Lab Protocols – Permeability of Soils

Adapted from ASTM Standard D2434-68 [redacted]

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Purpose

To determine the coefficient of permeability of coarse-grained soils using a constant head and falling head permeameter.

Procedures & Calculations for the Constant Head Permeameter.

1. Identify the constant head at the source and record it.
2. Measure the total length of the sample **(ΔL)** and determine sample cross-sectional area **(A)** in cm^2, (Note: the sample is situated in a 2.5" inside diameter acrylic pipe).
3. Using a 250ml beaker and a stopwatch, collect a volume of water as it flows out of the over flow spout on the down-gradient reservoir. **NOTE:** ***choose any time interval that will allow a sufficient volume of water to collect in the 250 ml beaker. Also be sure that the beaker is dried between readings***
4. Record water temperature and determine the mass of water collected using a scale accurate to 0.01g.
5. Repeat steps 4 and 5 at least three times to calculate an average flow rate.

Calculations

1. Convert mass of water to volume of water using an appropriate value for the density of water and calculate the flow for each trail **(Q_1, Q_2, Q_3)** as well as the average flow, **Q_{AVG}**.
2. Using Darcy's Law calculate the hydraulic conductivity, k in cm/s
3. Correct and report k to at a temperature of 10 °C.

Procedures & Calculations for the Falling Head Permeameter.

1. Measure the total length of the sample **(ΔL)** and determine sample cross-sectional area **(A)** in cm^2 as well as the cross-sectional area of the observation tube (Note: the sample is situated in a 2.5" inside diameter acrylic pipe and the observation tube has an inside diameter of 0.25".).
2. Record the initial head in the observation tube in (cm).
3. Using a stopwatch start recording the elapsed time once you have opened the stopcock at the bottom of the sample. Stop the watch and close the stopcock at the same time and record the final head in the observation tube
4. Record water temperature.

Calculations

1. Using Darcy's Law calculate the hydraulic conductivity, k in cm/s
2. Correct and report k to at a temperature of 10 °C.

Final Calculations

1. Plot the GSD provided for the samples you observed in both the constant and falling
2. Determine the D10 in mm for each sample
3. Calculate the hydraulic conductivity using Hazen's formula.

$$A = \frac{\pi}{4} D^2$$

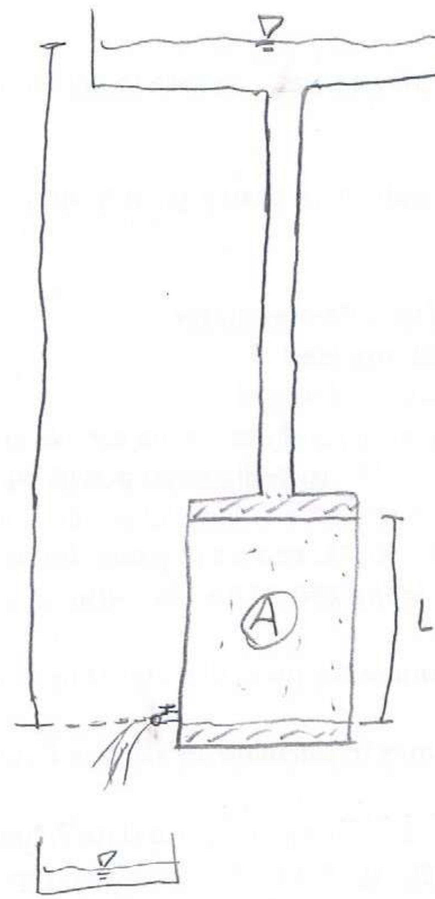
Constant Head

$$k_T = \frac{Q \Delta L}{\Delta H A} = \frac{V \Delta L}{t \Delta H A}$$

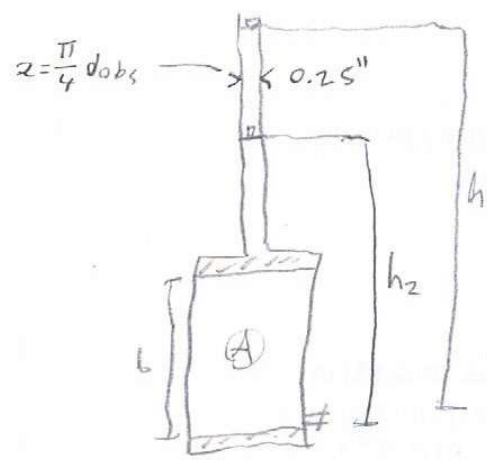
$$Q = \frac{V}{t} \quad \frac{23^\circ}{10^\circ} \quad \Big| \quad k_{10} = \frac{k_{23^\circ} \eta_{23}}{\eta_{10}}$$

Hydraulic conductivity H

$$Q = k i A \qquad Q = \left(\frac{vol}{tim}\right), \; i = \left(\frac{h}{L}\right)$$



