ORDRE DES INGÉNIEURS DU QUÉBEC

MARCH 2023 SESSION

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

14-EN-A3 GEOTECHNICAL AND HYDROGEOLOGICAL ENGINEERING

Question 1 (15 points)

Figure 1 shows the compaction curve that was obtained with a standard Proctor test for a soil that will be used to construct an embankment. The compaction specifications require a minimum relative compaction of 95 % with respect to the standard Proctor test. Evaluate the water content that will minimize the compaction effort (compaction energy). You can assume that the solid phase has a unit weight of 26.5 kN/m^3 (density of 2700 kg/m^3).

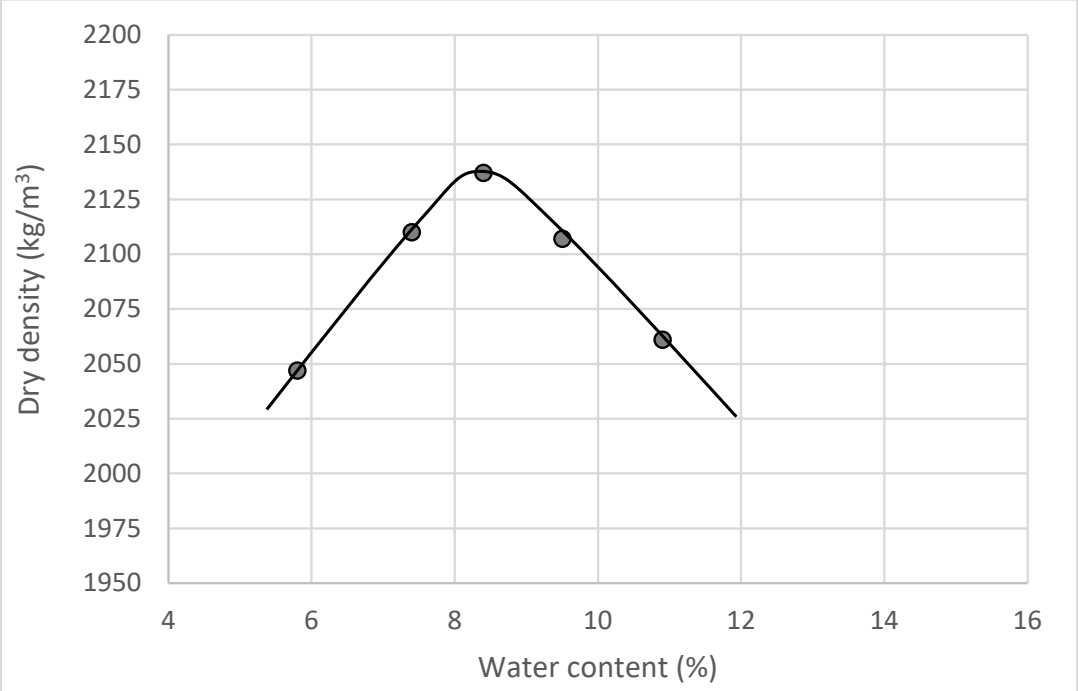

Figure 1: Compaction curve for Question 1.

Question 2 (15 points)

Using the United Soil Classification System (USCS) or the MTQ 1101 classification system, give the classification corresponding to the gradation curve shown in Figure 2. Assumes that the material passing the 425 μm sieve has no plasticity

