CE EN 341
Soil Mechanics Laboratory
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Section 6

The Constant Head Permeability Test in Sand

Submitted to:
Scott Anderson

by
Christopher Smemoe
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I. Introduction

Objective of the Constant Head Permeability Test

Since Darcy published his simple equation for the discharge velocity of water through saturated soils, $v=ki$, the coefficient of permeability, k, k has been a central perameter in the calculation of fluid flow through soils.

The objective in running the constant head permeability test was to determine the coefficient of permeability, k. With this coefficient, calculations can be made which determine the properties of fluids in a soil.

The constant head permeability test is used for coarse-grained soils with a high coefficient of permeability.

Purpose for Running the Test

As mentioned above, the purpose in running the constant head permeability test was to determine the coefficient of permeability. When designing an earth dam or needing to make calculations which have to do with seepage through soils, the coefficient of permeability is a very useful quantity. The coefficient of permeability is the main perameter used in computer programs which use finite element methods to determine the flow of fluids through soils and rocks.

When I performed the constant head permeability test, I was able to gain experience by performing the test myself. By the experience I gained, I will be able to better tell whether a lab technician is performing the permeability test correctly. Also, I will be able to better tell whether the technician's results seem accurate for the soil tested.

II. Test Procedure

We performed the constant head permeability test using the following procedure:

1. First, we prepared the specimen. We assembled the metal container which would hold the sand specimen by inserting a liner inside of it. Then we applied a vacuum to the metal container.
2. Next, we weighed some sand and filled the container to the top.
3. After weighing the sand and determining the weight of sand in the specimen, we placed O-rings on the specimen to keep it together.
4. Fourth, we removed the metal plates from the outside of the specimen. We then measured the length and diameter of the specimen.
5. After measuring the length and diameter of the specimen, we finished assembling the container for the specimen and began to fill it with water.
6. We ran water through the specimen many times, until most of the void spaces were filled and there were very little bubbles left.
7. When the specimen was fully prepared, we began the test. First, we began at a difference in pressure of 5 psi.
8. We read the initial volume of water in each test buret. Then, we allowed the water to flow through the specimen and read the final volume of water in each test buret.

9. While running the test, we recorded the time interval between opening and closing the valves on the specimen container.
10. Finally, we repeated the test at pressure differences of 2 and 7 psi. We recorded the results and made all the necessary calculations.

III. Results

Graphs and Tables

Table 1: Results from the Constant Head Permeability Test.

L=	16.65	cm
D=	7.03	cm
A=	38.82	cm^2
Dry Weight=	927.10	g
e=	0.85	
Gs=	2.65	
dry density=	14.07	mN/cm^3
Unit weight of water=	9.81	mN/cm^3

Test No.	Average flow Q (cm^3)	Time t (sec)	Temperature T (C)	Pressure difference (psi)	Head difference h (cm)	Coefficient of Permeability k (cm/sec)
1 (in)	19.5	15.0	20	5	351.68	0.00159
1 (out)	19.5	15.0	20	5	351.68	0.00159
2 (in)	19.1	18.5	20	5	351.68	0.00126
2 (out)	18.8	18.5	20	5	351.68	0.00124
3 (in)	17.5	30.5	20	2	140.67	0.00175
3 (out)	16.9	30.5	20	2	140.67	0.00169
4 (in)	22.5	41.3	20	2	140.67	0.00166
4 (out)	22.4	41.3	20	2	140.67	0.00165
5 (in)	19.7	35.5	20	2	140.67	0.00169
5 (out)	19.7	35.5	20	2	140.67	0.00169
6 (in)	19.4	14.6	20	7	492.35	0.00116
6 (out)	20.5	14.6	20	7	492.35	0.00122
7 (in)	20.9	16.0	20	7	492.35	0.00114
7 (out)	20.9	16.0	20	7	492.35	0.00114
8 (in)	21.2	16.4	20	7	492.35	0.00113
8 (out)	21.4	16.4	20	7	492.35	0.00114