Falling Head



$$k_T = \frac{La}{tA} \ln\left(\frac{h_1}{h_2}\right) = \frac{L \times \frac{\pi}{4} d_{obs}^2}{t \frac{\pi}{4} d_s^2} \ln \frac{h_1}{h_2}$$

$$= \frac{L d_{obs}}{t d_s^2} \ln\left(\frac{h_1}{h_2}\right)$$

CONSTANT HEAD PERMEABILITY TEST – DATA SHEET

Sample # 2 Sample description No fines, light brawen in colour, with some white 0% fives, 3% sand, 97 Gravcs, Hard to brake

Length of sample, **ΔL** cm	12.1
Diameter of sample, D (cm)	6.35
Area of sample, **A** cm^2	31.67
Constant head, **ΔH** cm	42.5

Trial No.	1	2	3	Average
Elapsed time, **t**, (sec)	10.50	15	20	
Mass of Water, (g)	47.56	61.83	85.93	
Volume of water, **V** cm^3	47.56	61.83	85.93	
Flow, **Q** (cm^3/s)	4.53 cm³/s	4.12	4.3	4.32
Average Water Temp, T (°C)				21°C

$$k_T = \frac{Q\Delta L}{\Delta HA} = \frac{V\Delta L}{t\Delta HA}$$

$$k = \frac{k_T \, x \, n_T}{n}$$

Coefficient $k_{@Temp}$, cm/s	4.07×10^{-2}
k_{10} (corrected to 10 °C) cm/s	3.05×10^{-2} cm/s

Temperature (°C)	Viscosity (poises)	Temperature (°C)	Viscosity (poises)	Temperature (°C)	Viscosity (poises)
10	**0.013077**	16	0.011111	22	0.009579
11	0.012713	17	0.010828	23	0.009358
12	0.012363	18	0.010559	24	0.009142
13	0.012028	19	0.010299	25	0.008937
14	0.011709	20	0.010050		
15	0.011404	21	0.009810		

FALLING HEAD PERMEABILITY TEST – DATA SHEET

Sample # 3 Sample description No fines, baige with some brawen, 1% fines, 2% course, 97% SAND.

Length of sample, **L** cm	11.5
Diameter of sample, d_s (cm)	6.35
Diameter of observation tube, d_{obs} (cm)	0.635
Initial head, h_1, (cm)	112.3
Final head, h_2, (cm)	71.8
Elapsed time, t (s)	37'80"

$$k_T = \frac{Ld_{obs}^2}{td_s^2} ln\left(\frac{h_1}{h_2}\right)$$

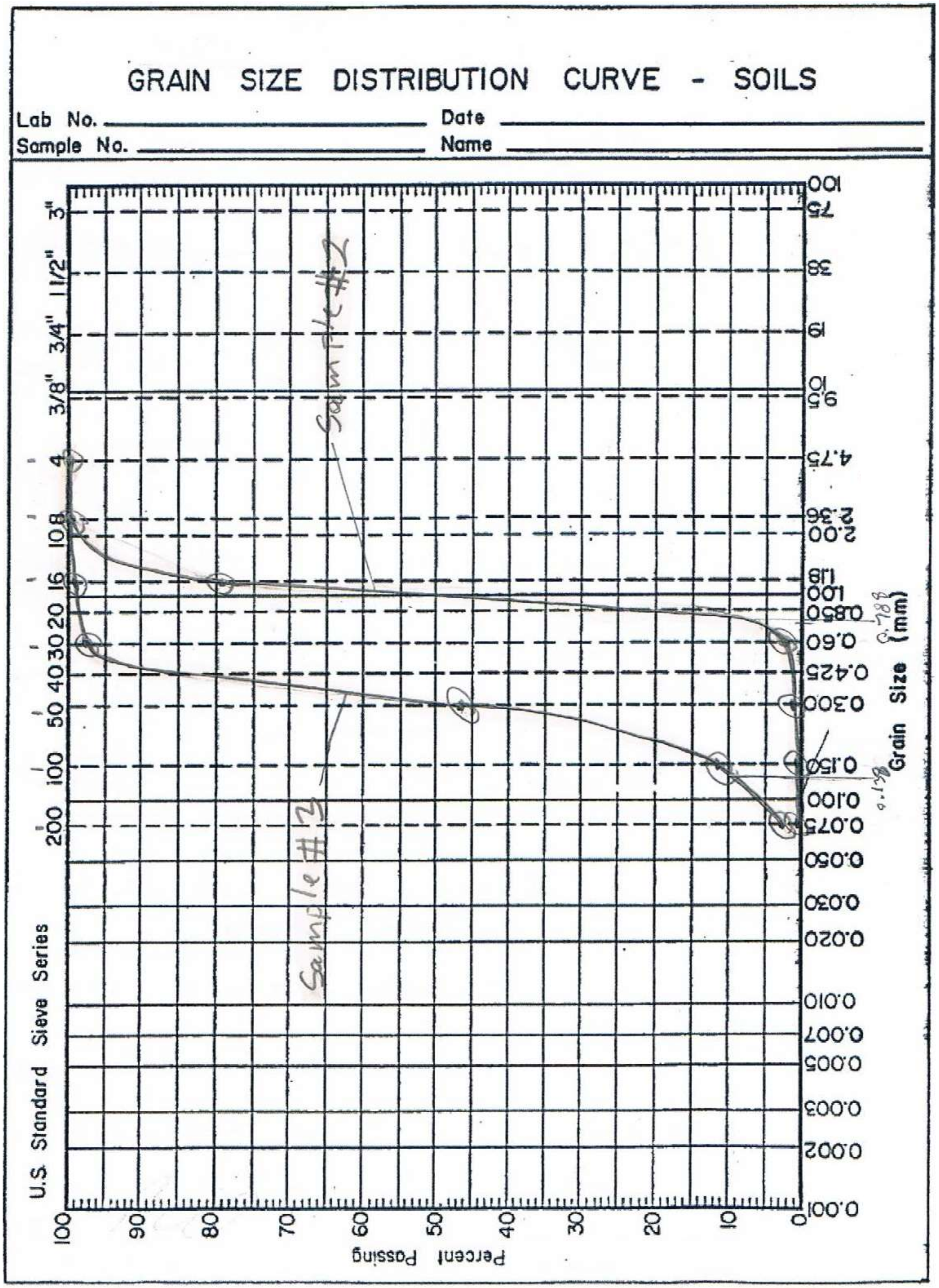
$$k_{10} \quad k = \frac{k_T \, x \, n_T}{n}$$

