ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2022 SESSION

Open-book examination
Calculators : only authorized models
Duration : 3 hours

14-EN-A3 GEOTECHNICAL AND HYDROGEOLOGICAL ENGINEERING

Question 1 (15 points)

Using the United Soil Classification System (USCS), give the classification corresponding to the gradation curve shown in Figure 1. Assumes that the material passing the 425 μm sieve has plastic and liquid limits of respectively w_L = 25 % and w_p = 15 %.

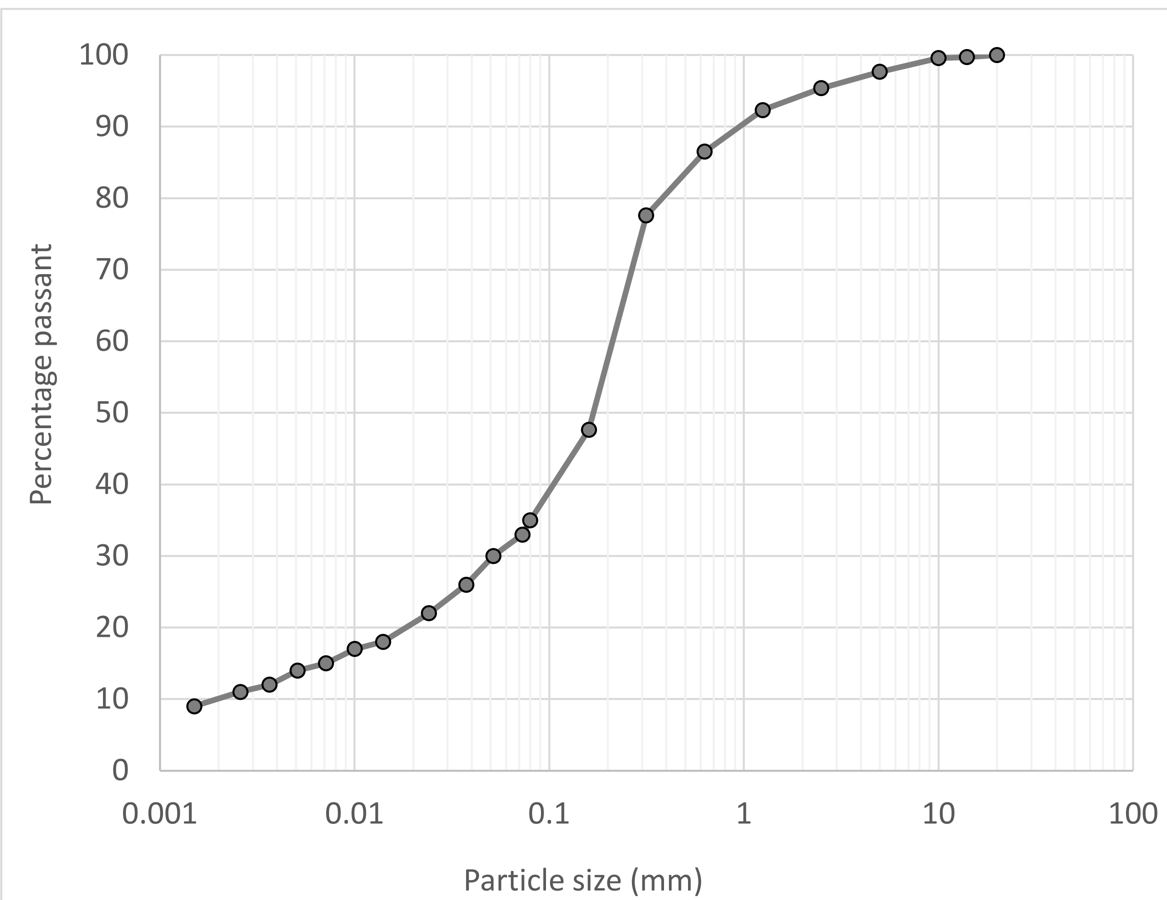

Figure 1: Grain size distribution for question 1.

