Version JPH/3

EGT2
ENGINEERING TRIPOS PART IIA

Thursday 1 May 2025 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
CUED approved calculator allowed
Attachment: 3D1 and 3D2 Geotechnical Engineering Data Book (21 pages)
Engineering Data Book

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 gravel embankment with a unit weight of 16 kN m^{-3} is constructed on a layer of overconsolidated London Clay while monitoring the pore pressure with a piezometer at a depth of 5 m below the original ground surface. Site investigation reveals the overconsolidated clay to have a K_0 value of 1.2 and the water table to be 2 m below the clay surface. The bulk unit weight of the overconsolidated clay is found to be 18 kN m^{-3} both above and below the water table.

It can be assumed that the increase in vertical stress at the piezometer is equal to the stress at the base of the embankment and that horizontal stresses increase by 20% of the vertical stress increase. It can also be assumed that plane-strain conditions exist.

Total and effective stress paths for the embankment construction detailed below should be plotted on a graph of σ_v vs σ_h.

(a) Assuming that the embankment is constructed in undrained conditions, at what height of embankment H will first yield occur in the clay at the piezometer? What will be the recorded pore pressure at this point? [30%]

(b) If construction continues in an undrained manner until the embankment height is $2H$, what will be the pore pressure measured at the piezometer? [30%]

(c) What undrained strength does the clay require to prevent collapse of the embankment at a height of $2H$? [10%]

(d) How could yield be identified from the construction records and piezometer data? [10%]

(e) Construction was instead paused at first yield and drainage was allowed to occur until half of the measured excess pore pressure had dissipated. At what height of the embankment will yield be observed during this second phase of construction? [20%]

2 A sample of London Clay is isotropically consolidated to 400 kPa before being allowed to swell in a triaxial device to an effective stress of 350 kPa. The sample is then subjected to a conventional triaxial compression test by increasing the vertical stress while keeping the cell pressure constant.

(a) Using the parameters for London Clay given in the 3D1 and 3D2 Geotechnical Engineering Data Book, calculate the initial specific volume of the clay sample prior to shearing. [15%]

(b) If the sample is sheared under undrained conditions, calculate the deviatoric stress and pore pressure observed in the sample at both yield and failure. [30%]

(c) If the sample is sheared under drained conditions, calculate the deviatoric stress and volumetric strain observed in the sample at both yield and failure. [30%]

(d) If the sample is loaded under drained conditions at what deviatoric stress will the sample experience a volumetric strain of 1%? [25%]

3 Figure 1 shows a cross section through a masonry retaining wall. The blocks of the wall are ‘dry stacked,’ meaning that no mortar is used, and the unit weight of the wall is γ = 18 kN m^{-3}. The soil consists of clay overlying silty sand, and the groundwater level (GWL) coincides with the top of the silty sand layer, as shown. Relevant properties and dimensions are indicated in Fig. 1. Assume that the wall is smooth, and clearly state any other assumptions necessary for your calculations.

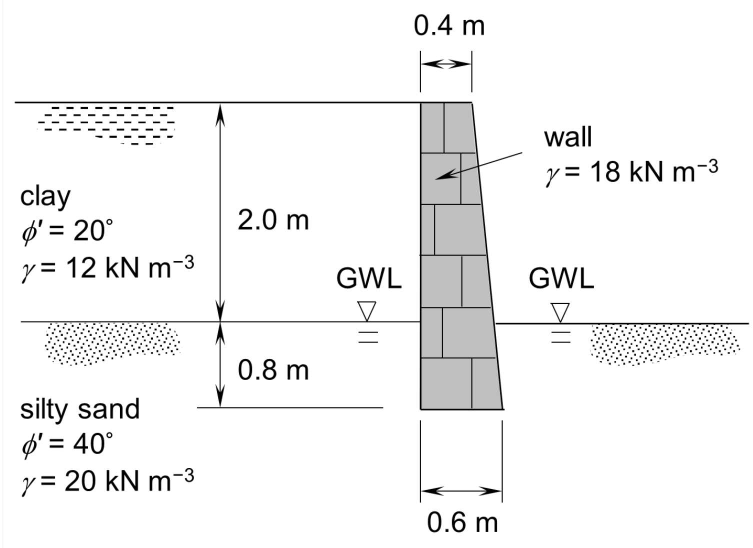

Fig. 1

(a) List the ways in which such a wall could potentially fail. [10%]

(b) Considering limiting equilibrium, evaluate the distribution of stress on the back of the wall (left face in Fig 1). Sketch the distribution. [25%]

(c) Assess the possibility of failure by sliding along the base. [20%]

(d) Assess the possibility of failure by overturning about the toe. [25%]

 (cont.

