FINAL REPORT

Examining the Variability of Granular Soil Permeability Testing Methodology across FDOT Districts

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EXECUTIVE STATEMENT

This report details the examination of the variability of the granular soil permeability testing methodology across FDOT Districts. Granular (cohesionless) soil permeability is an extremely important factor in the performance of rigid pavement systems in Florida. Lack of adequate drainability can result in excess pore water pressures developing which can ultimately produce pumping distress. For this reason, the FDOT embarked on an extensive broad based program to examine various facets of pavement drainage – in both the field and lab. However, the current Florida laboratory permeability test method (FM 1-T 215) often yields inconsistent results when various district laboratories conduct permeability tests on similar soil samples. This can create not only difficulties in the material approval/rejection process, but introduces uncertainty in the long-term serviceability of the pavement system. Therefore a review of the compaction and saturation procedures at three FDOT materials offices in Gainesville, Lake City, and Bartow was undertaken. A study of permeability results using the methods of the above test locations was conducted. In addition prototype flexible-wall and modified rigid-wall cylinder molds were created to study the potential reduction in piping between the apparatus wall and the sample. A parametric study was also initiated to better understand the overall effect that sample preparation and testing procedures can have on the resulting coefficient of permeability. After preliminary testing and analysis, a modified rigid-wall mold was shown to reduce the piping effect and limit the variability in the permeability testing methodology. Additional testing is required though in order to verify the results and to examine the variability in the testing methodology. Recommendations for additional experimentation and improvements to the permeameter setup are provided. A proposal for more consistent sample preparation and testing procedures statewide has also been included.

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CHAPTER 1
INTRODUCTION

The determination of the drainability of the base material for use in a rigid pavement system is of primary concern to the civil engineer. The coefficient of permeability of a soil, along with other geotechnical parameters, gives an insight into the long-term performance of the material. Therefore the ability to accurately and reliably test for permeability is needed in both the laboratory and the field.

Presently the Florida Department of Transportation (FDOT) employs the standards set forth in the Florida Method for (constant head) permeability of granular soils (FM 1-T 215) for laboratory testing. This standard is identical to the testing methods of the American Society for Testing and Materials (ASTM D 2434-68) and the American Association of State Highway and Transportation Officials (AASHTO T 215-70).

These methods employ a rigid-wall, or fixed-wall, permeameter. Assuming the standard preparation and procedure is followed statewide, similar results would be expected from one test location to the other, given a standard sample. Unfortunately, this does not seem to be the case. According to Daniel, et al., fixed-wall cells are subject to a number of drawbacks, the most detrimental being imperfect contact between the wall of the cell and the sample, resulting in sidewall leakage during the test. As a result, the corresponding permeability values tend to be high. This of course would fall on the unconservative side of the design envelope, since the actual in-place permeability would probably be lower than tested. In fact, independent tests performed at the University of Texas concerning this matter suggest that the permeability values can vary by at least one order of magnitude due to sidewall leakage. Others cited disadvantages of this type of permeameter include: incomplete saturation due to lack of backpressure, inability to determine the amount of swelling or shrinkage, and lack of control of stresses acting on the soil.

1.1 Review of Current Florida Method (FM 1-T 215)

This section provides an overview of the Florida Method and details the instructions outlined for sample preparation and the procedures for obtaining the coefficient of permeability. A copy of the standard testing methodology is given for reference in Appendix A.

1.1.1 Sample Preparation

This section describes the procedures for sample preparation as outlined in the Florida Method. The standard recommends minimum cylinder dimensions for the permeameter based on the grain size of the soil. The sub-sections detail the procedures and recommendations for compaction, saturation and air evacuation.

1.1.1.1 Compaction

The standard states that the soil can be placed in the permeameter to reach a minimum density (0 % relative density), maximum density (100 % relative density), or an intermediate density (between 0 % and 100 % relative density) based on the desired testing conditions. For a maximum density to be reached the standard states that the sample must be compacted by placing uniform layers of soil in succession and using one of the recommended methods of compaction. The recommended methods of compaction may be by means of a vibrating tamper, sliding weight tamper, or by other methods as listed in the standard. The standard requires that the method used must produce a uniform sample without segregation of particle sizes.

1.1.1.2 Saturation and Air Evacuation Methods

The current method recommends that the specimen be evacuated of air using a vacuum pump or suitable aspirator. It is stated that the sample be evacuated under a minimum of 500 mm (20 in) mercury for fifteen minutes to remove the air adhering to the soil particles and from the voids. The evacuation must be followed by a slow saturation of the sample from the bottom upward under a full vacuum in order to free any remaining air in the specimen. A typical air evacuation and saturation setup is provided in Figure 1.1. The standard also states that a continued saturation of the specimen can be maintained more adequately by the use of deaired water or water maintained at an in-flow temperature sufficiently high to cause a decreasing temperature gradient in the specimen during the test.

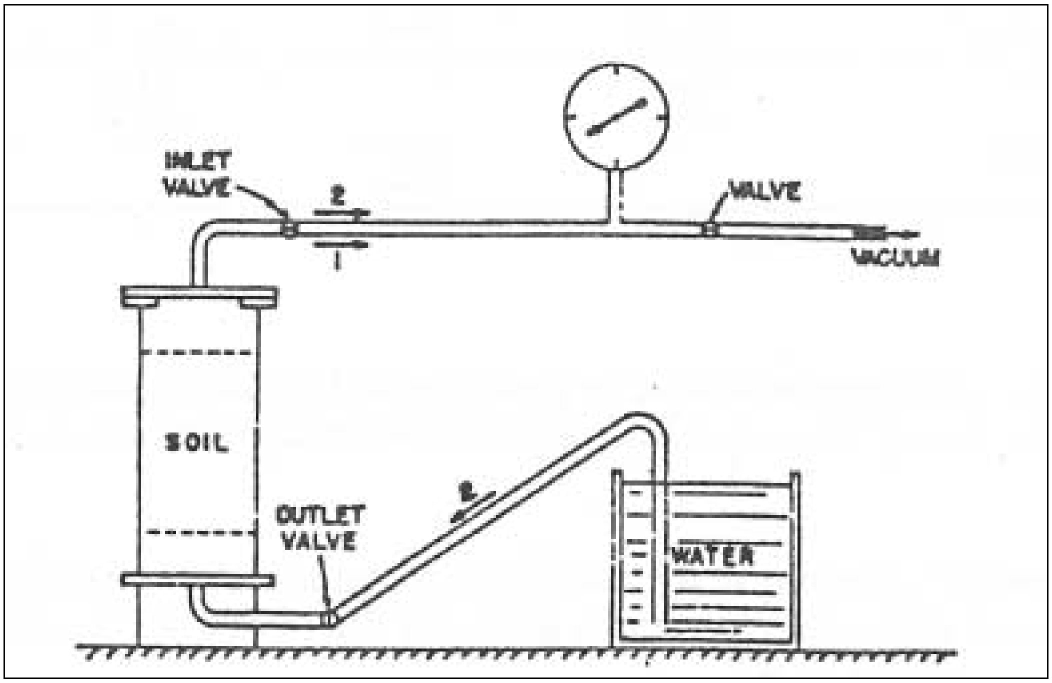


Figure 1.1. Device for Evacuating and Saturating Specimen

1.1.2 Permeability Testing and Calculations

This section describes the procedures for permeability testing and the calculations required for obtaining the coefficient of permeability. The equipment setup and requirements for the recommended constant head permeameter are also given in this section for reference purposes.

The standard recommends that a permeameter with manometer outlets installed be used in order to measure the loss of head across the length of the sample. A typical permeameter setup is given in Figure 1.2. Porous screens or disks must be used on the top and bottom of the sample. The top porous stone or disk should have a spring or weight attached in order to apply a light pressure of 22 to 45 N (5 to 10 lbf) once the top plate of the permeameter is attached. This is done to maintain the density of the sample during the test.

