EGT2
ENGINEERING TRIPOS PART IIA

Thursday 25 April 2019 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
Graph paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
Engineering Data Book
CUED approved calculator allowed
Attachment: 3D1 & 3D2 Geotechnical Engineering Data Book (19 pages)
Supplementary page: one copy of Fig. 1 & Fig. 2 Consolidation curve (Question 1)

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 The site for a new development consists of 12 m of clay above porous bedrock. The water table can be assumed to be at the surface. The specific gravity of the clay is 2.68. The results of an incremental consolidation test on a specimen retrieved from the centre of the clay layer are shown in Fig. 1. The settlement versus time curve for the increment from 50 kPa to 100 kPa is reproduced in Fig. 2 The specimen had a natural water content of 39.1%.

Additional copies of Fig. 1 and Fig. 2 are attached to the back of this paper. The page should be detached and handed in with your answers.

The commercial building proposed for this site will impose a bearing pressure of 100 kPa.

(a) Determine the soil consolidation parameters. [20%]

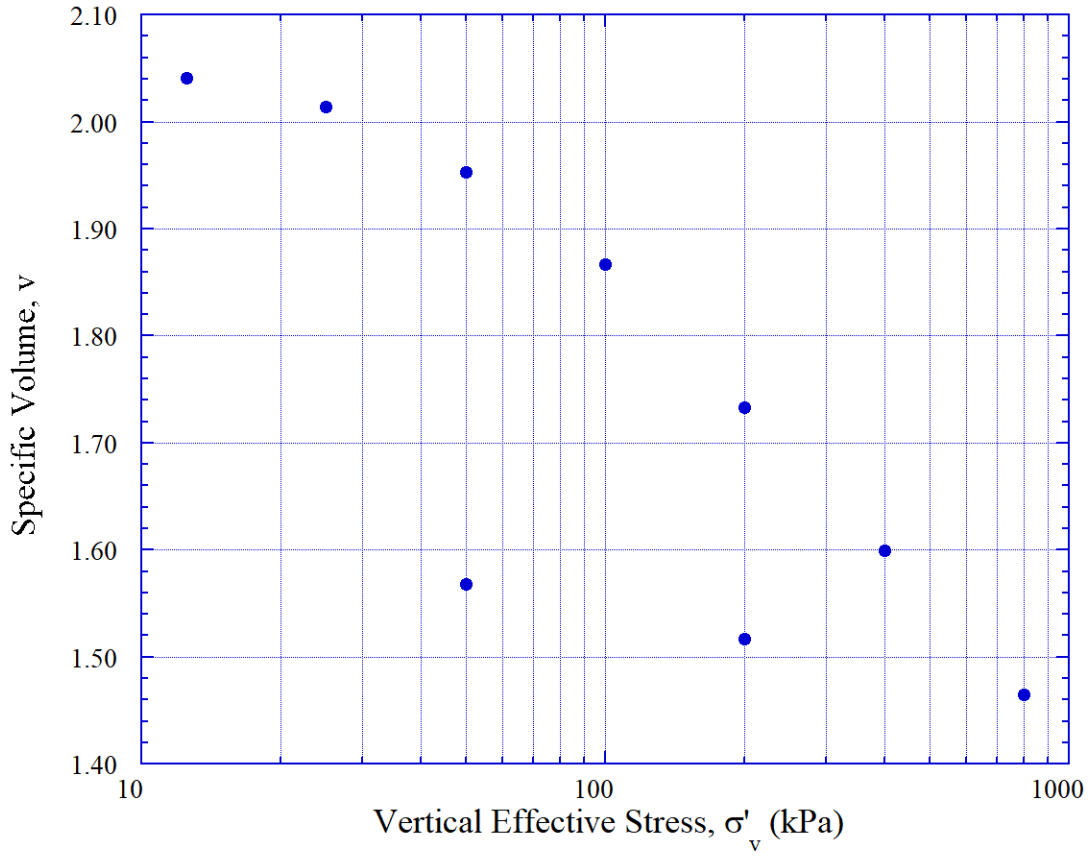
(b) Derive the unit weight of the clay and calculate total and effective stress at the centre of the clay layer. Assuming 1D conditions are acceptable, estimate the settlement caused by the construction of the building. [20%]

