ENGINEERING TRIPOS PART IIA

Tuesday 6 May 2008 9 to 10.30

Module 3D1

GEOTECHNICAL ENGINEERING I

*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: Soil Mechanics Data Book (19 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

1 (a) A quartz gravel can be compacted to a dry density of 1700 kg/m^3 in the field, as predicted by the Standard Proctor Compaction Test in the laboratory. Calculate corresponding values of the dry and saturated unit weight of the fill. Explain why the compacted fill might be regarded as incompressible under static loading from foundations, but might not be regarded as incompressible under dynamic loading. [20%]

(b) A clay is subject to a series of oedometer tests and is found to have a unique virgin normal compression line given by $v = 3.000 - 0.20 \ln \sigma'_v$, with a value $G_s = 2.75$ for the solids. At vertical effective stresses of 10 kPa and 100 kPa, find values of:

(i) the saturated unit weight γ,

(ii) the tangent stiffness E_o for drained, confined, normal compression. [30%]

(c) Explain the use of secant stiffness to calculate the response to finite changes of effective stress. Make an estimate of the ultimate, drained settlement to be expected when a 2 m thick layer of the gravel in (a) is compacted over a 10 m stratum of the virgin silty clay in (b), overlying rock. The water table is expected to remain coincident with the surface of the clay as it settles. You should make some explicit allowance for the variation of soil properties with depth, and with applied load. [40%]

(d) Indicate what additional allowances should be made in the calculations in order to determine the depth of fill which should be placed in order to achieve an ultimate surface elevation 2.0 m above the current clay surface. [10%]

2 A paved surface of negligible thickness was effective for many years in preventing the passage of water into, or out of, a 12 m deep stratum of overconsolidated clay underlain by impermeable rock. During this time the clay remained saturated with the water table steady at 5 m below the clay surface. The clay has a confined modulus E_o and a coefficient of consolidation C_v.

(a) The paving was then removed, exposing the clay to the atmosphere. Sketch profiles of gauge pore water pressure in the clay:

(i) prior to exposure,

(ii) if continuous gentle rainfall raised the water table to ground level, on the assumption that water can enter the clay only at its top surface. [10%]

(b) Sketch typical parabolic isochrones of excess pore pressure for the transition in (a) from state (i) to state (ii), taking care to label axes. Express the initial depth of influence L as a function of time. [30%]

(c) Assume, on the other hand, that a severe rainstorm deposits 25 mm of water in one hour which collects over the clay surface to create a pond. In the following calculations you may take constant values of $E_o = 4000$ kPa and $C_v = 4 \times 10^{-7}$ m^2/s for the clay, assuming it to be homogeneous.

(i) How long would it take for the surface water to soak completely into the ground? Sketch the corresponding isochrone of excess pore pressure at that time. [40%]

(ii) If the clay were then repaved, eliminating all external transfers of water to or from the clay, at what elevation would the water table in the clay eventually settle when hydrostatic conditions had been attained? [20%]

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3 A rigid strip foundation of width B is placed on top of a clay embankment as shown in Fig. 1. The slope angle of the embankment is β. The undrained shear strength of the clay is s_u.

(a) A vertical load V is applied at the centre of the foundation. Assuming the clay is weightless, a lower bound mechanism using stress fans is proposed as shown in Fig. 1. Sketch the Mohr's circle of stress for Zones 1 & 2 and derive the ultimate vertical load. [25%]

(b) The applied load is now inclined and has both vertical (V) and horizontal (H) components as shown in Fig. 2. For the stress state under the foundation, the angle between the major principal stress and the vertical direction is ψ as shown in the figure. Complete a lower bound mechanism using a stress fan. When the foundation fails, find a relationship between H and ψ, and derive an expression that shows the combination of limiting values of V and H. Assume that the clay is weightless. [25%]

(c) Evaluate H when the footing slides and find the corresponding maximum vertical load V. [20%]

(d) Discuss how the answers above will change if the clay is not assumed to be weightless. There is no need to show the exact solutions. [15%]

(e) The slope is now submerged with water up to the foundation level. How would the ultimate loads derived in the previous parts of this question change? There is no need to show the exact solution, but explain how you may want to solve the problem. [15%]

