ENGINEERING TRIPOS PART IIB

Thursday 26 April 2012 2.30 to 4

Module number 4D5

FOUNDATION ENGINEERING

Answer not more than **three** questions.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

All questions carry the same number of marks

Attachments: Foundation Engineering Databook (18 pages)

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

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

skh3

1 (a) Use the Mobilizable Strength Design method to derive an expression for the immediate settlement of a shallow, square (B x B) pad foundation on clay. Assume an initially parabolic stress-strain relation for the soil, up to a shear strain γ_u sufficient to mobilize the undrained shear strength s_u. Why is this approach only approximate? [40%]

(b) An overconsolidated clay has been found to be suitable for supporting the shallow foundations of industrial sheds on a trading estate. The designer of a multi-storey framed building is proposing that it could also be supported on individual footings. However, there is some concern about differential settlements which could damage the building's partitions. Some frames, which will be continuous over many footings, will be infilled with non-load-bearing panels for which the maximum tolerable relative displacement is 1.5×10^{-3}. Columns are to be spaced at 5 m intervals, and will transmit vertical loads of 600 kN to exterior footings and 300 kN to interior footings.

(i) What should be the relative proportions of the exterior and interior footings, in order to minimise differential settlements, if the clay is homogeneous? [10%]

(ii) Triaxial tests carried out on block samples recovered from trial pits reveal that the undrained shear strength of the clay at 1 m depth, which is the intended depth of the foundation bases, varies between 60 kPa and 80 kPa. The axial strain required to mobilize 50% of this strength were found to be 2%. Recommend dimensions for exterior and interior footings in order to protect the building from intolerable deformations during undrained loading. [30%]

(iii) Revise your estimate in (ii) if drainage, allowed after the undrained phase of the triaxial tests, indicated a Poisson's ratio of 0.25. [20%]

2 A stiff sandy clay with a unit weight of 20 kN m^{-3} is to be considered as the bearing stratum for strip foundations supporting a masonry arch. Structural considerations suggest that the thrust from the arch will be 400 kN m^{-1} inclined at 20° to the vertical.

(a) Cores were taken from trial pits sunk to 1 m depth and subjected to undrained triaxial compression tests with pore pressure measurement, at their natural water content. A typical test was conducted under a confining cell pressure of 50 kPa and failed at a maximum deviatoric stress of 200 kPa, whilst indicating a negative pore water pressure at failure of – 25 kPa. Deduce values for the undrained shear strength s_u and effective angle of internal friction ϕ' of the clay. [30%]

(b) Use stress characteristics and Mohr's circles of stress to explain, without calculation, why the vertical bearing capacity of a shallow foundation reduces if it is also required to transmit horizontal shear force. Estimate the undrained bearing capacity of the clay under the inclined load from the arch, and suggest a bearing width B for a strip foundation at 1 m depth, if it is to have a factor of safety of 2 against bearing failure. [40%]

(c) Assuming that the water table will coincide with the base of the foundation, check the drained bearing capacity of the design arrived at in (b), and make a new recommendation if necessary. [30%]

3 Piles can be installed using either displacement methods such as pile-driving or by non-displacement methods such as pile-boring, which may affect their subsequent behaviour.

(a) Describe the process of bored pile installation in sand. [20%]

(b) Describe the stress changes occurring around a bored pile during installation. How do these changes affect the performance of the pile during loading? [30%]

(c) The API (2000) design code limits the maximum allowable shaft friction for a driven pile in sand. How does soil behaviour during pile installation lead to this design guidance? [30%]

(d) Describe the mechanism of pile "plugging". How would one determine whether a pile would fail in a plugged or an unplugged manner? [20%]

4 (a) A steel tubular pile with an external diameter of 4 m and a wall thickness of 100 mm is to be installed offshore in normally consolidated clay as the foundation for a wind turbine. In-situ testing indicated that the undrained strength s_u increases linearly from zero at the mudline at a rate of 1.5 kPa m^{-1}. The unit weight, γ, of the clay can be taken as 16 kN m^{-3}, the Young's modulus of the steel is 220 GPa and the yield strength of the steel is 200 MPa.

(i) Calculate the plastic moment capacity M_p of the pile. [10%]

(ii) If the pile length in the clay is 30 m, calculate the maximum horizontal load that can be safely applied at the mudline. Recalculate the maximum safe horizontal load if it is to be applied 16 m above the mudline. [30%]

(iii) Assuming an unplugged mechanism and ignoring base resistance, calculate the vertical capacity of the pile foundation. [20%]

(b) As an alternative design, four 1 m diameter 50 mm thick steel tubular piles are used at the corners of a square pile cap with a pile centre spacing of 8 m.

(i) Ignoring base capacity and assuming an unplugged mechanism, what pile length is required to carry a total horizontal load of 2 MN, applied 15 m above the mudline, together with a vertical load of 6 MN? [20%]

(ii) If the horizontal load is shared equally between the piles, would these piles be suitable? [20%]

END OF PAPER

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4D5 2012 Numerical Answers

1) b)i) 1.59
   ii) B_{outer}=1.95m B_{inner}=1.23m
   iii) B_{outer} = 2.22m B_{inner}=1.40m

2) a) su=100 kPa φ=35°
   b)B=2.75m

4) a)i) 320MNm
   ii) 6MN, 3.5MN
   iii) 17MN

   b)i) 29.7m