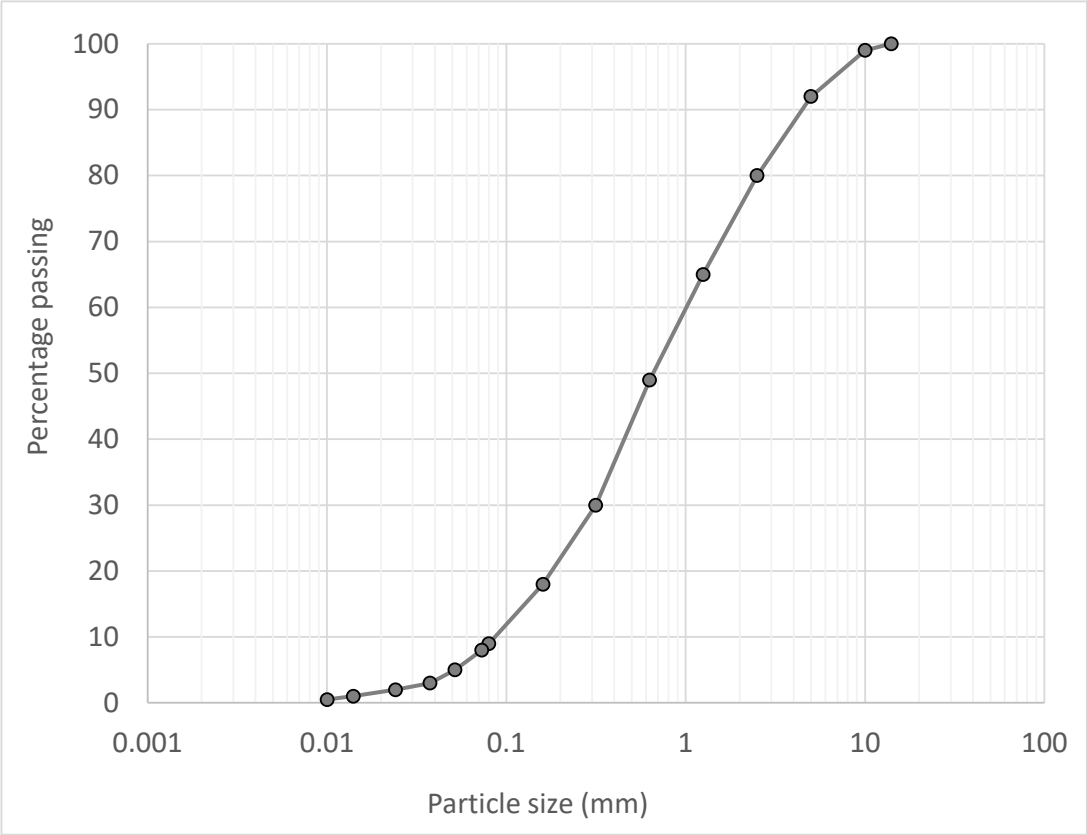

Figure 2: Grain size distribution for Question 2 (1 mm = 1000 μm).

Question 3 (30 points)

A very large embankment with a thickness of 3 m will be constructed over the soil profile shown in Figure 3. The soil profile includes a clay layer with a thickness of 6 m. The clay layer is located between two silty sand layers. The top silty sand layer has a thickness of 2 m. The water table is found 1 m below the initial ground surface in the silty sand layer. Figure 3 gives the main properties for the silty sand and the clay layers. Figure 3 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.

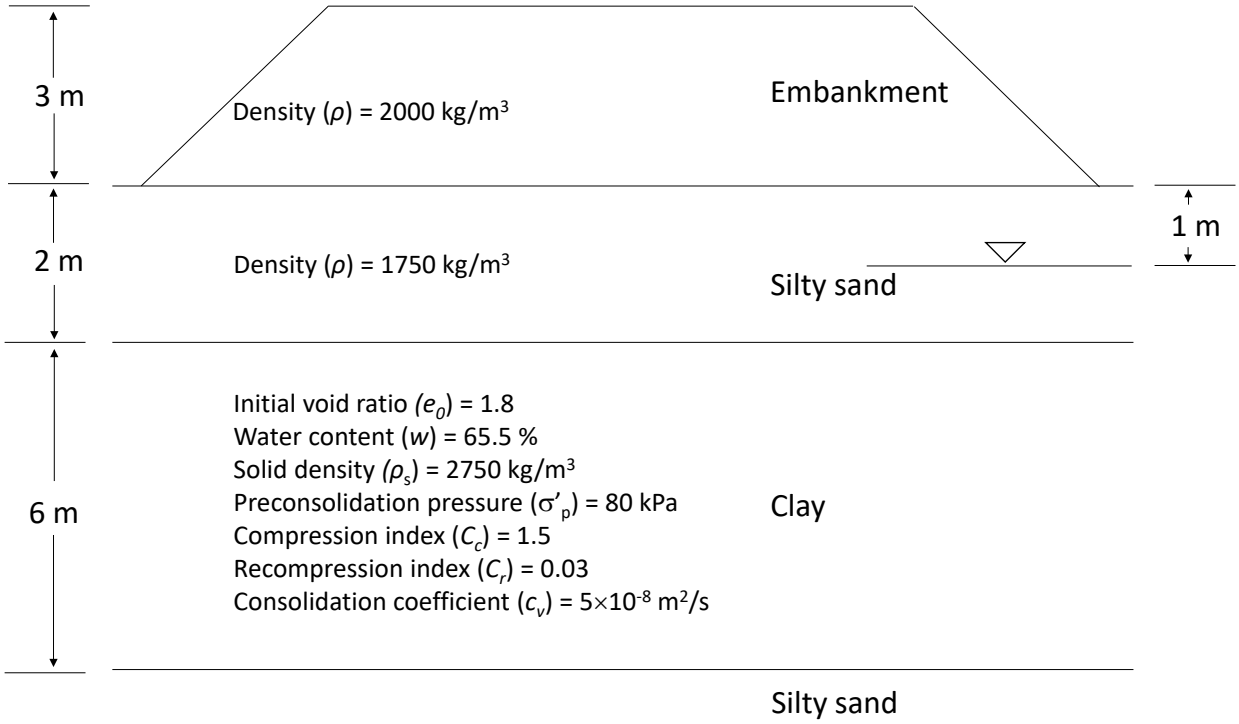

Figure 3: Soil profile and properties for Question 3 (<u>not to scale</u>).