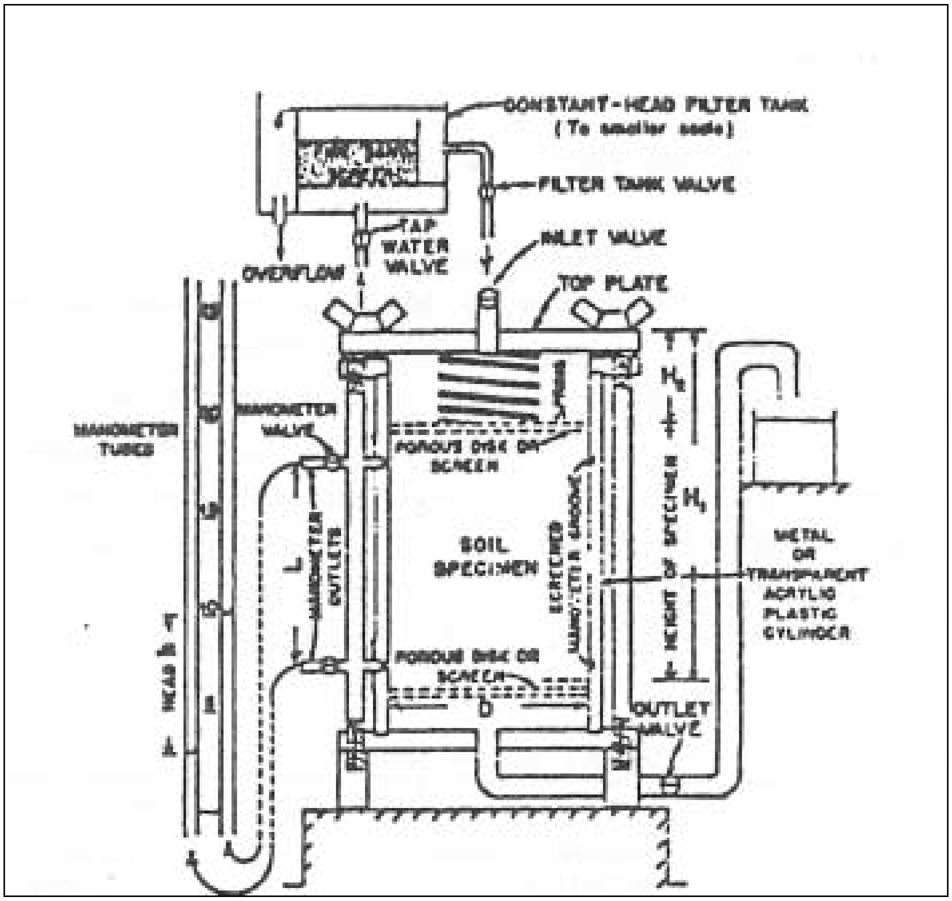


Figure 1.2. Constant Head Permeameter

<u>1.1.2.1 Testing Procedures</u>

The Florida Method states that after the sample has been saturated and the air has been removed, the top valve of the permeameter can be opened to induce flow through the sample. Testing conditions require that measurements of the quantity of flow be delayed until a stable head condition is reached and a steady-state flow has begun. Once these conditions have been satisfied, the experimenter measures and records the time, t, distance between manometers, L, difference in head on manometers, h, quantity of flow, Q, and water temperature, T. The standard recommends that repeat trials be made at increasing heads (increments of 5 mm) in order to accurately establish the region of laminar flow with velocity, v, (v = Q/At) directly proportional to the hydraulic gradient, i (i = hL). The head can be increased until a departure from the linear region of laminar flow becomes apparent. The flow can be carried into turbulent conditions if it is significant to understand permeability in this region for field conditions.

1.1.2.2 Calculations

The standard states that the coefficient of permeability, k, be calculated as follows:

$$k = \frac{QL}{Ath}, \qquad \textbf{Equation 1.1}$$

Where k = coefficient of permeability,

Q = quantity of water discharged,

L = distance between manometers,

A = cross-sectional area of the specimen,

t = total time of discharge, and

h = difference in head on manometers (FM 1-T 215).

The permeability is then to be corrected to a value found at a temperature of 20° C (68° F) by multiplying k by the ratio of the viscosity of water at 20° C (68° F). It is important to note that the Florida Method also states observations and data from the grain size analysis, classification, maximum particle size, and percentage of any oversized material not used be included with the results of the test. Other soil properties such as dry density, void ratio, relative density as placed, and maximum and minimum densities should also be included. Test curves plotting the velocity, Q/At, versus the hydraulic gradient, h/L, covering the ranges of soil identifications and of relative densities can also be made for evaluation purposes.

1.2 Purpose and Scope

As with other geotechnical laboratory tests, variations can occur in the preparation of the sample and the procedures that are followed. The combination of these disparities along with differences in the testing equipment used for the experimental work can affect the results found in the laboratory. The FDOT has found that variations have been noted in the determination of permeability for granular soils. The inability to accurately and repeatability measure this soil property can lead to incorrect assessments of the drainage ability of a particular material.

1.2.1 Purpose

The purpose of the work performed in this report was to investigate and examine the variability of granular soil permeability testing methodology across FDOT districts. Once the details of the variability in the methodology have been documented, an evaluation of the parameters that can influence the determination of the coefficient of permeability can be made. Based on the information gleaned from this study, recommendations on the standards used throughout the state can be made that will limit the variability in permeability values.

1.2.2 Scope

The scope of the research that was performed as part of this investigation involved:

- The examination of the variability of current FDOT laboratory procedures;
- The design and construction of prototype permeameters;
- A comparison of the prototype permeameters and the current LBR mold;
- A parametric evaluation of sample preparation and permeability testing;
- Recommendations for limiting the variability in permeability testing.

Chapter 2 of this report presents an overview of the evaluation of the sample preparation and testing methodology found in various FDOT districts. Chapter 3 details the design and construction of the prototype permeameters, as well as the procedures for permeability testing using these devices. Chapter 4 presents the outline of the comparative study and parametric evaluation that was conducted based on typical Florida soils. A summary of the results and analysis of the examinations performed is provided in Chapter 5. Chapter 6 presents the conclusions and recommendations that can be drawn from the information gained in this report.

CHAPTER 2
CURRENT FDOT LABORATORY PROCEDURES

This chapter examines the variations of the current procedures used at the FDOT testing facilities for sample preparation and permeability testing.

2.1 Sample Preparation

The following sub-sections provide a glance of the typical soil compaction equipment setup of the FDOT as well as the air evacuation and saturation methods employed for permeability specimen preparation.

2.1.1 Compaction Equipment Setup

The purpose of this evaluation was to examine the effect that a non-rigid base will have on the compactive effort transferred to a soil sample. Non-uniformity of compaction equipment was considered as a possible influence on density results. The test was performed by comparing the deformation of compressed American Society for Testing and Materials (ASTM) lead calibration cylinders from a manual compactor against lead cylinders from a mechanical compactor. This information should be particularly useful in addressing discrepancies between permeability values of similar soil samples.

The testing was performed at the FDOT State Materials Office in Gainesville. The lengths of five calibration lead cylinders were measured using a micrometer accurate to the nearest 0.0001 in. These cylinders were then placed in the Lead Deformation Apparatus Assembly (LDAA) as per ASTM D2168-90. A Modified Proctor manual hammer was used to strike the LDAA once for each of the five cylinders. An average deformation value of the five cylinders was obtained by summing the differences in length (final length minus initial length) and dividing by five. In order for the mean to be accepted as a representative value of compactive effort, all five deformations must fall within two percent of the mean. In the event that five trials did not provide sufficient data, additional cylinders were compacted until five such deformations were obtained (ASTM 2168-90).

Next, each mechanical compactor was turned on for no less than 25 blows and was allowed to strike a granular material in its respective mold. Upon completion, the LDAA was placed on the metal base of the compactor such that the foot of the compactor could contact the striking pin on the deformation assembly at or near the center of the foot. The compactor was turned on for exactly one blow and the average deformation was calculated as previously mentioned. All four Modified Proctor compactors were calibrated prior to testing.

A similar procedure was then followed for the calibration of the Standard Proctor mechanical compactors. The average deformation from the manual compactor was obtained, and the mechanical compactors were allowed to run for no less than 25 blows. Following completion of the blow count, the LDAA was set on the metal base plate and turned on for one blow. The average deformation value was obtained in a similar manner as stated previously, ensuring five representative data samples fell within two percent of the arithmetic mean.

According to ASTM a compactor is calibrated if the average deformation value from the mechanical compactor is within 2 % of the average deformation value from the manual compactor. The data was collected and the average deformation values for the manual compactors along with a range set at 98 % and 102 % of the deformation value was first created. If the average deformation for a given compactor fell within this range, the unit is then considered calibrated.

Of the six mechanical compactors tested, only two, one standard and one modified, fell within the two-percent limit. Closer inspection of the compactors that were outside the calibration specifications revealed that their foundations were set on monolithic concrete blocks. The compactors were attached by bolting one or two sheets of plywood with varying thickness to the block, then bolting the compactor to the plywood.

Table 2.1 contains the type of compactor, calibration results, and information pertaining to the thickness of the plywood foundation for each of the compactors.

Table 2.1. Summary of Compaction Study

Proctor Test	Calibration Limits	Mounting
Modified	Passed	2 sheets of 1-inch thick plywood
Modified	Failed	2 sheets of 1-inch thick plywood
Modified	Failed	1 sheet of 3/4-inch thick plywood
Modified	Failed	1 sheet of 1-inch thick plywood
Standard	Passed	1 sheet of 1-inch thick plywood
Standard	Failed	1 sheet of 1/2-inch thick plywood

2.1.2 Saturation and Air Evacuation Methods

This section details the saturation and air evacuation techniques and procedures for the three labs evaluated as part of this investigation.

