ENGINEERING TRIPOS PART IIA

Thursday 8 May 2003 2.30 to 4

Module 3D2

GEOTECHNICAL ENGINEERING

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.*

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

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1 A cylindrical oil storage tank 10 m in diameter and 15 m high is to be founded on the surface of the strata shown in Fig. 1, with the hydrostatic ground water table as indicated. The relevant properties of the sand and clay strata are as follows:

Sand: $\gamma = 18$ kN m^{-3} $\quad \gamma_{sat} = 21$ kN m^{-3}

Clay: $\gamma_{sat} = 18$ kN m^{-3} $\quad$ Critical state parameter, M = 1.0

At a depth of 5 m, the clay is overconsolidated, the coefficient of earth pressure at rest, $K_0 = 1.0$, and the undrained shear strength is 25 kPa.

Before filling the tank with oil, it is to be proof-tested by filling it with water. A piezometer is installed at point A beneath the centre of the tank to measure the pore pressure. From elastic theory, the total stress changes at point A due to a uniformly applied surface stress σ_s applied rapidly (under undrained conditions in the clay) are:

$$\Delta\sigma_v = 0.70\ \sigma_s$$

$$\Delta\sigma_h = 0.23\ \sigma_s$$

where $\Delta\sigma_v$ and $\Delta\sigma_h$ are the increases in total vertical and horizontal stresses respectively.

(a) Calculate the initial total and effective vertical stresses in the ground at point A before the proof test begins, ignoring the weight of the tank, and plot the effective and total stress paths in q-p' and q-p space as the tank begins to be rapidly filled with water. [35%]

(b) At point A the clay just yields when the height of the water in the tank H_1 = 8.5 m. Calculate the corresponding pore pressure measured at A. [15%]

(c) The height of the water is increased to H_2 when the clay at point A first attains its ultimate undrained strength. Find H_2 and the corresponding pore pressure measured at A. Assume that the elastic theory given above for the total stress changes remains applicable after yield occurs. Sketch the total and effective stress paths. [30%]

(d) Comment on what will happen if the water height is maintained at H_2 for a long period, showing the likely effective stress path (assuming the total stresses remain unchanged). What is the relevance of this to the eventual filling of the tank with oil of specific gravity 0.8? [20%]

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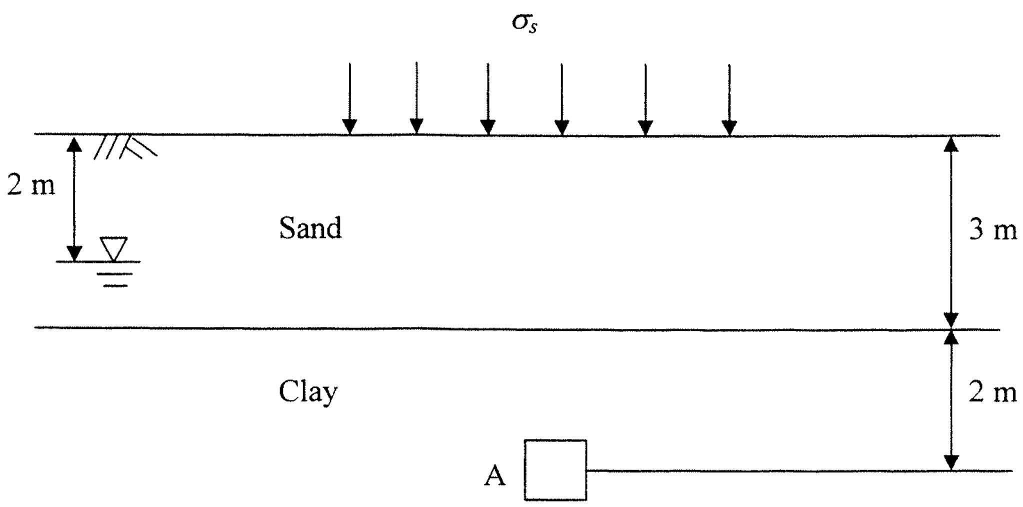

Fig. 1

2 (a) A strip footing 1.5 m wide is placed on a clay foundation as shown in Fig. 2. The clay has an undrained shear strength (c_u) of 50 kPa.

