Version SAS/3

EGT2
ENGINEERING TRIPOS PART IIA

Wednesday 4 May 2023 9.30 to 11.10

**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.*

*Write your candidate number* ***not*** *your name on the cover sheet.*

**STATIONERY REQUIREMENTS**
Single-sided script paper

**SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM**
Engineering Data Book
CUED approved calculator allowed
3D1 & 3D2: Geotechnical Engineering Data Book (21 pages)

**10 minutes reading time is allowed for this paper at the start of the exam.**

**You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.**

**You may not remove any stationery from the Examination Room.**

1 (a) Explain briefly how soil particles are formed from rocks. Describe the transportation of soil particles by wind and water and what effects this might have on their shape. [15%]

(b) Following the standard notations, derive the following equation for bulk unit weight of soil. [15%]

$$\gamma = \frac{[G_s + eS_r]\,\gamma_w}{(1+e)}$$

(c) An oedometer sample of Hostun sand has a diameter $D$ = 76 mm and height $H$ = 20 mm. The specific gravity of the sand grains $G_s$ = 2.65 and the maximum and minimum void ratios are 1.015 and 0.55 respectively. The $D_{10}$, $D_{20}$ and $D_{50}$ sizes for the Hostun sand sample are 0.1 mm, 0.15 mm and 0.3 mm, respectively.

(i) If the sample was constituted at a relative density of 40% and is fully saturated, calculate the unit weight of the sample and its moisture content. [10%]

(ii) What is the mass of the sand grains and mass of the water in the sample? [10%]

(iii) Estimate the number of sand grains in the sample. [10%]

(d) The Hostun sand has the same compression characteristics as the Ham River sand in the 3D1 databook, since both are silica sands.

(i) If the oedometer sample described in part (c) above is subjected to a vertical stress of 3 MPa, estimate the change in the sample height and hence the vertical strain in the sample. [15%]

(ii) If the sample is subsequently unloaded to a vertical stress of 1 MPa, estimate the recovery in the height of the sample. [15%]

(iii) Sketch the above loading and unloading phases in the $v$-ln $\sigma_v'$ space. [10%]

2 A building is to be built on the soil profile comprising of a thin layer of permeable made ground, a 10 m deep layer of silt overlying a 10 m deep layer of clay, founded on impervious bedrock. There is a thin free-draining sand lens between the silt and clay layers. The silt has an oedometric modulus $E_o$ = 5000 kN m$^{-2}$ and a permeability $k = 1 \times 10^{-8}$ m s$^{-1}$. The clay has an oedometric modulus $E_o$ = 2000 kN m$^{-2}$ and a permeability $k = 1 \times 10^{-9}$ m s$^{-1}$. The building is constructed rapidly and applies a pressure of 100 kN m$^{-2}$ to the soil.

(a) Calculate the ultimate settlement for both the silt and clay layers. [10%]

(b) Calculate the coefficient of consolidation for both the silt and clay layers. [10%]

(c) Use parabolic isochrones to identify the stage of consolidation after a period of 1 month has elapsed after construction. Determine the depth of penetration of the consolidation front and the maximum excess pore pressure in both the silt and clay layers and use these to sketch parabolic isochrones of excess pore pressure for both layers in dimensional terms. [40%]

(d) Estimate the percentage of the ultimate settlement that will have occurred 1 year after construction. [20%]

(e) Describe two methods of increasing the rate of consolidation that could have been employed prior to construction of the building. [20%]

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3 A circular foundation with diameter $D$ = 20 m is embedded to a depth $h$ = 1 m and is to be used to support a wind turbine, which weighs 10 MN and has a hub height of 75 m. The turbine is to be located on ground with a uniform undrained shear strength of 25 kN $m^{-2}$ and unit weight $\gamma$ = 15 kN $m^{-3}$.

(a) Calculate the ultimate undrained vertical capacity of the foundation accounting for shape and depth factors. [25%]

(b) Calculate the ultimate horizontal capacity assuming that the base of the foundation is rough and the ultimate moment capacity assuming no lift-off at the interface. [10%]

(c) Estimate the wind force at the hub height that would cause the foundation to fail taking the factor of safety as unity. Would the foundation ultimately fail in sliding or moment induced rotation? [50%]

(d) What are the implications of assuming that no lift-off occurs at the soil-foundation interface in parts (b) and (c). Describe how you would perform similar calculations accounting for lift-off (i.e. no further calculations are required). [15%]

4 A shallow foundation is to be constructed with a size of 3 m by 4 m and embedded to a depth of 1 m, with the groundwater table at significant depth (i.e. the sand may initially be considered to be dry). To aid in checking the design of the shallow foundation, a suite of drained triaxial tests were performed on sand samples recovered from the proposed construction location. The mineralogy of the sand is silicate and the voids ratio $e$ = 1.05.

(a) Describe the steps involved in performing a drained triaxial test. [15%]

(b) Interpret the peak and residual friction angles for the sand using the triaxial data given in Table 1. [20%]

Table 1

| Stress | Peak | | | Residual | | |
|---|---|---|---|---|---|---|
| $\sigma_c$ (kPa) | 100 | 200 | 300 | 100 | 200 | 300 |
| $q$ (kPa) | 340 | 610 | 840 | 245 | 500 | 730 |

(c) Using an appropriate angle of friction determine the ultimate bearing capacity of the proposed shallow foundation. [40%]

(d) Calculate the percentage reduction in the ultimate bearing capacity in the event that the groundwater table rose to the surface of the ground during a wet period. [25%]

**END OF PAPER**

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