2.1.2.1 Lake City

The sample is set in the permeameter on a dry porous stone covered by one sheet of filter paper. On top of the soil is placed another dry porous stone without a spring. The top of the mold is filled with water and the entire apparatus is sealed with O-rings. The constant head tank is attached to the top of the apparatus and allowed to run with the top valve open until water comes out of the valve. The valve is then closed and water is allowed to flow through the sample until a steady-state flow develops. The permeability test is then run after steady-state flow is initiated.

2.1.2.2 Bartow

The sample is set in the permeameter on a porous stone that has been soaking in water. Another wet porous stone is placed on top of the soil, as well as a spring to keep the stone firmly in contact with the soil. The top of the mold is filled with water up to ½-inch below the top of the mold and the top is then attached to the apparatus. The entire apparatus is sealed with lubricant and thick O-rings to prevent leaks.

A vacuum hose is attached to the bottom valve of the apparatus and a vacuum of 10 inches mercury is applied for 15 minutes. If no flow results after this time interval, the vacuum is increased to 30 inches mercury until flow initiates. After flow is achieved, the constant head tank is attached to the top of the apparatus and allowed to run until two volume readings spaced at 30 second intervals yield identical results. At this point, the permeability test is run.

2.1.2.3 Gainesville

The specimen is placed in a bath of standing water. The compaction base plate has holes in it that allow the water to saturate the sample by capillary rise. The sample is soaked for a minimum of 24 hours and then removed from the bath. The sample is then placed in a permeameter in which a wet porous stone and filter paper has been situated at the bottom. A top metal disk with holes in it is placed on the top of the sample and a plastic cylinder is inserted to secure the sample height. The top plate of the permeameter is attached with gaskets and sealant to prevent leakage. The constant head tank is attached to the top of the apparatus and allowed to run with the top valve open until water comes out of the valve. The valve is then closed and water is allowed to flow through the sample until a steady-state flow develops. The permeability test is then run after steady-state flow is initiated. It should also be noted that some samples are saturated by skipping the overnight saturation method and directly brought to the permeameter device. Once sealed, a flow is initiated through the top of the apparatus and readings are taken after a steady flow has been achieved for at least 30 minutes.

The effects and consequences for the variability in the evacuation and saturation methods used at the three laboratories studied will be discussed later in this report in Chapter 5.

2.2 Permeability Testing and Calculations

This section provides a brief overview of the procedures used for conducting the permeability test as well the calculations for the determination of the coefficient of permeability.

2.2.1 Testing Procedures

The permeability test for each of the three districts is conducted once a steady-state flow has been achieved. The equipment setup for the permeability test at the FDOT State Materials Lab is given in Figure 2.1 for reference.

Figure 2.1. Current FDOT Permeability Testing Setup

The equipment used at the three facilities can be considered comparable. The permeameters and equipment setup differed slightly in their use of o-rings or gaskets, types of inlet and outlet valves, age, types of porous stones or screens, use of springs or weights, and the device for maintaining a constant head. There were also slight variations in the collection of the discharge from the permeability test. The length of time for testing and the interval between discharge readings for each of the three laboratories differed based on the technician conducting the experiment.

2.2.2 Calculations

The three facilities use the same basic procedure for calculating the coefficient of permeability. The permeability value at the temperature of the water during the test is determined by the following equation:

$$K_T = \frac{QL}{thA}, \qquad \textbf{Equation 2.1}$$

Where K_T = coefficient of permeability at Temperature T,

h = total head,

Q = discharge,

L = length of the sample,

t = time, and

A = cross-sectional area.

The value is then corrected to that of the permeability at 20° C (68° F) by the following equation:

$$K_{20^\circ} = \left(\frac{\mu_T}{\mu_{20^\circ}}\right) K_T, \qquad \textbf{Equation 2.2}$$

Where K_{20° = coefficient of permeability at 20° C,

μ_T = viscosity of water at temperature T,

μ_{20° = viscosity of water at 20° C, and

K_T = coefficient of permeability at Temperature T.

The effects and consequences for the variability in the testing procedures and calculation of the permeability value at the three laboratories studied will be discussed later in this report in Chapter 5.

CHAPTER 3
PROTOTYPE PERMEABILITY MOLD DESIGNS

This chapter describes the designs of the prototype permeability molds used for experimental work in this investigation. The prototypes were constructed to allow the study of the sidewall leakage theory of the current fixed-wall permeameters. An outline of the procedures for assembly and use of the prototype molds are also provided if necessary.

3.1 Flexible-Wall Prototypes

This section describes the prototype flexible-wall permeameters that were designed in order to aid in the evaluation of the variability found in the current methodology for testing soil permeability.

3.1.1 Prototype 1

The permeameter will consist of a split mold with an inside diameter slightly greater than the standard six-inch Modified Proctor mold and a height of precisely 4.58 inches. However, when assembled for compaction, the cell will provide a nominal inside diameter of 6 inches and protect any grooves or holes in the mold from clogging. The design is given in Figure 3.1. The procedure for assembly and use of this prototype is given later in this section. Use of the Prototype 1 permeameter varies from the current permeability testing methodology in the preparation of the sample. Once the sample is prepared in the new device, the normal constant-head permeability test can be run.

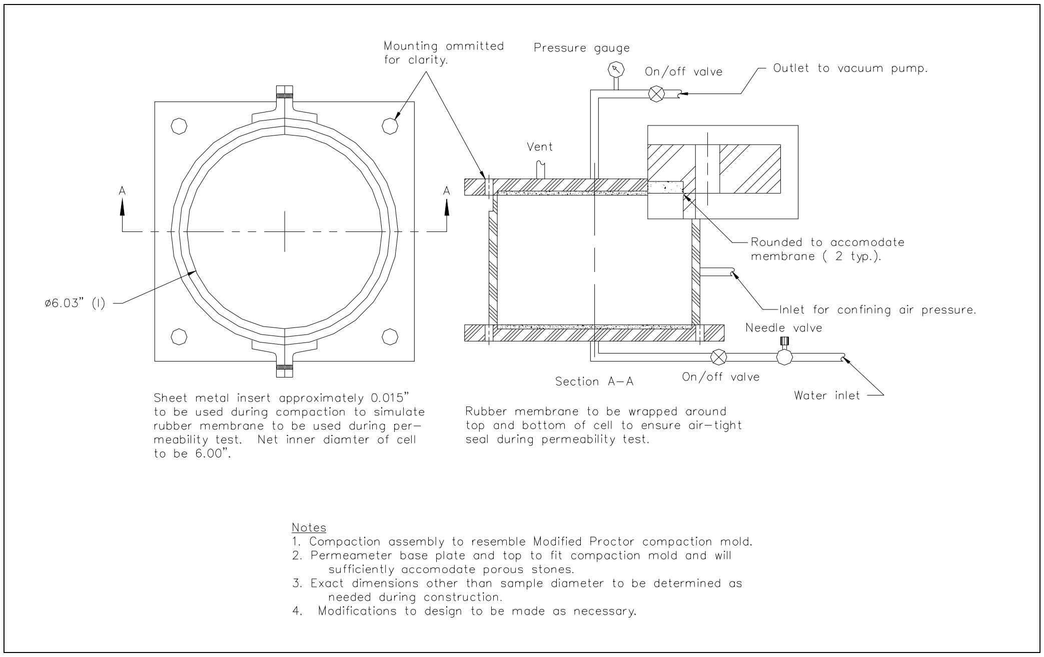


Figure 3.1. Flexible-Wall Prototype 1 Design

The sample will be compacted according to the standard method, i.e., sliding weight tamper. Upon completion, the top portion of the mold will be removed and the top of the sample screeded off flush with the top of the cylinder, as normally performed. The mold will then be split, at which time the metal insert should autonomously separate itself from the sample. Once the intact sample is successfully removed, the mold will be reassembled, this time with the rubber membrane wrapped over the top and bottom of the mold wall and clamped to the outside. Assuring an airtight seal at the top and bottom and along the openings in the sides, a vacuum will be applied to completely contract the membrane for sample insertion. The vacuum will then be released and the mold will be reassembled. This concept has the added advantage of reduced sidewall leakage without the need for an additional flexible-wall permeameter cell. The top and base of the mold are milled and ported to accommodate the insertion of porous stones. The top and bottom also have inlet and outlet valves placed for water flow through the soil sample. Slight air pressure will be applied to the sample sides via openings and grooves in the walls of the mold. The grooves will provide even distribution of the air pressure, which will maintain near-perfect contact between the membrane and the sample. The confining pressure, hydraulic gradient, vacuum intensity and other pertinent information will be determined once testing begins. Initially, one mold for compaction and testing was thought to be less costly and less time consuming. It was later realized that two separate molds were less complicated as far as ease of fabrication and procedure. These factors outweighed the cost of an additional mold. Photographs of the Prototype 1 flexible-wall mold are shown in Figures 3.2 through 3.5.

