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Set 4 Report 5

Hydraulic Conductivity Tests

Objective – To determine hydraulic conductivity using constant head test and falling head test.

Brief Theory – The property of a porous medium by virtue of which water flows through it is known as 'permeability'. It is an important property and determines the strength and deformation for soil. The flow of water through soil is governed by Darcy's Law.

$$Q = kiA$$

Q – Flow rate of water
k – Co-efficient of permeability/Hydraulic conductivity
i – Hydraulic gradient
A – Area of cross-section of soil specimen

1) Constant head test

This test is used to measure permeability of soils that have high permeability such as sands, gravels and coarse silts. The hydraulic head due to which flow occurs is kept constant. Thus, Darcy's law can be written as:

$$k = \frac{Q}{iA} = \frac{QL}{AH}$$

H – Hydraulic head causing flow (kept constant throughout)
L – Length of mould

2) Falling head test

This test is used for fine-grained soils. The head keeps on changing in this test and hence, k is obtained as

$$k = \frac{2.303aL}{A(\Delta t)} \log_{10}\left(\frac{h1}{h2}\right)$$

$\Delta t = t_2 - t_1$
h_1 – Hydraulic head at time t_1
h_2 – Hydraulic head at time t_2
a – Area of cross-section of sandpipe
A – Area of cross-section of specimen

Temperature correction

The reference temperature is 27°C. If the temperature at which experiment is carried out is not 27°C, a correction is done in order to get the results for the standard temperature.

$$k_{27} = k_T \times \frac{\mu\ (at\ T°C)}{\mu\ (at\ 27°C)}$$

k_T = Hydraulic conductivity at 27°C

Constant head test

Apparatus

1) Constant head permeameter
2) Balance
3) Thermometer
4) Graduated cylinder
5) Rubber tubing
6) Stop watch

Procedure

1) Measure mass of empty permeameter M_1 and diameter of the permeameter as well.
2) Fill the permeameter with oven-dried specimen at a given degree of compaction and measure its mass M_2.
3) Measure length of sample L and place the assembly near the sink.
4) Adjust the hydraulic head by sliding the steel tube up or down through the rubber stopper in the glass tube.
5) The water flows through the glass tube and comes out of the outlet. This should be allowed to occur for 10 minutes.
6) Record the volume of water collected in the given time t and take the average volume collected over numerous samplings. Use this to find the flow rate of water.
7) Repeat the experiment at different heads and record the temperature T.

Falling head test

Apparatus

1) Falling head permeameter
2) Thermometer
3) Balance
4) Stopwatch

Procedure

1) Measure mass of empty permeameter M_1 and diameter of the permeameter as well.
2) Fill the permeameter with oven-dried specimen at a given degree of compaction and measure its mass M_2.
3) Measure length of sample L and place the assembly near the sink.
4) Adjust the hydraulic head by sliding the steel tube up or down through the rubber stopper in the glass tube.
5) Supply water to the specimen and allow it to saturate.
6) Measure head h_1 from the standpipe and open the valve, allowing water to flow.
7) Measure the time t till the head reaches h_2.
8) Determine inner diameter of standpipe.
9) Repeat the experiment with different h_1 and h_2. Record the room temperature while performing the experiment.

Observations

Constant head test

Constant head H (mm)	Quantity of water Q (cm^3)	Average flow rate Q (cm^3/s)	Time t (s)	k (m/s)
384	25	0.452	52	1.502×10^{-5}
384	22		52	1.322×10^{-5}

Diameter of mould = 7.98 cm   Length of mould = 6cm

Falling head test

Initial head h_1 (mm)	Final head h_2 (mm)	Elapsed time $t_2 - t_1$ (s)	$\log_{10} \frac{h1}{h2}$	k (m/s)
399	351	60.01	0.0557	6.89×10^{-4}
351	335	59.50	0.0203	2.53×10^{-4}

Diameter of mould = 7.98 cm   Length of mould = 6cm   Diameter of sandpipe = 18.5 cm