Question 2 (30 points)

An embankment of 25 m by 25 m with a thickness of 3 m will be constructed over the soil profile shown in Figure 2. The soil profile includes a normally consolidated clay layer with a thickness of 4 m. The clay layer is located between a silty sand layer and the bedrock. The silty sand layer has a thickness of 5 m. The water table is found 2 m below the initial ground surface in the silty sand layer. Figure 2 gives the main properties for the silty sand and the clay. Figure 2 also gives the main results for a consolidation test that was conducted with a sample obtained from the centre of the clay layer using a thin-walled sampler.

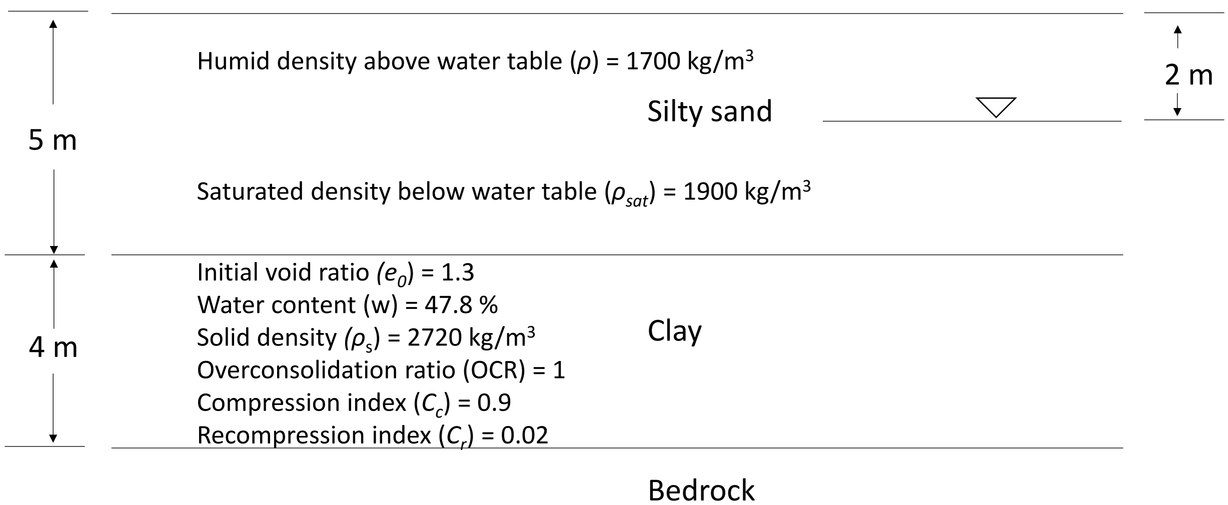

Figure 2: Soil profile and properties for Question 2 (<u>not to scale</u>).

a) A modified Proctor test was conducted with the granular material that will be used to construct the embankment. The optimum moisture content and the maximum dry density were respectively 8 % and 2000 kg/m^3. If the material is compacted at a relative compaction of 95 % and has a water content of 6 % after construction, calculate the total density (ρ) of the embankment material. You can assume that the solid density is ρ_s = 2700 kg/m^3 (5 points).

b) Calculate the initial effective stress, before the embankment construction, at the centre of the clay layer (10 points).

c) Calculate the final effective stress, after the embankment construction and pore pressure dissipation, at the centre of the clay layer (5 points).

d) Calculate the total consolidation settlement in the clay layer due to the embankment construction (10 points).

Question 3 (15 points)

A direct shear test was conducted with a uniform sand sample that was compacted at the maximum dry density determined with a modified Proctor test. The relationships between shear stress on the failure plane and deformation are presented on figure 3 for normal stress values of 50, 100 and 200 kPa.

