Version GB/3

EGT3
ENGINEERING TRIPOS PART IIB

Wednesday 27 April 2016 9.30 to 11

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

10 minutes reading time is allowed for this paper.

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

1 (a) A rigid vertical cylindrical pile of diameter 0.3 m and length 15 m carries a vertical load of 500 kN. The soil has a Poisson's ratio of 0.2 and a shear modulus G (MPa) = $0.6z$, where z is the depth below the surface in metres. Calculate the pile settlement assuming a radius of pile influence of 12 m. [25%]

(b) A pile group is formed by adding three additional identical piles to the pile in part (a). The piles are arranged with their centres at the corners of a square of side length 2 m. Calculate the soil settlement at the other three corners of the pile group due to the loading of the fourth pile as in part (a) above. [25%]

(c) If a rigid pile cap is then cast onto the pile group in part (b) and a vertical load of 2 MN is applied centrally, assuming that the pile cap does not bear on the soil, what is the settlement of the pile group? [25%]

(d) If in practice the pile cap also carries some of the load, comment qualitatively on how the settlement calculations might be modified to take this into account. [25%]

2 (a) Describe the stress changes that occur during the installation of a driven pile in sand. How does the API design code cope with these changes in stress when considering pile design? [40%]

(b) A 0.5 m diameter close-ended tubular steel pile with a wall thickness of 50 mm is to be driven into a submerged medium density sand with a saturated unit weight of $19\,\mathrm{kN\,m^{-3}}$. What is the minimum length of pile required to carry a vertical load of 2 MN? [20%]

(c) The pile in part (b) penetrates 25 m into the sand and is to be subjected to a horizontal load at a height of 4 m above the ground surface. The pile is manufactured from steel with a design strength of 300 MPa. Calculate the horizontal capacity of the pile and describe the failure mechanism. You may assume an angle of friction for the sand of 35°. [30%]

(d) If the pile is to be subjected simultaneously to both horizontal and vertical loads, comment qualitatively on how the calculations in parts (b) and (c) might change and why. [10%]

3 The preliminary plan for an industrial building shows columns spaced at 7 m centres. A typical column carries a vertical load of 958 kN. The site consists of normally consolidated clay with a thickness of 15 m, a saturated unit weight of 17 kN m^{-3}, undrained shear strength of 25 kPa, and specific gravity of 2.70. The water table is at the soil surface.

(a) Determine the size of square shallow footing required to support the vertical load on a column based on Eurocode 7 ultimate limit state ($\gamma_F = 1.35$, $\gamma_M = 1.4$). Assume the footing will have minimal embedment. [20%]

(b) Calculate the stress increase due to column load below the centre of the footing at depths of 2.5 m, 7.5 m and 12.5 m. [20%]

(c) Estimate the long term settlement of the footing using the results from part (b). The water content of the clay can be taken to be 56%, λ = 0.33, κ = 0.05. How could you improve the prediction of long term settlements? [30%]

(d) Are shallow footings a feasible foundation system for this building? Discuss the issues that may arise when shallow footings are used as foundations in general. How could you increase the capacity and improve the performance of shallow foundations? Justify your answer. [30%]

4 The subsurface profile at a site consists of silty sand with friction angle of 32°, dry unit weight γ_{dry} = 16.4 kN m^{-3}, and saturated unit weight γ_{sat} = 20 kN m^{-3}. The water table is at 1.5 m depth.

(a) Determine the size of a circular shallow footing able to support a column bearing a vertical load V = 820 kN using Eurocode 7 ultimate limit state design approach 1, combination 1 ($\gamma_F = 1.35$, $\gamma_M = 1.25$). Assume embedment of 1 m. Discuss how the depth of the water table affects the bearing capacity. What is the most reasonable assumption for location of the water table in bearing capacity calculations? [30%]

(b) Estimate the settlement of the footing in part (a). State any assumptions in your calculations. Use a shear modulus $G = 20$ MPa and Poisson's ratio $\nu = 0.3$. Is there concern about the serviceability limit state? [15%]

(c) In addition to the vertical load, the columns are subjected to overturning moments in two orthogonal directions, M_x = 123 kN m and M_y = 574 kN m. Verify that a rectangular footing of dimensions 2 m and 3 m would satisfy the ultimate limit state. Assume an embedment of 1 m. [40%]

(d) Horizontal loads are also associated with the moments in part (c). How do these loads affect the capacity? [15%]

END OF PAPER

THIS PAGE IS BLANK

Answers

Q1

(a) w = 4.8 mm; (b) w = 1.97 mm (adjacent corner), w= 1.58 mm (opposite corner); (c) r = 10.32 mm;

Q2

(b) L = 20 m; (c) Hult = 600 kN;

Q3

(a) B= 3 m; (b) Dsv = 59.4 kPa, 9.75 kPa; 4.24 kPa; (c) r = 109 cm;

Q4

(a) B = 1.7 m; (b) w = 9.5 mm; (c) Not verified.