

1.364 ADVANCED GEOTECHNICAL ENGINEERING
FINAL EXAM
DECEMBER 16TH 2003

3 HOURS; OPEN CLASS NOTES ONLY

1. Figure 1 shows a 15 m deep, 60 m wide braced excavation for a new underground highway to be constructed by the cut-and-cover method. The initial excavation is supported by a sheet pile wall (section AZ-18, with bending stiffness, $EI = 67\text{MN}\cdot\text{m}^2/\text{lin. m}$) driven to El. 10m, with three levels of cross-lot bracing (Fig. 1). The ground water table is close (3m deep) to the ground surface. Hence, the highway structure itself, must either be designed for the long term buoyant uplift pressures (most likely by means of a tie down system) OR the design must include a permanent dewatering system to reduce the water pressures on the foundation slab.
 - a) Estimate the largest strut load based on apparent earth pressures. [7 points]
 - b) By computing the conventional factor of safety (i.e., according to Terzaghi) against basal heave, estimate the maximum settlement of the adjacent structure. [8 points]
 - c) Compute the long term consolidation settlement of point A that will occur if a permanent dewatering system is installed assuming a) the water table remains at El. 15m inside the excavation; and b) there is no drawdown of the water table in the retained soil. [10 points]

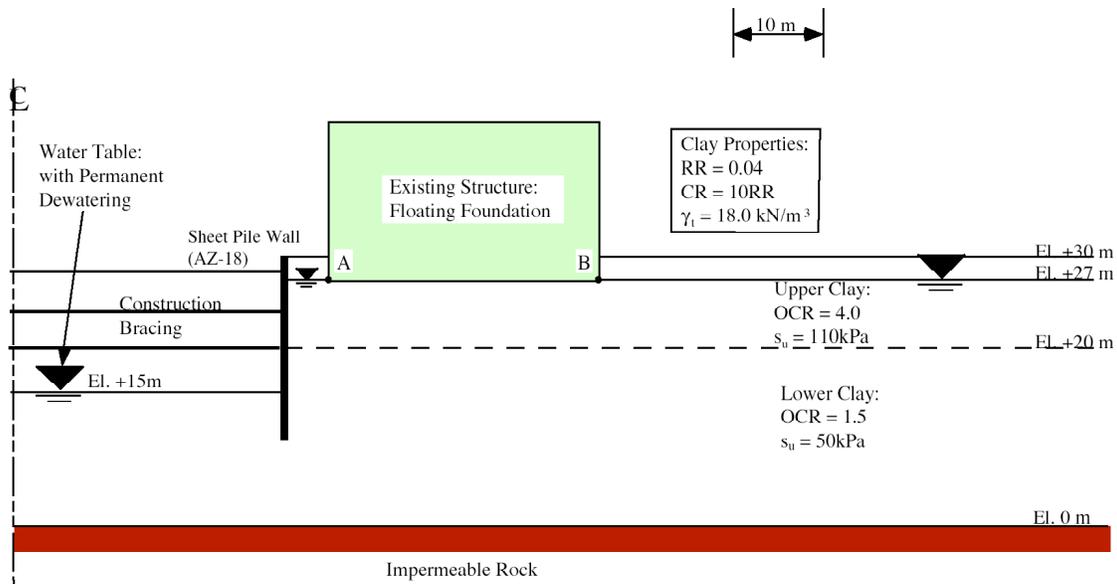


Figure 1. Braced excavation support and adjacent structure

2. A building with gross weight, $Q = 650\text{MN}$ and plan area, $30\text{m} \times 30\text{m}$ is to be constructed over a profile comprising layers of dense sands and hard clay. The basement of the foundation will be located 7m below the ground surface, groundwater pressures are hydrostatic with water table located at a depth of 11m . Assume total unit weights of the soils above and below the water table, $\gamma_t = 17, 19\text{kN/m}^3$, respectively.
- a) Compute the elastic settlement for the raft foundation based on properties given in Figure 2. [5 points]
- An alternative design (intended to reduce settlements) will use a group of $49 (7 \times 7)$, 0.8m diameter 20m long drilled shafts, with an average spacing of approximately 4m .
- b) Compute the capacity and pile head stiffness for a single pile in this group. What is the expected settlement of the pile foundation due to the dead load of the building? [15 points]
- c) In reality the raft and piles will act together as a piled raft. Make a revised estimate of the settlement of the piled raft based on your answers to parts (a) and (b). [5 points]