Figure 3.2. Prototype 1 with sintered steel porous stone installed

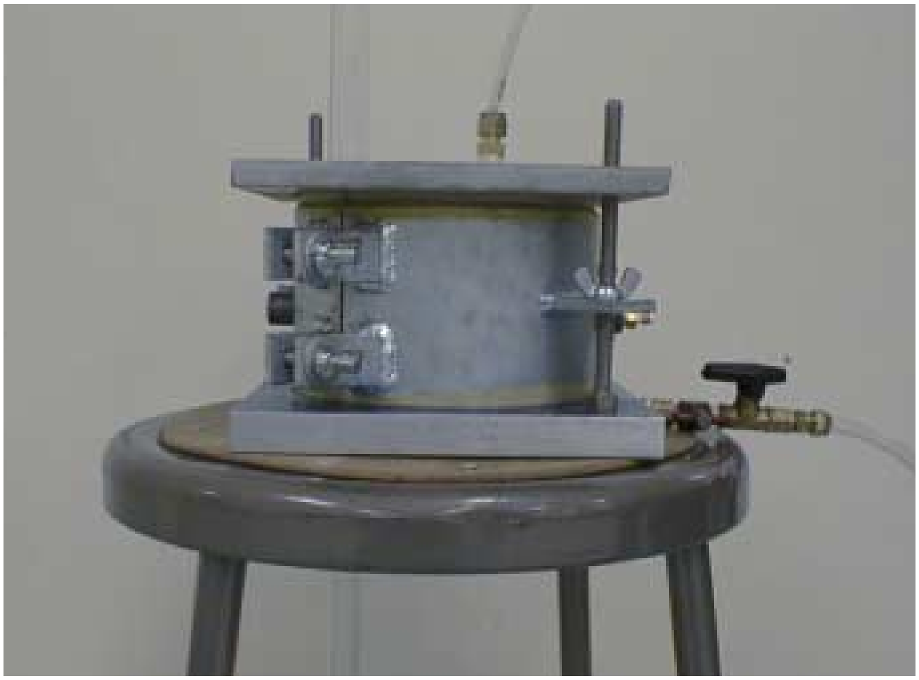


Figure 3.3. Assembled Prototype 1

Figure 3.4. Side view of Prototype 1 with flexible membrane attached

Figure 3.5. Prototype 1 with sintered steel porous stone removed

3.1.2 Prototype 2

A second prototype was constructed in order to test the possible use of an easier and more efficient design of a flexible-wall permeameter. Photographs of Prototype 2 are shown in Figures 3.6, 3.7, and 3.8. The assembly procedure is provided later in this section. Use of the Prototype 2 permeameter varies from the current permeability testing methodology in the preparation of the sample. Once the sample is prepared in the new device, the normal constant-head permeability test can be run.

Figure 3.6. Prototype 2 mold assembly and permeability testing housing

Figure 3.7. Prototype 2 membrane stretcher

Figure 3.8. Prototype 2 assembled permeability setup

The following is the procedure that has been outlined for assembling and preparing a specimen in the Prototype 2 flexible wall permeameter:

1. Assemble the compacting mold with the .012” plastic insert lining the inner wall.
2. Affix to the standard modified proctor compacting base.
3. Add the collar and compact the sample using the mechanical compactor.
4. Place a gasket on the permeameter base.
5. Center sintered steel porous disk on top of the gasket.
6. Move the compacting mold with the sample inside to the permeameter base on top of the porous disk.

7. Unbolt the compacting mold into semicircular halves and remove the plastic insert leaving the sample on the base. (Shown in Figure 3.6 without sample)
8. Place the 6” diameter flexible membrane along the inner wall of the permeameter folding the ends over the top and bottom edges of the cylinder. (Shown in Figure 3.7)
9. Fasten vacuum pump to the port on the outer wall of the permeameter and draw a vacuum until the membrane is flush with the inner wall. Straighten the membrane as necessary.
10. Slide cylinder with membrane in place over the sample.
11. Place porous stone on top of the sample and a gasket on top of the permeameter wall. Place the cover on the permeameter and fasten it to the base. (Shown in Figure 3.8)
12. Apply a confining pressure (magnitude to be determined) to the sample.
13. Saturate the sample.
14. Run the standard FDOT permeability test.

3.2 Modified Rigid-Wall Prototype

This section describes the design of a rigid-wall permeameter for use in the evaluation of the variability found in the current methodology for testing soil permeability. A modified rigid-wall mold was designed in order to test the reduction of sidewall leakage with the continued use of the current size Limerock Bearing Ratio (LBR) compaction molds. This would allow the use of the current sample preparation procedures currently employed.

3.2.1 Prototype 3

Another approach to reduce potential piping is through the use of seepage rings. Four 0.08" x 0.08" grooves are evenly spaced throughout a standard FDOT LBR compaction mold as shown in the cross-sections provided in Figure 3.9. Ideally, when a sample is compacted using the Modified Procter approach, the grooves will fill with soil creating barriers intended to interrupt piping, as demonstrated in Figure 3.10. A grooved LBR compaction mold was fabricated and is pictured in Figure 3.11.

