Version GB/4

EGT3
ENGINEERING TRIPOS PART IIB

Monday 20 April 2015 14.00 to 15.30

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

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 wind turbine is supported by a single steel monopile of diameter 4 m and wall thickness 50 mm. The design loads for the pile are: 6 MN in the vertical direction and 3 MN applied at 15 m above the mudline in the horizontal direction.

The soil at the site is clay with an undrained shear strength s_u increasing 5 kPa per metre depth starting from 0 kPa at the mudline. The saturated unit weight of the clay is 15.5 kN m^{-3}.

The steel can be assumed to have a yield stress of 200 MPa and a Young's modulus of 210 GPa.

(a) Estimate the minimum length of pile that can provide the required lateral capacity. [25%]

(b) Check if the thickness of the pile is sufficient to prevent plastic hinges from forming. If not, estimate the required pile thickness. [25%]

(c) Evaluate whether the pile embedment length calculated in part (a) is sufficient to support the vertical load. Disregard the self-weight of the monopile, but account for the possibility of plugging. [25%]

(d) Estimate the settlement at the mudline. You may neglect pile compressibility and assume that the clay has shear modulus of 150 s_u and Poisson's ratio of 0.3. [25%]

2 A new building, shown shaded in plan view in Fig. 1, is located close to an existing building (unshaded). The foundation of the new building will be a raft embedded 1 m below the ground surface, exerting an average net bearing pressure of 300 kPa. The soil is a clay with undrained shear strength increasing with depth z, $s_u = s_{uo} + k_{su}\, z$ with s_{uo} = 100 kPa and k_{su} = 5 kPa per metre depth.

(a) (i) Predict the undrained settlement of the raft using Mobilisable Strength Design. Assume the reference strain $\gamma_{M=2}$ is 0.008. [30%]

(ii) Calculate the undrained elastic settlement of the raft assuming the foundation is rigid. Use a shear modulus G = 25 MPa. [10%]

(iii) Estimate the undrained settlement at the corner and centre of the raft assuming the foundation is fully flexible. Calculate the average distortion. [25%]

(iv) An actual foundation is neither rigid nor fully flexible. Discuss implications of foundation flexibility for the estimate of settlements and the design of foundations. [15%]

(b) Estimate the increase in stress 20 m under locations A and B as shown in Fig. 1. [20%]

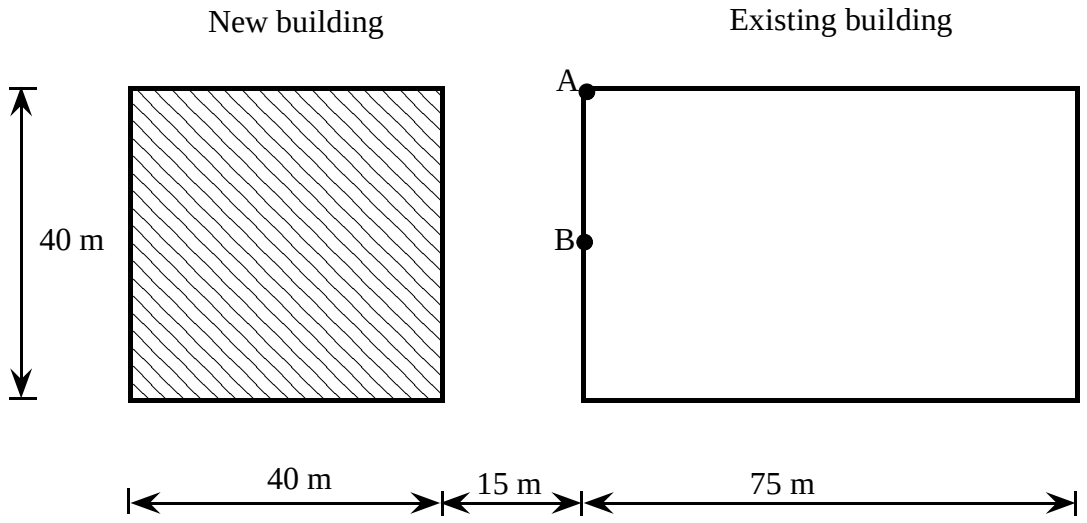

Fig. 1

3 An offshore structure is to be installed at a site comprising 30 m of loose sand overlying dense sand. Assume both have a saturated unit weight of 20 kN m^{-3} and their relative densities are 50% and 75% respectively. Each leg of the structure is supported by groups of identical 0.8 m diameter closed-ended tubular driven piles. The design storm compression and tension loads that each leg must sustain are 50 MN and 25 MN respectively.

(a) Using the API (2000) guidelines, find the variation in end bearing and shaft friction over the depth range 0 to 50 m. Sketch your results. [25%]

(b) Assuming the piles are at least 30 m long, derive expressions for the compression and tension capacities of the piles as a function of length. [35%]

(c) Determine the optimum number of piles and their length to the nearest 1 m, neglecting any interaction effects and applying a partial factor of 2.5 to the calculated capacity. [40%]

4 A warehouse is to be constructed at a site characterised by a medium dense, well-graded quartz sand with relative density I_D of about 65%, estimated using field testing. The water table is at 0.5 m depth. The columns of the warehouse will need to carry a vertical load of 1.5 MN each. The pads are initially taken to be square with side length 1.5 m and need to be embedded to a depth of 1 m.

(a) You are performing a very preliminary assessment of the site. Make a reasonable estimate of the peak friction angle of the sand. State any assumptions you have made in order to make the estimate. [40%]

(b) Verify that the size of the shallow foundation is adequate. Use the peak friction angle you estimated in part (a). Use Eurocode 7 partial material factor of 1.25 for ULS. [30%]

(c) How does the actual size of the foundation affect the estimate of peak friction angle you made in part (a)? [10%]

(d) The pads may need to accommodate off-centre columns. Find the maximum eccentricity to ensure that failure does not occur. [20%]

END OF PAPER

THIS PAGE IS BLANK

Answers

1. (a) $D \approx 16$ m;
   (b) Moment capacity is sufficient;
   (c) Lateral capacity is sufficient;
   (d) $w \approx 1.3 \times 10^{-2}$ m.

2. (a) (i) $w \approx 0.113$ m; (ii) $w_r \approx 0.108$ m; (iii) $w_{corner} \approx 0.067$ m; $w_{centre} \approx 0.135$ m;
   (b) $\Delta\sigma_{corrner} \approx 19.5$ kPa; $\Delta\sigma_{centre} \approx 33$ kPa.

3. (a) For shaft resistance $z_{lim} = 20.6$ m, for end bearing $z_{lim} = 24.1$ m;
   (b) $Q_{ten} = 251z - 3827$; $Q_{comp} = 251z + 998$;
   (c) N = 13 piles; L = 35 m.

4. (a) $\varphi \approx 39°$;
   (b) $V_{ult} = 1.84$ MPa;
   (d) e = 0.14 m.