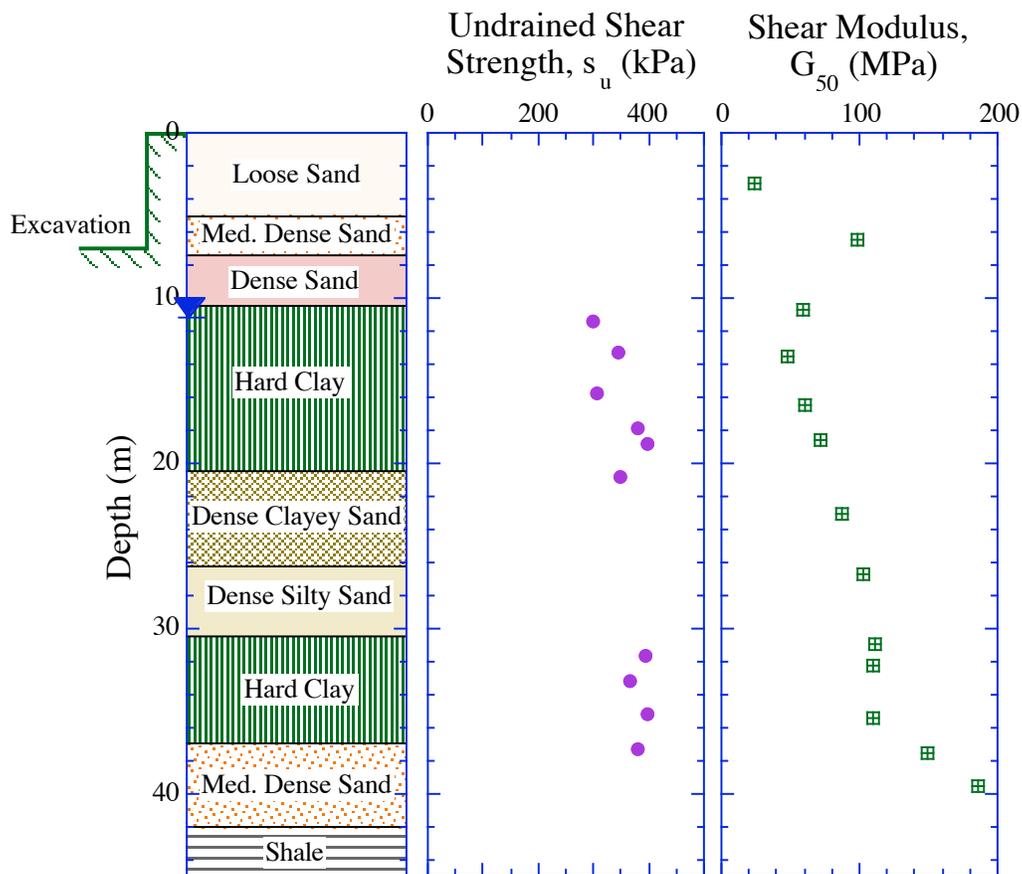


Figure 2. Soil profile for building foundation

3. Figure 3 shows an idealised representation of a generic lightweight tower to be used as a passage marking beacon for a navigation channel. The structure can be represented as a single column which is loaded in winter by a lateral ice force, H , acting at an elevation +10m above the mudline. Below the mudline, the structure will be designed as a steel pipe section pile with diameter, $d = 1\text{m}$, and wall thickness $t = 5\text{mm}$. The underlying soil deposits comprise deep cohesive sediments, whose strength profile must be determined at each site.
- The minimum embedment length, L , is selected to ensure that the pile will yield at the ultimate lateral load. Assuming that the undrained shear strength is constant with depth, develop and plot design curves relating the measured s_u (kPa) to a) ultimate lateral capacity, H_{ult} , and b) the required embedment length, L (m). Assume that the strength range of interest is $10 \leq s_u \leq 500\text{kPa}$. [10 points]
 - Based on this information, what methods would you recommend for measuring the shear strength of the clay? [5 points]
 - Estimate the pile head deflection if the ice exerts a force, $H = 300\text{kN}$, on a pile embedded to a depth of 15m in clay with $s_u = 100\text{kPa}$. Explain clearly your selection of stiffness parameters. [10 points]