a) Calculate the clay density (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 (5 points).
e) Estimate the time required to dissipate 50 % of the excess pore pressure at the centre of the clay layer, at a depth of 5 m from the initial ground surface (5 points).

Question 4 (10 points)

Figure 4 shows the profile of a slope in a clay deposit with a constant undrained shear strength of c_u = 30 kPa and a constant unit weight of 16 kN/m^3. A trial failure circle that includes 85 m^2 of clay is drawn on the figure. The centre of gravity of the clay in the trial circle is also shown in the figure. Calculate the factor of safety for undrained shear failure along the trial failure circle.

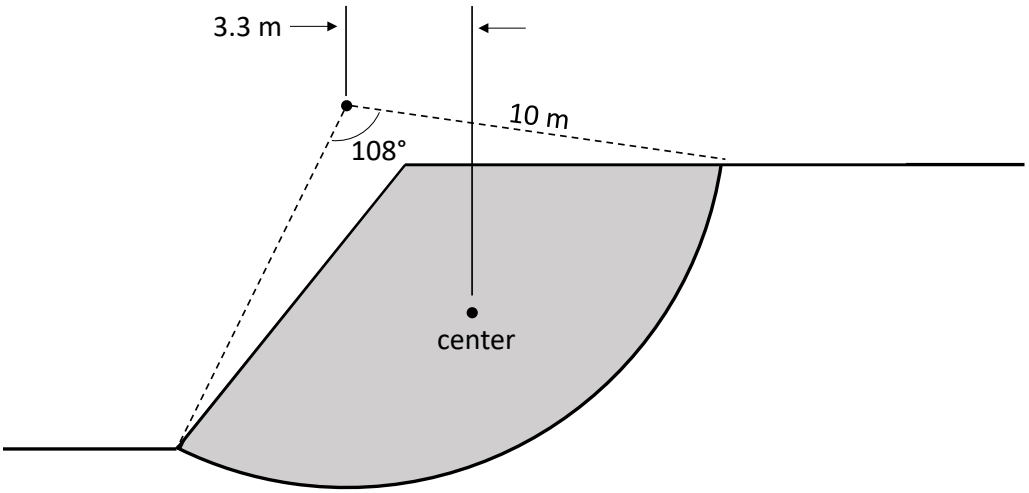

Figure 4: Clay slope and trial failure circle for Question 4 (not to scale).

Question 5 (20 points)

A pumping test was conducted in a confined aquifer with a thickness of 6 m. The flow rate during the pumping test was 19 L/min. Figure 5 shows the curve matching for the Theis method for a piezometer 30 m from the pumping well.

a) Using the Theis method and Figure 5, calculate the transmissivity (*T*) and storativity (*S*) of the aquifer (10 points).
b) Estimate the drawdown that would be observed at a distance of 60 m from the pumping well 1 hour after the test beginning (10 points).

