ORDRE DES INGÉNIEURS DU QUÉBEC

MAI 2020 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) or the MTQ 1101 classification system, give the classification corresponding to the gradation curve shown in Figure 1. Assume that the fines are nonplastic.

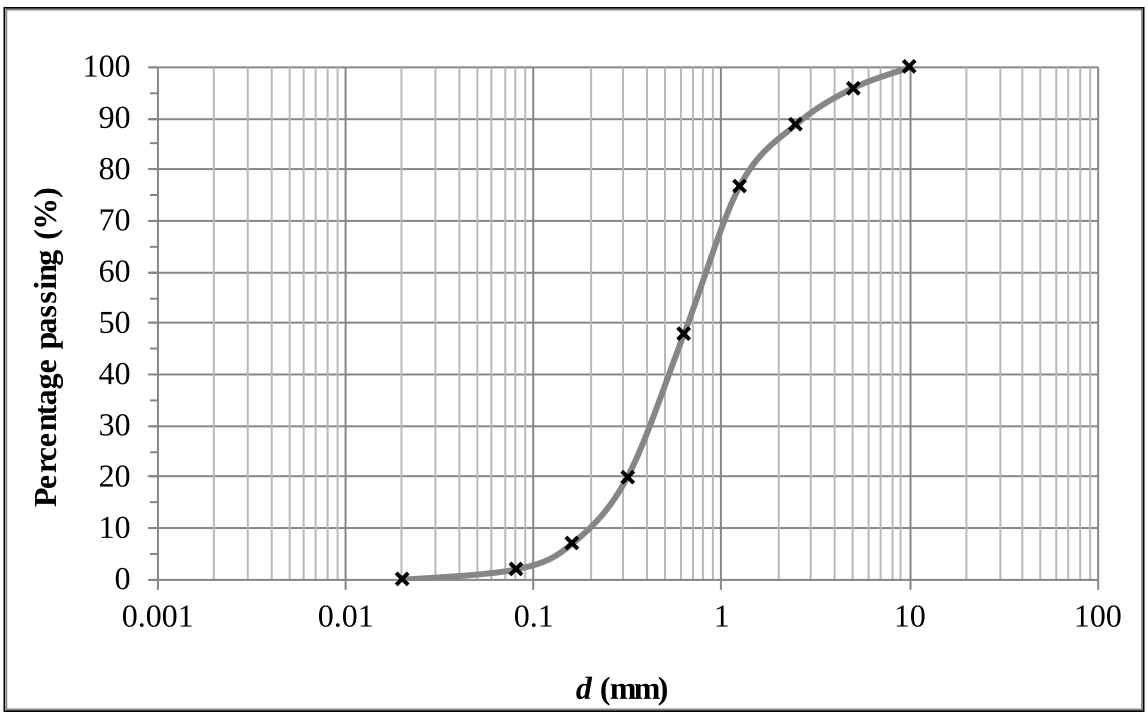

Figure 1: Grain size distribution for question 1.

Question 2 (20 points)

Figure 2 shows a flow net describing seepage under a dam with a length of 600 m. You can assume that the flow net is drawn using squares. The soil under the dam is a quartz sand. It has a coefficient of permeability $k = 2\times10^{-5}$ m/s and a dry unit weight $\gamma_d = 18.7$ kN/m^3.

a) Calculate the flow rate in the soil under the dam (6 points).

b) If a piezometer is installed to measure the hydraulic head at point A in Figure 2, what will be the water level in the piezometer pipe? Use the elevation reference system shown in Figure 2 (4 points).

c) Calculate the water pressure u at point A (3 points).

d) Calculate the Darcy (discharge) velocity and the actual water velocity (for example the velocity of a tracer or a contaminant in the groundwater) at point A (4 points).

e) Estimate the maximum hydraulic gradient for this flow net (3 points).

