ENGINEERING TRIPOS PART IIA

Tuesday 1 May 2007 9 to 10.30

Module 3D6

ENVIRONMENTAL ENGINEERING II

*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.*

Attachments: Special data sheets (6 pages)

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed
Extra copy of Fig. 1 (Question 1)

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 site consists of a uniform, horizontal deposit of silty soil overlying bed rock. The thickness of the soil layer is 11 m. The water table was found to be 3 m below the soil surface. The dry and saturated unit weight of the silty soil may be taken as 14.5 kNm^{-3} and 19.5 kNm^{-3} respectively. Sketch the variation of total vertical stress, pore water pressure and effective vertical stress distribution with depth, if:

(i) the silty soil above the water table remains saturated;

(ii) the silty soil above the water table is dry. [20%]

(b) A concrete gravity dam was constructed across a river to retain 10 m of water as shown in Fig. 1. An inclined rock deposit of shale is present at this site above which a fine sand deposit extends to the ground surface. The hydraulic conductivity of the fine sand is 3.2×10^{-4} m s^{-1}.

(i) Draw a flownet for seepage on the copy of Fig. 1 provided in the attachments. This sheet must be handed in with your answer. Draw attention to any shortcomings in your solution. [20%]

(ii) Estimate the rate of leakage due to seepage of water through the fine sand deposit, considering a 1 m section of the concrete dam into the plane of the paper. [10%]

(iii) Estimate the uplift pressure distribution along the base of the concrete dam. [20%]

(c) Estimate the factor of safety against sliding of the dam. For a conservative estimate, you may ignore the passive resistance offered by the soil near the downstream toe of the dam. The density of concrete may be assumed to be 2800 kg m^{-3}. The friction angle between concrete and the fine sand may be taken as 25°. [30%]

(cont.