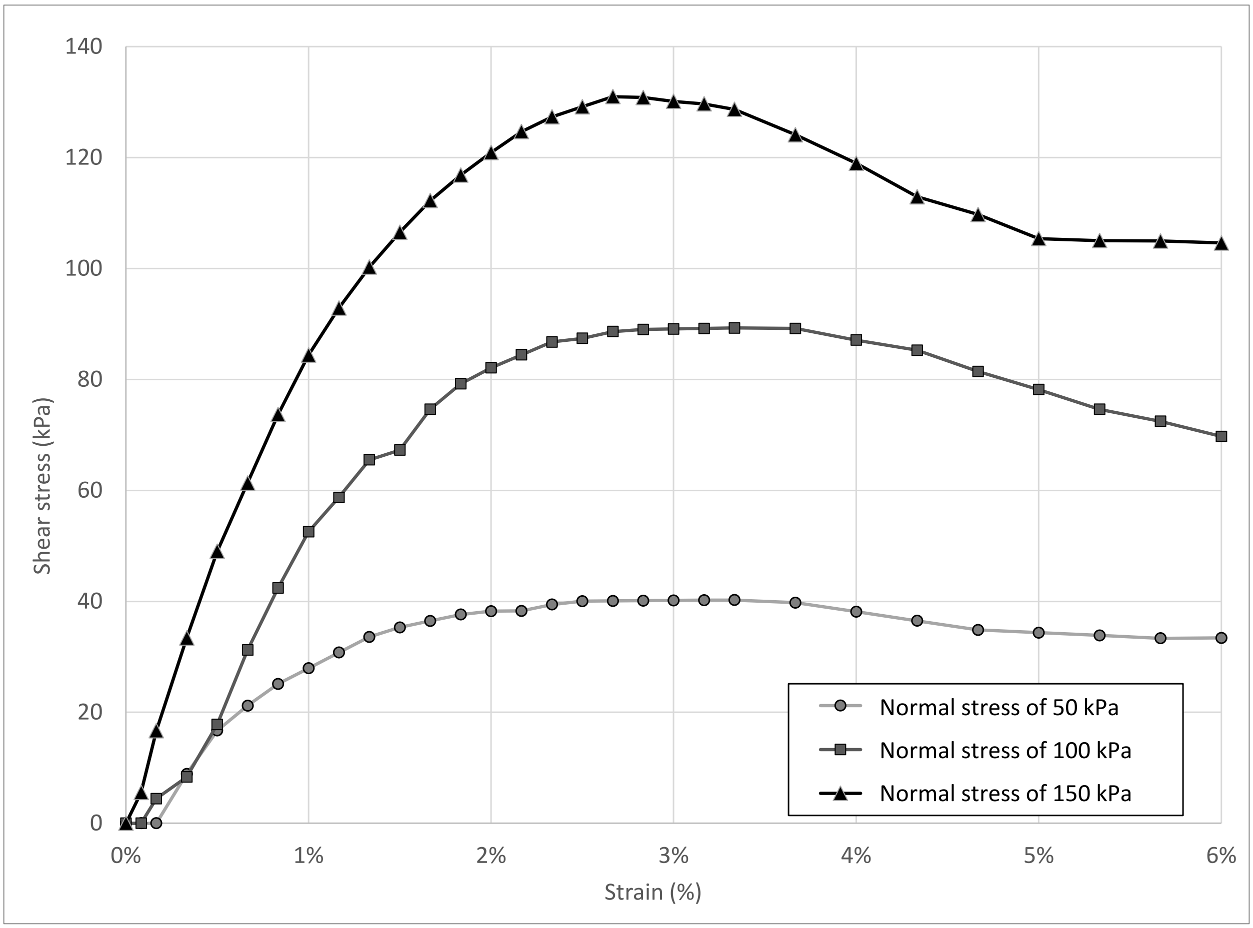

Figure 3: Relationship between shear stress and deformation for the direct shear test

a) Calculate the internal friction angle (ϕ') of the sand (10 points).
b) Based on the test results and the description of the sample, describe the volume changes that occurred in the specimens during the direct shear test (5 points).

Question 4 (20 points)

A pumping test was conducted in a confined aquifer with a thickness of 4 m. The pumping well is fully penetrating the aquifer. Before the pumping test, a piezometer was installed at a distance of 10 m from the pumping well. During the test, a constant flow rate of 40 L/minute was maintained. Figure 4 shows the drawdown that was observed in the piezometer with respect to the time elapsed since the beginning of the pumping test.