(c) Estimate the time it will take for 90% of the settlement to occur. [10%]

(d) After 3 years from construction, the building settled 70 cm. Assuming your calculation for total settlement is still correct, back calculate the coefficient of consolidation for this site. Explain the reasons for any discrepancies between the laboratory measurement and the field value and calculate the corrected time to 90% consolidation. [30%]

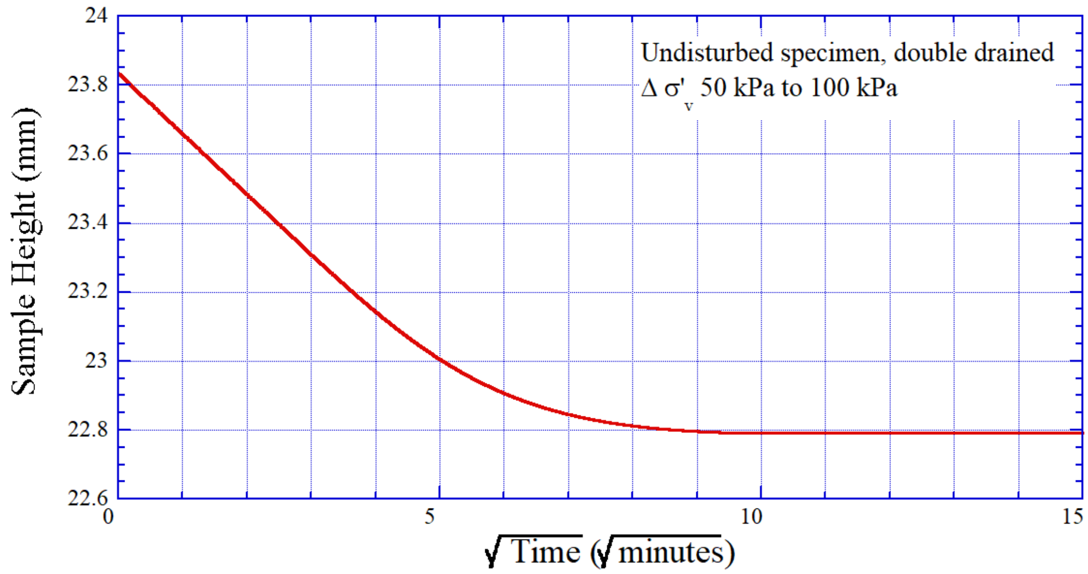
(e) An extension is built at the end of the third year. The new wing of the building has a lower bearing pressure of 75 kPa. Assuming each building settles independently, what is the maximum relative displacement between them? [10%]

(f) Estimate the coefficient of consolidation in unloading from 200 kPa to 50 kPa. [10%]



2.10
2.00
1.90
1.80
1.70
1.60
1.50
1.40
Specific Volume, v
10
100
1000
Vertical Effective Stress, σ'v (kPa)

Fig. 1



24
23.8
23.6
23.4
23.2
23
22.8
22.6
Sample Height (mm)
0
5
10
15
√Time (√minutes)
Undisturbed specimen, double drained
Δ σ'v 50 kPa to 100 kPa

Fig. 2

2 Water pumping from wells without a permit is illegal in many countries, but not always easy to detect. Satellite technology can be used to measure soil displacement, which may be related to illegal or excessive water abstraction. A particular area under investigation is characterised by a 6 m surficial medium dense sand layer, underlain by silty clay to a total depth of 30 m. A thick layer of fine sand is located below the silty clay and above bedrock. The water table is relatively stable at 1.5 m depth and the undisturbed aquifer is unconfined, i.e. pore pressures are hydrostatic through the whole soil profile.