(e) As shown in Fig. 2, the stability of the wall could be improved by means of a line of horizontal anchors of length L (measured from the back of the wall), installed through the wall at a height of 1.0 m below the surface and spaced at 1.0 m centres along the length of the wall. Calculate the length L of the anchors needed to stabilise the wall. Assume that the anchors are made of flat strips of width 100 mm and that the angle of friction between the anchor and clay is 20°. [20%]

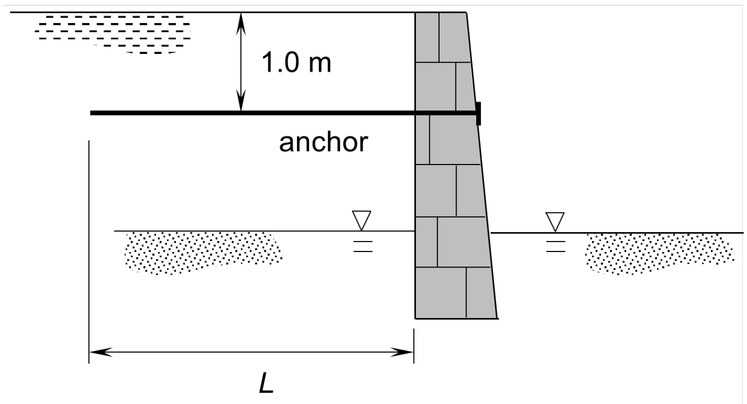

Fig. 2

4 Figure 3 shows a cross-section through part of a long slope at an angle of inclination to the horizontal β, through which water is flowing at an inclination θ.

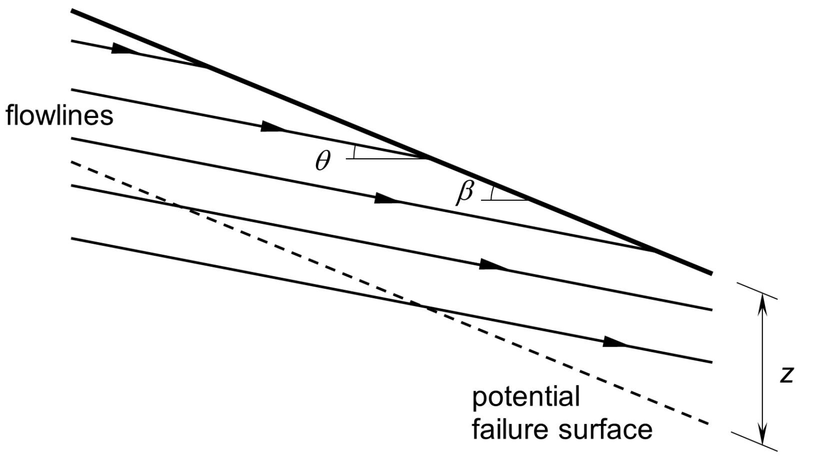

Fig. 3

(a) Derive an expression for the pore water pressure on a potential failure plane at a depth z vertically below the surface of the slope. The expression depends on β, θ, z, and the unit weight of water γ_w. [20%]

(b) By considering the limiting equilibrium of an element of the slope, derive an expression relating θ and β to the effective angle of friction of the soil ϕ' when the slope is on the verge of failure. The expression depends on β, θ, ϕ', γ_w, and the saturated unit weight of the soil γ. [20%]

(c) In the particular cases $\theta = 90°$ and $\theta = 0$, what does your expression in part (b) reduce to? Provide a physical interpretation and discuss the engineering significance. [20%]

(cont.