Water Temp, T (°C)	21
Coefficient $k_{@Temp}$, cm/s	1.35×10^{-3}
k_{10} (corrected to 10 °C) cm/s	1.01×10^{-3}

Plot the GSD provided below and use Hazen's formula, k (cm/s) = D_{10}^2 (mm) to estimate the hydraulic conductivity of the soils in both the constant and falling head test.

	Sample 1		Sample 2		Sample 3		Sample 4	
Original Mass (g)	369.34		328.78		265.04		98.02	
Sieve Size (mm)	Cumul. Retained Mass (g)	% passing	Cumul. Retained Mass (g)	% passing	Cumul. Retained Mass (g)	% passing	Cumul. Retained Mass (g)	% passing
4.75	0		0	100	0	100	0	
2.36	195.77		0.16	99.95	0	100	0	
1.18	353.99		67.33	79.52	1.25	99.53	2.86	
0.60	368.35		321.75	2.14	18.19	93.14	4.56	
0.30	369.26		328.4	0.12	141.27	46.70	13.84	
0.15	369.31		328.61	0.052	234.75	11.43	45.71	
0.075	369.36		328.63	0.046	257.57	2.82	86.05	
Pan	369.36	-	328.65	-	264.57	-	97.52	-
D_{10} (mm)	—		0.788		0.138		—	
K (cm/s)	—		0.621		0.019		—	

$k = (D_{10})^2$


GRAIN SIZE DISTRIBUTION CURVE - SOILS
Lab No.
Date
Sample No.
Name
U.S. Standard Sieve Series
Percent Passing
Grain Size (mm)
Sample #2
Sample #3

Constant Head

$$K_{21} = \frac{Q \Delta L}{\Delta H A} = \frac{V \Delta L}{t \Delta H A}$$

4.32

$$K_{21} = \frac{4.32 cm^3/s \times 12.1 cm}{42.5 cm \times 31.67 cm^2}$$

$$K_{21} = \frac{52.272 cm^4/s}{1{,}345.975 cm^3} = 3.88 \times 10^{-2} cm/s$$

0.039

$$K_{10} = \frac{K_T \times \eta_T}{\eta_{10}}$$

$$K_{10} = \frac{3.88 \times 10^{-2} cm/s \times 9.81 \times 10^{-3} poises}{1.308 \times 10^{-2} poises}$$

$$K_{10} = \frac{3.81 \times 10^{-4}}{1.308 \times 10^{-2}} = 2.91 \times 10^{-2} cm/s$$

Falling Head

$$K_T = \frac{L d_{obs}^2}{t d_s^2} \ln\left(\frac{h_1}{h_2}\right)$$

$$K_{21} = \frac{11.5 cm \times 0.635^2 cm}{37.80 s \times 6.35^2 cm} \ln\left(\frac{112.3 cm}{71.8 cm}\right)$$

$$K_{21} = \frac{4.637 cm^2}{1{,}524.191 cm/s} \ln 1.56 = 1.35 \times 10^{-3} cm/s$$

$$K = \frac{K_T \times \eta_T}{\eta_{10}}$$

$$K_{10} = \frac{1.35 \times 10^{-3} cm/s \times 9.81 \times 10^{-3} poises}{1.308 \times 10^{-2} poises}$$

$$K_{10} = \frac{1.32 \times 10^{-5} cm/s \cdot poises}{1.308 \times 10^{-2} poises} = 1.01 \times 10^{-3} cm/s$$

$$\% \text{ Passing} = \frac{(\text{Total Mass} - \text{Retained Mass})}{\text{Retained Mass}} \times 100$$

D_{10} from grain size Distribution curve

$$k = (D_{10})^2$$

Sample #2

$k = 0.788^2 mm$

$k = 0.621 cm/s$

Sample #3

$k = 0.138^2 mm$

$k = 0.019 cm/s$