(i) Using the failure mechanism of the strip footing shown in Fig. 3, show that an upper bound of the ultimate load that can be applied to the footing is 450 kN m^{-1}. [30%]

(ii) Using the lower bound theorem with a stress discontinuity fan, show that 385.5 kN m^{-1} is a lower bound. [30%]

(b) A square concrete footing 1.5 m × 1.5 m is placed in dry sand, which has a friction angle (ϕ') of 30 degrees and a unit weight (γ) of 16 kN m^{-3}, as shown in Fig. 4. The load to be applied to the footing is P = 1000 kN.

(i) Using Terzaghi's bearing capacity equation in the Soil Mechanics Databook, calculate the required depth of embedment (D). [20%]

(ii) If the water table in (b)(i) is located at a depth of 0.5 m from the surface, re-evaluate the depth of embedment (D) required. The saturated unit weight of the sand is 20 kN m^{-3}. [20%]

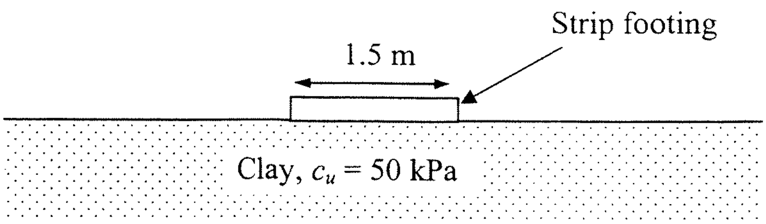

Fig. 2

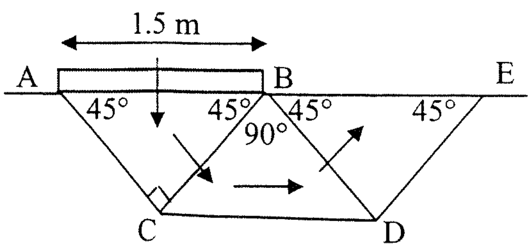

Fig. 3

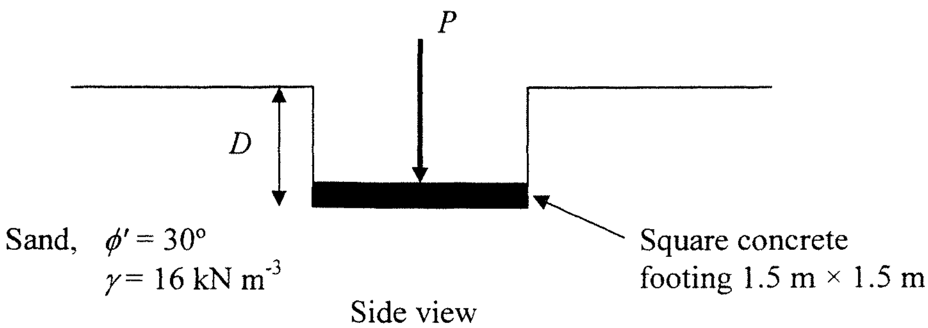

Fig. 4

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3 A concrete retaining wall is to be constructed on a clay foundation. The retaining wall is L-shaped with dimensions shown in Fig. 5. The clay has an undrained shear strength of 50 kPa. Sand is used as the backfill and is compacted to achieve a friction angle of $\phi' = 35°$. Assume that the unit weights of the concrete and sand are 24 kN m^{-3} and 18 kN m^{-3}, respectively.

