EGT3
ENGINEERING TRIPOS PART IIB

Thursday 4 May 2017 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 structure is supported by 1.5 m diameter steel tubular piles driven to a depth of 25 m in over-consolidated clay. The clay can be assumed to have a uniform shear strength of 20 kPa. The piles are fully restrained at the head and sufficiently far apart for interaction to be ignored.

(a) Sketch the lateral resistance profile of one of the piles with depth, marking salient values. [10%]

(b) Derive an expression for the horizontal capacity of a single pile, ignoring the possibility of bending failure. [20%]

(c) Derive expressions for the horizontal capacity of a single pile if failure is by bending. You may assume that any hinges, except that at the pile cap, form at greater than 5 m depth. [50%]

(d) Calculate the pile wall thickness to prevent bending failure. Assume a steel yield stress of 200 MPa. Comment on the result. [20%]

2 (a) Describe the stress changes occurring around a driven pile in sand during its installation. [25%]

(b) Describe the origins of the effect known as "friction fatigue" and explain with sketches what effect this has on the shaft resistance of driven piles in sand. Discuss whether this effect is accounted for appropriately in the API design method. [45%]

(c) Tubular open ended piles can fail in either a plugged or an unplugged manner. By considering the equilibrium of an element of soil of effective unit weight γ' within a tubular pile of diameter D, show that the vertical effective stress q'_{plug} at the base of a plug of length h can be given as

$$\frac{q'_{plug}}{\gamma' h} = \frac{e^{\lambda} - 1}{\lambda}$$

where the ratio of shear stress acting between the soil and the pile to vertical effective stress is given by $\tau / \sigma'_v = \beta$ and $\lambda = \frac{4\beta h}{D}$. [30%]

3 An approach light for a navigational channel is supported on a 40 m high, four-legged frame structure with a square base as shown in Fig. 1. The foundation consists of four circular pads of 4 m diameter at a distance of 10 m on centre. The total vertical load V, including the structure and light, is 1 MN. Wave and wind loading can be simplified to a horizontal force H applied through the centre of the base at 30 m above the foundation level. The soil consists of clay with a shear strength of 25 kPa.

(a) Sketch at least four distinct possible mechanisms of failure for the foundation system. What factors will determine which mechanism will prevail? [30%]

(b) It may be assumed that: the foundations are not interacting, the horizontal load can be divided equally among the footings, and the connections between legs and foundation pads can be idealised as pin joints. Calculate the maximum horizontal load the foundation system can support:

(i) when tension is not allowed. [30%]

(ii) when tension is allowed. [20%]

(c) How can soil support tension? Discuss practical ways to implement tension resistance in soil and discuss any concerns. [10%]

(d) What is the consequence of restraining rotations at the connections between the legs and the foundation pads? [10%]

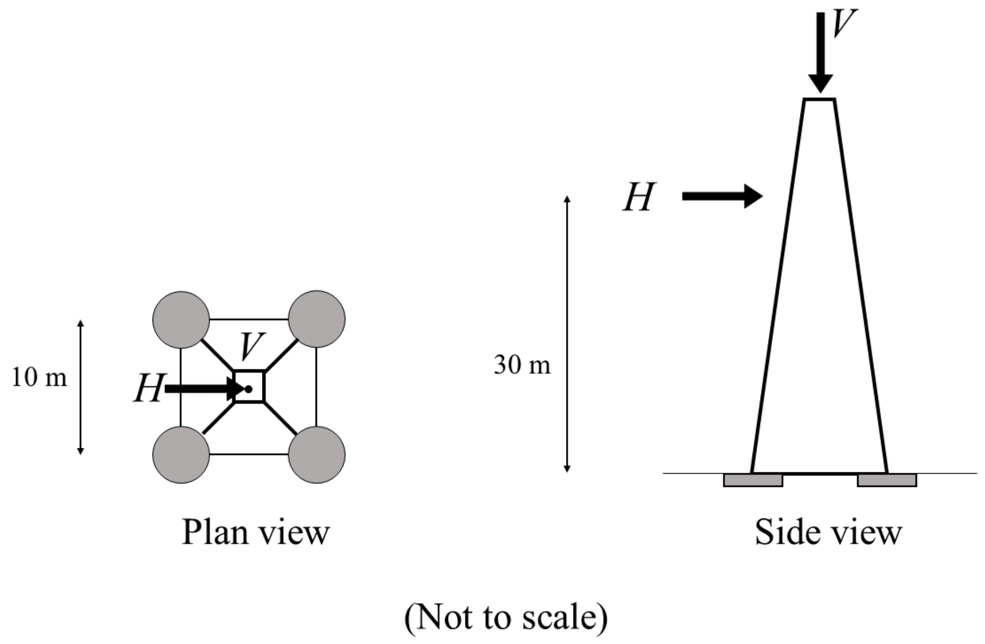

Fig. 1

4 A warehouse structure is founded on surface footings. The perimeter columns carry a vertical load of 1000 kN, while internal columns carry a vertical load of 500 kN. The subsoil consists of stiff clay with a unit weight of 18 kN m^{-3} and an undrained shear strength of 40 kPa at the surface and 120 kPa at 4 m depth. You can assume the variation of strength with depth is linear.

(a) Verify that a square footing with side length of 2.5 m is sufficient to safely support the perimeter columns. Consider Eurocode 7 ultimate limit state design approach 1. [20%]

(b) Estimate the settlement of the perimeter footing using Mobilisable Strength Design (MSD). Assume the reference strain is $\gamma_{M=2} = 0.02$. [20%]

(c) Estimate the undrained elastic settlement of a perimeter footing, assuming it is rigid. Compare this to the settlement calculated with MSD and comment on the results. [20%]

(d) The heavily loaded columns on the perimeter lie 6 m centre-to-centre from the lightly loaded internal columns. Determine the size of the internal square footing that will result in acceptable distortion due to undrained settlements. [40%]

END OF PAPER

ANSWERS
1) F = 6.2775 MN; t = 186 mm
2)
3) Hult=0.16 MN with no tension; Hult=1.05 MN with tension;
4) b) w = 35 mm; c) w = 61 mm; d) B = 1.6 m