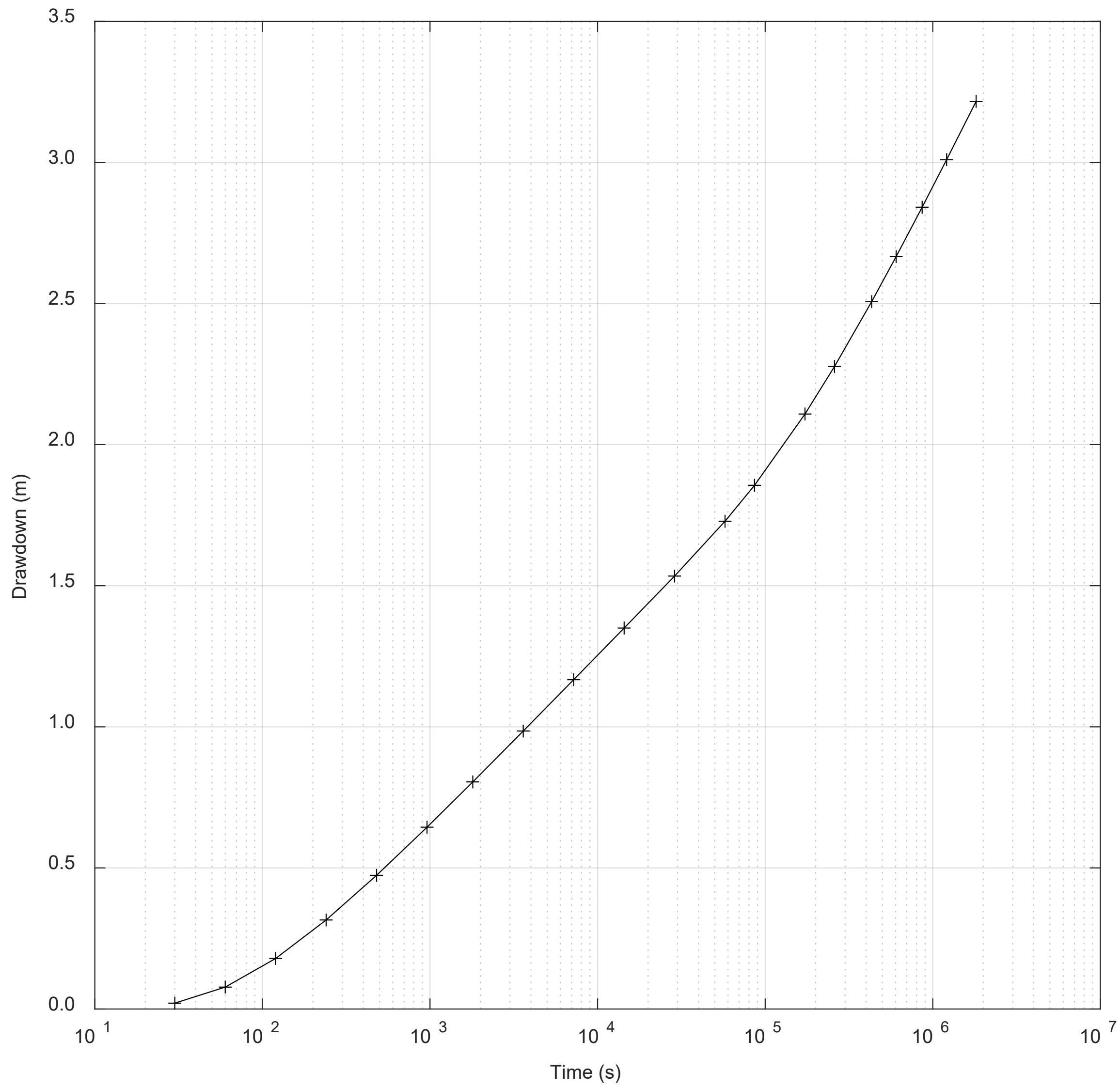

Figure 4: Semi-log plot of the drawdown

a) Identify the type of aquifer boundary that is influencing the test results (5 points).
b) Using the data presented in Figure 4 and the Cooper-Jacob method, calculate the transmissivity (*T*) and the storativity (*S*) of the confined aquifer (15 points).