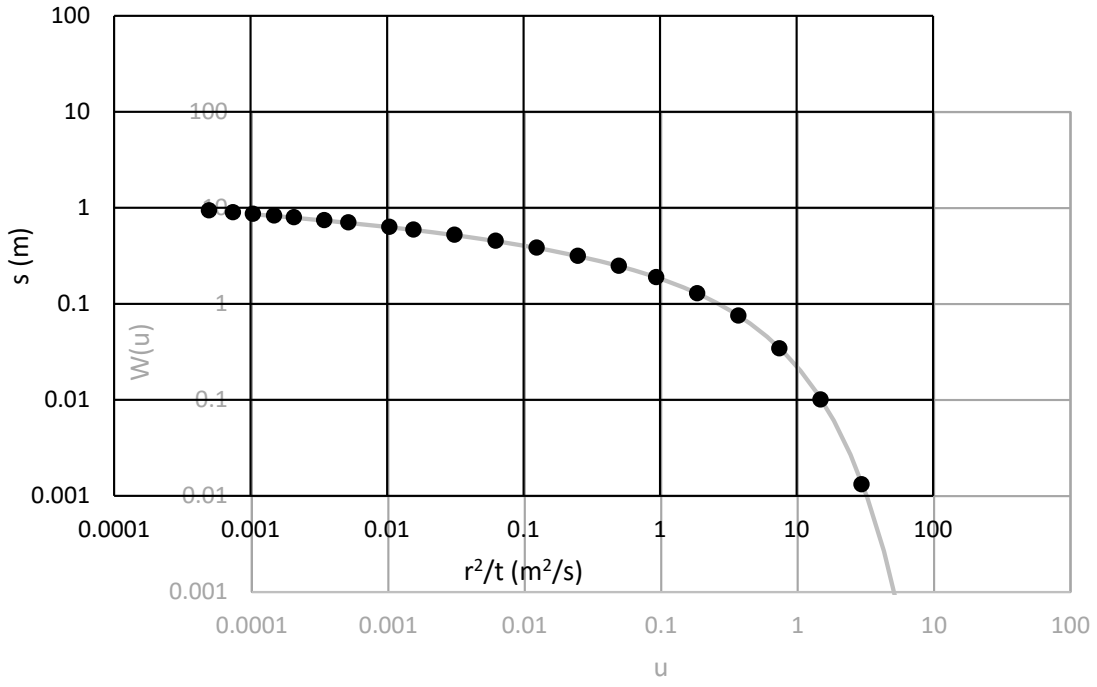

Figure 5: Curve matching for Question 5 (type curve in grey and experimental data in black).

Question 6 (10 points)

Figure 6 shows a cylindrical permeameter that was used to conduct a constant-head permeability test on a sample of clean sand. The sample had a diameter (D) of 10 cm and a length (L) of 20 cm. The flow rate (Q) during the test was 2 cm^3/s for a water level difference (h) of 25 cm. The sand had a saturated density (ρ_{sat}) of 1.8 g/cm^3 during the test. You can assume a solid density (ρ_s) of 2.65 g/cm^3 for your calculations.

a) Calculate the hydraulic conductivity of the sand (5 points)
b) Estimate the time needed for a contaminant or a conservative tracer to move across the sample shown on Figure 6 during the permeability test (5 points)

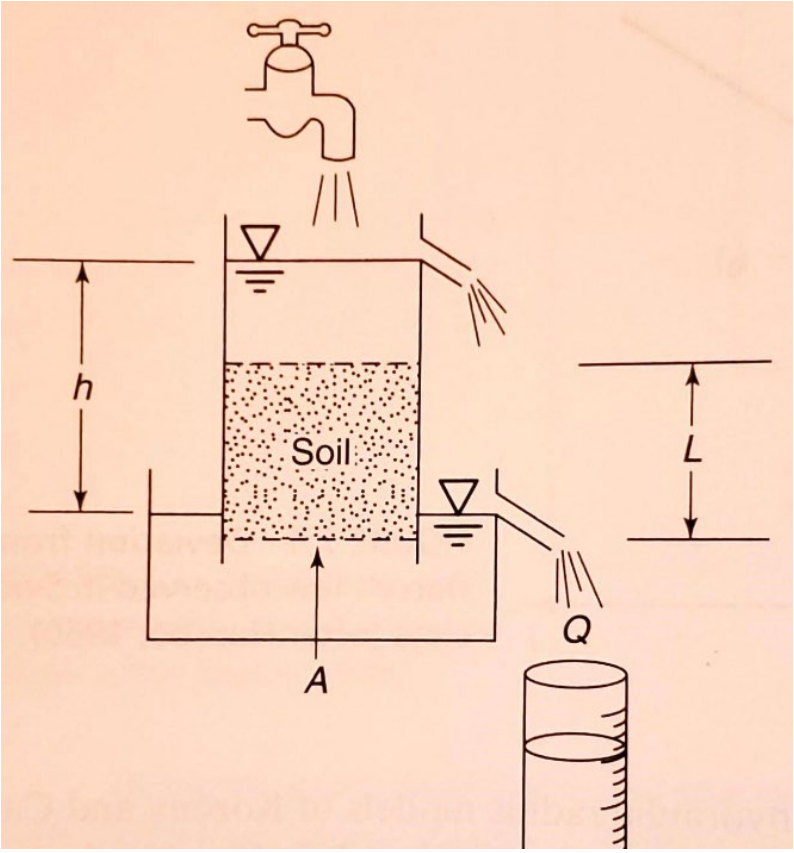

Figure 6: Permeameter for Question 6 (not to scale).