EGT3
ENGINEERING TRIPOS PART IIB

Wednesday 27 April 09.30 to 11.10

Module 4D5

FOUNDATION ENGINEERING

*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
4D5: Foundation Engineering Data Book (19 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 new building is constructed with plan dimensions and proximity to an existing building as illustrated in Figure 1. The building is founded on sand with a Poisson's ratio ν of 0.3 and Young's Modulus E of 50 MPa.

(a) Calculate the increase in vertical and horizontal stresses 10 m beneath point A caused by construction of the new building using Boussinesq's strip solution. [20%]

(b) Check the increase in vertical stress calculation using Fadum's chart and superposition. [20%]

(c) Justify the difference between the two estimates of the vertical stress 10 m beneath point A with reference to the different boundary conditions assumed. [10%]

(d) Compute the settlement beneath the centre and the corner of the foundation of the new building assuming that the applied bearing pressure q of 100 kPa is uniform. [20%]

(e) Repeat the settlement calculation required by part (d) assuming that the foundation is perfectly rigid. [20%]

(f) Justify the magnitudes of the three settlement estimates relative to each other with reference to the implied stiffness of the foundation. [10%]

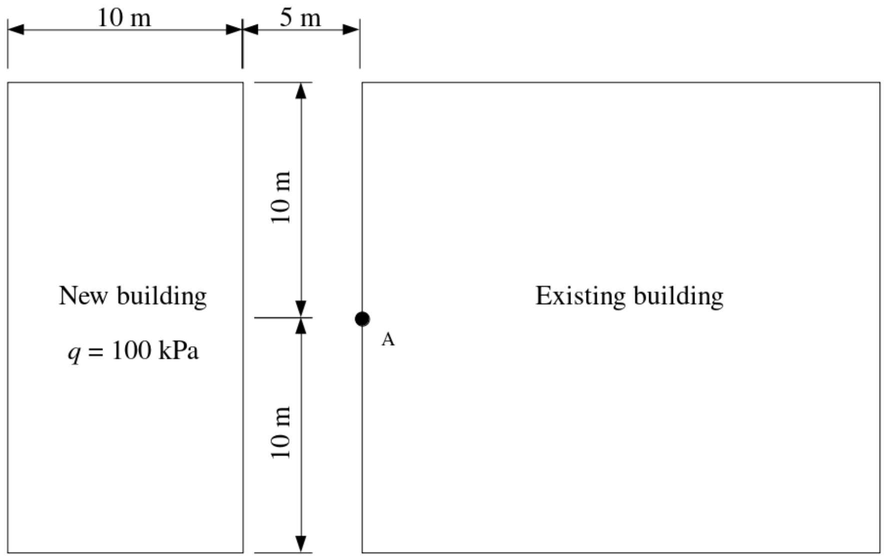

Fig. 1

2 A 4WD vehicle with weight of 25 kN is travelling along a beach close to the waterline. The sand has a friction angle ϕ of 35° and a total unit weight γ of 20 kNm^{-3}. The driver briefly allows the vehicle to roll to a stop to take in the view. However, when they attempt to get the vehicle moving again they find that they are stuck. The wheels are embedded to a depth of 100 mm such that each tyre has a projected bearing area with width B of 200 mm and length L of 400 mm.

(a) Calculate the ultimate vertical bearing capacity of one of the wheels. [40%]

(b) Calculate the horizontal force that can be generated by the vehicle at the tyre-soil interface as the 4WD sinks further into the sand assuming a value of coefficient t_h of 0.5. [20%]

(c) Estimate the maximum horizontal force that can be generated by the vehicle and determine the mass that would need to be removed from the vehicle in order to mobilise it. [20%]

(d) Suggest two ways by which the driver could improve their chances of getting the vehicle moving again without resorting to the removal of mass and explain why your suggestions would work in respect to the underlying soil mechanics. [20%]

3 A railway overhead line support structure is founded on a steel tubular pile of 0.76 m in diameter, with a wall thickness of 35 mm, Young's modulus of E_p = 200 GPa and yield stress σ_y = 350 MPa. The pile is embedded to a length of 5 m into soft uniform clay, with undrained shear strength s_u = 20 kPa. The shear modulus to undrained shear strength ratio G/s_u = 300 and the Poisson's ratio ν = 0.5.

The maximum operational loads acting on the overhead line support structure are summarised in Fig. 2 and comprise:
- the weight of the mast W_M = 27 kN
- a horizontal load caused by the wind of H = 2.3 kN, applied at a height y = 7.7 m above the clay surface (Fig. 2)
- the cantilever boom and the electric line it supports have a total weight W_P = 24 kN, acting downwards at an eccentricity x = 5.5 m from the centroid of the foundation.

(a) What are the forces acting at the top of the foundation? Explain why the effects of the vertical load can be considered separately from that of the horizontal and moment load. [10%]

(b) In order for the structure to fulfil serviceability limits on operational vertical load deflection, the immediate settlement of the foundation has to be <0.1% of the diameter. Calculate the expected pile settlement under operational vertical load. Justify which method you choose to employ for your calculation and conclude on the operational load design. Use the following expression for the dimensionless zone of influence:

$$\zeta = ln\left(5\rho\,(1-\nu)\,\frac{L}{D}\right)$$

[40%]

(c) Postulate and draw a diagram of the failure mechanism surrounding the pile under horizontal load. [15%]

(d) The pile needs to be able to withstand the maximum operational loads with an overall safety factor against horizontal and moment load failure of at least 3. Assume that the ultimate moment and horizontal loads can be linked by an equivalent height $h_e = \dfrac{M_{ult}}{H_{ult}}$ equal to the same equivalent height obtained from the maximum operational loads $h_e = \dfrac{M_{op}}{H_{op}}$ calculated in part 3(a). Perform calculations to determine whether the required factor of safety is met. [35%]

(cont.