Calculations

For constant head test :

$$Q_{avg} = \frac{(25+22) \times 0.5}{52} = 0.452 \text{ cm}^3/\text{s}$$

$$k_{avg} = \frac{Q(avg)L}{AH} = \underline{1.412 \times 10^{-3}\ \text{cm/s}} = \underline{1.412 \times 10^{-5}\ \text{m/s}}$$

<u>For falling head test</u> :

<u>For first observation,</u>

$$k = \frac{2.303aL}{A(\Delta t)} \log_{10}\left(\frac{h1}{h2}\right)$$
$$= \frac{(2.303)(18.5)(18.5)(6)}{(7.98)(7.98)(60.01)} \log_{10}\left(\frac{399}{351}\right) = \underline{6.89 \times 10^{-4}\ \text{m/s}}$$

<u>Temperature correction</u> (T = 30°C)

μ_{27} = 0.00855 poise

μ_{30} = 0.00801 poise

<u>For constant head test</u>:

$$k_{27} = 1.412 \times 10^{-5} \times \frac{0.00801}{0.00855}$$
$$= \underline{1.323 \times 10^{-5}\ \text{m/s}}$$

<u>For falling head test</u>:

$$k_{27} = 4.71 \times 10^{-4} \times \frac{0.00801}{0.00855}$$
$$= \underline{4.41 \times 10^{-4}\ \text{m/s}}$$

<u>Results</u>

<u>Before temperature correction</u>

k_{avg} (constant head test) = 1.412×10^{-5} m/s
k_{avg} (falling head test) = 4.71×10^{-4} m/s

<u>After temperature correction</u>

k_{27} (constant head test) = 1.323×10^{-5} m/s
k_{27} (falling head test) = 4.41×10^{-4} m/s

<u>Discussion</u>

The constant head test and the falling head test represent 2 completely different approaches to finding the hydraulic conductivity of a given soil specimen. In this case, both tests were used to find the value of hydraulic conductivity of the given soil sample. The given soil sample is a clayey soil. It is fine-grained and thus, the falling head test is more likely to have given a correct value of k as compared to the constant head test. The given experiment was carried out at 30°C. Thus, in order to get the hydraulic conductivity at 27°C, temperature correction had to be done. After temperature correction, the value of k_{27} comes out as roughly 0.937 times (~ 93.7%) the average value obtained experimentally in both the tests.

The constant head test is used for coarse grained soils because they tend to have a high permeability. The flow of water through these coarse soils is more rapid as compared to fine soils, which is why constant head test is preferred for coarse soils. For fine soils, falling head test tends to be used more often because even though the flow may not be rapid due to low permeability of the soils, the time intervals at which heads are to be measured can be easily modified. In the above experiment, two reading were taken in each test. For the constant head test, flow rate of water was averaged out to get the k_{avg} whereas in the falling head test, fall in head was measured for roughly equal intervals of time of close to 1 minute. The values of hydraulic conductivity obtained are of the power 0.0001 m/s (0.01 cm/s). Generally, desiccated and fissured clays have a hydraulic coefficient of the order 10^{-4} m/s. This indicates that the soil sample has a low hydraulic conductivity. The flow of water through the given sample won't be as rapid as compared to a coarser soil (which has a greater k). This is not much of a surprise, given that in the earlier experiments, we found out that this soil sample is clayey in nature and thus, this specimen is that of a fine-grained soil.

The constant head test gives a smaller reading for k for the same sample of soil. The difference in reading given by both tests is due to the fact that the constant head test isn't entirely suitable for this specific soil sample due to its fine nature. The average reading given by the falling head test is more likely to be closer to the correct value for permeability of the given soil. The constant head test would be suitable for granular soil but since this soil is fine-grained, the value of k given by the falling head test should be considered as the more accurate one.

Inference

The values of hydraulic coefficient obtained after averaging out all observations are 1.412×10^{-5} m/s for the constant head test and 4.71×10^{-4} m/s for the falling head test, which are small and hence, indicate a fine-grained soil. After temperature correction, the values of k obtained are 1.323×10^{-5} m/s and 4.41×10^{-4} m/s respectively.