(a) Considering the soil above the heel to be part of the retaining wall system, estimate the active force P_A acting on the dotted line shown in Fig. 6. For the estimation, use the force equilibrium method on a soil wedge with an angle of $45° - \phi'/2$ as shown in the figure. Assume that the direction of the active force is horizontal. [20%]

(b) Identify and compute other forces acting on the combined soil-wall system in Fig. 6 and compute the factor of safety against sliding. Assume that the undrained shear strength of the clay fully mobilises along the clay-wall interface. [20%]

(c) Estimate the eccentricity and inclination of the load applied to the base of the retaining wall and compute the factor of safety against bearing capacity failure of the clay foundation. Use the appropriate correction factors listed in the Soil Mechanics Databook. [30%]

(d) There is a concern that a water table may form in the backfill. Compute the factors of safety against sliding and bearing capacity failure when the water table is at 4 m above the base. Propose possible mitigation methods. Assume that the saturated unit weight of the sand is 21 kN m^{-3}. [30%]

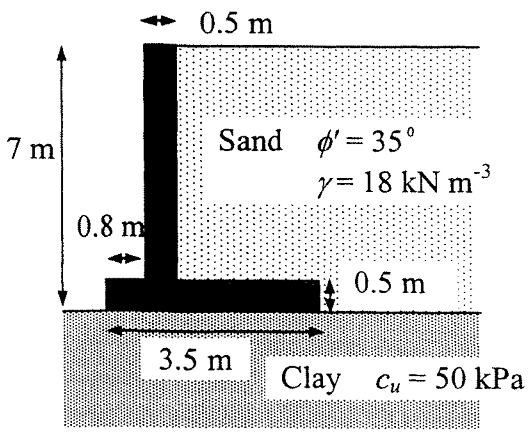

Fig. 5

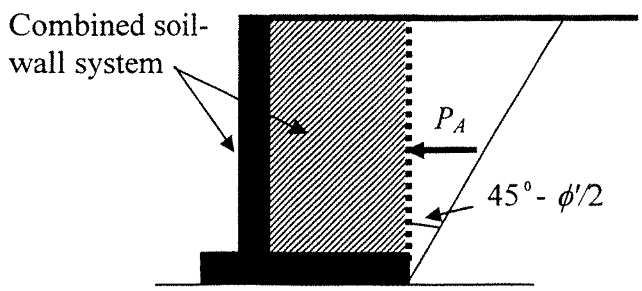

Fig. 6

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4 A self-boring pressuremeter test is undertaken in a soft clay at a depth of 3 m. The clay is overconsolidated, its bulk unit weight $\gamma = 16$ kN m^{-3} and its critical state angle of friction $\phi_{crit} = 29$ degrees. The water table is at 0.5 m below ground level.

The pressuremeter device is cylindrical with a diameter of 82 mm. As the pressure in the device is increased, the average increase in radius is measured by displacement transducers as follows:

Pressure (kN m^{-2})	Increase in radius (mm)
0	0
25	0
50	0
75	0.02
100	0.08
150	0.31
200	0.90
250	2.67

(a) By estimating the lift-off pressure, deduce an approximate value of the coefficient of horizontal earth pressure at rest, K_0. [20%]

(b) For this particular clay, the following relationship has been derived:

$$K_0 = K_{0nc}\, OCR^{0.9}$$

where K_{0nc} = coefficient of horizontal earth pressure for clay in a normally consolidated state, and OCR = overconsolidation ratio.

Using your answer from (a), estimate the maximum effective vertical stress to which the clay has been subjected. [20%]

(c) By plotting the pressuremeter test results given above in a suitable form, estimate the undrained shear strength of the clay. [40%]

(d) A transducer incorporated in the pressuremeter measures the pore water pressure in the soil at the cavity wall. Using your answers from (a) and (c), estimate the pore pressure that is measured when the pressuremeter pressure reaches 250 kN m^{-2}. [20%]

END OF PAPER

Part IIA Module 3D2 Geotechnical Engineering 2003 Solutions

1.

(a) $p = 93$ kPa, $p' = 63$ kPa and $q = 0$ kPa

(b) $u = 63.1$ kPa

(c) $H_2 = 10.6$ m, $u = 84.3$ kPa

(d) –

2.

(a) –

(b) –

(c) $D = 0.51$ m

(d) $D = 0.64$ m

3.

(a) 120 kN/m

(b) 1.46

(c) 1.28

(d) 0.96

4.

(a) $K_0 = 1.52$

(b) 76 kPa

(c) 47 kPa

(d) 168 kPa