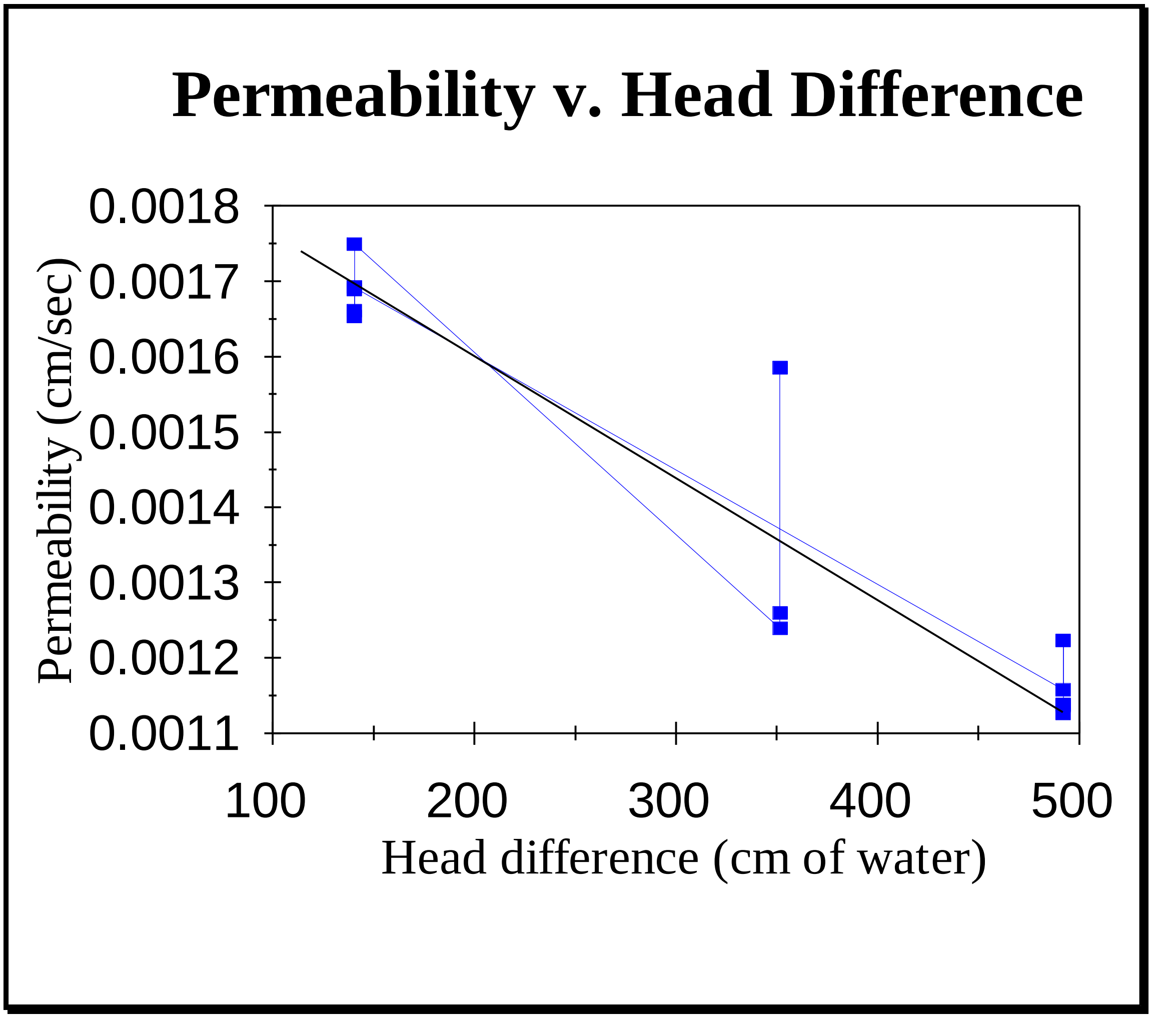

Figure 1: A Plot of the Permeability v. the Head Difference in the Specimen.

Results From the Constant Head Permeability Test

The results from the constant head permeability test are located in table 1 and figure 1. At a head difference of 141 cm, we found the permeability to be about 0.0017 cm/sec. At a head difference of 352 cm, we found the permeability to be about 0.0014 cm/sec. Finally, at a head difference of 492 cm, we found the permeability to be about 0.0011 cm/sec.

Determination of the Void Ratio of the Compacted Specimen

First, we found the dry density of the specimen by dividing the measured weight of the specimen by the volume of its container. Then, we found the void ratio of the specimen according to the following equation:

$$e = \frac{G_s \, g_w}{g_d} - 1$$

Where e is the void ratio, G_s is the specific gravity of the soil solids, γ_w is the unit weight of water, and γ_d is the dry unit weight of the soil specimen. The void ratio of the soil specimen was found to be 0.85.

Determination of the Permeability of the Soil

After we performed the constant head permeability test at different pressure heads, I calculated the permeability of the soil using the equation:

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

A plot of the head difference v. the permeability of the soil can be found in figure 1. As the head difference between the two cylinders increased, the permeability tended to decrease.

