

11

Falling-Head Permeability Test in Sand

11.1 Introduction

The procedure for conducting the constant-head permeability tests in sand was discussed in the preceding chapter. The falling-head permeability test is another experimental procedure to determine the coefficient of permeability of sand.

11.2 Equipment

1. Falling-head permeameter
2. Balance sensitive to 0.1 g
3. Thermometer
4. Stopwatch

11.3 Falling-Head Permeameter

A schematic diagram of a falling-head permeameter is shown in Fig. 11.1. Its specimen tube is essentially the same as that used in the constant-head test. The top of the specimen tube is connected to a burette by plastic tubing. The specimen tube and the burette are held vertically by clamps from a stand. The bottom of the specimen tube is connected to a plastic funnel by a plastic tube. The funnel is held vertically by a clamp from another stand. A scale is also fixed vertically to this stand.

11.4 Procedure

- 1–9. Follow the same procedure for the preparation of the specimen as described in Chapter 10.

10. Supply water using a plastic tube from the water inlet to the burette. The water will flow from the burette to the specimen and then to the funnel. Check to see that there is no leak. Remove all air bubbles.
11. Allow the water to flow for some time in order to saturate the specimen. When the funnel is full, water will flow out of it into the sink.
12. Using the pinch cock, close the flow of water through the specimen. The pinch cock is located on the plastic pipe connecting the bottom of the specimen to the funnel.
13. Measure the head difference h_1 (cm) (see Fig. 11.1). (*Note: Do not add any more water to the burette.*)
14. Open the pinch cock. Water will flow through the burette to the specimen and then out of the funnel. Record time t with a stopwatch until the head difference is equal to h_2 (cm) (Fig. 11.1). Close the flow of water through the specimen using the pinch cock.
15. Determine the volume V_w of water (cm^3) that is drained from burette.
16. Add more water to the burette to make another run. Repeat Steps 13, 14, and 15. However, h_1 and h_2 should be changed for each run.
17. Record the temperature T of the water to the nearest degree ($^{\circ}\text{C}$).

11.5 Calculations

The coefficient of permeability can be expressed by the relation

$$k = 2.303 \frac{aL}{At} \log \frac{h_1}{h_2} \quad (11.1)$$

where a is the inside cross-sectional area of the burette,¹

$$a = \frac{V_w}{h_1 - h_2} \quad (11.2)$$

Therefore,

$$k = \frac{2.303V_wL}{(h_1 - h_2)tA} \log \frac{h_1}{h_2} \quad (11.3)$$

where A is the area of the specimen.

As in Chapter 10,

$$k_{20^{\circ}\text{C}} = k_{T^{\circ}\text{C}} \frac{\eta_{T^{\circ}\text{C}}}{\eta_{20^{\circ}\text{C}}} \quad (11.4)$$

Sample calculations are shown in Tables 11.1 and 11.2.

¹ For an example of the derivation, see the References (Das, 2006).

