ENGINEERING TRIPOS PART IIA

Tuesday 24 April 2012 9 to 10.30

Module 3D2

GEOTECHNICAL 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.*

Attachment: Geotechnical Engineering Data Book (19 pages)

STATIONERY REQUIREMENTS
Single-sided script paper
Graph 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

FINAL Version

1 A triaxial compression test is performed on a marine clay sample retrieved at a depth of 10 m from the ground surface. The total unit weight of the clay is found to be 20 kNm^{-3} and is constant throughout the depth. The water table is at a depth of 2 m and the clay above the water table is fully saturated. The clay is found to have properties similar to those listed for London clay in the Data Book. Use the Cam Clay model, when necessary, to answer the following questions.

(a) The clay at a depth of 10 m is found to be overconsolidated with OCR = 5. Estimate the current effective vertical and horizontal stresses at this depth. The coefficient of earth pressure at rest is $K_0 = 0.61$ for normally consolidated condition, whereas it is $K_0 = 1.30$ when OCR = 5. [10%]

(b) The sample is consolidated in a triaxial apparatus precisely to the stress state found in the field.

(i) Based on the stress history of the clay sample, evaluate the Cam Clay plastic normal stress p'_c. Plot the Cam Clay yield surface and the consolidated stress state in $p' - q$ space, where $q = \sigma'_a - \sigma'_r$. [25%]

(ii) Estimate the specific volume v. Plot the stress state in $v - \ln p'$ space. Also plot the isotropic normal compression line and the swelling line on the same graph. [25%]

(c) The consolidated clay sample is then sheared in undrained conditions. The axial stress is increased and the radial stress is kept constant.

(i) Find the yield stress and the undrained shear strength. [25%]

(ii) Plot the effective stress and the total stress paths on the diagram drawn in question (b)(i). [15%]

2 A self-boring pressuremeter test is undertaken in a clay at a depth of 10 m. The water table is at a depth of 1 m. The measured cavity strains at different cavity pressures are listed below. The unit weight of the clay is 20 kNm^{-3}.

Cavity pressure σ_c kNm^{-2}	Cavity strain ε_c %
0	0
50	0
100	0
150	0
200	0.1
250	0.25
350	0.8
450	1.7
400	1.6
350	1.5
400	1.6
450	1.75
550	4.0
650	9.0
750	20.0

(a) Evaluate the lift-off pressure and estimate the coefficient of horizontal earth pressure at rest K_0. [25%]

(b) Deduce the initial shear modulus G_i and the unload-reload shear modulus G_{ur} from the data. [25%]

(c) Estimate the undrained shear strength of the clay. [25%]

(d) A vertical shaft of 4 m diameter is constructed in the clay. Assuming the deformation mechanism to be plane strain cavity contraction, estimate the radial support pressure needed to keep the radial displacement of the shaft wall at a depth of 10 m to be less than 5 mm. Use the soil properties derived in the above for the estimation. [25%]

(TURN OVER

3 An infinitely long sandy soil layer with an angle of 27 degrees is shown in Fig. 1. The layer is 5 m thick and is underlain by a rock formation. The in situ void ratio of the soil layer is 0.6. The soil is uniform rounded quartz sand, which has maximum and minimum void ratios of 0.8 and 0.4, respectively. The specific gravity of the sand is 2.65.

(a) Find the dry and saturated unit weights of the sandy soil. [25%]

(b) If the slope is dry, find the stress states at the interface between the soil and the rock. Evaluate the peak friction angle of the soil for the given confining stress. Estimate the factor of safety against (i) the peak friction angle ϕ'_p and (ii) the critical state friction angle ϕ'_{crit}. The factor of safety is defined as $\tan\phi'_p/\tan\phi'_{mob}$ or $\tan\phi'_{crit}/\tan\phi'_{mob}$. [30%]

(c) Due to heavy rain, the water table gradually rises inside the sand layer as shown in Fig. 2. The water table is parallel to the ground surface. At what water table level h_w and at what depth is the slope likely to fail? Use the critical state friction angle for the evaluation. [30%]

(d) What are possible engineering solutions so that the risk of slope failure by heavy rain will be reduced? [15%]

