Version AAT/5

EGT3
ENGINEERING TRIPOS PART IIB

Friday 30 April 2021 9 to 10.40

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.*

Write your candidate number ***not*** *your name on the cover sheet and at the top of each answer sheet .*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed.
Attachment: Module 4D14 data sheet – Waste Containment (3 pages).
You are allowed access to the electronic version of the Engineering Data Books.

10 minutes reading time is allowed for this paper at the start of the exam.

The time taken for scanning/uploading answers is 15 minutes.

Your script is to be uploaded as a single consolidated pdf containing all answers.

1 (a) Explain what type of hazardous waste might be present in the municipal solid waste collected from a residential area. Give at least three examples. [10%]

(b) What are the main components of a well-engineered landfill? Explain what type of geo-synthetics can be used in each component and state their function. [15%]

(c) A battery assembly plant is sited at a distance of 1.6 km from a potable water reservoir. Site investigations revealed that bedrock is located 10 m below the ground with a silty sand layer with a void ratio of 0.65 extending from the ground surface to the bedrock. It was observed that the ground water is flowing through the silty sand layer from the battery assembly plant towards the water reservoir. Using miniature pore pressure transducers a pressure drop of 30 kPa was observed between two locations separated by a horizontal distance of 12 m. The hydraulic conductivity of the silty sand is 3.2×10^{-4} m s^{-1} and the unit weight of water can be taken as 9.8 kN m^{-3}.

(i) A chemical spillage occurs at the battery plant. Estimate the time it takes for the contaminant to reach the water reservoir. Comment on why such a spillage is a cause for concern. [20%]

(ii) Comment on the remedial measures that may be taken to protect the water reservoir from getting contaminated. [15%]

(d) A slurry wall that is 1 m thick is to be constructed upstream of the water reservoir to protect it from accidental spillage at the battery plant. A filter cake thickness of 3 mm is expected to form on the sides of the slurry wall. The slurry wall backfill material and the filter cake have hydraulic conductivities of 8.3×10^{-8} m s^{-1} and 1.8×10^{-9} m s^{-1}, respectively.

(i) Calculate the overall hydraulic conductivity of the slurry wall. [20%]

(ii) Estimate the time it takes for the accidental spillage described in part (c) to reach the water reservoir once the slurry wall is constructed, if the measured pore pressure drop now reduces to 20 kPa. Comment on the effectiveness of this protection. [20%]

2 (a) What is an 'oxygen minimum zone' in the ocean? How does this affect the disposal of waste into the ocean? [10%]

(b) Describe briefly how the seabed topography can affect the spread of waste disposed into the ocean. [15%]

(c) Explain the siting criterion for an injection well from a hydro-geological perspective. [10%]

(d) A landfill has a 1 m thick side slope that is at an angle of 70° with respect to the horizontal as shown in Fig. 1. A geomembrane of thickness 4 mm and mass per unit area 23 kg m^{-2} is laid on this slope. The friction angle of the geomembrane with respect to the clay side slope is 12° and the same with respect to the waste is 8°.

(i) Calculate the tensile stress in the geomembrane due to its self-weight. [20%]

(ii) The waste is filled to a height of 8 m above the ground level with a slope angle of 45° with the horizontal as shown in Fig. 1. The waste is well compacted and has a unit weight of 7.5 kN m^{-3}. Estimate the tensile stress in the geomembrane due to down-drag. Justify any assumptions you had to make. [25%]

(iii) Design a suitable flat-bed anchor for the geomembrane. Assume that a soil berm 0.5 m high will be constructed on top of the geomembrane. The unit weight of the soil can be taken as 17 kN m^{-3}. [20%]

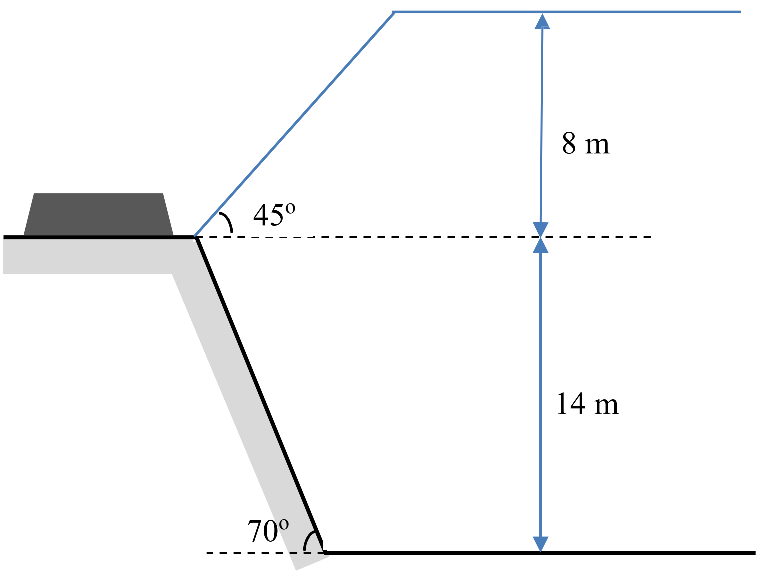

Fig. 1 (not to scale)

3 (a) The London Olympic Park was built on the largest contaminated site ever to have been remediated in the UK.

(i) Describe two techniques which were used for the clean-up process, identifying the contaminant groups that were targetted, and briefly discuss the effectiveness of their remediation principles on this specific site. [30%]

(ii) Describe the operating principles of two techniques that would be appropriate for the analysis of the contaminants present in the site soils and highlight challenges in sample preparation. [30%]

(b) List three receptors in the context of the source-pathway-receptor model for land remediation and give an example of when each would become a critical receptor. [10%]

(c) Phytoremediation exploits six different mechanisms for different environmental conditions on a given site depending on specific contaminants, site conditions, remedial objectives and regulatory issues. Describe two of these mechanisms, the processes involved and the contaminant groups they would be suitable for. [20%]

(d) Briefly describe four positive and four negative environmental impacts of land remediation. [10%]

4 (a) Contaminated land remediation techniques are generally grouped, according to the processes used, into chemical, thermal and biological techniques. In order to consider the appropriateness of each of those remediation process categories, state the following:

(i) the soil properties that need to be investigated; [25%]

(ii) the contaminant properties that need to be investigated. [25%]

(b) What is the purpose of a chemical investigation on a site contaminated with organics? [15%]

(c) What are the important considerations when calculating the tolerable daily soil intake (TDSI) in the Contaminated Land Exposure Assessment (CLEA) model for non-threshold chemicals? [10%]

(d) Explain the significance of the three elements of Risk-Based Land Management (RBLM). [10%]

(e) Stakeholder satisfaction has become a very important factor in the selection of an effective contaminated land remediation solution. For a major infrastructure project such as HS2: [15%]

(i) Who are the relevant groups of stakeholders?

(ii) List two main challenges in dealing with such stakeholders.

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Engineering Tripos Part IIB/EIST Part II
FOURTH YEAR

Module 4D14: Contaminated Land and Waste Containment

Data Sheets - WASTE CONTAINMENT

Population rise:

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

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 hydraulic conductivity 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:

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

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 2013

4D14 – Contaminated Land and Waste Containment

2020-2021

Numerical Answers

Q1 (c) (i) Time = 89.4 years

(d) (i) $K_{\text{slurry wall}}$ 6.5×10^{-8} m/s

(ii) Time of arrival = 1808.3 years.

Q2 (d) (i) $\sigma_{TA} = 0.73$ MPa

(ii) $(\sigma_T)_{\text{downdrag}} = 4.38$ MPa

(iii) Length of anchor = 0.97m, hence use 1m lengths.