National Exams May 2012

07-Str-B5, Foundation Engineering

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper.
   The first five questions as they appear in the answer book will be marked.

4. Each question is of equal value.

5. Clarity and organization of the answer are important.

1. Shallow Foundations (30 marks)

Briefly discuss the following, using diagrams or equations whenever possible:

a. Ultimate limit state and serviceability limit state for shallow foundations. (1.5 marks)
b. Overburden pressure, and distribution of stress increase within the supporting soil due to a shallow foundation's load. (1.5 marks).

An advertisement board is to be supported on a square spread footing. The bottom of this footing will be 2.0 m below the adjacent ground surface. The footing is 1.8 m x 1.8m and is subjected to a vertical load of 1200 kN, and moments $M_x = M_y = 360$ kN.m. The underlying soils are clayey silt and the groundwater table is at a depth of 2.0 m. The soil unit weight above the water table is $\gamma = 18.0$ kN/m^3 and below the water table the saturated unit weight is $\gamma_{sat} = 19.81$ kN/m^3. The representative soil properties obtained from laboratory tests are $\phi' = 36°$ and $c' = 20$ kPa. It is specified that the settlement of the foundation should not exceed 30 mm.

a) Calculate the total (overall) factor of safety of the square footing. (10 marks)
b) For the estimated drained values of the soil Young's modulus $E_s = 40$ MPa and Poisson's ratio $\nu = 0.3$ check if the foundation satisfies the serviceability (settlement) limit state. (10 marks)
c) If the given axial load is a specified dead load (DL) and the given moments M_x and M_y are specified wind loads (W), check if the foundation satisfies the ultimate limit state (bearing resistance). Use resistance factors $f_c = 0.6$ and $f_\phi = 0.8$, and load factor 1.25 for DL and 1.4 for W. Comment on the results. (10 marks)

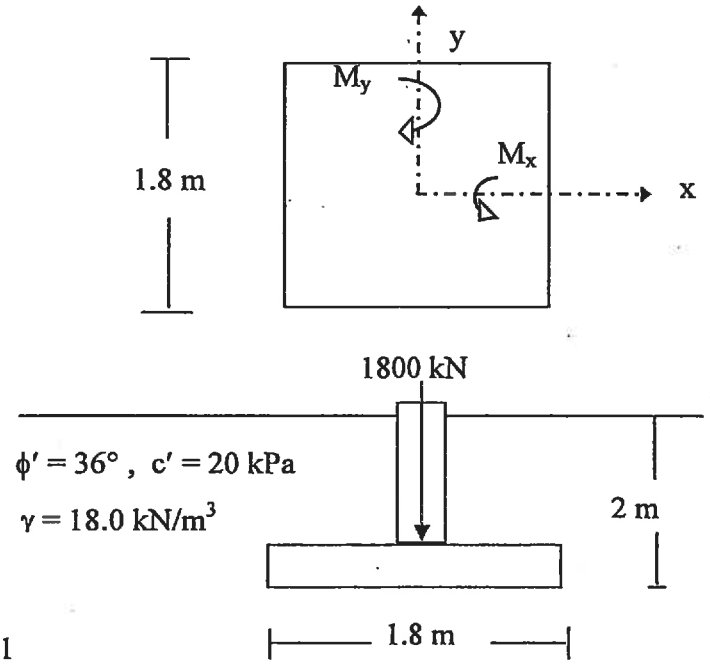

Figure 1 for Question 1

2. Deep Foundations (30 marks)

It is proposed to use a pile foundation to support heavy equipment in a petrochemical plant. The foundation is expected to support a total specified (unfactored) vertical dead load of 12 MN (including the weight of the pile cap). The foundation will also support a live load of 4 MN due to the emergency loads of the equipment. The pile cap will be 2m thick and the elevation of the top of the concrete of the pile cap is at the existing ground level. The proposed piles are 50 m long steel piles with a diameter of 0.406 m. The pile wall thickness will be 12.7 mm. The piles will be driven in silty clay layers whose properties are given in Table 1 and will be founded on the till (bedrock). The ground water table (GWT) may rise to 10m below the ground surface. The submerged unit weight of the soil is γ_{sub} = 10 kN/m^3. The recommended pile spacing is 4 to 5 times the pile diameter. The elastic modulus of the pile E_P = 200 GPa, its cross-sectional area is 15,700 mm^2 and cross-sectional moment of inertia is 305x10^6 mm^4. The allowable vertical settlement is 25 mm. The equipment layout requires that the dimension of the pile cap be 30 m x 7.4 m.

a) Determine the ultimate pile capacity of a single pile using the static analysis approach (i.e. using soil strength parameters) considering both undrained and drained conditions. (15 marks)
b) Design the pile group using a total (overall) factor of safety = 3 (10 marks)
c) Check that the serviceability limit state (total settlement) is satisfied using the equivalent raft method (using elastic analysis) (5 marks)