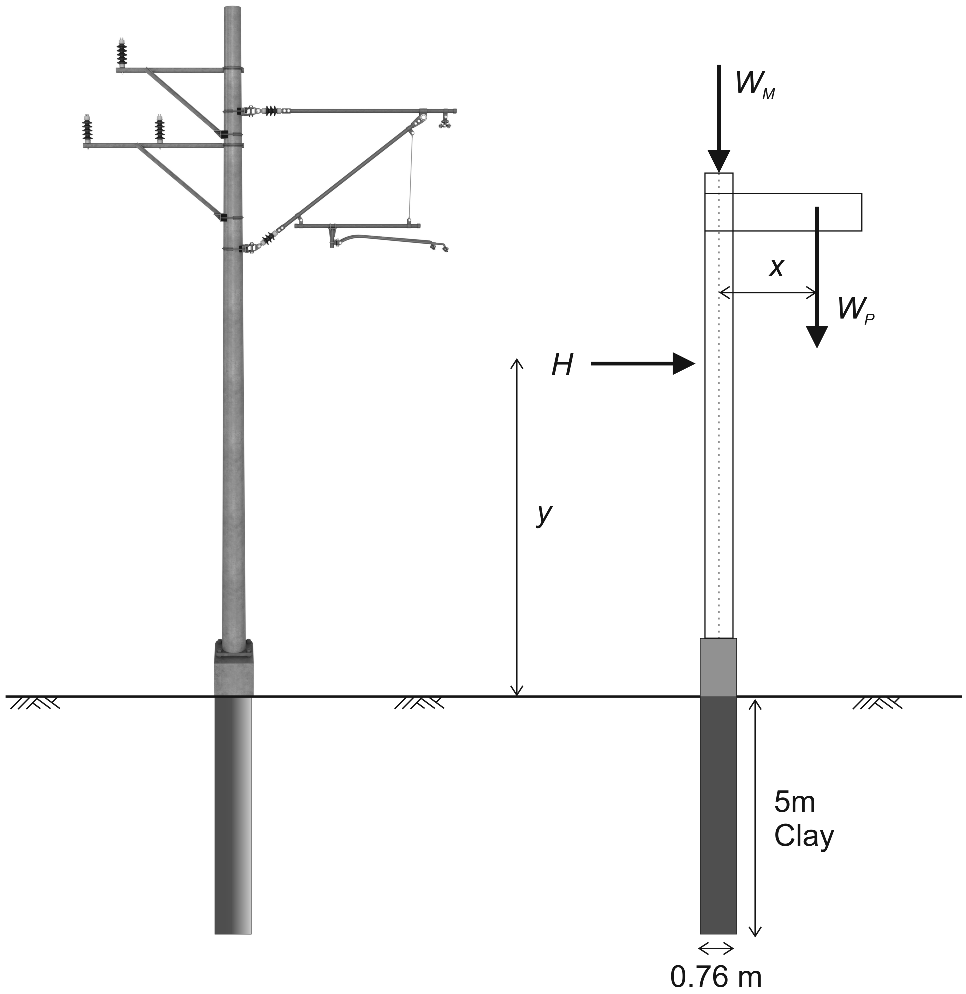

Fig. 2

(TURN OVER

4 In order to assess the suitability of the API method for driven piles in loose sand, a maintained load test on a driven open-ended concrete pile is performed. The pile is 0.8 m in diameter, has a wall thickness of 25 mm and is driven to a depth of 29.2 m in loose saturated silty sand of effective unit weight $\gamma' = 10$ kN.m^{-3}. After installation, the sand level within the pile is 4.7 m below the ground surface.

(a) Explain why the internal shaft resistance is not equal to the external shaft resistance in the case of open-ended driven piles in sand. [15%]

(b) Assuming that the sand friction angle is $\phi = 31°$, estimate the available internal shaft resistance. Take the soil-pile interface friction angle equal to $\delta = 15°$. Measured cone resistance at a depth of 29.2 m at this site is equal to $q_c = 10$ MPa. Conclude as to whether the pile fails in a plugged or unplugged manner. [30%]

(c) Results from the static test are provided in Fig. 3. Describe what a maintained load test consists of and the advantages and disadvantages of this method over other pile testing methods available. [15%]

(d) Calculate the theoretical capacity of the pile using the API method. Ignore the weight of the pile and the weight of the soil plug. Compare your prediction with the measured capacity from Fig. 3 and comment on the differences. [40%]

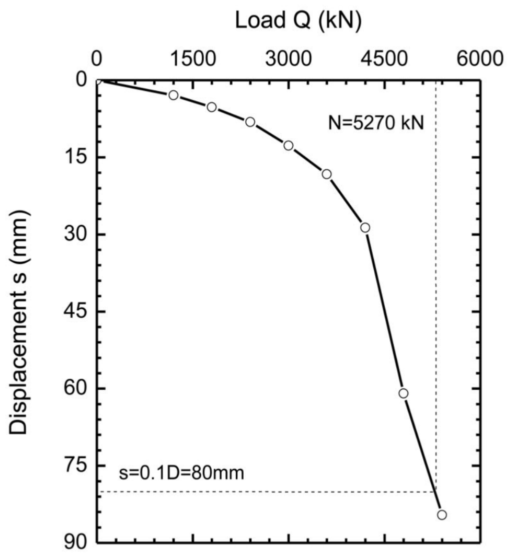

Fig. 3

END OF PAPER