ENGINEERING TRIPOS PART IIB

Tuesday 9 May 2006 2.30 to 4.00

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.*

Attachment: 4D5 Supplementary Databook (14 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

Version 4

1 The offshore structure shown in Fig. 1 is supported on 2 strip foundations, of width b and length l, which can be idealised as plane strain ($l>>b$). The centre-to-centre distance between the foundations is a. The seabed is uniform clay, with undrained strength s_u. The vertical load on the foundations, due to the weight of the structure, V, is equal to $3bls_u$.

First, consider failure modes that do not involve interaction between the foundations.

(a) If the foundation-leg connections are idealised as a pin-joints, and the foundations cannot sustain tension, calculate the horizontal load H, applied at a distance $3a$ above the seabed, that will cause failure. You may ignore interaction between the foundations, and assume that the foundations mobilise equal horizontal reactions. State the mode of failure.

[30%]

(b) Calculate the horizontal load at failure if the foundations can sustain tension. Explain your result using a V-H interaction diagram.

[40%]

Now consider a failure mode that does involve interaction between the foundations.

(c) Calculate the horizontal load that will cause failure on a circular slip surface passing through the outer edge of each foundation, with the centre located at point P. Assume that $b = a/2$, and comment on how your result compares with parts (a) and (b).

[20%]

(d) Discuss how the answers to parts (b) and (c) would change if there were a stiff crust of thickness $b/2$ and strength $1.5s_u$ at the seabed surface.

[10%]

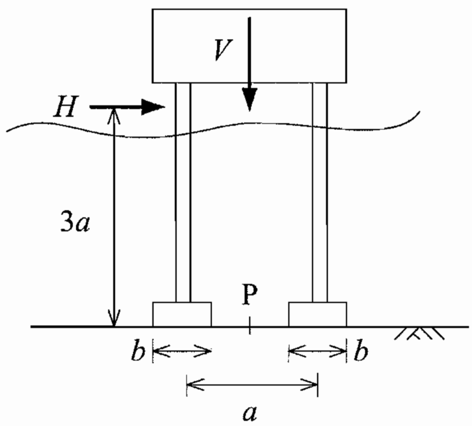

Fig. 1.

2 A new building, shown shaded in plan view in Fig. 2, is located close to an existing building (unshaded), which is made from brick and has windows. The foundation of the new building will be a raft embedded 1 m below the ground surface, exerting an average net bearing pressure of 250 kPa (allowing for the weight of the excavated soil). The ground comprises over-consolidated clay to great depth. A shear modulus of 20 MPa was estimated from triaxial tests conducted on samples taken from the site.

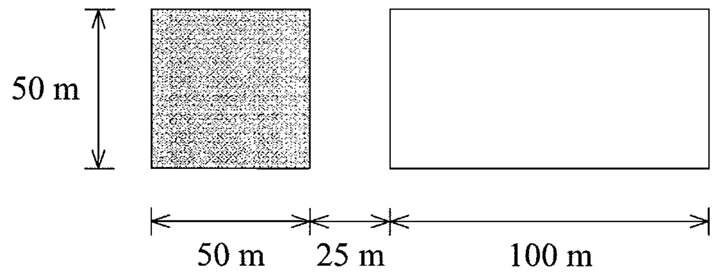

Fig. 2.

(a) Ignoring the stiffness of the new foundation raft and building, predict the immediate (undrained) settlement at the centre and corner, and evaluate the deflection ratio.

[30%]

(b) Assuming that the foundation raft is rigid, predict the settlement.

[10%]

(c) Making a simplifying assumption, predict the tilt and deflection ratio induced in the existing building.

[25%]

(d) Describe which part of the existing building you would expect to show signs of damage first.

[10%]

(e) During construction, it was found that the answer to (c) was a significant over-estimate of the induced deformation. Give some possible reasons for this discrepancy.

[25%]

3 An offshore structure in shallow water is to be supported on a single open-ended monopile of diameter 4 m and wall thickness 50 mm. The site comprises normally-consolidated soft clay with an undrained strength $s_u = 1.5z$ kPa, where z (m) is the depth below the mudline. The effective unit weight γ', is 6 kNm^{-3} and the coefficient of horizontal consolidation c_h, is 15 m^2/year.

The design storm load comprises a vertical compressive force of 6 MN, and a horizontal force of 1 MN applied 10 m above the mudline.

Consolidation around a driven pile in clay is 90% complete after an equivalent dimensionless time of $T_{eq} = c_h t/(D_{eq}^2) = 10$.

(a) By considering the vertical capacity of the pile, make a preliminary calculation of the required pile length using the API design method. You may assume that the pile fails in a plugged manner.

[40%]

(b) Evaluate whether this pile length needs to be increased to resist the horizontal load. You may ignore the possibility of structural failure of the pile.

[25%]

(c) Calculate the equivalent diameter of the pile, D_{eq}, (assuming it was unplugged during driving) and estimate the set-up period that should be allowed after pile installation before the structure is attached.

[15%]

(d) If the pile wall thickness is now changed to 75 mm, explain which of the answers to (a), (b) and (c) would be different, and why.

[20%]

4 The cylindrical drop anchor shown on the left in Fig. 3 is installed by free-fall through water, before embedding into the seabed. After installation, the anchor is loaded by a chain attached to the rear. The seabed comprises soft clay, with strength proportional to depth, as shown on the right in Fig. 3. The anchor reaches a terminal velocity of 40 ms^{-1} prior to impact.

In the following calculations, assume a shaft adhesion factor α = 0.3, and a bearing capacity factor N_c = 9. You may also assume that the anchor length is small compared to the embedment depth.

(a) Estimate the submerged weight of the anchor.

[20%]

(b) Estimate the final embedded depth of the anchor.

[50%]

(c) Estimate the efficiency of the anchor, defined as the pullout capacity under a sustained load divided by the dry weight.

[30%]

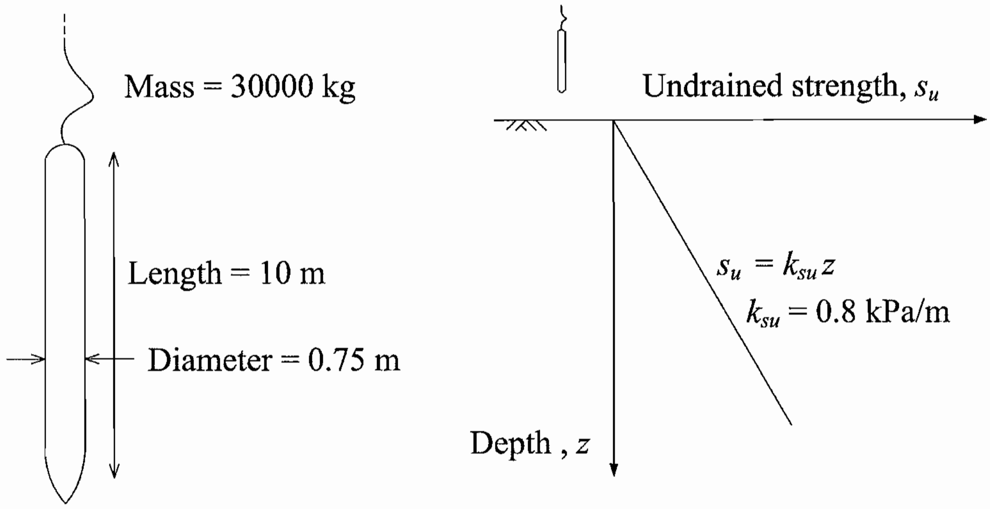

Fig. 3.

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