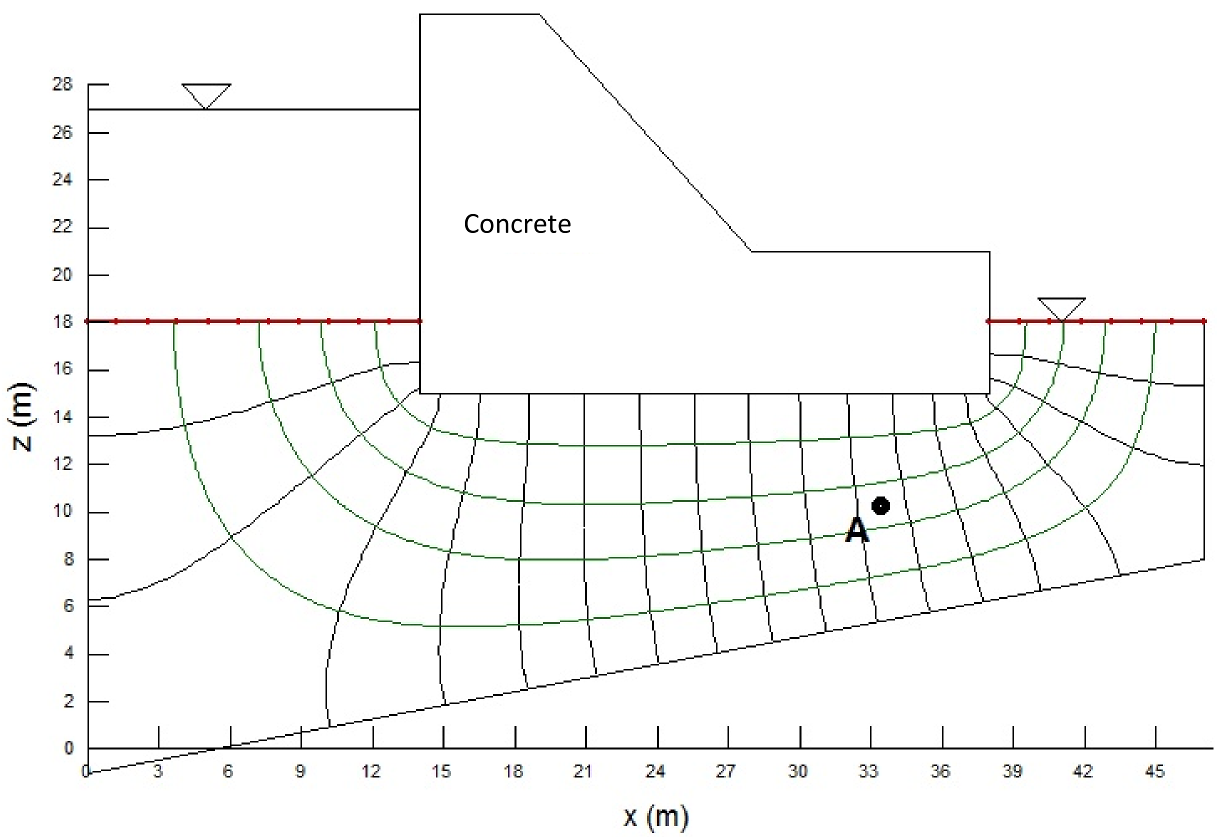

Figure 2: Flow net for question 2.

Question 3 (30 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, three piezometers were installed at different distances from the pumping well. During the test, a constant flow rate of 26 L/minute was maintained.

a) Table 1 gives the drawdown for Piezometer P2 as a function of time elapsed since the beginning of pumping. Piezometer P2 is located 10 m away from the pumping well. Using the Cooper-Jacob method, calculate the transmissivity (T) and the storativity (S) of the confined aquifer. You can use the semi-log plot in Figure 3 to plot the drawdown curve (12 points).