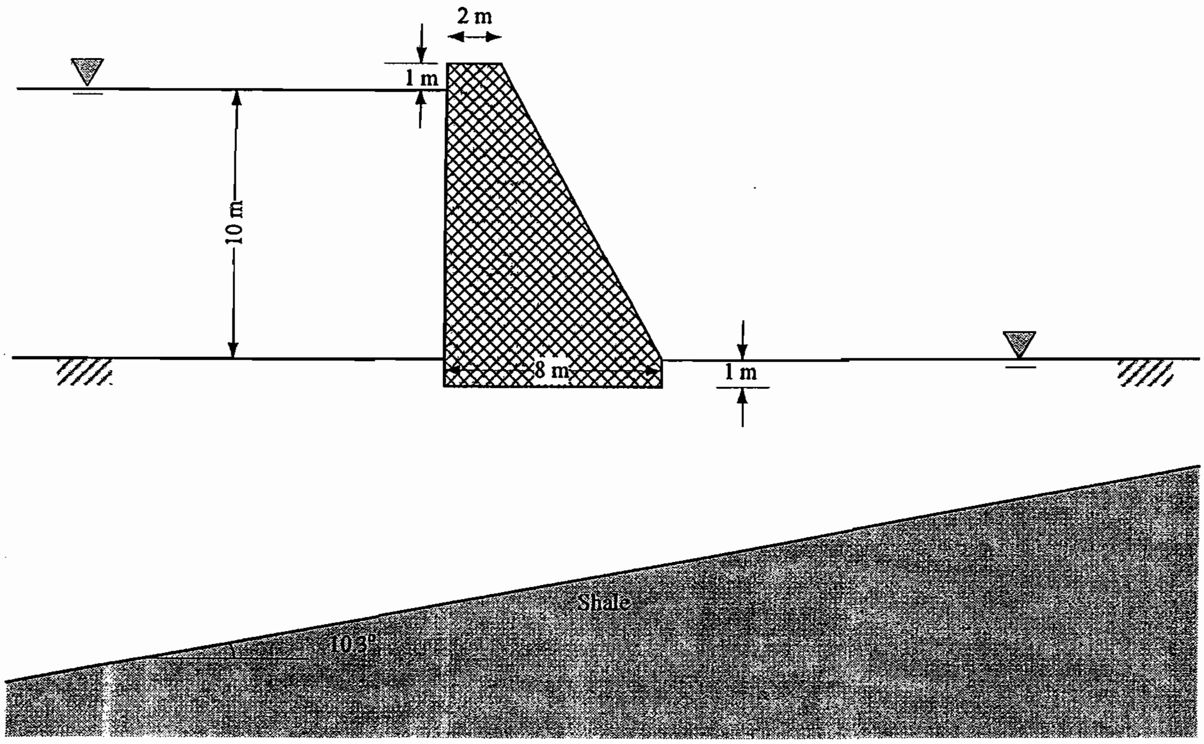

Fig. 1

(TURN OVER

2 (a) Describe briefly how you would use a constant head permeameter to determine the hydraulic conductivity of a soil sample. Derive the necessary expression for the hydraulic conductivity of a sample tested in this apparatus. What types of soils can be tested in this apparatus? [20%]

(b) Sedimentary soil deposits are often layered horizontally. If the hydraulic conductivities of such layers are K_1, K_2, ...K_n and their thicknesses are L_1, L_2, ...L_n respectively, show that the equivalent vertical hydraulic conductivity of the system can be expressed as:

$$K_{eq} = \frac{L_1 + L_2 + \ldots + L_n}{\frac{L_1}{K_1} + \frac{L_2}{K_2} + \ldots + \frac{L_n}{K_n}}$$

[30%]

(c) An undisturbed sample of fine silt was obtained from the field. The sample was 200 mm in diameter and 300 mm long. When a constant head of 1 m was applied across this sample, 600 mL of water was collected in 8 minutes. Determine the hydraulic conductivity of the fine silt sample. Comment on the validity of your answer. [20%]

(d) A second sample obtained from the same field was tested in the same apparatus as that used in part (c). The dimensions of the sample were the same but the head used in this test was 1.5 m. Under these conditions, 300 mL of water was collected in 12 minutes. The site investigation carried out in the field revealed that this second sample may have contained a thin, horizontal 'rogue' layer of clay. The hydraulic conductivity of this clay may be assumed to be 3.2×10^{-9} m s^{-1}. Estimate the thickness of this 'rogue' clay layer in the sample. [30%]

3 (a) A number of 'engineered solutions' are available to remediate a contaminated site. Explain briefly how you would use the following techniques to remediate a site, giving the advantages and disadvantages of each technique:

(i) Electro-kinetic remediation; [10%]

(ii) Thermal methods of clean-up; [20%]

(iii) Provision of in-ground barriers. [20%]

(b) (i) Nine regional development agencies were set up in the UK in the last few years. What is their primary role and what are their five statutory purposes? [20%]

(ii) SnOasis is the proposal for the world's largest indoor real snow ski complex to be built in a former cement quarry near Ipswich. The project team applied the South East of England Development Agency (SEEDA) sustainability checklist to assess the sustainability credentials of SnOasis. The checklist is broken down into ten areas ranging from transport and energy to community and business. In the area of energy, explain the problems associated with energy use in construction and in buildings and outline how they are addressed in the SEEDA checklist and how the SnOasis project intends to implement the SEEDA recommendations. [30%]

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4 (a) Explain the terms 'sorption' and 'de-sorption' in the context of contaminant transport through a porous medium. What effect does sorption have on the rate of contaminant transport? [10%]

