

CE EN 341
Soil Mechanics Laboratory
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Section 6

The Constant Head Permeability Test in Sand

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by
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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 parameter 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.

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 parameter 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:

First, we prepared the specimen. We attached a vacuum

III. Results

Graphs and Tables

Table 1: Data and Results from the Sand Cone Test.

Calibration of Unit Weight of Ottawa Sand

Weight of sand in the mold:	6.10lbs.
Volume of the mold:	0.08ft ³
Dry unit weight of the sand:	81.39pcf (use 81.28 pcf)

Calibration Cone

Weight of bottle + cone + sand (before use):	15.06lbs.
Weight of bottle + cone + sand (after use):	11.74lbs.
Weight of sand to fill the cone:	3.32lbs.

Results from Field Test

Weight of bottle + cone + sand (before use):	15.21 lbs.
Weight of bottle + cone + sand (after use):	8.74 lbs.
Volume of the hole:	0.04 ft ³
Weight of the can:	0.60 lbs.
Weight of the can + moist soil:	5.90 lbs.
Weight of the can + dry soil:	5.42 lbs.
Weight of the moist soil:	5.30 lbs.
Moist unit weight of soil in the field:	136.79 pcf
Moisture content in the field:	9.90%
Dry unit weight on the field:	124.46 pcf

Table 2: Data from the Nuclear Density Test.

Proctor Maximum Dry Density: 125 pcf

Test 1 (8 inches deep)

Wet Density:	131.20 pcf
Moisture Content:	11.40%
Dry Density:	117.77 pcf
Relative Compaction:	94.22%

Test 2 (4 inches deep)

Wet Density:	137.30 pcf
Moisture Content:	10.00%
Dry Density:	124.82 pcf
Relative Compaction:	99.85%

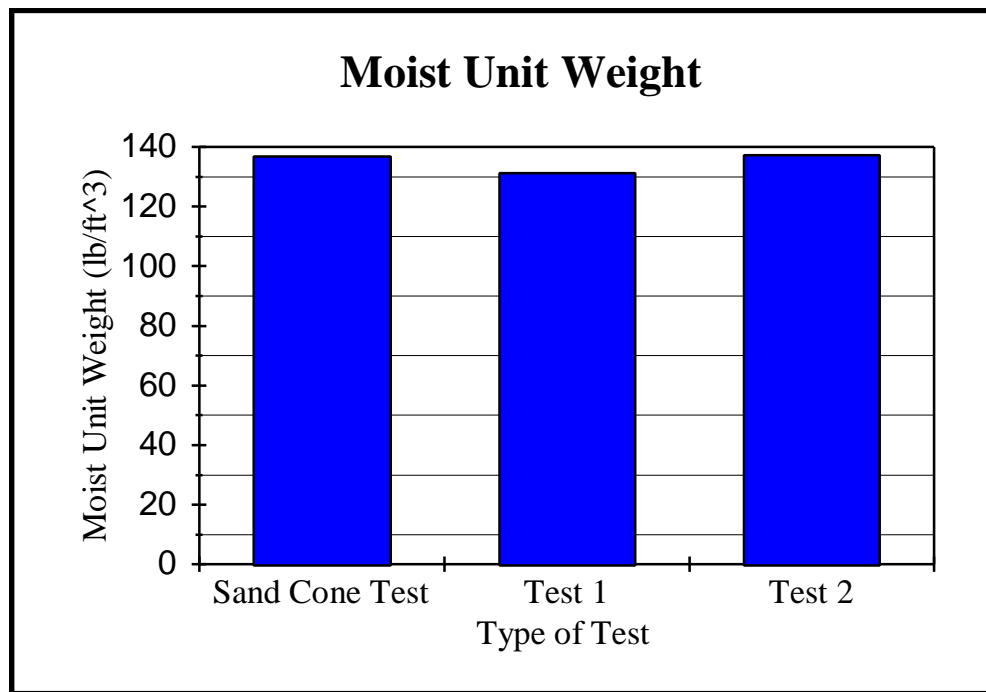


Figure 1: A Comparison of the Moist Unit Weights Obtained in each of the Three Tests.

Table 3: A Comparison of the Moist Unit Weights Obtained in each of the Three Tests.