Table 1 Soil Properties

Soil Type	Thickness (m)	C_u (kPa)	c′ (kPa)	ϕ′ (°)	γ (kN/m^3)	E (MPa)	ν
Native silty clay	5	50	10	28	20.5	50	0.5
Native silty clay	7.5	40	0	24	20	40	0.5
Native silty clay	18	50	0	24	20	50	0.5
Silty clay	17	60	10	28	20	60	0.5
Silty clay	2.5	120	20	30	22	120	0.3
Till (bedrock)	---	400	50	32	22	400	0.3

3. Slope Stability (30 marks)

Part 1

A cutting 20m deep is to be excavated with a slope angle, $\beta = 20°$ in a clay soil of unit weight 19 kN/m^3. The relevant shear strength parameters are $c' = 30$ kN/m^2 and $\phi' = 25°$. The pore water pressure ratio for the slope, $r_u = 0.25$.

a) Sketch the slip surface for this cutting and state the expected form of failure surface (i.e. based on the location of the failure surface). (5 marks)

b) State the approximations made in derivations of the ordinary method of slices; Bishop's simplified method; and Spencer's method. (5 marks)

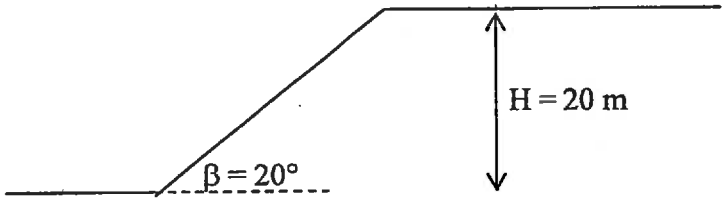

Figure 2 for Part 1 of Question 3.

Part 2

For the construction of a railway, a slope was excavated in a deep over-consolidated clay deposit. The slope is 2H:1V and 6 m high. A large number of laboratory drained triaxial tests showed that $\phi' = 25°$ and $c' = 6.8$ kN/m^2. The bulk unit weight of the soil is 17 kN/m^3.

(a) Use the ordinary method of slices to estimate the factor of safety of the slope when the ground water reached steady seepage. (10 marks)

(b) The slope failed in a rainy season. The observed failure circle passed through the toe of the slope. Estimate how much the pore pressure has increased in terms of r_u. (10 marks)

4. Retaining Structures (30 marks)

A cantilever wall 6 m high is designed as shown in Figure 3. The proposed backfill material is a granular A with the following properties: $\phi' = 30°$, and $\gamma = 18$ kN/m^3. The properties of the foundation soil are: $\gamma = 19$ kN/m^3, $\phi' = 20°$ and $c' = 40$ kPa. The water table is at least 4 m below the base of the retaining wall.

a) Use Rankine's theory to determine the distribution of the lateral pressure on the wall (2 marks)
b) Calculate the factor of safety with respect to overturning. (9 marks)
c) Calculate the factor of safety with respect to sliding. (9 marks)
d) Calculate the factor of safety with respect to bearing capacity. (5 marks)
e) If the water table rises to the level of the base of the retaining wall, what would be the factor of safety with respect to bearing capacity? (5 marks)