Table 1: Drawdown values for piezometer P2

Time (minutes)	Drawdown (cm)	Time (minutes)	Drawdown (cm)
0.25	1.1	8	11.6
0.5	2.8	10	12.0
1	5.2	30	13.0
2	7.9	60	13.2
4	10.1	120	13.4
6	11.1	240	13.5

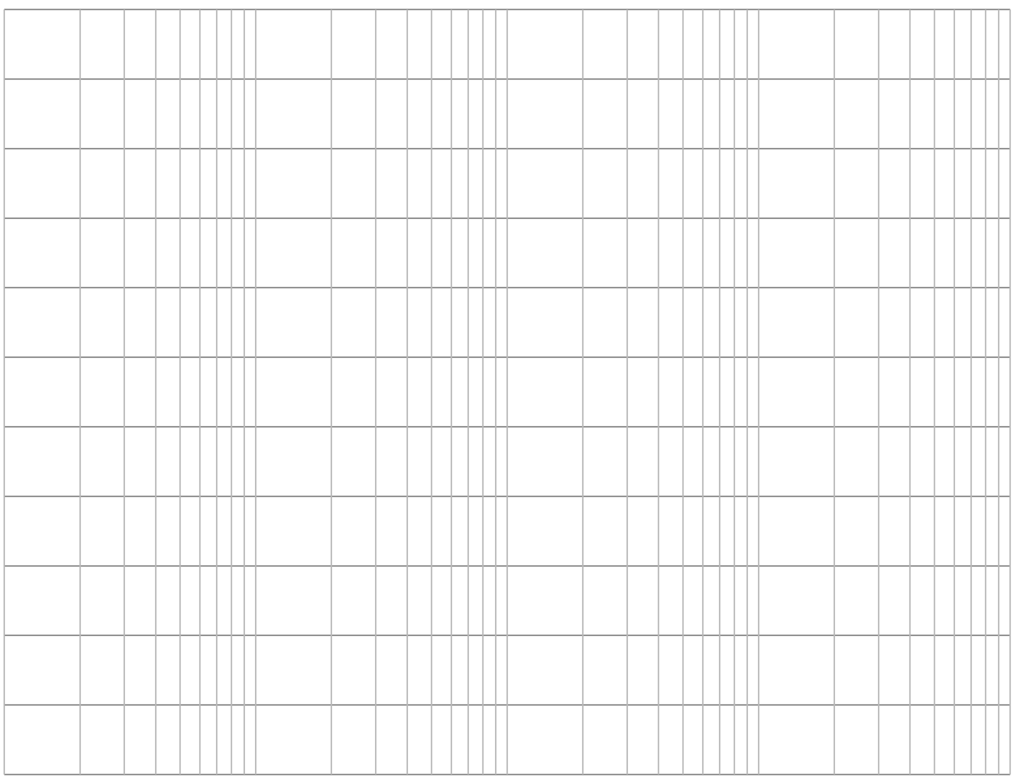

Figure 3: Semi-log plot for the drawdown curve with the Cooper-Jacob method.

b) What type of aquifer boundary can be observed with the drawdown data in Table 1 (3 points)?

c) During the same pumping test, the drawdown values for the three piezometers reached a steady state. The drawdown values and the distance from the pumping well for each piezometer are given in Table 2. Use the Table 2 data to calculate the transmissivity (*T*). You can use the semi-log plot in Figure 4 (10 points).

d) Assuming a regional hydraulic gradient of 0.01 with water flowing from east to west, describe the area of the aquifer that contributes to the flow rate of 26 L/minute (zone of contribution (ZOC) in EPA/625/R-94/001) (5 points).

Table 2: Steady-state drawdown values for piezometers P1, P2, and P3

Piezometer	Distance between piezometer and pumping well (m)	Steady-state drawdown (cm)
P1	6	18.5
P2	10	13.5
P3	20	6.9