(b) A surface impoundment is to be sited on the top of an intact, 12 m thick, clay layer. The void ratio of the clay is 0.8 and its hydraulic conductivity is 1.2×10^{-9} m s^{-1}. An aquifer exists 12 m below the landfill. The maximum concentration of the contaminant in the surface impoundment is 8.4 mg L^{-1}. The surface impoundment will be designed to hold the liquid contaminant at 3 m above the top of the clay layer. The effective diffusion coefficient of the contaminant in this clay $D_d^* = 2.3 \times 10^{-9}$ m^2 s^{-1} and the longitudinal dispersivity of the clay is $\alpha_l = 0.3$ m. The concentration of the contaminant c in the soil may be related to the maximum concentration of the contaminant c_o using the following expression:

$$\frac{c}{c_o} = \frac{1}{2} erfc\left[\frac{z - v_f t}{\sqrt{4 D_l t}}\right]$$

where *erfc* is the complementary error function, z is the depth, D_l is the longitudinal dispersion coefficient, v_f is the mean pore fluid velocity and t is time. Assume that the flow is one-dimensional and that sorption of this contaminant is negligible. You may also assume that the maximum concentration of this contaminant remains constant in the landfill.

(i) How long will it take for the first sign of the contaminant to reach the aquifer? You may assume that the concentration of the contaminant in the aquifer will reach 8.4×10^{-4} mg L^{-1} at this stage. [20%]

(ii) Sketch the distribution of the concentration of the contaminant with the thickness of the clay layer at this stage, marking the concentrations in terms of c_o at the quarter, half and three quarter points within the clay layer. [20%]

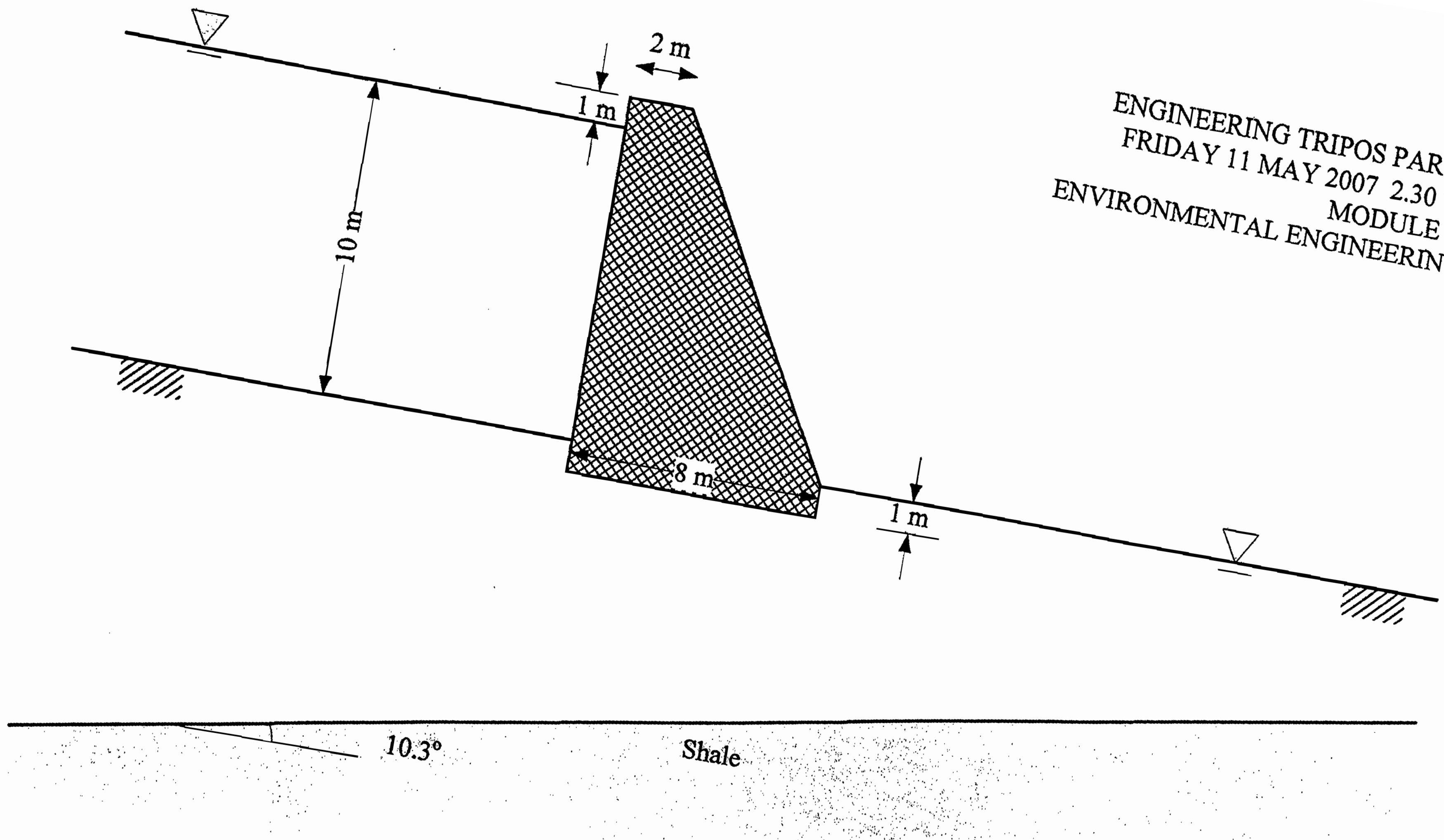
(cont.