(d) Figure 4 shows a cross-section through a waste tip, which is initially dry. After a prolonged period of heavy rain, the material becomes saturated with water and a shallow pond develops on the top horizontal surface. Assume $\phi' = 35°$, $\gamma = 18$ kN m^{-3}, and that subsequent rainfall is sufficient to keep the top horizontal surface under a thin layer of water. Using your results from parts (b) and (c), estimate the largest value of slope angle β for which the waste tip is stable. Discuss possible sources of error and how stability could be assessed more rigorously. [20%]

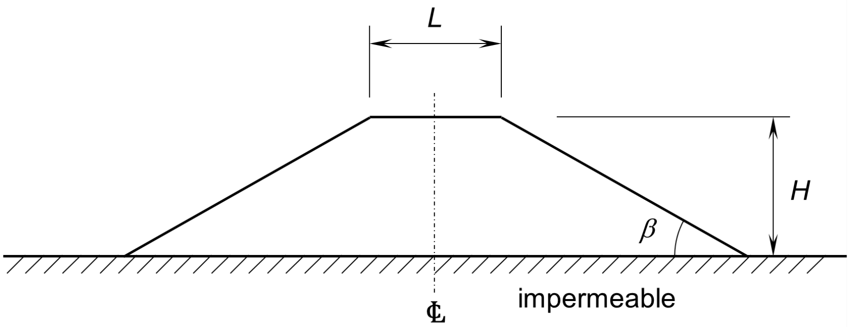

Fig. 4

(e) Suppose that the configuration of the waste tip is such that the slope is stable but nearly at failure. Under these circumstances, is it possible that a uniform surcharge q can be applied at the top of the waste tip, as shown in Fig. 5? Why or why not? If it is possible, describe an approach for estimating the maximum surcharge that can be applied. Is your estimate safe or unsafe? [20%]

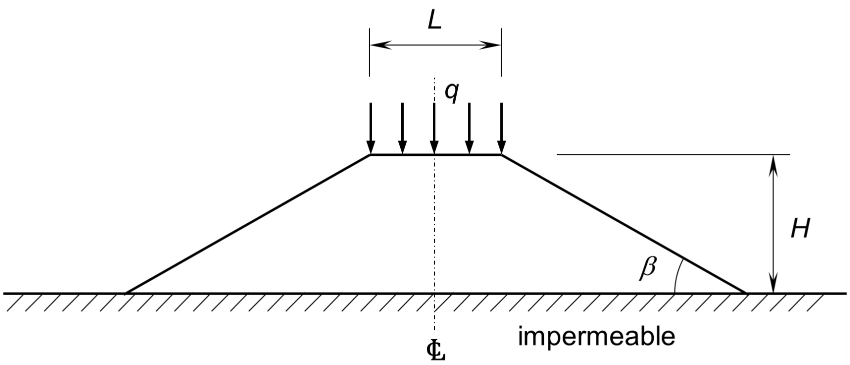

Fig. 5

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Answers, 3D2 Exam 2025

Question 1
(a) $H = 5.0$ m, $u = 78$ kPa
(b) $u = 43.8$ kPa
(c) $s_u = 57.5$ kPa
(d) plot height versus pore pressure and look for kink in graph at yield
(e) $H = 5.3$ m

Question 2
(a) $v_i = 1.902$
(b) yield: $q = 41.6$ kPa, $u = 13.9$ kPa; failure: $q = 182$ kPa, $u = 206$ kPa
(c) yield: $q = 33.0$ kPa, $\varepsilon_V = 0.1\%$; failure: $q = 443$ kPa, $\varepsilon_V = 7.5\%$
(d) $q = 72$ kPa

Question 3
(a) sliding along base; overturning about toe; exceeding bearing capacity; sliding between blocks (above base); overturning/toppling within blocks (above toe)
(b) see distribution sketched in crib
(c) $SF = 0.91$ (fails)
(d) $SF = 0.68$ (fails)
(e) $L = 5.3$ m

Question 4
(a) $u = \gamma_w z/(1+\tan\theta\tan\beta)$
(b) $\tan\phi' = \tan\beta\,/\,[\,1 - \gamma_w/\gamma\,(1+\tan^2\beta)\,/\,(1+\tan\theta\tan\beta)\,]$
(c) $\theta = 90°$: $\tan\phi' = \tan\beta$ corresponding to free (downward) drainage, which is the same as the stability criterion without water; $\theta = 0$: $\tan\phi' = \tan\beta\,/\,[\,1 - \gamma_w/\gamma\,(1+\tan^2\beta)\,]$ corresponding to horizontal flow (when drainage is impeded), for which stability is always less than for free drainage since the term in brackets is always greater than unity
(d) assume $\theta = 0$ since lower boundary is impermeable and flow is roughly horizontal: $\beta = 16°$; flow is fact complex and locally θ could take on range of values; compute distribution of pore pressures (e.g., using flow nets or finite element method) and consider <u>finite</u> slope failure to be more rigorous
(e) see crib