ENGINEERING TRIPOS PART IIB

Wednesday 21 April 2010 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: 4D14 Data Sheets (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

aa02

1 (a) Describe the aerobic and anaerobic reactions that take place in municipal solid waste (MSW) giving examples of the products that may form as a result of these reactions. [20%]

(b) Explain the significance of a diffused double layer of water between clay particles with respect to contaminant transport. What factors influence the thickness of the diffused double layer? [20%]

(c) A new landfill site is being developed to serve a growing township whose population at the beginning of the year 2010 was 38,000, and which will grow at a rate of 5% up to the end of 2012 and at a rate of 3% after that. The average solid waste generated per person is expected to be 30 kg per week until the end of 2012 and will then drop to 20 kg per week thereafter, due to increased recycling facilities. The landfill cell has dimensions of 125 m × 175 m and a depth of 15 m. The waste is to be compacted to a unit weight of 8 kN m^{-3}. Estimate how long the landfill site will be able to serve the township. [30%]

(d) A vertical barrier wall is to be constructed in a silty clay layer that has an undrained shear strength of 40 kPa. The water table at the site is 15 m below ground level. The silty clay remains saturated at all times with a saturated unit weight of 18.5 kN m^{-3}. Calculate the depth of vertical barrier wall that can be constructed if:

(i) no slurry is to be used, but excavating machinery may apply a surcharge of 20 kPa next to the trench; [15%]

(ii) a back-fill slurry of unit weight 9 kN m^{-3} is to be used, but the slurry mixing plant applies a surcharge of 30 kPa next to the trench. [15%]

2 (a) Norfolk-Norwich Waste Management Services are planning to build a landfill with a plan area of 300 m × 400 m. The thickness of the drainage layer at the base will be 1.5 m and its permeability will be 2.5×10^{-3} m s^{-1}. The design brief assumes that the level of leachate will be kept 100 mm below the top surface of the drainage layer. Large PVC pipes with an outer diameter of 560 mm are laid at a spacing of 200 m. The natural slope at the site in the short direction is 1:2000.

Assuming that 10% of the rainfall will end up as leachate in the landfill, calculate the maximum rainfall at the site, in mm yr^{-1}, that will ensure that the pipes will only run half-full. Also, calculate the flow velocity in the PVC pipes. [50%]

(b) Explain how the temperature and ocean floor topography can affect the distribution of solid waste disposed into the sea. [30%]

(c) Explain how liquid waste can be disposed of into solution-mined caverns by using the brine balance method. [20%]

3 (a) Petroleum hydrocarbons, MTBE (methyl t-butyl ether, $(CH3)_3COCH_3$) and chlorinated solvents are the three most common organic contaminants present in groundwater. Discuss the properties of each of the above three organic contaminant groups that affect the remediation techniques selected and how effective they are likely to be. [45%]

(b) Chemical oxidation and air sparging are two remediation techniques which have been applied in the remediation of the above contaminant groups in groundwater.

(i) Briefly explain the principles behind chemical oxidation and how it can be used to deal with the above contaminant groups, giving examples. How is chemical oxidation applied in-situ? [30%]

(ii) Briefly explain the principles behind air sparging, using a sketch, and the factors which affect its degree of success. [25%]

4 The Ardeer explosives site in Scotland was used by ICI for around 40 years to contain waste resulting from the manufacture of silicones. In the early 1990s there were major concerns that contaminated leachates from this site were polluting the nearby Clyde estuary and river Garnick. Various remediation methods were considered for this site, and the decision was made to use in-situ stabilisation/solidification.

(a) Briefly describe what site investigation (mainly chemical but also geotechnical) would have taken place prior to any remediation work on such a site. [20%]

(b) What is stabilisation/solidification and how does it work for different contaminant groups? [20%]

(c) How is stabilisation/solidification applied in-situ? [10%]

(d) List three common binders used in stabilisation/solidification treatments and explain how they work. [30%]

(e) What are the advantages and disadvantages of stabilisation/solidification as a treatment technique. [10%]

(f) How is the effectiveness of the stabilisation/solidification treatment commonly assessed? [10%]

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

SP Gopal Madabhushi
Michaelmas 2006