The medium dense sand has a dry density of $1700\,\mathrm{kg\,m^{-3}}$ and a specific gravity of 2.65. The water content of the silty clay is 54.6% through the depth of the soil. The specific gravity of the silty clay is 2.61.

(a) Estimate dry and saturated unit weight of the medium dense sand, and the saturated unit weight of the silty clay. Plot the total and effective vertical stresses with depth to the end of the clay layer. [20%]

(b) Pumping from the lower fine sand layer would result in a reduction of pore water pressure in this stratum. Assume the change is $\Delta u = -50\,\mathrm{kPa}$. Plot the profile of the pore water pressure to a depth of 30 m prior to any pumping taking place and after the change in pore water pressure reaches steady state for a pumping rate maintaining a constant reduction of the pressures. Draw the profile of excess pore water pressure in the silty clay layer and sketch the isochrones showing the transient response explaining their shape. [30%]

(c) Oedometer testing determined OCR = 1.75 in the specimen retrieved from 11 m and OCR = 1 in the deep specimen. Assuming the properties of the silty clay are similar to those of kaolin reported in the Data Book, calculate the change in specific volume at 11 m and 23 m. Estimate the subsidence due to a permanent 50 kPa drawdown. Clearly state your assumptions. [40%]

(d) Can the effects of water pumping be reversed? Discuss. [10%]

3 An anchor of width x is installed in a uniform soft clay with an undrained shear strength c_u. The anchor can be assumed to act in 2D plane-strain, analogous to a strip foundation and to be installed deeply enough that the mechanism does not intercept the soil surface. The anchor is triangular in section with its lower face horizontal and its upper faces sloped at an angle α to the horizontal as shown in Fig. 3. The anchor is subjected to a vertical load F.

(a) State the upper and lower bound theorems of plasticity. [10%]

(b) Assuming the surfaces of the anchor to be smooth, calculate a lower bound on the anchor capacity per unit length as a function of α. [35%]

(c) Calculate an upper bound on the capacity of the anchor per unit length as a function of α. [35%]

(d) If the anchor in reality is rough and has finite length, comment qualitatively on how you might assess the impact of these parameters on the anchor capacity. [20%]

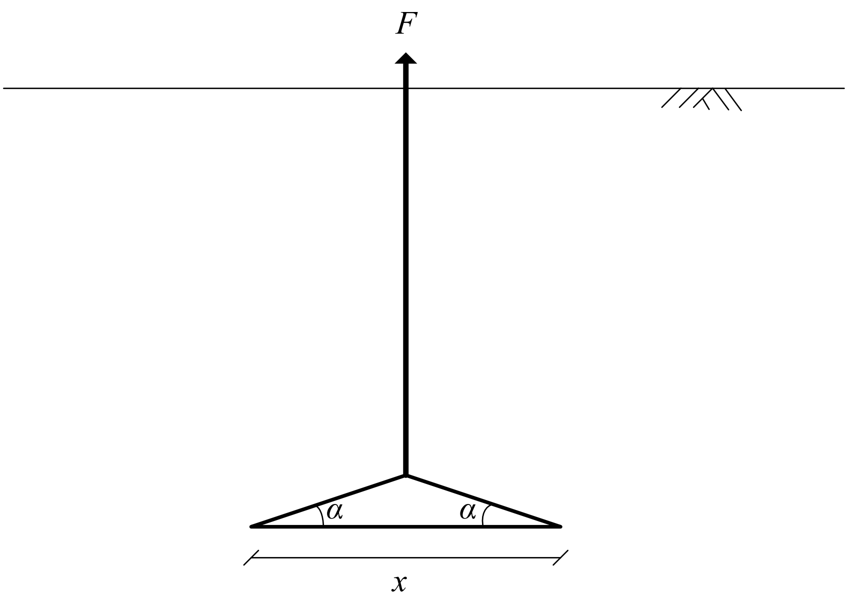


Fig. 3

4 An L-shaped reinforced concrete retaining wall is constructed on the surface of a uniform clay of undrained strength $c_u = 25\,\text{kPa}$ retaining 5 m of sand fill as shown in Fig. 4. The sand has an internal friction angle $\phi = 30°$ and both the fill and the concrete can be assumed to have a unit weight of $18\,\text{kN m}^{-3}$. The water table can be assumed to be coincident with the surface of the clay.