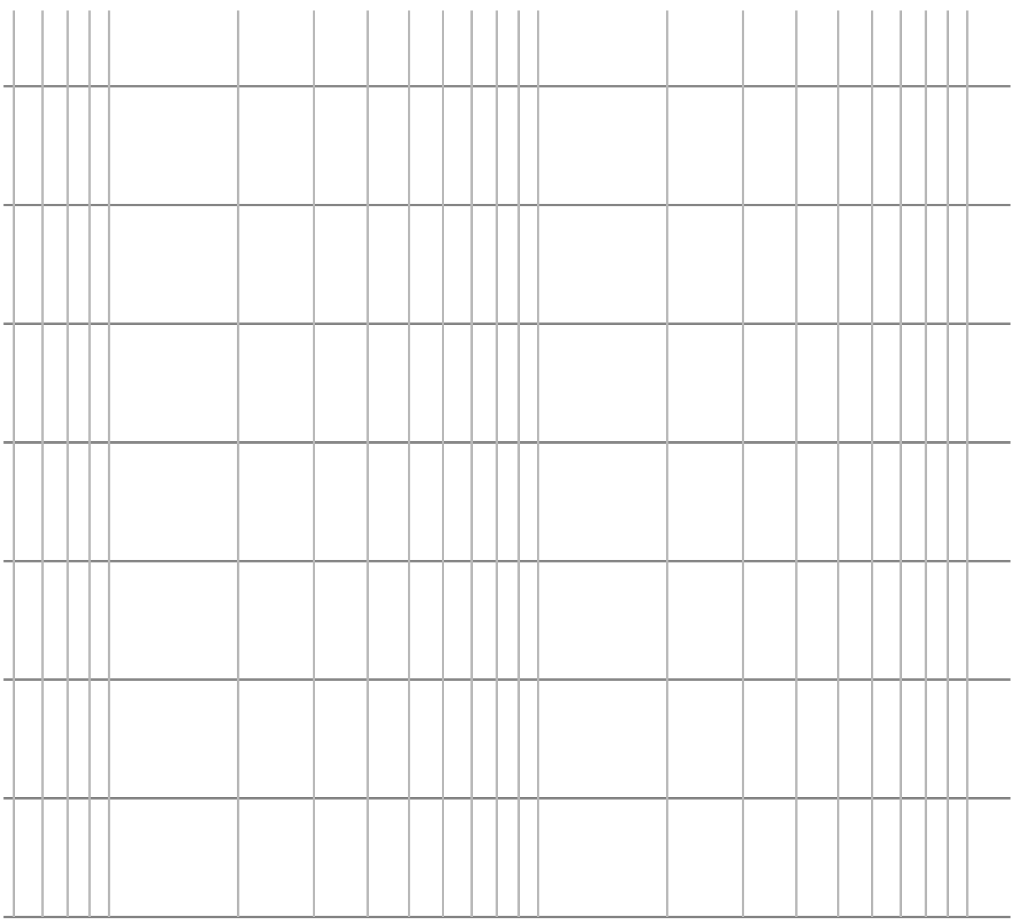

Figure 4: Semi-log plot for the calculation of the transmissivity from the steady-state drawdown.

Question 4 (25 points)

A laterally extensive earth fill with a thickness of 5.0 m will be put in place over the soil profile shown in Figure 5. The soil profile includes a clay layer with a thickness of 7.0 m located between two sand layers. The top sand layer has a thickness of 4.5 m. The water table is found 3.0 m below the initial ground surface. Figure 5 gives the main properties for the earth fill, sand layers, and clay layer. For the clay layer, Figure 5 also gives the main results for a consolidation test that was conducted with a sample obtained at the centre of the clay layer.

