10
Constant Head Permeability Test in Sand

Introduction

The rate of flow of water through a soil specimen of gross cross-sectional area, A, can be expressed as

$$q = kiA \tag{10.1}$$

where q = flow in unit time
k = coefficient of permeability
i = hydraulic gradient

For coarse sands, the value of the coefficient of permeability may vary from 1 to 0.01 cm/s and, for fine sand, it may be in the range of 0.01 to 0.001 cm/s.

Several relations between k and the void ratio, e, for sandy soils have been proposed. They are of the form

$$k \propto e^2 \tag{10.2}$$

$$k \propto \frac{e^2}{1+e} \tag{10.3}$$

$$k \propto \frac{e^3}{1+e} \tag{10.4}$$

The coefficient of permeability of sands can be easily determined in the laboratory by two simple methods. They are (a) the constant head test and (b) the variable head test. In this chapter, the *constant head test method* will be discussed.

Equipment

1. Constant head permeameter
2. Graduated cylinder (250 cc or 500 cc)
3. Balance, sensitive up to 0.1 g
4. Thermometer, sensitive up to 0.1°C
5. Rubber tubing
6. Stop watch

Constant Head Permeameter

A schematic diagram of a constant head permeameter is shown in Fig. 10–1. This can be assembled in the laboratory at very low cost. It essentially consists of a plastic soil specimen cylinder, two porous stones, two rubber stoppers, one spring, one constant head chamber, a large funnel, a stand, a scale, three clamps, and some plastic tubes. The plastic cylinder may have an inside diameter of 2.5 in. (63.5 mm). This is because 2.5 in. (63.5 mm) diameter porous stones are usually available in most soils laboratories. The length of the specimen tube may be about 12 in. (304.8 mm).

Procedure

1. Determine the mass of the plastic specimen tube, the porous stones, the spring, and the two rubber stoppers (W_1).
2. Slip the bottom porous stone into the specimen tube, and then fix the bottom rubber stopper to the specimen tube.
3. Collect oven-dry sand in a container. Use a spoon, pour the sand into the specimen tube in small layers, and compact it by vibration and/or other compacting means.
   Note: By changing the degree of compaction, a number of test specimens having different void ratios can be prepared.
4. When the length of the specimen tube is about two-third the length of the tube, slip the top porous stone into the tube to rest firmly on the specimen.
5. Place a spring on the top porous stone, if necessary.
6. Fix a rubber stopper to the top of the specimen tube.
   Note: The spring in the assembled position will not allow any expansion of the specimen volume, and thus the void ratio, during the test.
7. Determine the mass of the assembly (Step 6 – W_2).
8. Measure the length (L) of the compacted specimen in the tube.
9. Assemble the permeameter near a sink, as shown in Fig. 10–1.
10. Run water into the top of the large funnel fixed to the stand through a plastic tube from the water inlet. The water will flow through the specimen to the constant head chamber. After some time, the water will flow into the sink through the outlet in the constant head chamber.

Note: Make sure that water does not leak from the specimen tube.