(c) Under the EU Landfill Directive, there is a three level hierarchy of characterisation and testing for waste going to landfill.

(i) List the three stages of characterisation and testing explaining their purpose. [30%]

(ii) The waste acceptance criteria (WAC) was developed based on a new EU batch leaching test. Briefly describe the stages of this leaching test and how its results are related to the WAC. [20%]

END OF PAPER



Extra Copy of Fig. 1

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Engineering Tripos Part IIA Paper 3D6

ENVIRONMENTAL ENGINEERING II

DATA BOOK

January 2003

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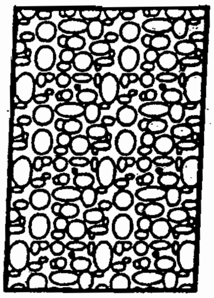
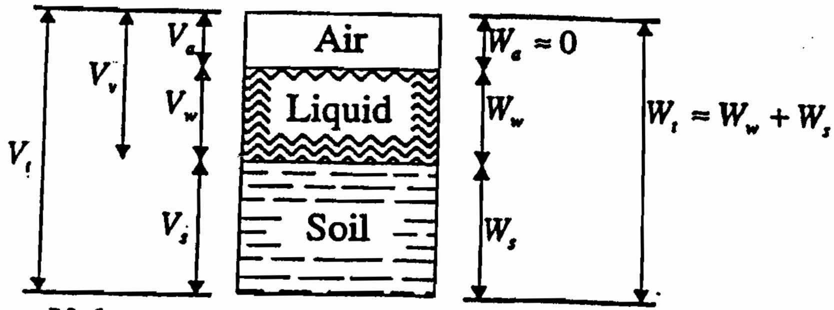
Groundwater