NOTE: The yield moment, $M_y = f_y I/r_0$,

where r_0 is the outside radius of the pile

$$I = \frac{\pi}{4} (r_0^4 - r_i^4)$$

The yield stress for steel, $f_y = 250 \times 10^3 \text{ kN/m}^2$

The Young's modulus of steel, $E = 207\text{GPa}$

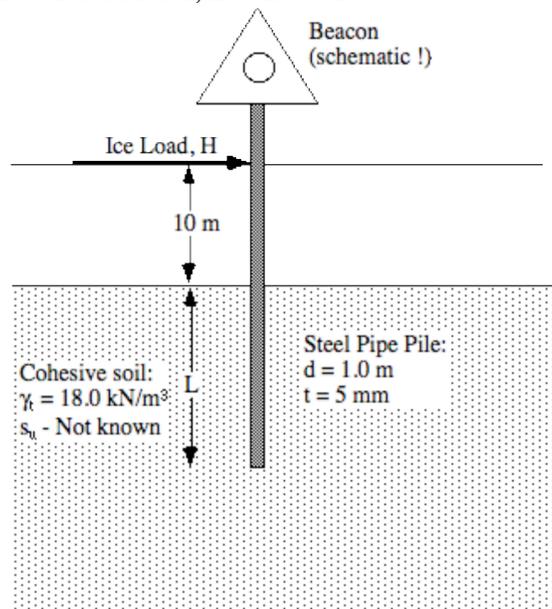


Figure 3. Ice Loading of a Lightweight Tower

3. Figure 4 shows the abutment of a four lane bridge constructed on top of cohesionless soils (profile characterized by SPT data only) with a 14.75ft compacted soil backfill.
 - a) Estimate the distribution of bearing pressure imposed by the abutment and bridge deck prior to placement and compaction of the fill. [5 points]
 - b) Using the available SPT data, estimate the settlement and tilt of the abutment. State clearly any assumptions you make. [10 points]
 - c) Check the stability of the wall due to compaction of the backfill. How much additional settlement will this induce at the base of the abutment? [10 points]

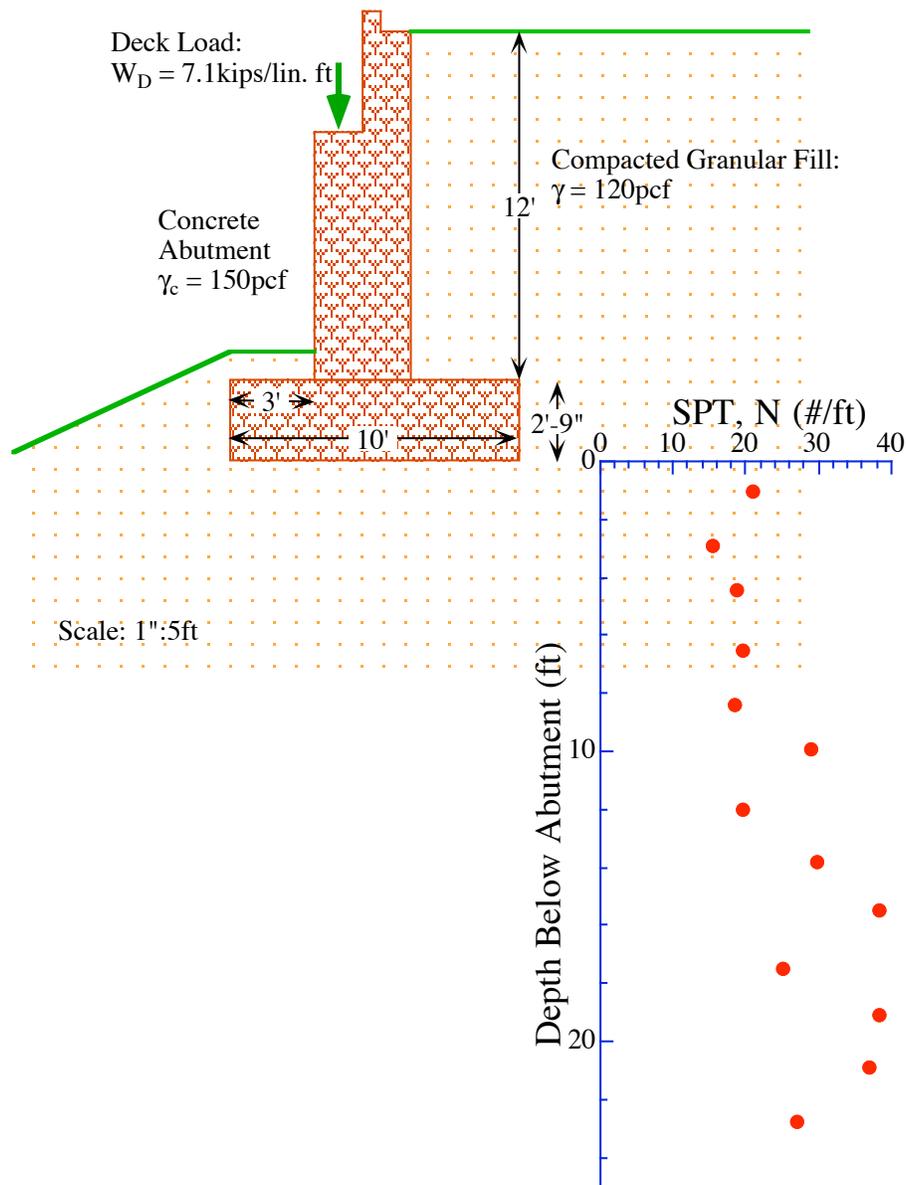


Figure 4. Settlement of Bridge Abutment on Compacted Fill