Type of Test	Moist Unit Weight
Sand Cone	136.79
Nuclear--8 inches deep	131.20
Nuclear--4 inches deep	137.30

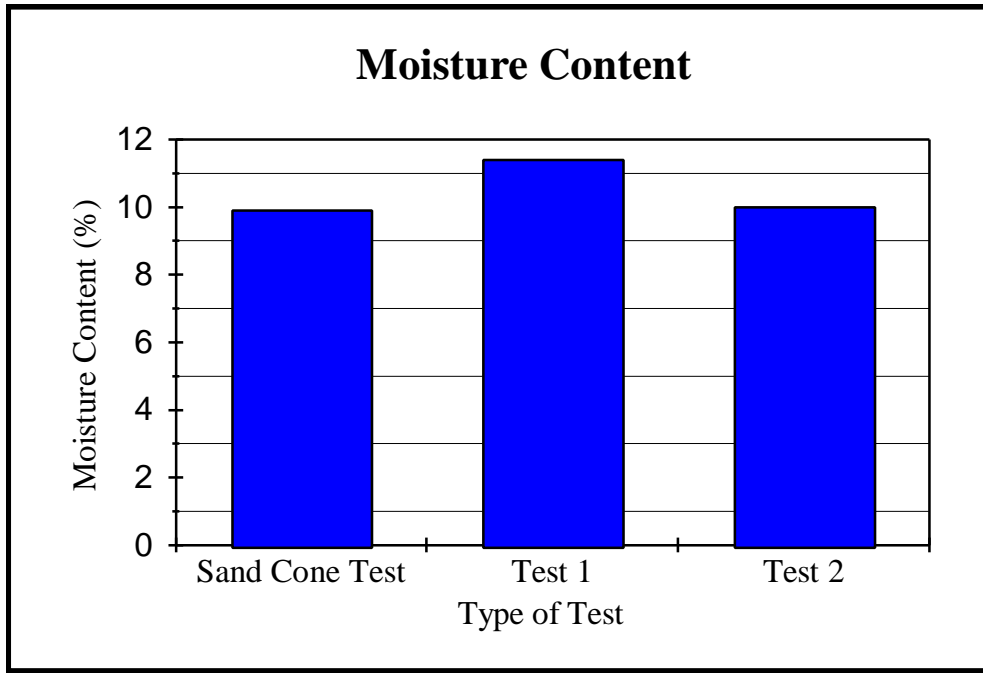


Figure 2: A Comparison of the Moisture Content Values Obtained in each of the Three Tests.

Table 4: A Comparison of the Moisture Content Values Obtained in each of the Three Tests.

Type of Test	Moisture Content
Sand Cone	9.90%
Nuclear--8 inches deep	11.40
Nuclear--4 inches deep	10.00

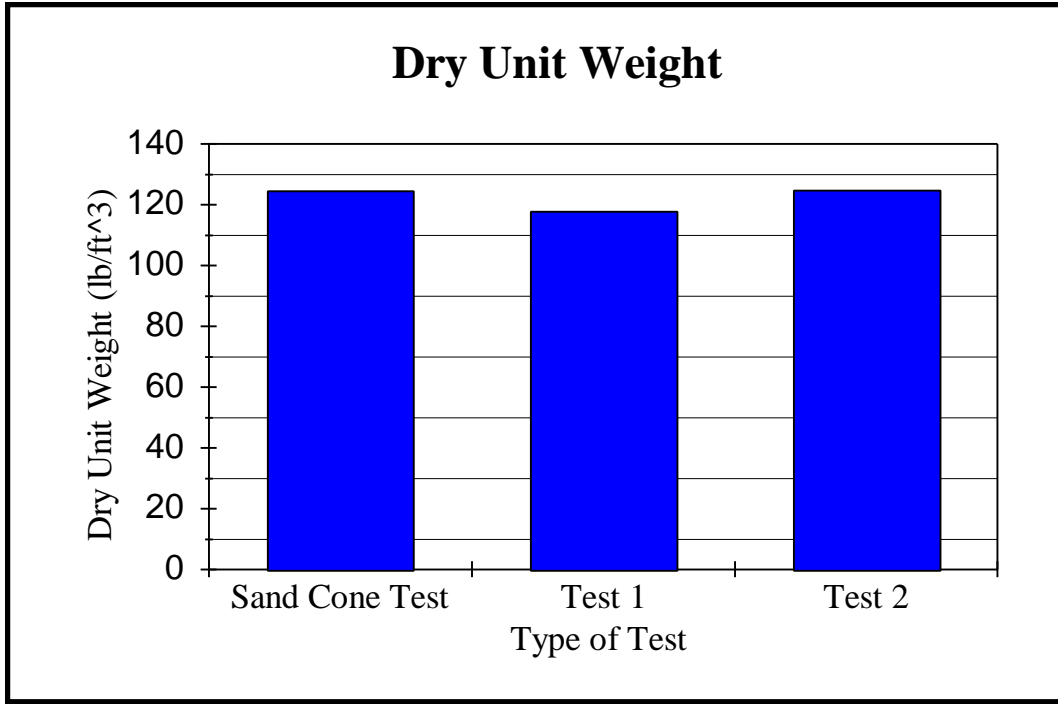


Figure 3: A Comparison of the Dry Unit Weights Obtained in each of the Three Tests.