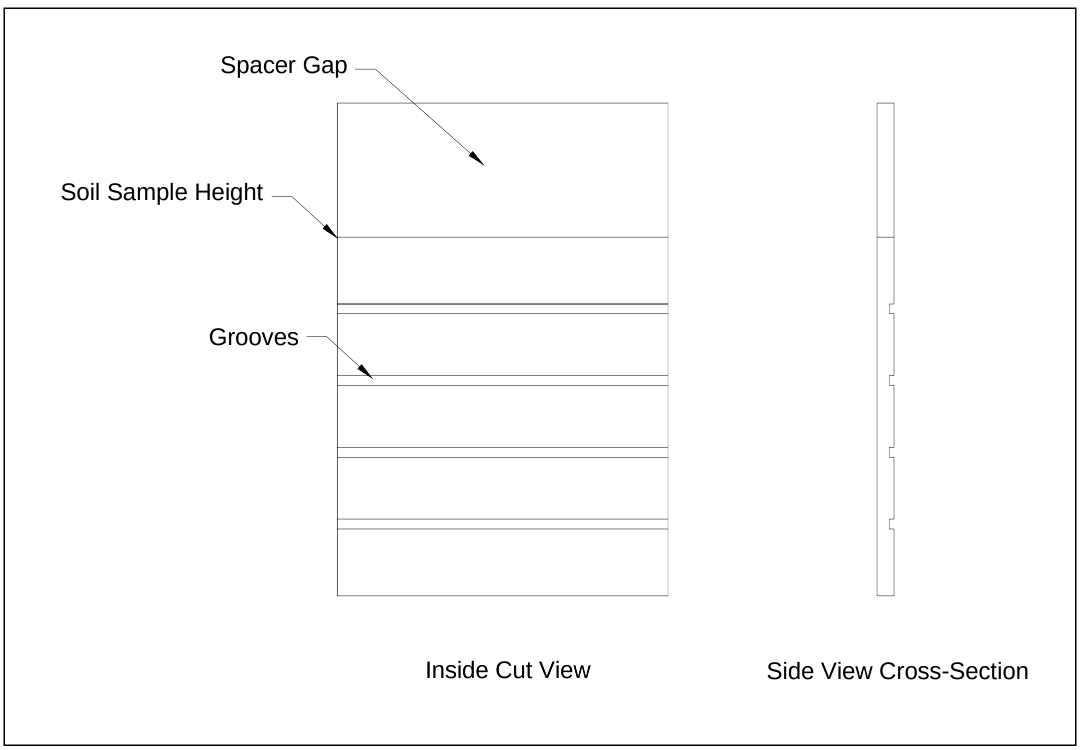


Figure 3.9. Prototype 3 Conceptual Design

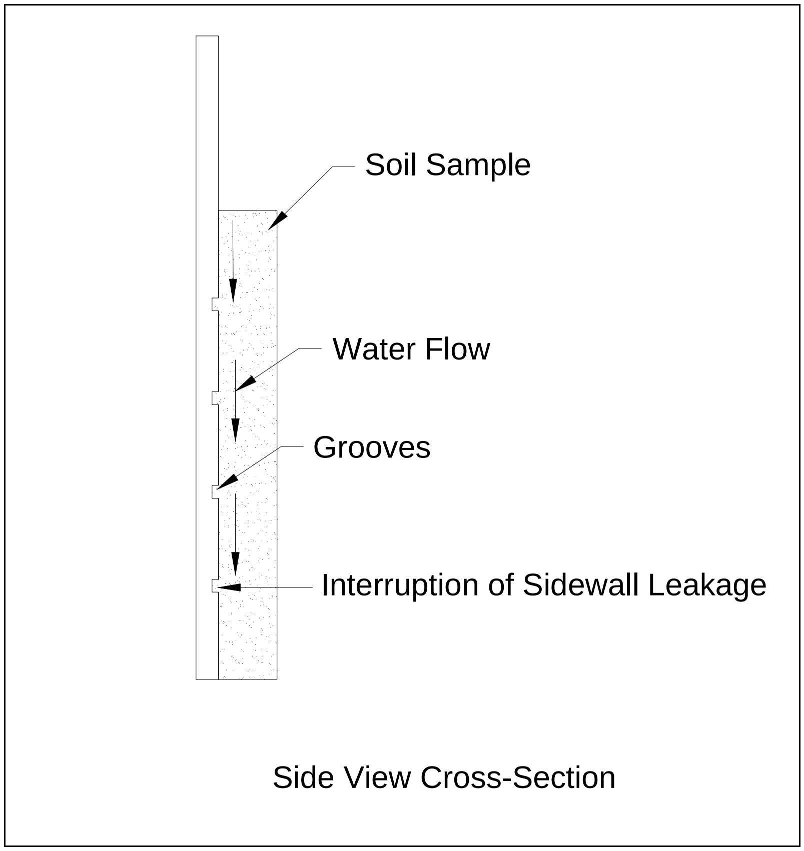


Figure 3.10. Prototype 3 Conceptual Sidewall Leakage Interruption

Figure 3.11. Prototype 3 - Modified Rigid-Wall Grooved Mold

CHAPTER 4
OUTLINE OF PERMEABILITY VARIABILITY STUDY

This chapter details the soil material used and the background of the investigation performed on the variability of permeability testing methodology. A testing scenario was established in order to compare the results of permeability testing using the current LBR cylinder mold to the results seen using the prototype molds. In addition an examination of the effects of altering certain sample preparation parameters was initiated to see their overall effect on permeability values.

4.1 Flexible-Wall Prototypes

The flexible-wall permeameters described in Chapter 3 were used to run tests on soil samples provided by the FDOT. A comparative study was initiated in order to examine the effect of using flexible-wall permeameters on the overall permeability values reached using the current Florida Method as well as to verify the feasibility, repeatability, and reliability of the new designs. The tests were run on soil material that was collected from the State Materials Office in Gainesville, FL. The sub-sections below detail the types of soil material and testing that was conducted for use in each study.

4.1.1 Comparative Study using Prototype 1

The study conducted using Prototype 1 consisted of performing permeability tests on A-2-4 soil material and comparing the results with the values reached when using the current LBR mold. The samples were prepared using the procedures detailed in Chapter 3 and testing was conducted using the instructions outlined in the Florida Method. A testing scenario consisting of five trials with ten readings each was set as the determinant for testing Prototype 1. The results and issues related with this comparative study are provided in Chapter 5.

4.1.2 Comparative Study using Prototype 2

The study conducted using Prototype 2 consisted of performing permeability tests on A-2-4 soil material and comparing the results with the values reached when using the current LBR mold. The samples were prepared using the procedures detailed in Chapter 3 and testing was conducted using the instructions outlined in the Florida Method. A testing scenario consisting of five trials with ten readings each was set as the determinant for testing Prototype 2. The results and issues related with this comparative study are provided in Chapter 5.

4.2 Modified Rigid-Wall Prototype

The modified rigid-wall permeameter described in Chapter 3 was used to run tests on soil samples provided by the FDOT. A comparative study was initiated in order to examine the effect of using a modified rigid-wall permeameter on the overall permeability values reached using the current Florida Method. The tests were run on soil material that was collected from the State Materials Office in Gainesville, FL. Soil testing was done on the material in order to verify the soil characteristics provided. A parametric study was also conceived in order to determine the effect of sample preparation techniques on the resulting permeability values. The sub-sections below detail the types of material and testing conducted for use in each study.

4.2.1 Comparative Study using Prototype 3

A comparative study was initiated to determine the permeability values reached when using the modified rigid-wall mold and the standard LBR mold using A-2-4 and A-3 soil samples (material used on I-4) from the FDOT State Materials Office in Gainesville, FL. The sample properties are provided in Table 4.1. Samples were also prepared using the saturation procedures for each of the FDOT districts detailed in Chapter 2 and testing was conducted using the instructions outlined in the Florida Method. A testing scenario consisting of ten trials with five readings each was set as the determinant for this comparison. The results and issues related with this comparative study are provided in Chapter 5.

Table 4.1. I-4 Soil Sample Properties

Sample	STA. From	Mod. Proctor (pcf)	Moisture (%)	LL / PI	AASHTO	# 40	# 60	# 200
19518	843+09	111.2	11.7	N.P.	A-3	98	83	8
19519	848+00	110.0	11.0	N.P.	A-2-4	98	83	16
19522	851+38	112.0	10.6	N.P.	A-3	98	76	7
19523	848+00	112.3	11.4	N.P.	A-3	99	84	9
19530	1206+95	114.0	11.4	N.P.	A-3	95	78	7
19531	1219+43	111.7	11.0	N.P.	A-3	95	78	7
19533	1187+00	110.0	13.0	N.P.	A-3	95	88	7
19534	1206+62	112.0	11.0	N.P.	A-2-4	97	86	12
19536	1219+17	111.0	11.0	N.P.	A-3	97	82	8

4.2.2 Parametric Study using Prototype 3

A study of the effect of altering the preparation procedures was undertaken in order to better understand the influence that each parameter can have on the coefficient of permeability. The study was initiated to determine the permeability values reached when using the modified rigid-wall mold and the standard LBR mold using A-2-4 and A-3 soil samples (different from the I-4 soil) from the FDOT State Materials Office in Gainesville, FL. The parameters used in the permeability parametric study were determined by combining the variations seen in the sample preparation procedures across the FDOT districts. These include the saturation methodology, air evacuation technique, and top porous material employed during preparation for testing. Table 4.2 demonstrates how the parameters were determined in order to evaluate all the possible combinations. Table 4.3 outlines the test codes and their respective saturation method, vacuum technique, and top porous material.

Table 4.2. Determination of the Sample Preparation Parameters

		Test Code							
		A	B	C	D	E	F	G	H
Saturation	30 Min	x	x	x	x				
	Overnight					x	x	x	x
Vacuum	No	x	x			x	x		
	Yes			x	x			x	x
Screen	Yes	x		x		x		x	
Disk	Yes		x		x		x		x

Table 4.3. Types of Sample Preparation Techniques

Test Code	Type of Sample Preparation
A	30 Minute Saturation Method, No Vacuum, and Top Steel Disk
B	30 Minute Saturation Method, No Vacuum, and Top Porous Stone
C	30 Minute Saturation Method, Vacuum, and Top Steel Disk
D	30 Minute Saturation Method, Vacuum, and Top Porous Stone
E	Overnight Saturation Method, No Vacuum, and Top Steel Disk
F	Overnight Saturation Method, No Vacuum, and Top Porous Stone
G	Overnight Saturation Method, Vacuum, and Top Steel Disk
H	Overnight Saturation Method, Vacuum, and Top Porous Stone

The compaction equipment setup for the study is shown in Figure 4.1. A Rainhardt Automatic Compactor was used for compaction purposes. The compactor was set on a monolithic concrete block with a sheet of plywood attached as a dampener. The device was calibrated by ASTM standards as stated in Chapter 2.

Figure 4.1. Rainhardt Automatic Compaction Machine

Figure 4.2. University of Florida Permeability Test Setup

The permeability test setup is provided in Figure 4.2. Two identical permeameters were purchased for use in this study. LBR molds were also purchased in order to limit the variability in the equipment used as part of this investigation.

The soil properties of the material provided by the FDOT are summarized in Tables 4.3 and 4.4. The FDOT data sheets for this material are provided in Appendix B. The University of Florida conducted an independent evaluation of the material in order to verify the soil properties. Sieve analyses were performed on the two soil samples using

U.S. standard sieves. The procedure followed ASTM D422. The results of the grain size analyses are presented in Figure 4.3 and 4.4.