Question 5 (20 points)

Figure 5 shows the hydraulic heads that were obtained with a series of piezometers installed on a contaminated site with a thick (> 10 m) unconfined aquifer. The ground surface has a gentle slope with a decreasing surface elevation toward the east. The unconfined aquifer is a relatively uniform sand with a hydraulic conductivity of 2×10^{-4} m/s.

a) Draw four equipotential lines corresponding to hydraulic head values of 59.1, 59.0, 58.9 and 58.8 m, and one flow line on Figure 5 (10 points).
b) Estimate the time needed for a contaminant or a conservative tracer to move across the lot outlined on Figure 5 along a flow line (10 points)

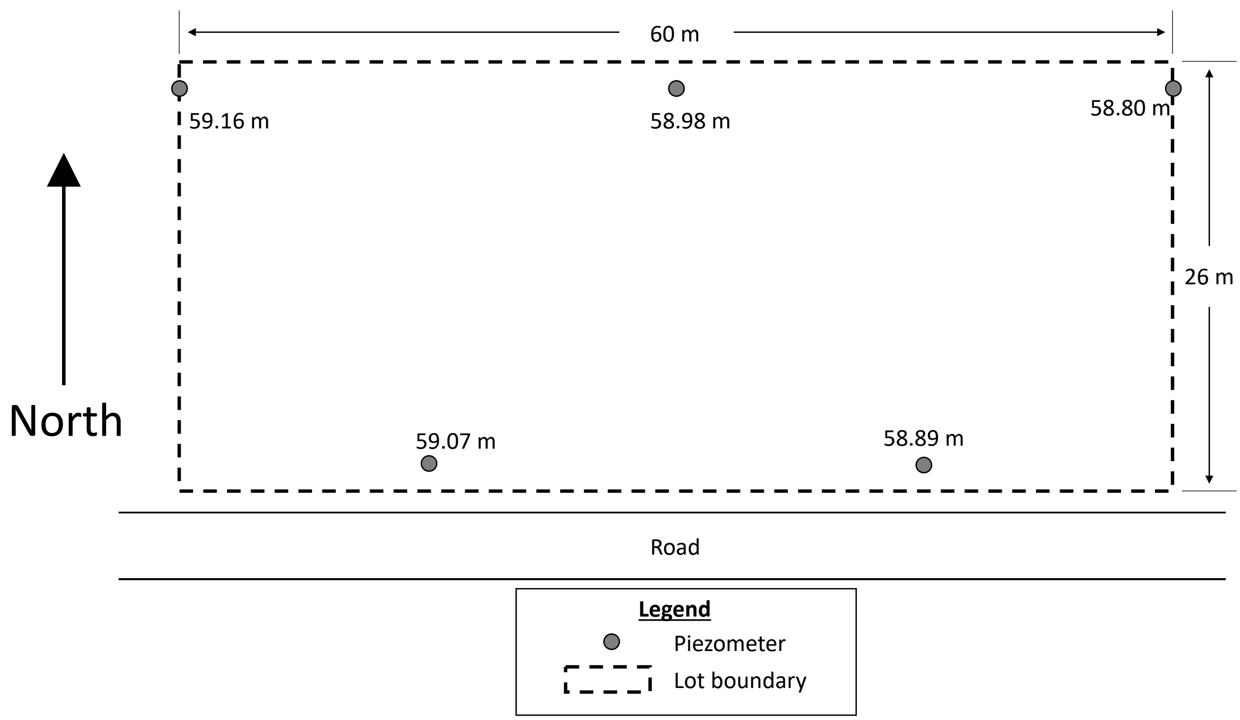

Figure 5: Piezometric map for question 5 with the hydraulic head values for each piezometer.