Table 5: A Comparison of the Dry Unit Weights Obtained in each of the Three Tests.

Type of Test	Dry Unit Weight
Sand Cone	124.46
Nuclear--8 inches deep	117.77
Nuclear--4 inches deep	124.82

Results From the Sand Cone and Nuclear Density Tests

The results from the sand cone and nuclear density tests are located in figures one through five. For the sand cone test, we found the moist unit weight to be 136.8 lb/ft³, the moisture content to be 9.90%, and the dry unit weight to be 124.5 lb/ft³. For the nuclear density test at 8 inches, we found the moist unit weight to be 131.2 lb/ft³, the moisture content to be 11.4%, and the dry unit weight to be 117.8 lb/ft³. For the nuclear density test at 4 inches, we found the moist unit weight to be 137.3 lb/ft³, the moisture content to be 10.0%, and the dry unit weight to be 124.8 lb/ft³.

Determination of the Volume of the Hole

The volume of the hole we dug was calculated according to the equation:

$$V = \frac{W_{sand}}{\gamma_{(sand)}}$$

Where W_{sand} is the weight of the sand placed in the hole. After determining the volume of the hole and the moist weight of the soil in the hole, I was able to determine the moist unit weight of soil in the field.

Determination of the Moist Unit Weight of Soil in the Field

After the volume and moist weight of the soil in the hole was determined, it was easy to determine the moist unit weight of the soil in the hole. The moist unit weight was determined by the following equation:

$$g_{\text{moist}} = \frac{W_{\text{moist}}}{V_{\text{hole}}}$$

Where W_{moist} is the weight of moist soil from the hole and V_{hole} is the volume of the hole. The moist unit weight from the sand cone test was found to be 136.79 lb/ft³.

Determination of the Moisture Content of the Soil in the Field

After I determined the moist unit weight, I found the moisture content of the soil in the field. The moisture content is simply defined as:

$$w(\%) = \frac{W_w}{W_s}$$

Where W_w is the weight of water in a particular volume of soil and W_s is the weight of soil solids in that same volume of soil. The moisture content from the sand cone test was found to be 9.90%.

Determination of the Dry Unit Weight

After determining the moisture content of the soil specimen, I determined the dry unit weight using the following equation:

$$g = \frac{\epsilon_{\text{moist}}}{1 + \frac{w(\%)}{100}}$$

The dry unit weight of the soil specimen was found to be 124.46 lb/ft³.

Summary of Test Results

A good summary of the test results can be found in tables three, four, and five. These results are represented graphically in figures one, two, and three. The nuclear density test at a depth of 4 inches gave similar results to the results from the sand cone test.

IV. Discussion

What do the Results Mean?

The purpose in running the sand cone or nuclear density test is to determine the dry unit weight and moisture content of a soil that is being constructed. After determining the dry unit weight, that unit weight can be compared with the maximum Proctor dry unit weight and the relative compaction of the soil can be determined.

In-place moisture content. The in-place moisture content of the soil can have a large effect on the maximum dry unit weight a soil can obtain by standard compaction methods. If the soil's moisture content is too far on the wet or dry side of optimum, it will be difficult to obtain the relative compaction required for earth work.

The optimum moisture content is determined from the Proctor compaction test. Then, when working out in the field, a moisture content can be specified and the sand cone or nuclear density test can be used to determine the in-place moisture content.

Table 4 gave the moisture contents for the soils tested by the various methods. The moisture content at 8 inches deep may have been higher than the others because it had rained previous to the test. The rainwater may have flowed below the 4 inch test area, but not below the 8 inch test area.

In-place dry unit weight. The in-place dry unit weight of the soil is a measure of the relationship between mass and volume for the dry soil specimen. Relative compaction is defined as the ratio of the in-place dry unit weight to the maximum dry unit weight:

$$R(\%) = \frac{\gamma_{d(field)}}{\gamma_{d(max-lab)}} \times 100$$

Normally, a relative compaction of 90-95% will be specified for earth work. The maximum dry density is determined from the Proctor compaction test and the field dry unit weight is determined from the sand cone or nuclear density test.

If the soil is compacted on the wet side of optimum moisture content, it will have low permeability, low strength, and high ductility. But if the soil is compacted on the dry side of optimum, it will have the opposite properties. Table 4.2 in Das (1994) gives tentative requirements for relative compaction of all types of soils.

Table 5 gave the dry unit weights for the soils tested by the various methods. Once again, the dry unit weight at 8 inches deep may have been lower than the others because it had rained previous to the test. The rainwater may have caused a higher moisture content and, thus, a lower moist and dry unit weight.

A summary of the dry densities and moisture contents obtained by the sand cone and the nuclear density tests is located in table 6.

Table 6: A summary of the Dry Densities and Moisture Contents Obtained by the Sand Cone and the Nuclear Density Tests.