Table 4.3. FDOT Soil Properties Summary of Sample #1

Material Description	Sand	
Intended Use	Embankment	
Maximum Density	110	pcf
Optimal Moisture Content	10%	
LBR	28.0	
Liquid Limit	N.P.	
Plastic Index	N.P.	
Pass #40	94%	
Pass #60	76%	
Pass #200	12%	
Average Permeability	3.594E-04	cm/s
T-180 LBR Classification		
AASHTO Classification - A-2-4		

Table 4.4. FDOT Soil Properties Summary of Sample #2

Material Description	Sand	
Intended Use	Embankment	
Maximum Density	113	pcf
Optimal Moisture Content	12%	
LBR	32.0	
Liquid Limit	N.P.	
Plastic Index	N.P.	
Pass #40	83%	
Pass #60	43%	
Pass #200	6%	
Average Permeability	6.228E-04	cm/s
T-180 LBR Classification		
AASHTO Classification - A-3		

Figure 4.3. Grain Size Distribution of Sample #1

Figure 4.4. Grain Size Distribution of Sample #2

The parametric study will yield a comparison between the permeability values reached when using the Prototype 3 mold and the current LBR mold employing the sample preparation techniques described by test codes A-H. A testing scenario consisting of five trials with five readings for each test code was set as the determinant for this comparison. The results and issues related with this study are provided in Chapter 5.

CHAPTER 5
RESULTS AND ANALYSIS OF VARIABILITY STUDY

This chapter presents the summary of the results and analysis of the examination of permeability variability using the comparative study and parametric evaluation conducted on typical Florida soils described in the preceding chapter.

5.1 Flexible-Wall Prototypes

This section provides the comparative analysis of Prototypes 1 and 2 versus the current LBR mold. A discussion of the reliability and feasibility of the prototypes is also included.

5.1.1 Comparative Analysis of Prototype 1 versus Current LBR Mold

The permeability results from the successful tests are summarized in Table 5.1. A graphical representation of the results is provided in Figure 5.1. Lower permeability values resulted when using Prototype 1, implying that piping had been reduced.

Table 5.1. Summary of Prototype 1 vs. Current LBR Permeability Results

	Prototype 1		Current LBR	
Trial	k (cm/s)	Dry Density (pcf)	k (cm/s)	Dry Density (pcf)
1	5.59E-03	106.9	5.94E-03	107.1
2	4.18E-03	107.4	6.16E-03	107.5
3	4.53E-03	107.2	6.38E-03	108.3
4	4.57E-03	108.3	6.20E-03	107.6
5	4.59E-03	108.5	6.68E-03	108.1
Avg.	4.69E-03	107.7	6.27E-03	107.7

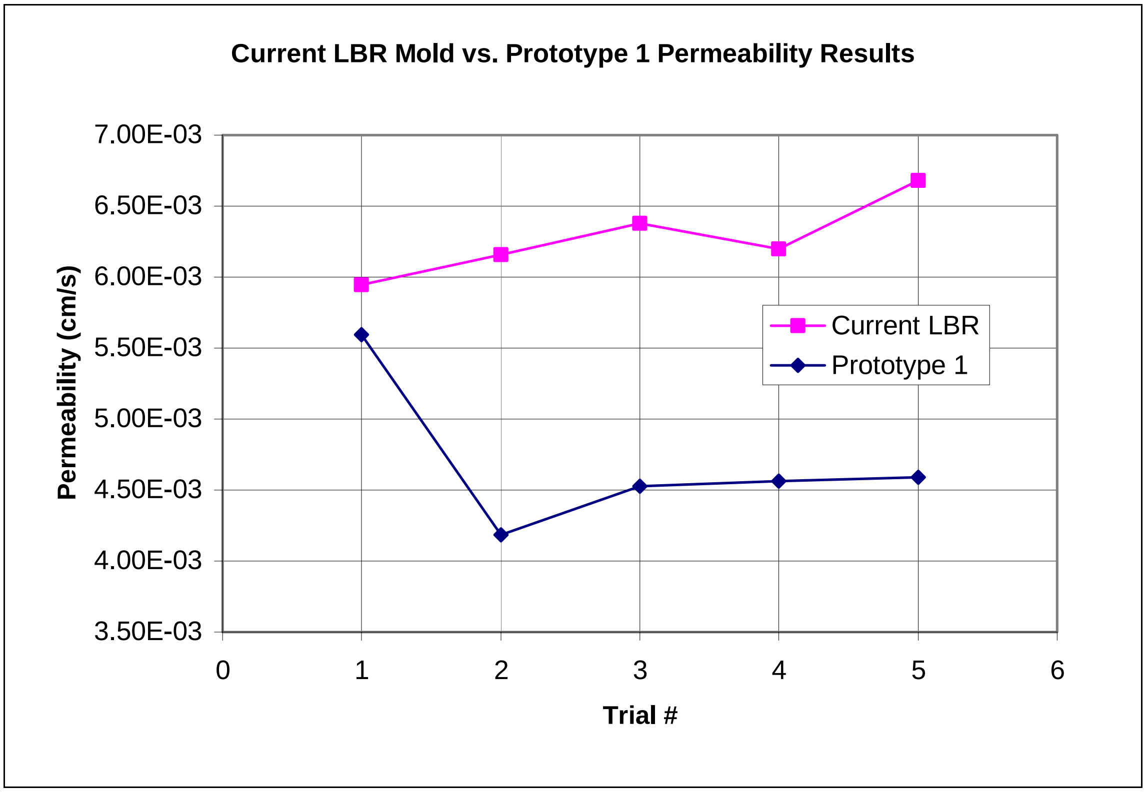


Figure 5.1. Prototype 1 vs. Current LBR Permeability Results

5.1.2 Comparative Analysis of Prototype 2 versus Current LBR Mold

The permeability results from the successful tests are summarized in Table 5.2. A graphical representation of the results is provided in Figure 5.2. Lower permeability values resulted when using Prototype 2, implying that piping had been reduced.

Table 5.2. Summary of Prototype 2 vs. Current LBR Permeability Results

	Prototype 2		Current LBR	
Trial	k (cm/s)	Dry Density (pcf)	k (cm/s)	Dry Density (pcf)
1	4.95E-03	108.2	5.94E-03	107.1
2	4.34E-03	107.6	6.16E-03	107.5
3	4.06E-03	108.8	6.38E-03	108.3
4	4.12E-03	107.9	6.20E-03	107.6
5	4.17E-03	107.3	6.68E-03	108.1
Avg.	4.33E-03	108.0	6.27E-03	107.7

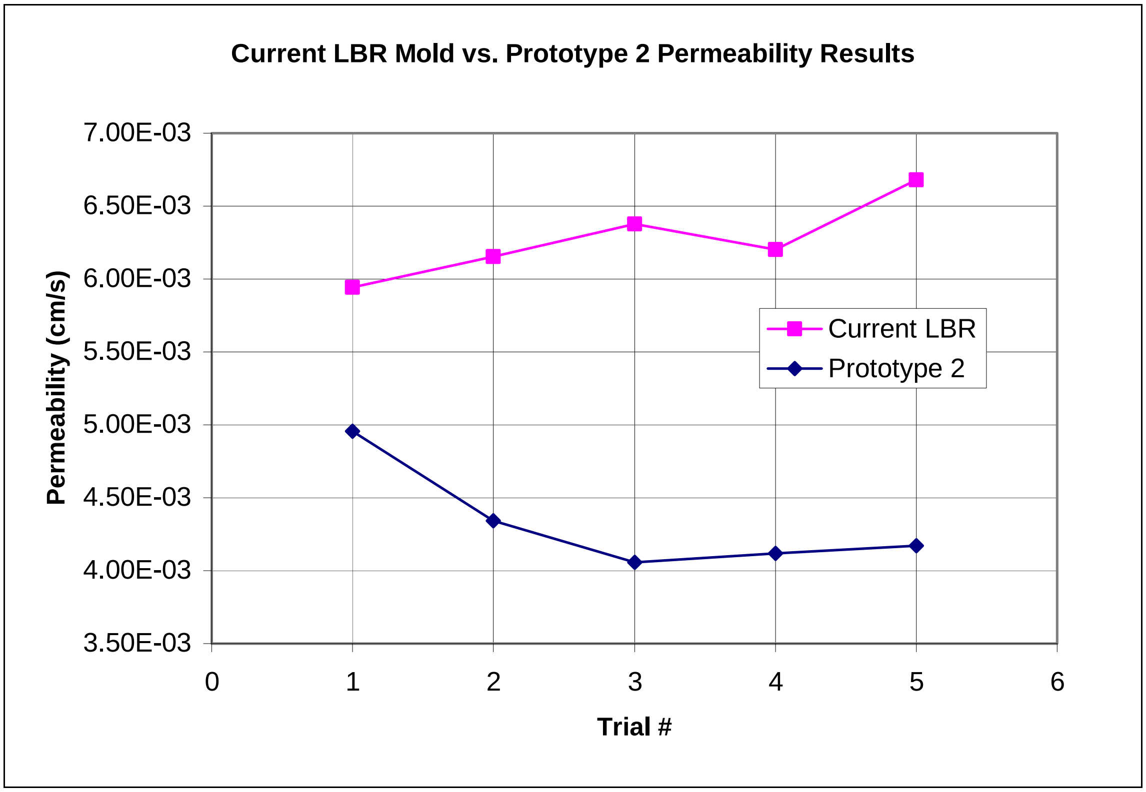


Figure 5.2. Prototype 2 vs. Current LBR Permeability Results

Testing with Prototypes 1 and 2 revealed a few negative design issues. Sample preparation was difficult with the use of both prototype permeameters. The rigidity of the metal insert caused the sample to deform once the permeameter was split into halves. The tight clearance between the mold and the sample made it very difficult to slide the mold over the sample after the flexible wall had been affixed to the inner wall. The prototypes also produced leaks during many unsuccessful tests. The use of silicon sealant to mitigate the leaks allowed a few successful tests to be performed. Overall the reliability and feasibility of using Prototypes 1 and 2 was considered poor. A more detailed discussion is provided in a later section of this chapter and overall conclusions and recommendations are supplied in Chapter 6.