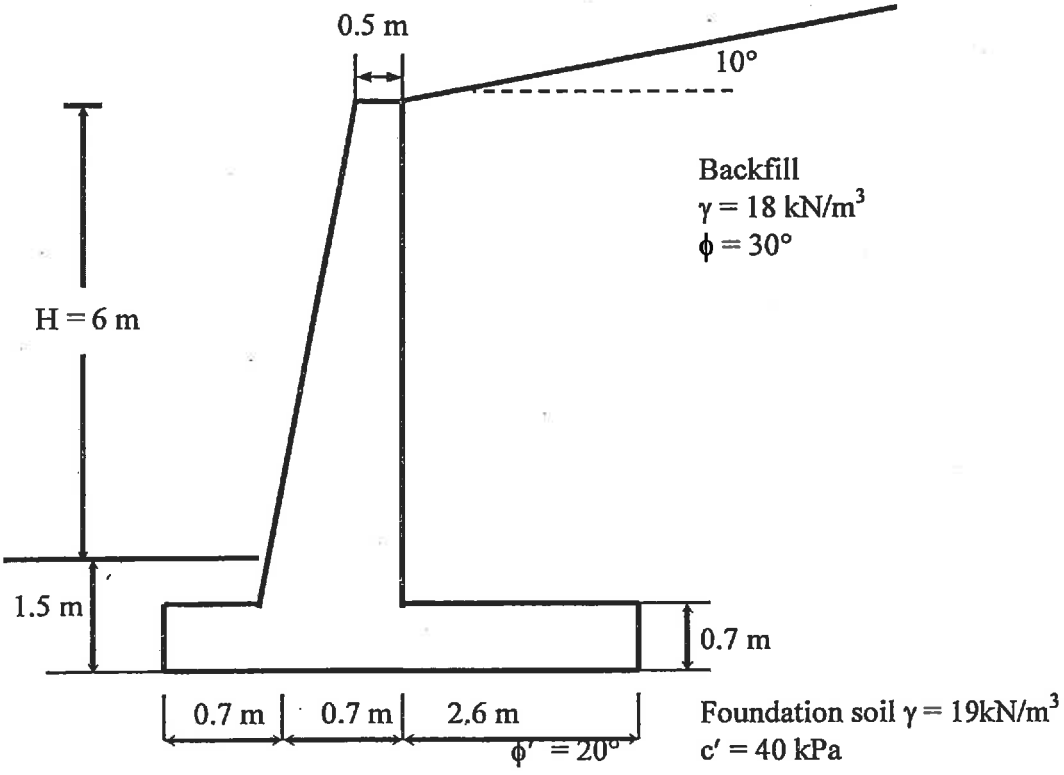

Figure 3 for Question 4 (Retaining structures)

5. Deep Foundations (30 marks)

It is required to establish the axial capacity for 0.90 m diameter pile for a foundation that will be situated at the location of Borehole shown in Figure 1, which provides the SPT values at that location. Based on the SPT data, establish the shaft frictional resistance and the toe bearing pressures. Using these shaft and toe resistance values, establish the pile capacity for an 8 m long pile for the following two cases:

a) The pile head is at the existing grade. (10 marks)
b) The pile head is at 2.00 m below existing grade. (10 marks)
c) Considering the pile option in part (b), design a pile group to support a square foundation carrying a total load of 10 MN using a total (overall) factor of safety = 3, and considering a pile spacing, S = 3d, where d is pile diameter. (10 marks)

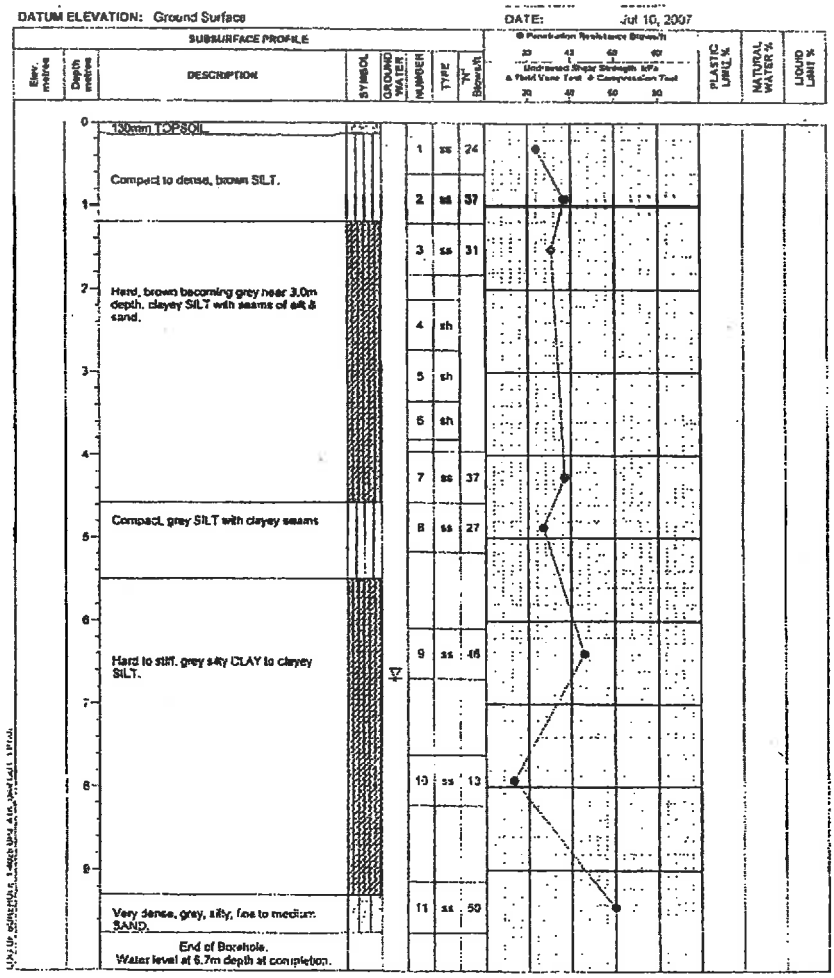

Figure 4 for Question 5: Borehole log

6. Shallow Foundations (30 marks)

It is proposed to use a shallow foundation to support the equipment in Question 1. The foundation will be embedded to a depth of 2.5 m in the silty clay layers whose properties are given in Table 1. The ground water table (GWT) may rise to 15m below the ground surface. The submerged unit weight of the soil is γ_{sub} = 10 kN/m^3. The allowable vertical settlement is 25 mm. The supported equipment layout requires that the dimensions of the foundation be at least 20 m x 10 m.

a. Determine the ultimate bearing capacity considering both undrained and drained conditions. (10 marks)

b. Design the foundation using a total (overall) factor of safety = 3. (10 marks)

c. Check that the serviceability limit state (total settlement) is satisfied. (10 marks)