Type of Test	Moisture Content	Dry Unit Weight
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Sand Cone	9.90%	124.46
Nuclear--8 inches deep	11.40	117.77
Nuclear--4 inches deep	10.00	124.82

How Can the Soil be Classified?

Although the sand cone test and the nuclear density tests were not used to classify the soil, we can compare the soil's dry unit weight with the maximum Proctor dry unit weight of other soils. From Figure 4.5 in Das (1994), we can see the standard compaction curves for a sandy silt, a silty clay, a highly plastic clay, and a poorly graded sand. The approximate maximum dry unit weights for these soils are the following:

Table 5: Maximum Dry Densities for Various Types of Soils.

Type of Soil	Maximum Dry Density
Sandy Silt	119 lb/ft ³
Silty Clay	116 lb/ft ³
Highly Plastic Clay	111 lb/ft ³
Poorly Graded Sand	108 lb/ft ³

The dry unit weight for the soil we tested was found (by the sand cone method) to be 124.5 lb/ft³. This dry unit weight comes closest to that of a sandy silt.

What Were the Sources of Error?

The nuclear density method. The nuclear densometer measures the unit weight and moisture content of the soil by sending gamma rays and fast neutrons up through the soil. A detector on the nuclear densometer measures the number of gamma rays passing through the soil. The higher the number of gamma rays passing through the soil and detected by the densometer, the lower the density of the soil. Also, the fast neutrons are slowed down as they hit hydrogen atoms in water molecules. The water content is proportional to the number of slow neutrons which are counted by the detector. Three factors can cause errors to occur when performing a nuclear density test:

1. Hydrocarbons in the soil can artificially increase the measured water content since the densometer measures the number of hydrogen atoms in the soil.
2. Soils with a high salt content increase the water content of a soil.
3. Someone with experience must periodically test and calibrate the nuclear equipment.

These three factors may have resulted in the higher water content obtained by the nuclear test. Finally, since the soil tested by the nuclear test (at 8 inches below the surface) was deeper, the properties of the deeper soil may have been different than the soil at the surface.

The sand cone method. The following were possible sources of error in the sand cone method:

1. With all the weights we had to obtain, the measured weights of the soil, the molds, and the containers may have been slightly different than what was read because of inaccuracy in the scale.
2. The volume calculation for the soil removed from the ground may have been slightly inaccurate because some of the spaces may not have been filled with sand.
3. When digging the soil out of the ground, we may have dropped some of the in-place soil. This soil may not have made it to the bag. Thus, we may have obtained an inaccurate reading for the weight of the soil in the volume we dug out of the ground.
4. The soil may not have completely dried in the oven, resulting in a low moisture content.

The sand cone method is the traditional, proven method. But an inaccurate dry unit weight of sand or an inaccurate weight of soil can cause you to get a bogus unit weight or moisture content in the tested soil.

What Could be done to Reduce the Error?

The nuclear density method. To reduce the error in the nuclear density test, we could simply reverse the effects of the errors above by:

1. Insuring that there are few hydrocarbons in the soil by taking the soil to the laboratory and testing it for hydrocarbons before or after performing the nuclear density test.
2. Insuring that there is a low salt content in the soil.
3. Insuring that someone periodically tests and calibrates the nuclear equipment.
4. Remembering that the properties of the soil change with depth. Deeper soils may have a higher water content.

The sand cone method. To reduce the error in the sand cone test, we could:

1. Insure that the scale is accurate.
2. Insure that there are no areas in the hole which the sand cannot reach.
3. Insure that all the soil dug out of the ground reaches the bag or soil container.
4. Insure that the soil completely dries in the oven before measuring its dry weight.

V. Conclusion

From performing the sand cone and nuclear density tests, I have learned the proper method for determination of the moist density, dry density, and the moisture content for an in-place soil. Also, I have learned the causes of differences in the dry density and the moisture content obtained by the nuclear density and the sand cone tests.

The properties of the soil for each of the three tests are repeated below, in table 6. The nuclear density test may have resulted in a high moisture content count because the nuclear densometer may have counted the hydrocarbons in addition to the water molecules in the soil.

If the maximum Proctor dry density and the desired relative compaction of the soil are known, the dry unit weight of 124.46 pcf can be compared with the maximum lab dry density. From the max. lab dry density and the in-place dry density, the relative compaction of the soil can be determined. If the soil is not compacted enough, it must then be compacted more until the soil meets specifications.

Table 6: Results from the Sand Cone and Nuclear Density Tests.

Type of Test	Moisture Content	Dry Unit Weight
Sand Cone	9.90%	124.46 pcf
Nuclear--8 inches deep	11.40%	117.77 pcf
Nuclear--4 inches deep	10.00%	124.82 pcf

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.