5.2 Modified Rigid-Wall Prototype

This section provides the comparative analysis and parametric evaluation of Prototype 3 versus the current LBR mold. A discussion of the reliability and feasibility of the prototype is also included.

5.2.1 Comparative Analysis of Prototype 3 versus Current LBR Mold

The permeability results from the successful tests are summarized in Table 5.3. A graphical comparison of the results for each soil sample is provided in Figures 5.3 - 5.11. Five samples showed a lower permeability value using Prototype 3 while four samples resulted in a greater value.

Table 5.3. Summary of Prototype 3 vs. Current LBR Permeability Results

	Prototype 3		Current LBR	
Sample	k (cm/s)	Dry Density (pcf)	k (cm/s)	Dry Density (pcf)
19518	2.10E-05	111.5	6.58E-05	111.7
19519	1.20E-04	110.5	7.50E-05	110.2
19522	1.55E-05	111.8	3.40E-05	111.2
19523	8.25E-05	112.5	2.00E-05	112.9
19530	1.20E-05	113.5	1.35E-04	114.2
19531	3.10E-05	111.2	7.40E-05	111.9
19533	4.00E-05	109.8	8.75E-05	110.6
19534	3.60E-05	112.3	2.82E-05	113.1
19536	3.82E-05	110.8	7.00E-06	111.3