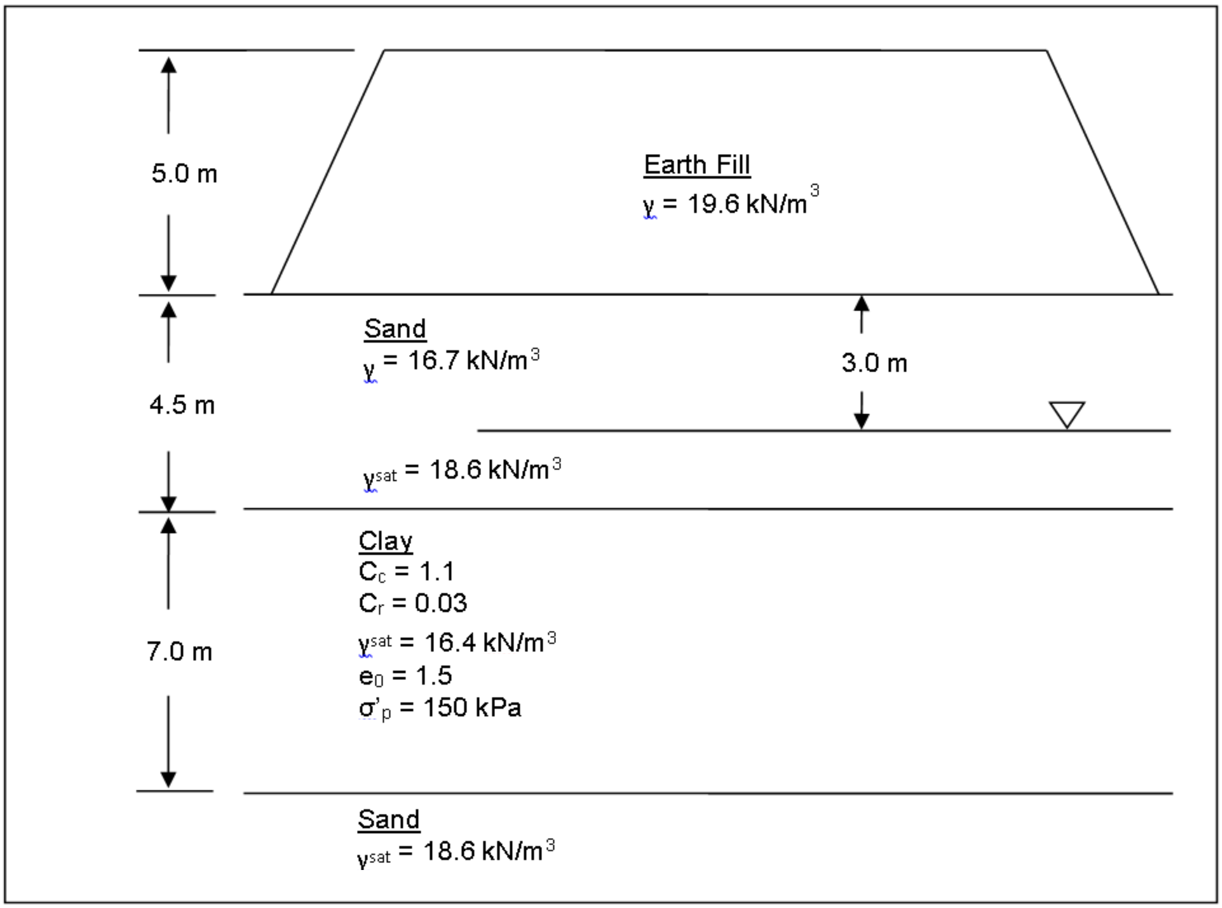

Figure 5: Soil profile and properties for Question 4 (not to scale).

a) Calculate the total consolidation settlement caused by the earth fill (12 points).
b) The consolidation test that was conducted with a clay sample gave a coefficient of consolidation c_v = 1.5 m^2/year. Calculate the time needed to reach a settlement of 100 mm after the earth fill construction (8 points).
c) A piezometer was installed at the centre of the clay layer after the earth fill construction to monitor the consolidation and to estimate the real c_v value in the field. 10 months after the earth fill construction, the piezometer measured a total water pressure u = 131 kPa. Estimate the c_v value from the pore pressure (5 points).

Question 5 (10 points)

A series of isotropically consolidated and drained triaxial tests (CID) were conducted on a sand at confining pressures (σ'_3) of 100, 200 and 400 kPa. Failure occurred at deviatoric stress values ($\Delta\sigma'_1$) of respectively 270, 540 and 1100 kPa. Give the c' and ϕ' values that best describe the Mohr-Coulomb failure envelope for this sand.