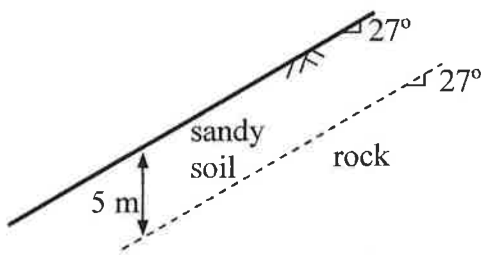

Fig. 1

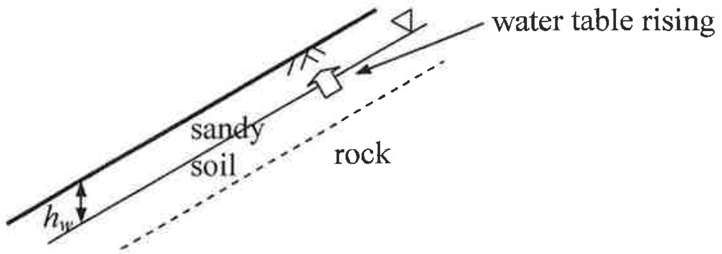

Fig. 2

4 A road embankment is to be constructed on a clay foundation as shown in Fig. 3. The total unit weight of the clay is found to be 20 kNm^{-3} and the water table is at the ground surface. The clay is found to have a friction angle of $\phi' = 24°$.

(a) The stress state at Element A, which is located along the centre line of the embankment at a depth of 5 m from the original ground surface (see Fig. 3), is considered to be in biaxial plane strain conditions during embankment construction. The embankment construction gives increment total stresses of $\Delta\sigma_v$ = 40 kPa and $\Delta\sigma_h$ = 30 kPa.

(i) The clay at this depth is lightly overconsolidated with OCR = 1.7. Evaluate the stress state in s, s' and t before the embankment construction. [25%]

(ii) In undrained conditions, the soil is found to yield at $t = (\sigma_v - \sigma_h)/2 = \pm 9$ kPa and to fail at $t = \pm 12.4$ kPa. Plot the possible total and effective stress paths of the embankment construction in (s or s') – t space for Element A. Use 10 kPa per 10 mm for s & s' and 2.5 kPa per 10 mm for t. [30%]

(iii) The clay then consolidates by the dissipation of excess pore pressure. If it is assumed that, throughout the consolidation process, the total stress state remains the same and the deviator stress is constant, show the effective stress path on the graph plotted in (ii). [15%]

(b) If the height of the embankment is immediately raised to create undrained failure, show the possible total and effective stress paths in (s or s') – t space for Element B, which is located at a depth of 5 m as shown in Fig. 3. [30%]

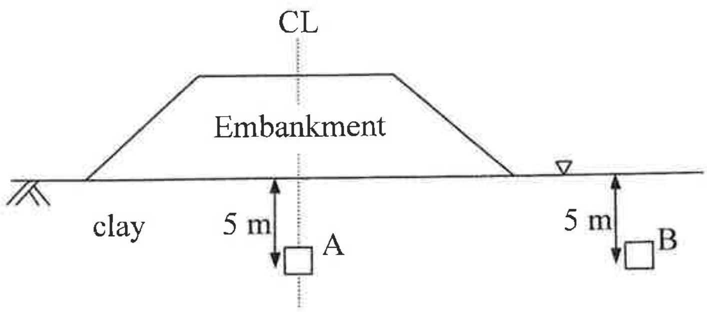

Fig. 3

END OF PAPER

FINAL Version

ENGINEERING TRIPOS PART IIA 2011/2012
MODULE 3D2: GEOTECHNICAL ENGINEERING II

(a) Using γ_w = 10 kN/m^3, σ_v' = 120 kPa, σ_h' = 156 kPa
(b) (i) p_c = 801 kPa
(ii) v = 1.888
(c) (i) Yield stress p' = 144 kPa, q = 220 kPa, Undrained shear strength = 199 kPa
(ii) –

1. (a) 167 kPa, K_0 = 0.7
(b) G = 16.7 MPa, G_{ur} = 25 MPa
(c) c_u = 125 kPa
(d) 92.6 kPa

2. (a) γ_{dry} = 16.6 kN/m^3, γ_{sat} = 20.3 kN/m^3
(b) F.S. = 1.72 for peak and 1.23 for critical
(c) h_w = 3.35 m, fail at 5 m depth
(d) -

3. (a) (i) s = 94.1 kPa, s' = 44.1 kPa, t = 5.9 kPa
(ii) –
(iii) –
(b) –