Version SKH/3

EGT2
ENGINEERING TRIPOS PART IIA

Tuesday 30 April 2019 14.00 to 15.40

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.*

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

STATIONERY REQUIREMENTS
Single-sided script paper
Graph paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
Engineering Data Book
Attachment: Geotechnical Engineering Data Book (19 pages)
CUED approved calculator allowed

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.

1 A long 8 m diameter tunnel is constructed at a depth of 30 m in a saturated clay deposit. The clay has a unit weight γ = 20 kN m^{-3}, a coefficient of earth pressure at rest K_0 = 1, and can be idealised as a linear elastic-perfectly plastic material with an elastic shear modulus G = 30 MPa and undrained shear strength s_u = 100 kPa. The settlement measured at the tunnel crown is ρ_c = 80 mm. Assume that the tunnel construction process can be considered to be an axisymmetric cylindrical cavity contracting under undrained conditions, supported by a smooth tunnel lining.

(a) After yield has occurred, there is a plastic zone around the tunnel surrounded by an elastic zone. Within the elastic zone, at any radius r, the radial and circumferential stresses, σ_r and σ_θ respectively, are given by the following expressions:

$$\sigma_r = \sigma_0 - G\frac{\delta A}{\pi r^2}$$

$$\sigma_\theta = \sigma_0 + G\frac{\delta A}{\pi r^2}$$

where σ_0 is the original in situ total stress in the ground, G is the elastic shear modulus and δA is the reduction in the cross-sectional area of the cavity. Show that the radius of the plastic zone, r_p, is given by the following expression:

$$\frac{r_p}{r_c} = \left(\frac{G}{s_u}\frac{\delta A}{A}\right)^{0.5}$$

where r_c is the radius of the cavity, A is the cross sectional area of the cavity and the other symbols are as above. [30%]

(b) Calculate the average radial stress acting on the tunnel lining after excavation. [25%]

(c) At one location, the tunnel underpasses a piled foundation supporting a sensitive building, as shown in Fig. 1. Ignoring any effects of the loading on the foundation, calculate the maximum settlement at the toe of the piles. [20%]

(d) By how much will the pile immediately above the centre line extend into the plastic zone? [25%]

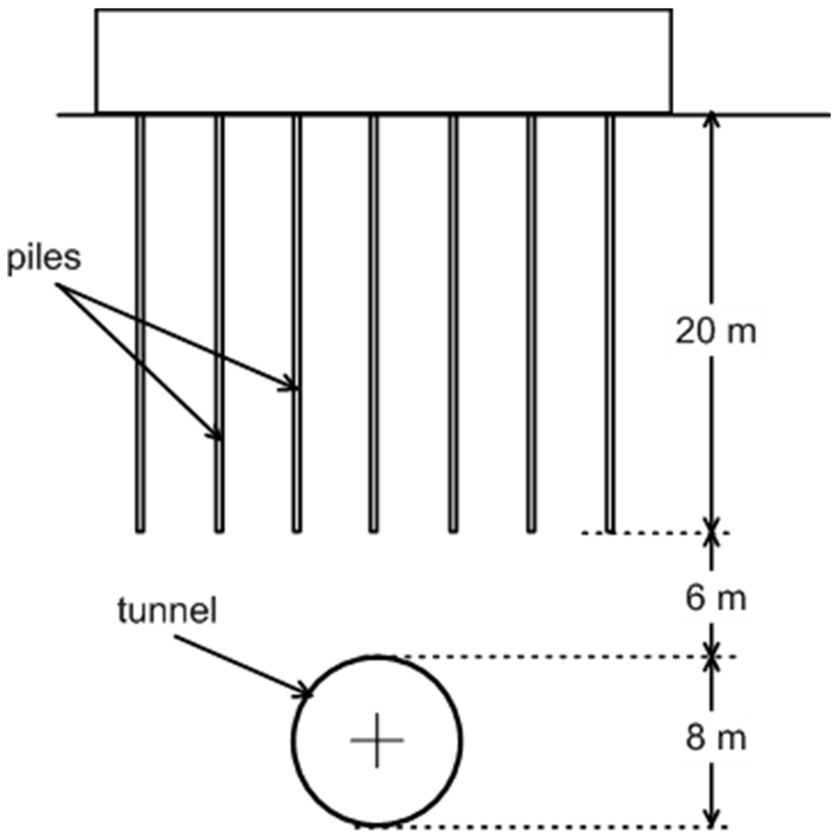

Fig. 1

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2 (a) What are the main challenges for excavations and engineered slopes in soils whose specific volume lies below the critical state line drawn on a (v, ln σ') plot? Discuss the relative dangers incurred in drained and undrained conditions. [20%]

(b) A long slope is to be cut in an apparently homogeneous glacial till of silty sand with unit weight γ = 20 kN m^{-3}. After removal of more than half the depth of the pre-existing material, the slope will have an angle of 25° and form a parallel layer 6 m deep, resting on top of a sloping impermeable bedrock. Groundwater monitoring over a 12 month period showed that the phreatic surface in the silty sand ran parallel to the bedrock at elevations of 4 m and 1 m above the bedrock in the wet and dry seasons respectively. Three drained direct shear tests on samples retrieved from the till were conducted under effective normal stresses of 25 kPa, 100 kPa, and 400 kPa, and the recorded peak shear stresses were 20 kPa, 70 kPa, and 240 kPa, respectively. The laboratory noted that whereas the two samples tested at lower stress dilated, the third sample contracted in volume before reaching failure under large, uniform strains.

(i) Find the peak secant angle of friction, ϕ_{max}, of each of the three samples of glacial till. [20%]

(ii) Deduce a value for the critical state friction angle ϕ_{crit}, and obtain an approximate expression for the linear variation of ϕ_{max} with the natural logarithm of the normal effective stress σ', for values of σ' less than some stated critical value σ'_{crit}. [20%]

(iii) Use infinite slope analysis, and other carefully justified assumptions, to determine whether the slope should fail in the dry season or the following wet season, if the corresponding groundwater conditions from the previous monitoring exercise are exactly duplicated. [30%]

(iv) Should the engineer be concerned about the long term stability of the slope? If so, explain why. [10%]

3 A sample of London Clay is consolidated from a slurry to a vertical effective stress of 300 kPa, before being allowed to swell. A sample of this consolidated clay is loaded into a triaxial apparatus, the cell pressure is increased to 200 kPa and the sample is allowed to consolidate.

(a) If the sample is subjected to drained triaxial compression, calculate the undrained strengths at yield and ultimate failure, together with the volumetric strains suffered during this process. [30%]

(b) If the sample is subjected to undrained triaxial compression, calculate the drained strengtsh at yield and ultimate failure, together with the excess pore pressures observed at these states. [30%]

(c) If the clay has a permeability of 10^{-8} ms^{-1} and the sample has a height of 100 mm and a diameter of 50 mm, estimate the maximum axial strain rate that might be appropriate to give drained behaviour if an excess pore-pressure of 1 kPa is deemed to be acceptable. [40%]

4 (a) Describe what is meant by the critical state of a soil and explain why this is a function of confining stress. [20%]

(b) Why does the slope of the critical state line in $q - p'$ space, M, vary between axial compression and axial tension in triaxial conditions? [10%]

(c) Explain the assumptions that are used derive the shape of the Cam-Clay yield envelope. [20%]

(d) Using these assumptions, derive the Cam-Clay yield surface equation for simple shear conditions:

$$\frac{\tau}{\sigma'} = \mu_{crit} \ln\left(\frac{\sigma'_c}{\sigma'}\right)$$

[50%]

END OF PAPER

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