Summary of Test Results

A good summary of the test results can be found in table two. On this table, you can see that as the pressure head of the specimen increased, the permeability decreased. The average permeability of the specimen was found to be 0.0014 cm/sec.

Table 2: A Summary of the Test Results.

Permeability at 141 cm Head	Permeability at 352 cm head	Permeability at 492 cm head	Average Permeability
0.0017 cm/sec	0.0014 cm/sec	0.0012 cm/sec	0.0014 cm/sec

IV. Discussion

What do the Results Mean?

The purpose in running the constant head permeability test was to determine the permeability of the soil. After calculating the permeability, you can use the permeability obtained to make calculations which involve flow of the fluid through the soil. The discharge velocity, as stated by Darcy's law, is directly proportional to the hydraulic gradient. The constant of proportionality for a given soil is the coefficient of permeability.

For example, since the average permeability of the Ottawa sand used in this experiment was found to be 0.0014 cm/sec, you could use this value of k in $v=ki$ to compute the discharge velocity in the soil.

How Can the Soil be Classified?

Although the constant head permeability test is not used to classify the soil, we can compare the values obtained from this test with typical values of the coefficient of permeability. Typical values of permeability coefficients for different types of soils are located in table 3.

Table 3: Typical Values of Permeability Coefficients. (from Das, 1993).

Type of Soil	Permeability Coefficient (cm/sec)
Clean Gravel	1.0-100
Coarse Sand	1.0-0.01
Fine Sand	0.01-0.001
Silty Clay	0.001-0.00001
Clay	less than 0.000001
Ottawa Sand (our test results)	0.0014

The permeability coefficient for the Ottawa sand we tested was found to be 0.0014. This permeability coefficient falls in the range of a fine sand, which is what we expected.

What Were the Sources of Error?

The following were possible sources of error in the permeability test:

1. The weight of the sand may have been slightly different than what was read because of inaccuracy in the scale.
2. The measurements of the length and diameter of the specimen were slightly off. It was impossible to get a completely accurate measurement of the length and diameter of the sand specimen.
3. The time of collection for each test was not completely accurate, as the timer attempted to time the "walking velocity" of people passing by throughout the test.
4. The temperature of the water may not have remained at 20 degrees C throughout the test, causing a slight change in the value of the permeability coefficient for the specimen.
5. All of the air bubbles in the specimen may not have been released before performing the test. The water which would normally flow through the soil would then fill these air bubbles and the flow value would be incorrect.

The values of permeability at a head difference of 5 psi (352 cm) were quite a bit different from each other (see figure 1 and table 1). This may have been due to initial air bubbles in the specimen or some other unknown cause. Performing the test another time at this pressure would have given us a surer value for the permeability at this pressure.

What Could be done to Reduce the Error?

To reduce the error in the constant head permeability test, we could simply reverse the effects of the errors above by:

1. Insuring that the scale is correct and the weight of the soil obtained is accurate.
2. Attempting to get an exact value for the length and diameter of the specimen.
3. Insuring that the time of collection of the water is accurately measured for each test.
4. Getting an accurate measurement of the temperature of the water at the beginning of the test and trying to keep the water at a constant temperature throughout the test.

5. Insuring that all or most of the air bubbles are released from the specimen before beginning the test.
6. Insuring that each test is performed correctly and exactly according to ASTM standards.

V. Conclusion

From performing the constant head permeability test on the "permeability board", I have learned the proper method for determination of the void ratio and permeability for a coarse-grained soil.

The permeabilities of the Ottawa sand at different pressures are repeated below, in table 4. The average permeability of 0.0014 appears to be accurate since the permeability of a fine sand is normally between 0.01 and 0.001, as in table 3.

After determining the average value of the permeability coefficient by constant head permeability test, you can use this value in computer seepage analysis programs to perform flow analyses under dams and through soils. You can also use the coefficient of permeability to make calculations by hand. Seepage under dams is highly important, as seepage was one of the main causes of the failure of the Teton dam.

Table 4: A Summary of the Test Results.

Permeability at 141 cm Head	Permeability at 352 cm head	Permeability at 492 cm head	Average Permeability
0.0017 cm/sec	0.0014 cm/sec	0.0012 cm/sec	0.0014 cm/sec

VI. Appendix

References

Das, B. M. (1993). Principles of geotechnical engineering, PWS Publishing Company, Boston.

Das, B. M. (1992). Soil Mechanics Laboratory Manual, Engineering Press, Inc., San Jose, California.

Data and Calculations

**Raw data and calculations are located on the following pages.