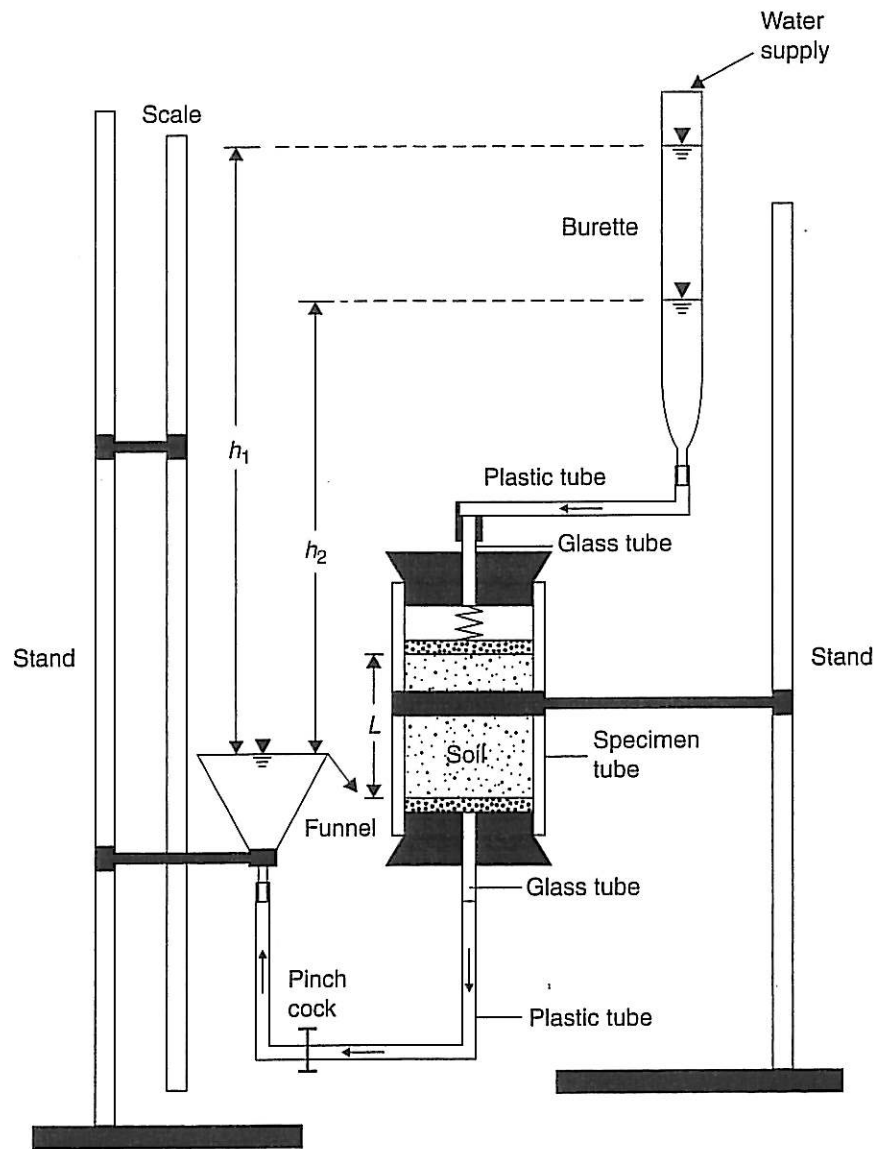


Figure 11.1. Schematic diagram of falling-head permeability test setup.

11.6 Discussion

The permeability test procedures described in Chapters 10 and 11 are using *rigid-wall permeameters*. In advanced geotechnical engineering courses, students will be exposed to flexible-wall permeameters, which is beyond the scope of this laboratory manual. However, generally speaking, flexible-wall permeability tests (constant and falling head) are performed in triaxial cells (see Chapter 18). According to ASTM test designation D-5084 the flexible-wall permeameter can be used for tests on soils having k less than about 10^{-4} cm/s. In a triaxial cell, interchangeable base pedestals and top caps permit the test of specimens with diameters from 40 to 150 mm. Drainage lines at the top and bottom of

Table 11.1. Determination of Void Ratio of Specimen—Falling-Head Permeability Test

Description of soil Uniform sand Sample no. _____
 Location _____
 Length of specimen L 13.2 cm Diameter of specimen D 6.35 cm
 Tested by _____ Date _____

Volume of specimen, $V = \frac{\pi}{4}D^2L$ (cm ³)	418.03
Specific gravity of soil solids, G_s	2.66
Mass of specimen tube with fittings, M_1 (g)	238.4
Mass of tube with fittings and specimen, M_2 (g)	965.3
Dry density of specimen, $\rho_d = \frac{M_2 - M_1}{V}$ (g/cm ³)	1.74

Void ratio of specimen $e = \frac{G_s \rho_w}{\rho_d} - 1 = \underline{0.53}$

(Note: $\rho_w = 1$ g/cm³)

the specimen facilitate the flushing of air bubbles from hydraulic lines and direct measurement of the pressure drop across the soil specimen using a differentially acting electrical pressure transducer. Separate pressure controls maintain the cell pressure and the pressures acting at the top and bottom of the soil specimen. Normally the specimen is back pressured prior to permeation to ensure full saturation.