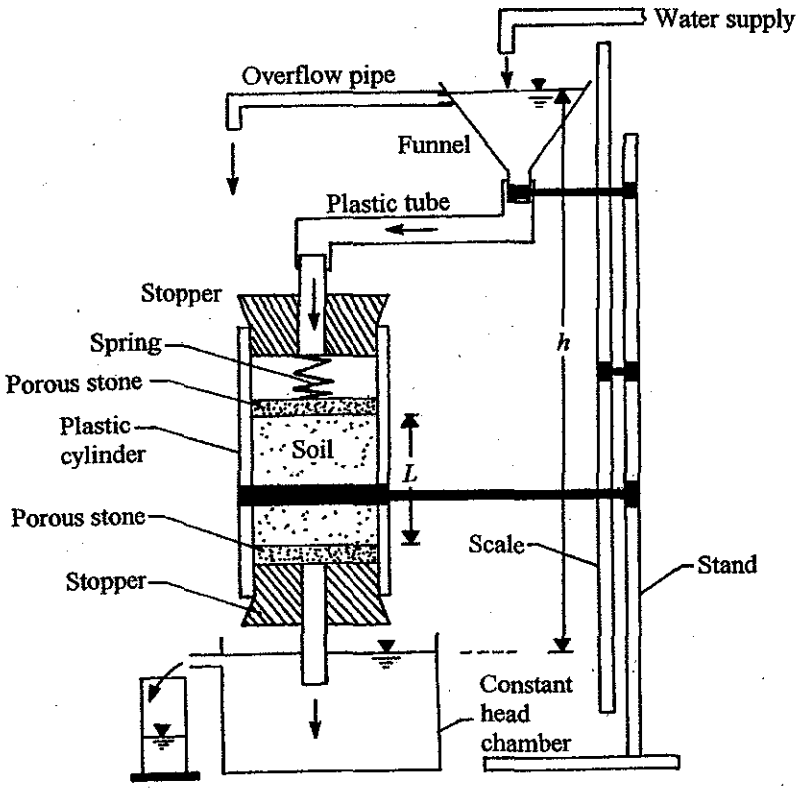

Figure 10–1. Schematic diagram of constant head permeability test setup.

11. Adjust the supply of water to the funnel so that the water level in the funnel remains constant. At the same time, allow the flow to continue for about 10 minutes in order to saturate the specimen.
    Note: Some air bubbles may appear in the plastic tube connecting the funnel to the specimen tube. Remove the air bubbles.
12. After a steady flow is established (that is, once the head difference h is constant), collect the water flowing out of the constant head chamber (Q) in a graduated cylinder. Record the collection time (t) with a stop watch.
13. Repeat Step 12 three times. Keep the collection time (t) the same and determine Q. Then find the average value of Q.
14. Change the head difference, h, and repeat Steps 11, 12 and 13 about three times.
15. Record the temperature, T, of the water to the nearest degree.
    Note: This value is sufficiently accurate for this type of test.

Calculation

1. Calculate the void ratio of the compacted specimen as follows:
   Dry density, ρ_d, of the soil specimen as

$$\rho_d = \frac{W_2 - W_1}{\frac{\pi}{4} D^2 L}$$

   Thus

$$e = \frac{G_s \rho_w}{\rho_d} - 1 \tag{10.5}$$

   where G_s = specific gravity of soil solids
   ρ_w = density of water
   D = diameter of the specimen
   L = length of the specimen

2. Calculate k as

$$k = \frac{QL}{Aht} \tag{10.6}$$

   where A = area of specimen = $\frac{\pi}{4} D^2$

3. The value k is usually given for a test temperature of water at 20°C. So calculate $k_{20°C}$ as

$$k_{20°C} = k_{T°C} \frac{\eta_{T°C}}{\eta_{20°C}} \tag{10.7}$$

   where $\eta_{T°C}$ and $\eta_{20°C}$ are viscosities of water at T°C and 20°C, respectively.

   Table 10–1 gives the values of $\frac{\eta_{T°C}}{\eta_{20°C}}$ for various values of T (in °C).

   Tables 10–2 and 10–3 give sample calculations for the permeability test.

Table 10–1. Variation of $\eta_{T°C}/\eta_{20°C}$

Temperature, T (°C)	$\eta_{T°C}/\eta_{20°C}$	Temperature, T (°C)	$\eta_{T°C}/\eta_{20°C}$
15	1.135	23	0.931
16	1.106	24	0.910
17	1.077	25	0.889
18	1.051	26	0.869
19	1.025	27	0.850
20	1.000	28	0.832
21	0.976	29	0.814
22	0.953	30	0.797

Table 10–2. Constant Head Permeability Test

Determination of Void Ratio of Specimen

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, $V = \frac{\pi}{4} D^2 L \ (\text{cm}^2)$	*418.03*
Specific gravity of soil solids, G_s	*2.66*
Mass of specimen tube with fittings, W_1 (g)	*238.4*
Mass of tube with fittings and specimen, W_2 (g)	*965.3*
Dry density of specimen, $\rho_d = \frac{W_2 - W_1}{V} \ (\text{g/cm}^3)$	*1.74*
Void ratio of specimen, $e = \frac{G_s \rho_w}{\rho_d} - 1$ (*Note:* $\rho_w = 1 \text{ g/cm}^3$)	*0.53*

Table 10–3. Constant Head Permeability Test

Determination of Coefficient of Permeability

Test No.	1	2	3
Average flow, Q (cm^3)	305	375	395
Time of collection, t (s)	60	60	60
Temperature of water, T (°C)	25	25	25
Head difference, h (cm)	60	70	80
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, $A = \frac{\pi}{4}D^2$ (cm^2)	31.67	31.67	31.67
$k = \frac{QL}{Aht}$ (cm / s)	0.035	0.037	0.034
Average k = 0.035 cm/s			
$k_{20°C} = k_{T°C}\frac{\eta_{T°C}}{\eta_{20°C}}$ = 0.035(0.889) = 0.031 cm/s			