(a) What width of retaining wall x is required to prevent overturning of the wall? [30%]

(b) Assuming the wall base to carry vertical and horizontal loads but no moments, what wall width x is required to prevent a bearing capacity failure beneath the wall? [30%]

(c) Explain with diagrams what further failure mechanism should be assessed in design and how this might be achieved qualitatively. [20%]

(d) If the water table in the fill rose to the ground surface, how would this affect the stability of the wall? [20%]

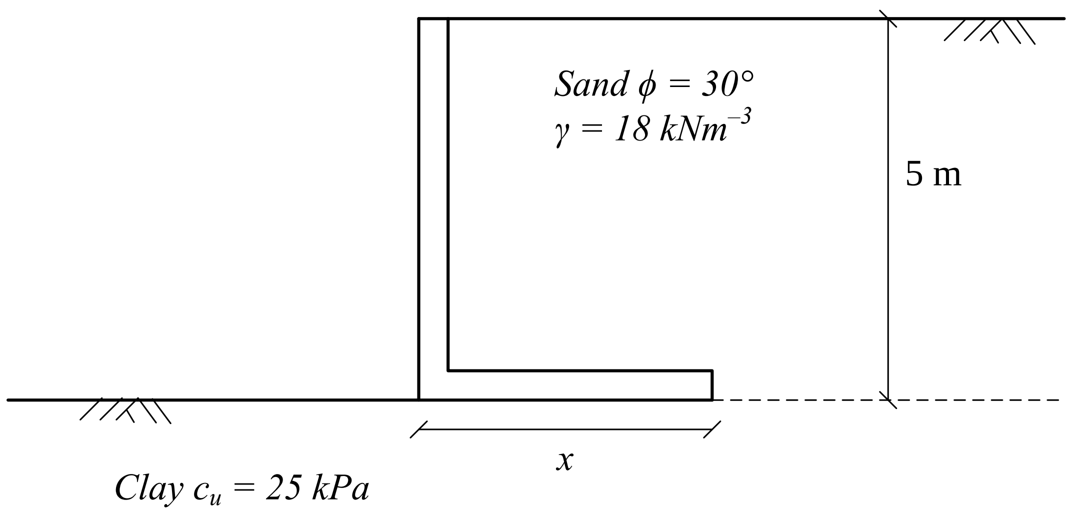


Fig. 4

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Version GB/2 Candidate Number:

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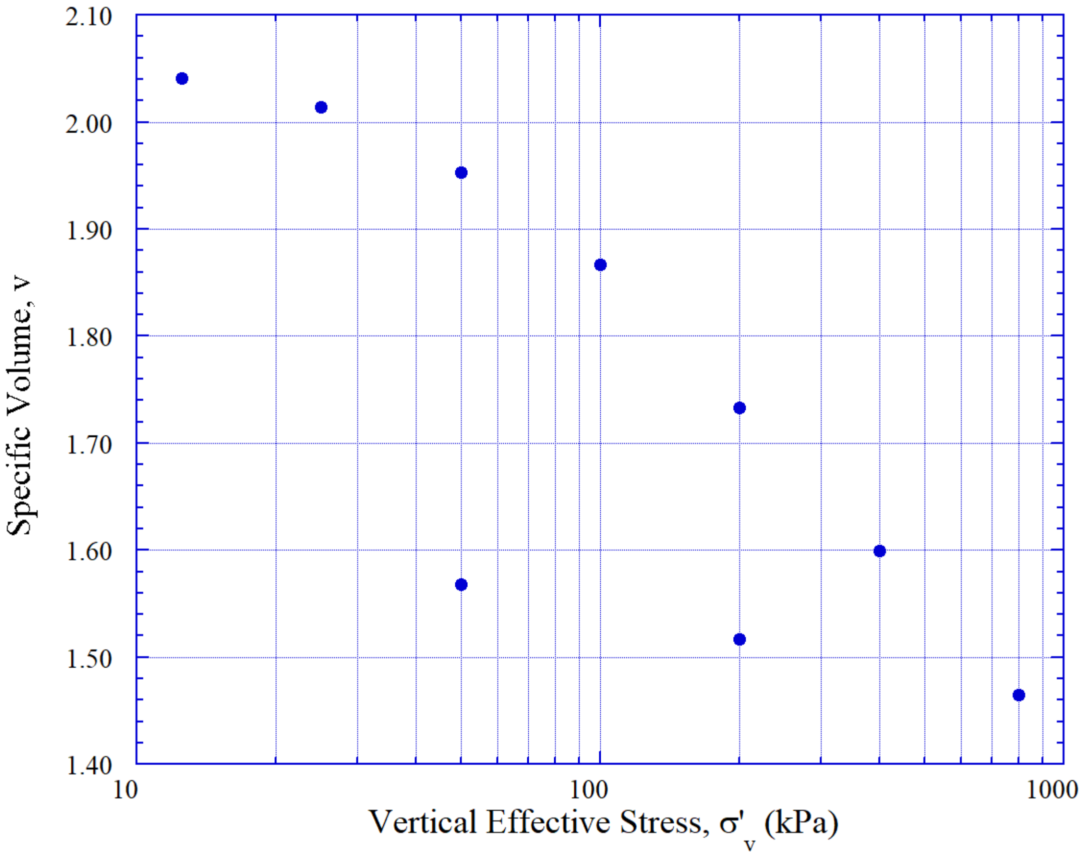
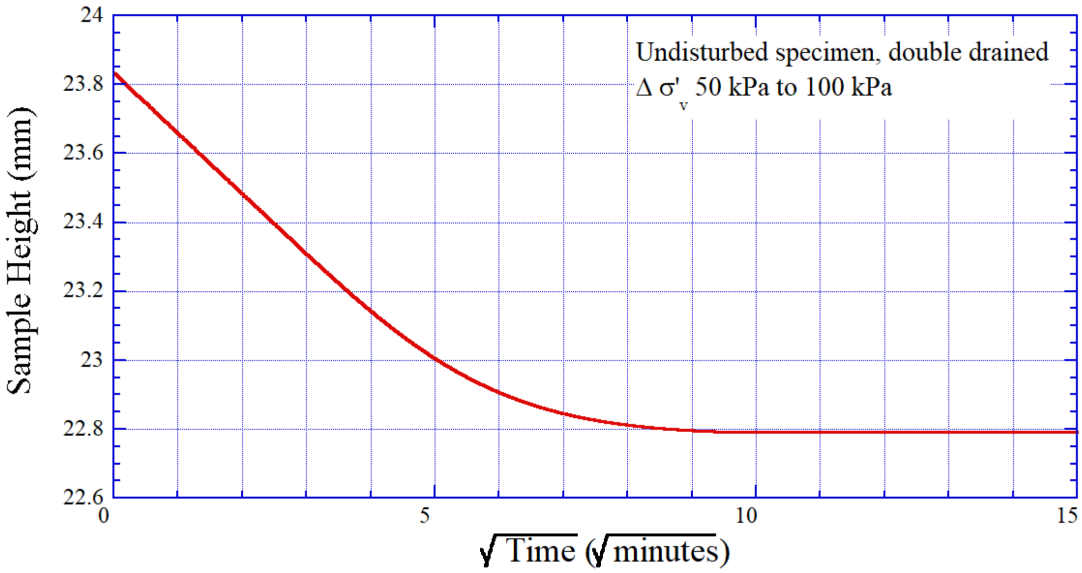
Thursday 25 April 2019, Module 3D1, Question 1.



Extra copy of Fig. 1: Consolidation curve for question 1.



Extra copy of Fig. 2: Consolidation curve for question 1.