Soil: general definitions



Soil structure

considered as

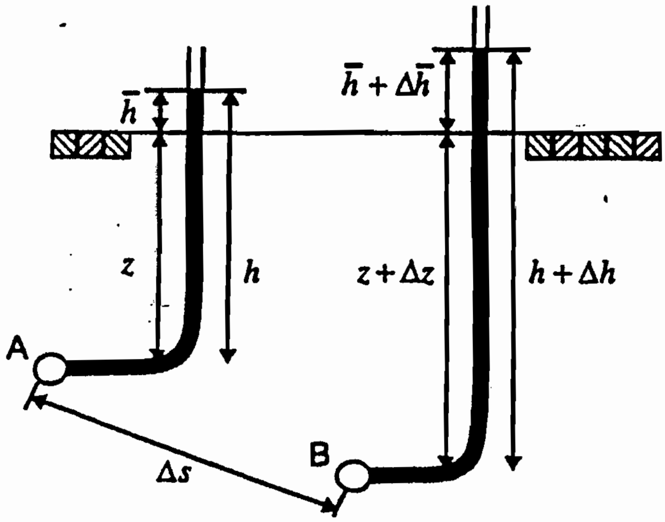


Volumes   Weights

Specific gravity of solid	G_s
Voids ratio	$e = V_v/V_s = n/(1-n)$
Specific volume	$v = V_t/V_s = 1+e$
Porosity	$n = V_v/V_t = e/(1+e)$
Water content	$w = W_w/W_s$
Degree of saturation	$S_r = V_w/V_v = wG_s/e$
Unit weight of water	$\gamma_w = 9.81\ \text{kN/m}^3$
Unit weight of soil	$\gamma = W_t/V_t = \left(\dfrac{G_s + S_r e}{1 + e}\right)\gamma_w$
Buoyant unit weight	$\gamma' = \gamma - \gamma_w = \left(\dfrac{G_s - 1}{1 + e}\right)\gamma_w$ (soil saturated)
Unit weight of dry soil	$\gamma_d = W_s/V_t = \left(\dfrac{G_s}{1 + e}\right)\gamma_w$

Seepage

Excess pore water pressure



Total gauge pore water pressure at A: $p=\gamma_w h=\gamma_w(\bar{h}+z)$

B: $p+\Delta p=\gamma_w(h+\Delta h)=\gamma_w(\bar{h}+z+\Delta\bar{h}+\Delta z)$

Excess pore water pressure at A: $\bar{p}=\gamma_w\bar{h}$

B: $\bar{p}+\Delta\bar{p}=\gamma_w(\bar{h}+\Delta\bar{h})$

Hydraulic gradient A B $\quad i=-\dfrac{\Delta\bar{h}}{\Delta s}=-\dfrac{1}{\gamma_w}\dfrac{\Delta\bar{p}}{\Delta s}$

Darcy's law $\quad v = Ki$

v = superficial seepage velocity

K = coefficient of permeability or hydraulic conductivity

Typical hydraulic conductivities

$D_{10} > 10$ mm	:	non-laminar flow
$10\text{ mm} > D_{10} > 1\mu\text{m}$	:	$K \cong 0.01\,(D_{10}\text{ in mm})^2$ m/s
clays	:	$K \cong 10^{-9}$ to 10^{-11} m/s

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Error function tables

Relationships:

$$\mathrm{erf}(\beta)=\frac{2}{\sqrt{\pi}}\int_0^\beta \exp(-t^2)\,dt$$

$$\mathrm{erfc}(\beta)=1-\mathrm{erf}(\beta)$$

$$\mathrm{erf}(-\beta)=-\mathrm{erf}(\beta)$$

$$\mathrm{erfc}(-\beta)=1+\mathrm{erf}(\beta)$$

Tables (to four significant figures)

β	$\mathrm{erf}(\beta)$	$\mathrm{erfc}(\beta)$
0.00	0.0000	1.0000
0.05	0.0564	0.9436
0.10	0.1125	0.8875
0.15	0.1680	0.8320
0.20	0.2227	0.7773
0.25	0.2763	0.7237
0.30	0.3286	0.6714
0.35	0.3794	0.6206
0.40	0.4284	0.5716
0.45	0.4755	0.5245
0.50	0.5205	0.4795
0.55	0.5633	0.4367
0.60	0.6039	0.3961
0.65	0.6420	0.3580
0.70	0.6778	0.3222
0.75	0.7112	0.2888
0.80	0.7421	0.2579
0.85	0.7707	0.2293
0.90	0.7969	0.2031
0.95	0.8209	0.1791
1.00	0.8427	0.1573
1.10	0.8802	0.1198
1.20	0.9103	0.0897
1.30	0.9340	0.0660
1.40	0.9523	0.0477
1.50	0.9661	0.0339
1.60	0.9763	0.0237
1.70	0.9838	0.0162
1.80	0.9891	0.0109
1.90	0.9928	0.0072
2.00	0.9953	0.0047
2.20	0.9981	0.0019
2.40	0.9993	0.0007
2.60	0.9998	0.0002
2.80	0.9999	0.0001
3.00	1.0000	0.0000