The University of Iowa
Department of Civil & Environmental Engineering
SOIL MECHANICS 53:030
Final Examination
2 Hours, 100 points

Fall 1999 Instructor: C.C. Swan

Problem #1: (25 points)

Two consolidated, drained (CD) triaxial compression tests were performed on over-consolidated silty soil samples removed from the field. The objective of the two tests was to measure the soil's cohesion c and drained friction angle ϕ_D. The results of the two tests are as follows:

- Test 1: at failure, σ_1 = 287.94kPa; σ_3=100kPa; u = 0 kPa
- Test 2: at failure, σ_1 = 491.90kPa; σ_3=200kPa; u = 0 kPa

a. Using the Mohr's circle and Mohr-Coulomb failure geometry shown below in Figure 1, find a relationship between σ_1' and σ_3' at shear failure in terms of the cohesion c and friction angle ϕ_D. **To receive credit, show all work.**

b. Using this relationship, and the results of the two CD triax tests, solve for the cohesion c and drained friction angle ϕ_D for the soil.

c. During the triaxial compression tests on the soil samples, what would be the expected orientation θ of the shear failure planes in the soil samples? (Use the Pole Method, and assume that σ_1 is applied in the horizontal direction and σ_3 in the vertical direction.) **Again, show all work to receive credit.**

d. For Test 1 above, compute the normal and shear stresses on the shear failure plane.

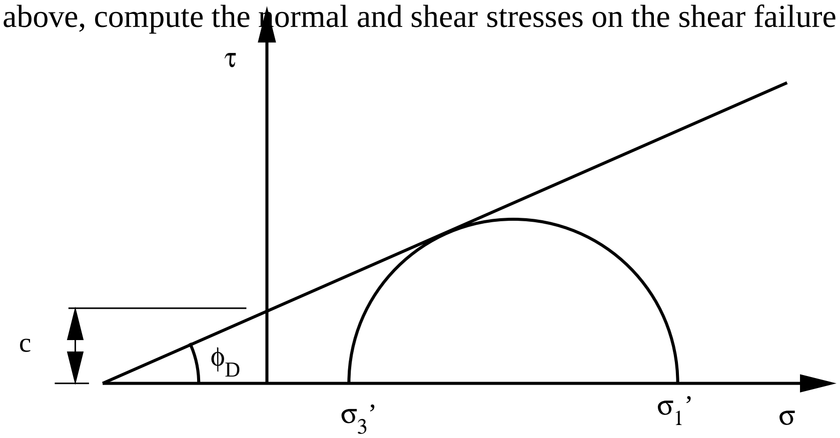

Figure 1. Mohr-Coulomb failure envelope and Mohr's circle for CD triaxial compression tests.

Problem #2: (25 points)

Steady state seepage is occuring in the soil profile shown in Figure 2. Note the standpipes inserted at points B and C.

a. How high (h) is the water standing in the standpipe located at B?
b. Compute the magnitude of the hydraulic gradient in the sand layer.
c. Compute the vertical effective stress at point A in the sand layer.
d. How high (h) would the water have to stand in the standpipe at B to cause a quick (boiling) condition in the silty sand layer? (Note that the height of water in the standpipe at C will change from its original height.)