The flexible-wall cell has several advantages. Undisturbed samples can be easily tested because minimal trimming is required and irregular surfaces on the specimen are easily accommodated. Back pressure is normally used, which helps to saturate the soil.

Flexible-wall cells have several disadvantages as well. The membranes used to confine the soil are normally made of latex, butyl, or neoprene rubber, which can be attacked and destroyed by certain chemicals. In order to maintain contact between the membrane and the soil specimen, the pressure in the cell liquid must be higher than the pore pressure in the specimen. In order to test with an elevated hydraulic gradient, the effective stress at one end of the specimen must be fairly large and the effective confining pressure cannot be less than the pressure drop across the specimen.

The coefficient of permeability k of fine-grained soils can also be determined from consolidation tests, which are discussed in Chapter 17.

Table 11.2. Determination of Coefficient of Permeability—Falling-Head Permeability Test

Description of soil Uniform sand Sample no. _____
 Location _____
 Length of specimen L 13.2 cm Diameter of specimen D 6.35 cm
 Tested by _____ Date _____

Test No.	1	2	3
Diameter of specimen, D (cm)	6.35	6.35	6.35
Length of specimen, L (cm)	13.2	13.2	13.2
Area of specimen, A (cm ²)	31.67	31.67	31.67
Beginning head difference, h_1 (cm)	85.0	76.0	65.0
Ending head difference, h_2 (cm)	24.0	20.0	20.0
Test duration, t (s)	15.4	15.3	14.4
Volume of water flow through specimen, V_w (cm ³)	64	58	47
$k = \frac{2.303V_wL}{(h_1 - h_2)tA} \log \frac{h_1}{h_2}$ (cm/s)	0.036	0.038	0.036

Average $k = \underline{0.037}$ cm/s

$$k_{20^\circ\text{C}} = k_{T^\circ\text{C}} \frac{\eta_{T^\circ\text{C}}}{\eta_{20^\circ\text{C}}} = \underline{0.037 \times 0.889} = \underline{0.033}$$
 cm/s

Falling-Head Permeability Test

Determination of Void Ratio of Specimen

Description of soil _____ Sample no. _____

Location _____

Length of specimen L _____ cm Diameter of specimen D _____ cm

Tested by _____ Date _____

Volume of specimen, $V = \frac{\pi}{4}D^2L$ (cm ³)	
Specific gravity of soil solids, G_s	
Mass of specimen tube with fittings, M_1 (g)	
Mass of tube with fittings and specimen, M_2 (g)	
Dry density of specimen, $\rho_d = \frac{M_2 - M_1}{V}$ (g/cm ³)	

Void ratio of specimen $e = \frac{G_s \rho_w}{\rho_d} - 1 =$ _____

(Note: $\rho_w = 1$ g/cm³)

Falling-Head Permeability Test

Determination of Coefficient of Permeability

Description of soil _____ Sample no. _____

Location _____

Length of specimen L _____ cm Diameter of specimen D _____ cm

Tested by _____ Date _____

Test No.	1	2	3
Diameter of specimen, D (cm)			
Length of specimen, L (cm)			
Area of specimen, A (cm ²)			
Beginning head difference, h_1 (cm)			
Ending head difference, h_2 (cm)			
Test duration, t (s)			
Volume of water flow through specimen, V_w (cm ³)			
$k = \frac{2.303V_w L}{(h_1 - h_2)tA} \log \frac{h_1}{h_2}$ (cm/s)			

Average $k =$ _____ cm/s

$$k_{20^\circ\text{C}} = k_{T^\circ\text{C}} \frac{\eta_{T^\circ\text{C}}}{\eta_{20^\circ\text{C}}} = \text{_____} = \text{_____} \text{ cm/s}$$