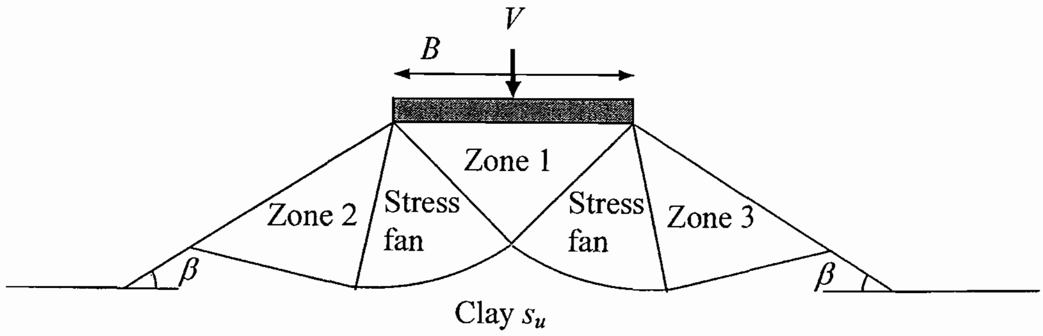

Fig. 1

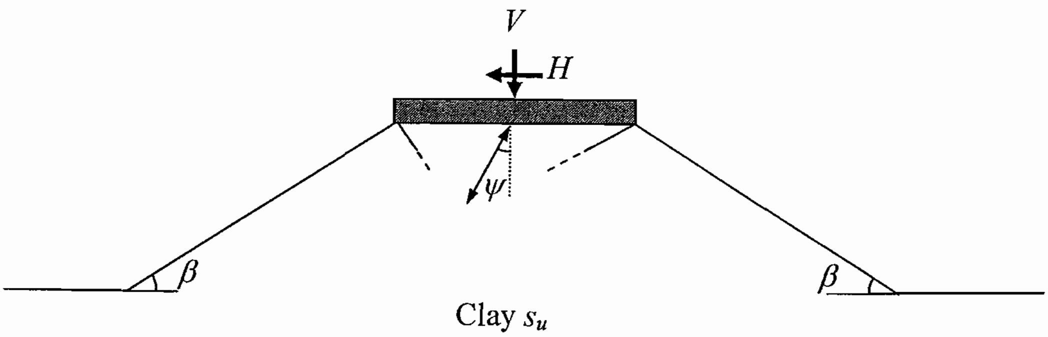

Fig. 2

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4 A long excavation is made in clayey soils. The clay has an undrained shear strength of 50 kPa. The total unit weight of the clay is 20 kN/m^3. A surcharge σ_s of 10 kPa is applied at the ground surface as shown in Fig. 3.

(a) The excavation is made without any horizontal support as shown in Fig. 3.

(i) Using the upper bound mechanism shown in the figure, derive the maximum excavation depth. [30%]

(ii) Sketch an upper bound mechanism better than the one shown in Fig. 3 and discuss how you will find the maximum excavation depth. There is no need to show the exact solution. [20%]

(b) The excavation is made using a retaining wall with a horizontal support at the ground surface as shown in Fig. 4. The excavation depth is 8 m. The depth of wall embedment is 2 m. The clay at the excavation side is to be improved by jet grouting.

(i) Based on the failure mechanism of the wall illustrated in the figure, sketch the stress profile acting on the wall when the ground is at failure. [20%]

(ii) Determine the minimum undrained shear strength X of the improved ground that is required to prevent failure of the wall. Evaluate the horizontal prop force H_p under this condition. [30%]

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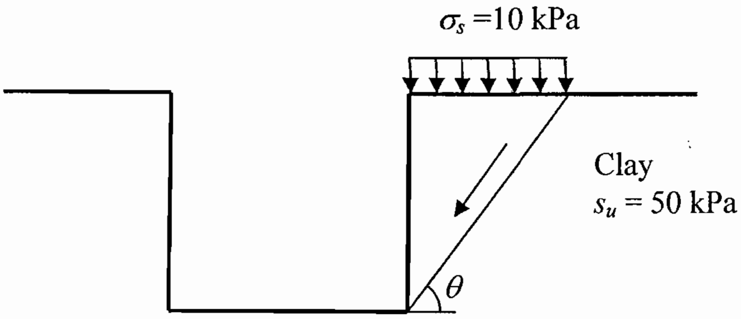

Fig. 3

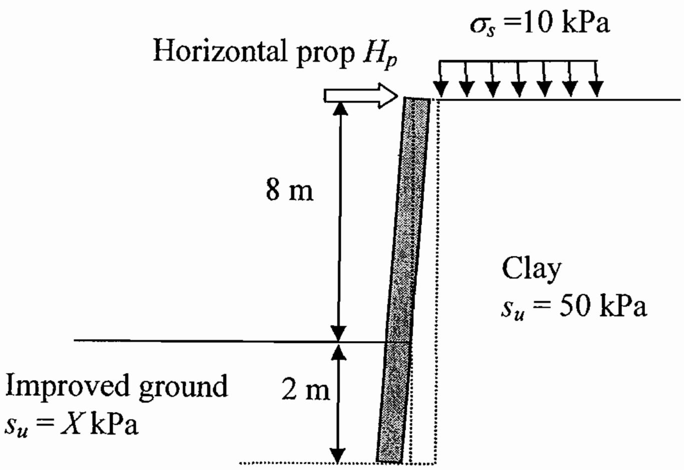

Fig. 4

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