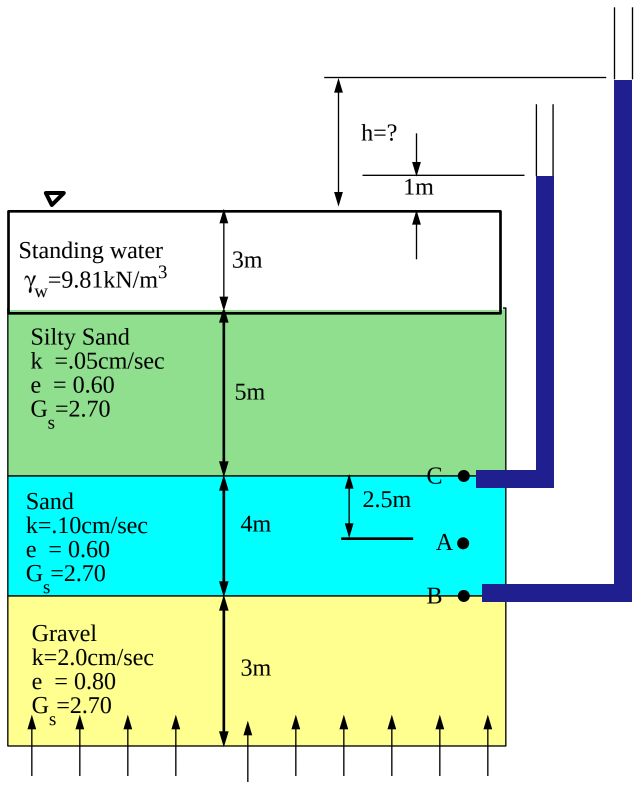

Figure 2. Uniform upward seepage in a multi-layered soil deposit.

Problem #3: (25 points)

As an engineer working for a major oil company, you are assigned the task of preparing the site shown below for construction of an oil storage tank. The tank will weigh 20,000 tons when full and rest on a circular flexible foundation of radius 75 feet. A rupture failure of the tank could have potentially disastrous environmental consequences. Therefore, to minimize settlements (and the possibility of tank rupture), you are considering pre-loading of the site as shown. In this plan:

i. How many feet of dry pre-loading fill (at unit weight γ = 113.8lbs/ft^3) would you need to bring in to the site so that at the center of the clay layer directly under under the center of each tank $(\Delta\sigma_v)_{fill}$ = $(\Delta\sigma_v)_{tank}$? That is, how thick should the fill layer be?

ii. Assuming that you wanted to leave the fill in place until 90% percent consolidation is achieved before building the tank, how long would you have to wait?

iii. What would be the ultimate (100%) primary consolidation settlement under the fill loading?

iv. What would be the void ratio in the clay soil after 90% consolidation under the pre-load?

