock. The groundwater table is at the top of the sand and gravel and the groundwater flow is towards the river. Both the site soils and groundwater are contaminated. The soils are contaminated with a mixture of heavy metals and organics while the groundwater is mainly contaminated with organics, including LNAPLs and dissolved phases.

The following seven remediation methods have been considered by the remediation contractor, each of which can deal with some but not all of the contamination problems on the site:

(i) Low permeability cut-off wall;
(ii) Pump and treat;
(iii) Dual Phase extraction;
(iv) Permeable reactive barriers;
(v) On-site bioremediation;
(vi) In-situ stabilisation/solidification;
(vii) Monitored natural attenuation.

(a) Briefly describe each remediation process stating what contaminant conditions it is designed for and use the site in question to explain how each one works. [70%]

(b) Design a suitable remediation strategy for the site employing a number of the remediation methods above to deal collectively with all the site contamination, clearly describing how the strategy was formulated and what it will achieve. Also explain the reasons for your selection over the other remediation methods available. Your answer should also reflect aspects such as cost and environmental impact. [30%]

END OF PAPER