Version SKH/3

EGT3
ENGINEERING TRIPOS PART IIB

Tuesday 22 April 2014 2 to 3.30

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
CUED approved calculator allowed
Attachment: 4D5 Foundation Engineering data sheet (18 pages).
Engineering Data Book

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

1 The soil profile at a site is characterised by a 0.6 m thick stiff, clayey sand crust, underlain by a soft, normally-consolidated, clay down to a depth of 12 m, where weathered permeable rock is encountered. Groundwater is at the bottom of the sand layer. The properties of the soils are:

Clayey sand	
Friction angle, ϕ	37^o
Saturated unit weight, γ	19 kN m^{-3}
Shear Modulus, G	6 MPa
Poisson's ratio, υ	0.3
Clay	
Undrained shear strength, s_u	30 kPa
Saturated unit weight, γ	17 kN m^{-3}
Compressibility index, λ	0.41
Compressibility index, κ	0.06
Young's modulus, E_u	12 MPa
Natural water content, w_o	39%

A warehouse is to be built at this site and rectangular shallow footings are selected as the foundation system for the relatively light building. The footings along the long sides of the warehouse will have plan dimensions of 1.5 m × 2.5 m, supporting columns each transmitting a vertical load of 300 kN.

(a) Calculate the settlement of a side footing, including:

(i) immediate settlement; [10%]

(ii) drained settlement, using two layers of equal thickness. [30%]

(b) Columns are spaced at 8 m on centre. Are you concerned about interaction between the loads at depth? State any assumptions you may need to make to assess load interaction. [15%]

(c) (i) Draw a sketch of the soil profile and the cross-section of the footing (across the short side). Draw your best estimate of the failure mechanism for this foundation, assuming that it can be idealised as a strip footing. Discuss your choice of failure mechanism. [10%]

(ii) Estimate the allowable bearing capacity for the rectangular footing. Discuss your choice of strength properties. Is the footing sized correctly? [15%]

(d) The columns at the corners of the warehouse support a lower load than the side columns.

(i) How can we ensure that distortions will be acceptable? [10%]

(ii) In your judgement, would you advise the client to follow the proposed preliminary design? Discuss your concerns with the proposed design. [10%]

2 A seafloor processing plant is to be founded on a square rigid raft of size 15 m × 15 m. The site comprises soft clay having a uniform shear strength of 7 kPa.

(a) Estimate the ultimate bearing capacity under purely vertical loads. [15%]

(b) The submerged weight of the equipment to be placed on the raft is 6.5 MN. Although no other vertical loads will be applied, the pipelines coming into the processing plant exert horizontal loads due to temperature effects.

Assuming that the horizontal load acts in the centre of the raft at the mudline, what is the maximum horizontal load that can be applied to the foundation? [20%]

(c) The intakes and outtakes for the plant are also likely to be above the mudline.

(i) What is the effect on the bearing capacity of applying the horizontal loads above the foundation plane? [15%]

(ii) The designers can arrange the plant in such a way that the resultant of all horizontal loads will be 0.8 MN acting parallel to one of the sides and applied at a height of 5 m above the mudline. Is the foundation still safe? [30%]

(d) It is very unlikely that a processing plant will have a single entry/exit point in the middle of the raft on which horizontal loads are applied. Assuming that no other loads are acting and that there is no embedment, what would be your proposed upper bound plastic mechanism for the case of a shallow foundation loaded eccentrically in the horizontal plane? [20%]

3 (a) Foundations can be either deep or shallow. What are the advantages and disadvantages of deep foundations in comparison to shallow ones? [25%]

(b) A foundation is to be constructed to carry an ultimate vertical load of 10 MN at a site consisting of clay with a uniform strength s_u of 50 kPa, a shear modulus G of 4 MPa and a unit weight of 16 kN m^{-3}. You may assume that the water table is at the ground surface.

(i) If the foundation is to be a square pad resting on the soil surface, what size foundation would be required to carry the vertical load and what would be the immediate settlement under a working load of 4 MN? [20%]

(ii) If the foundation is to consist of four 0.5 m diameter piles, what length of piles would be required to carry the ultimate vertical load and what would be the settlement under the working load of 4 MN if the piles were considered rigid? [25%]

(iii) If the foundation consisted of a 6 m × 6 m raft supported on four 0.5 m diameter piles with length as calculated in part (ii), estimate the settlement under the working load of 4 MN. State what assumptions are made in determining load sharing between the raft and piles and discuss whether these assumptions are justified. [30%]

4 (a) Piled foundations can be constructed using either displacement or non-displacement methods. Describe how each of the methods might be implemented for onshore pile construction and discuss the advantages and disadvantages of the two methods both in terms of the construction process and of the finished pile performance. [40%]

(b) An offshore wind turbine is to be supported using a piled jacket structure founded on four 1 m diameter tubular steel piles, one at each corner of the jacket. The site consists of a normally-consolidated clay whose strength is zero at the mudline and increases with depth at a rate of 5 kPa m^{-1}.

(i) If the horizontal loads on the turbine system have a magnitude of 4 MN and act at 50 m above the mudline, what are the minimum plastic moment capacity M_p and length l of the piles that are required to carry the horizontal loads? [20%]

(ii) What other considerations must be taken into account when designing the foundation piles? [10%]

(c) If the wind turbine is instead to be supported on a monopile foundation;

(i) what is the minimum length and plastic moment capacity of the 4 m diameter monopile that would be needed to carry the applied lateral loads? [20%]

(ii) what other design considerations must be taken into account when designing the monopile foundation? [10%]

END OF PAPER