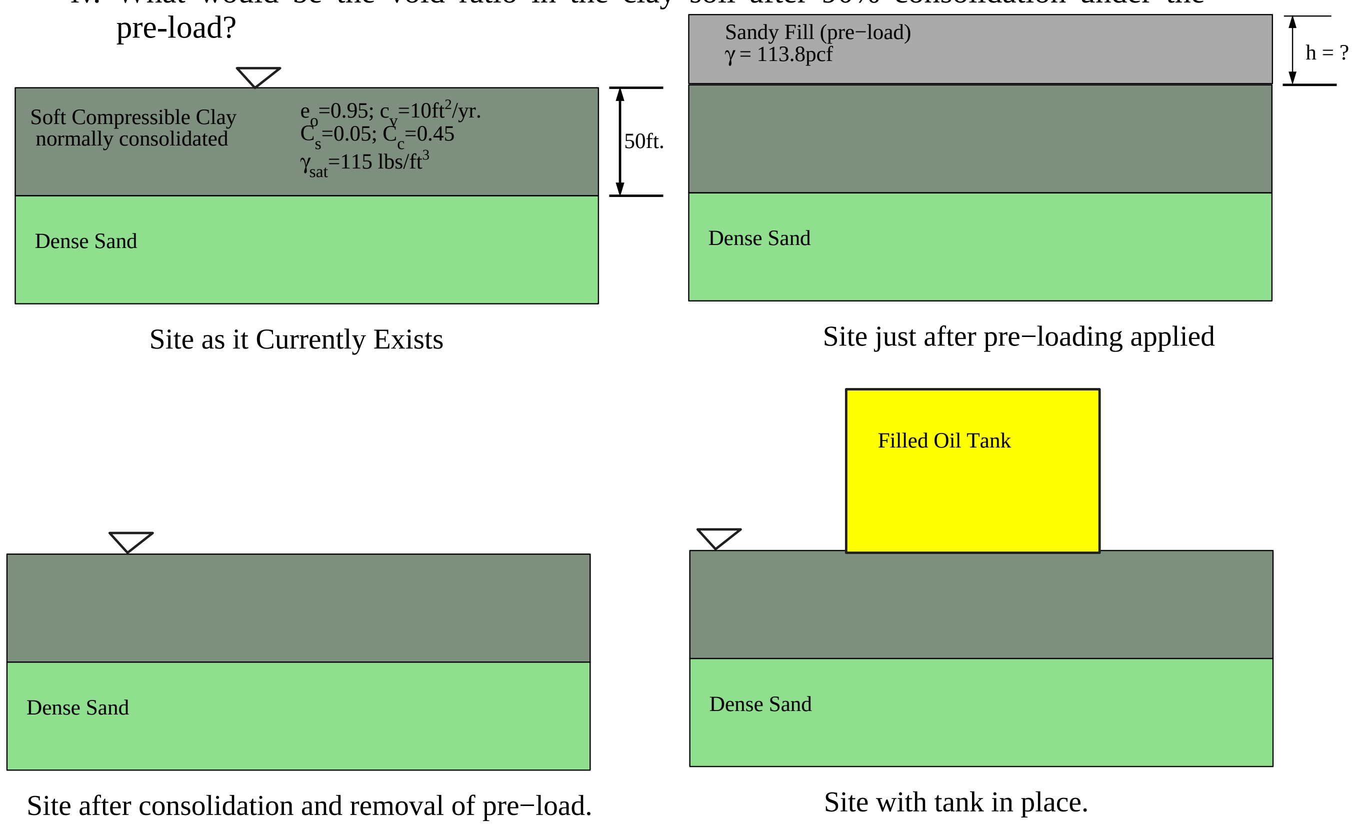

Figure 3. Existing site and proposed construction sequence.

Problem #4: (25 points)

Consider the steady flow down the slope shown in Figure 4. The flow direction is parallel to the slope. For the geometry shown:

a. Draw a flow-net over the flow domain.

b. What is the magnitude of the hydraulic gradient?

c. What is the flow rate q in the permeable layer per unit width out of plane?

d. What is the pore pressure along the sand/rock interface?

e. Assume that at the sand/rock interface the total vertical stress is given by the expression $\sigma_v = H \cdot \gamma_{sat}$. What is the vertical effective stress at the sand/rock layer?

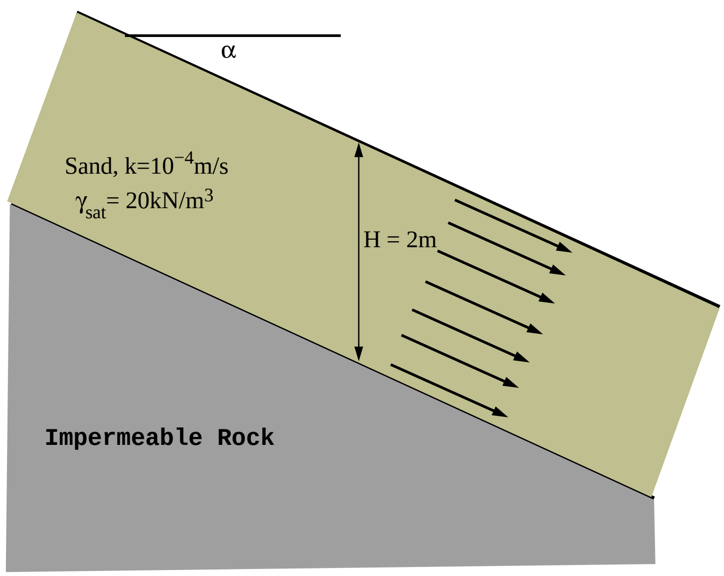

Figure 4. Seepage in a sand layer on an infinite uniform slope.

Miscellaneous Useful Information

The increase in vertical stress below the center of a uniformly loaded circular flexible area is:

$$\Delta p = q\left[1 - \left[(R/z)^2 + 1\right]^{-3/2}\right]$$

where R is the radius of the loaded region and z is the depth below the center.