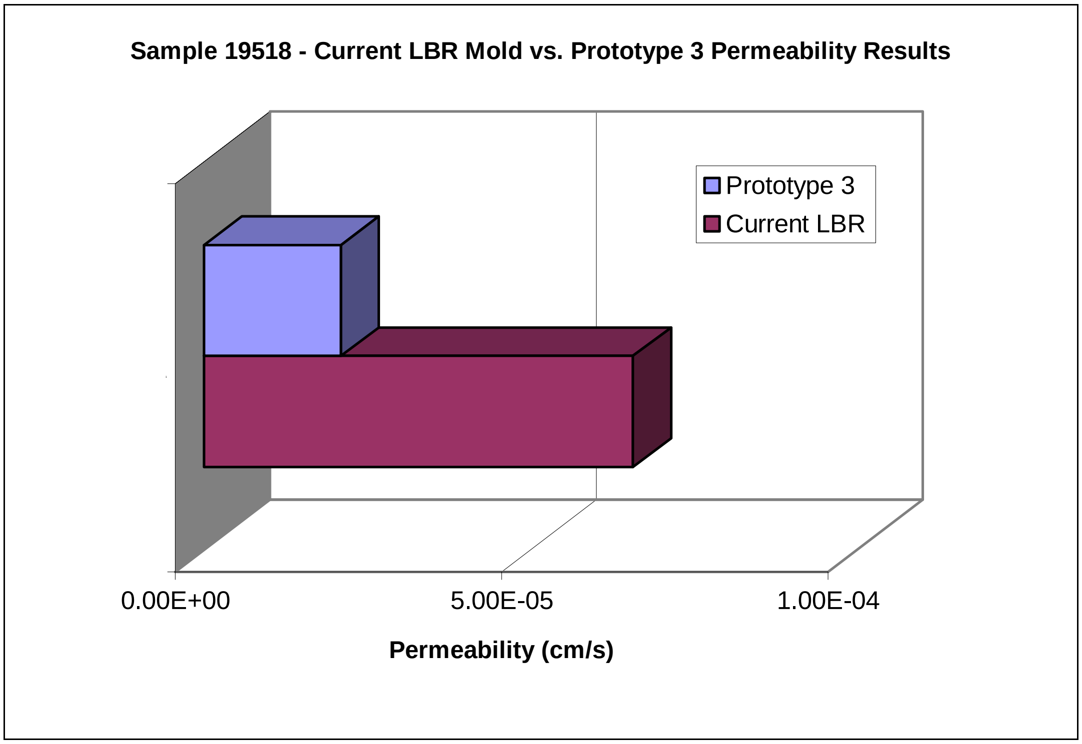


Figure 5.3. Permeability Results of Sample 19518

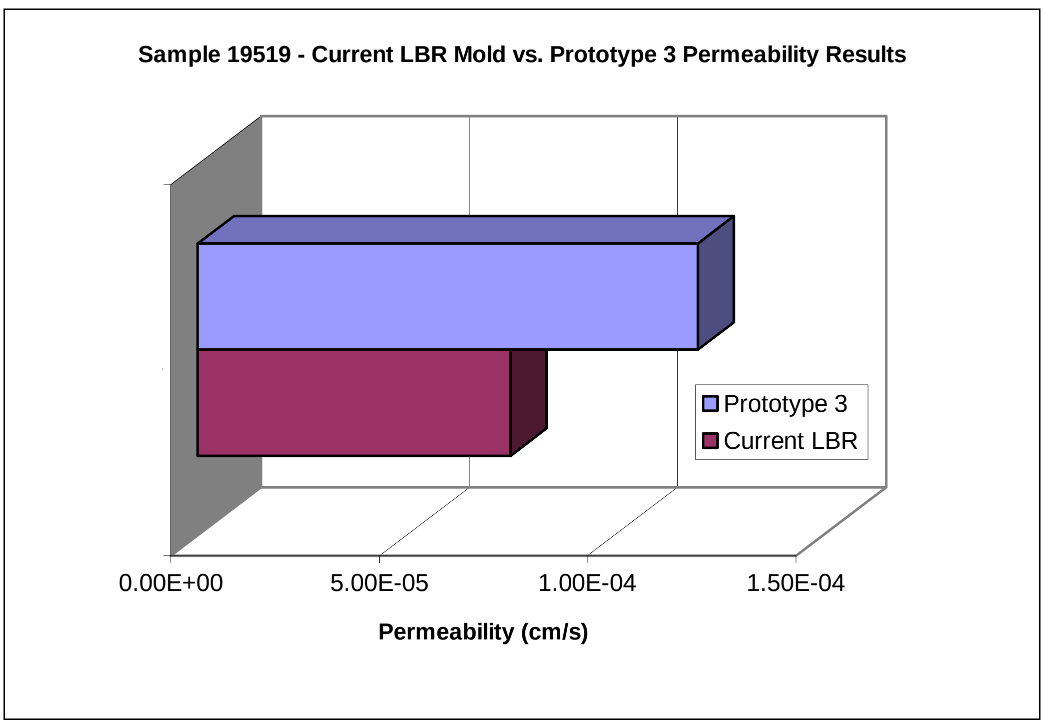


Figure 5.4. Permeability Results of Sample 19519

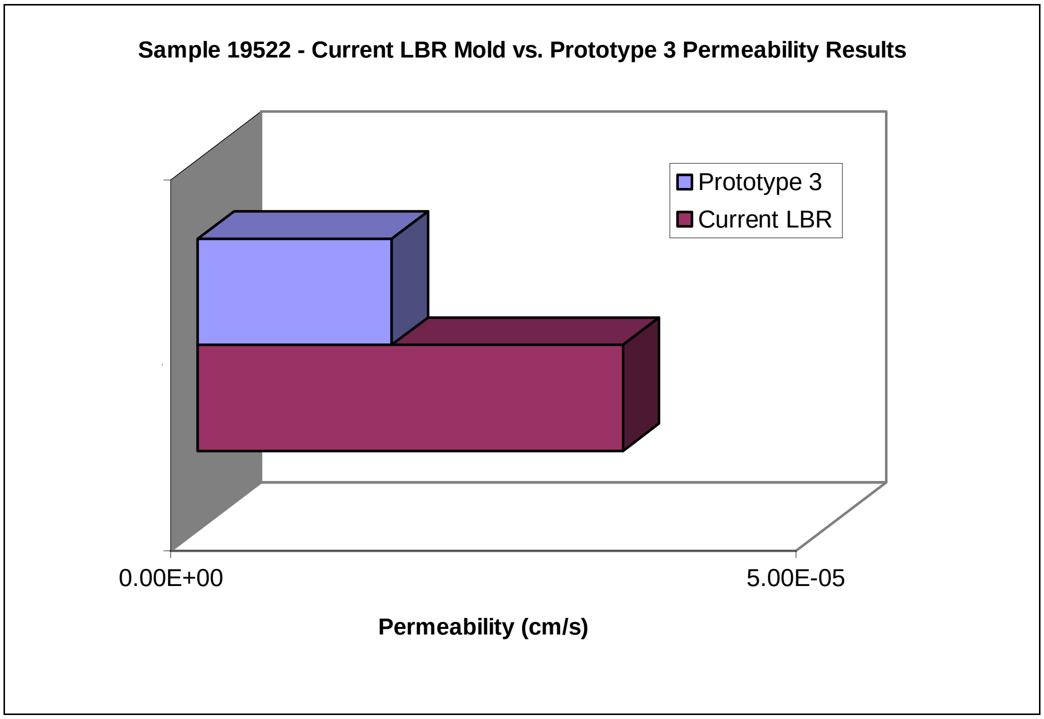


Figure 5.5. Permeability Results of Sample 19522

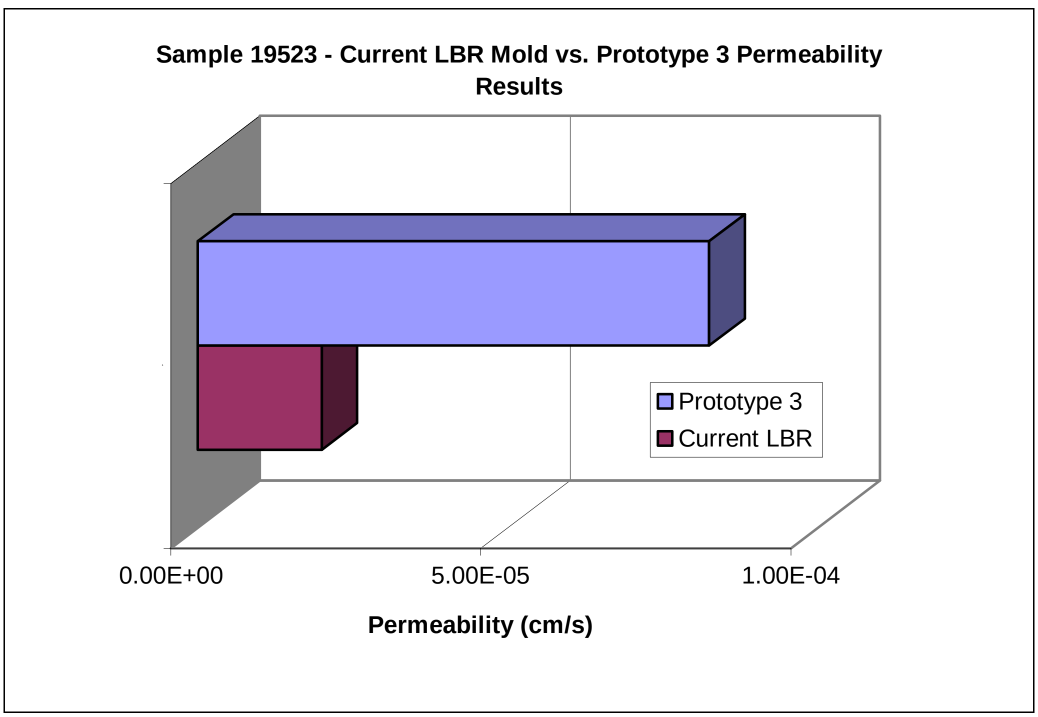


Figure 5.6. Permeability Results of Sample 19523

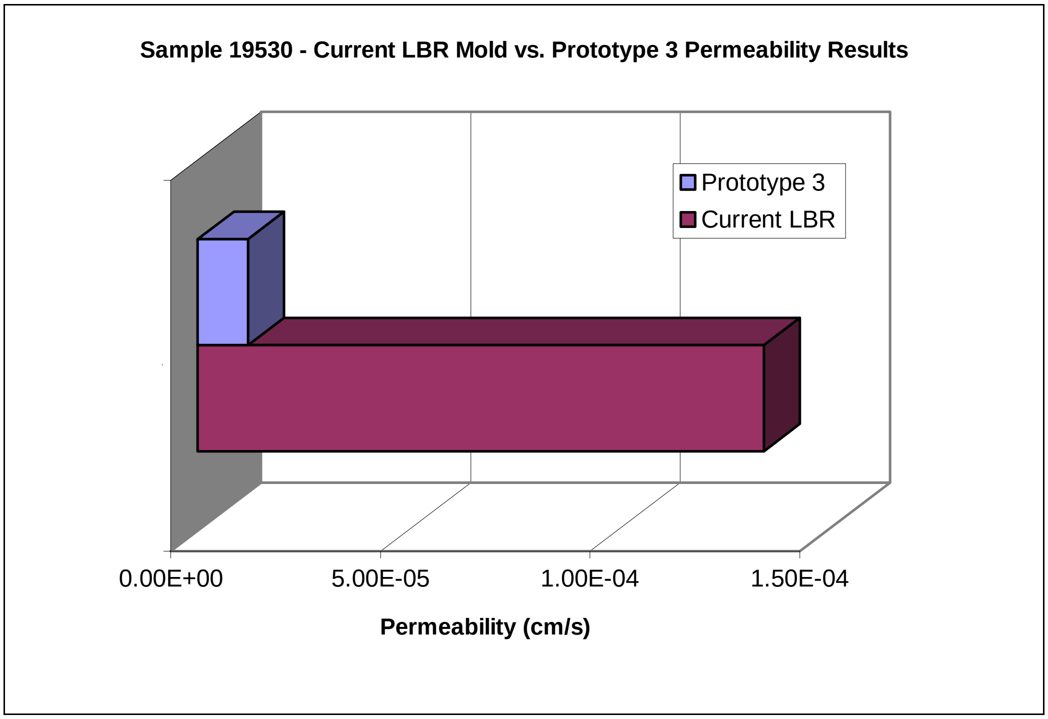


Figure 5.7. Permeability Results of Sample 19530

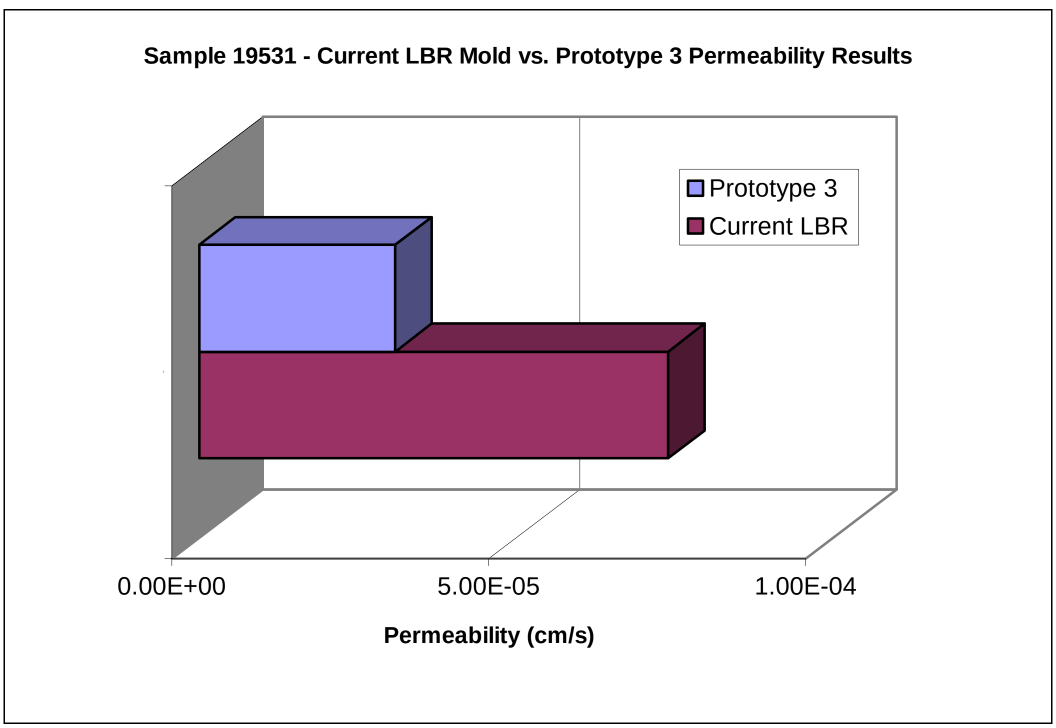


Figure 5.8. Permeability Results of Sample 19531

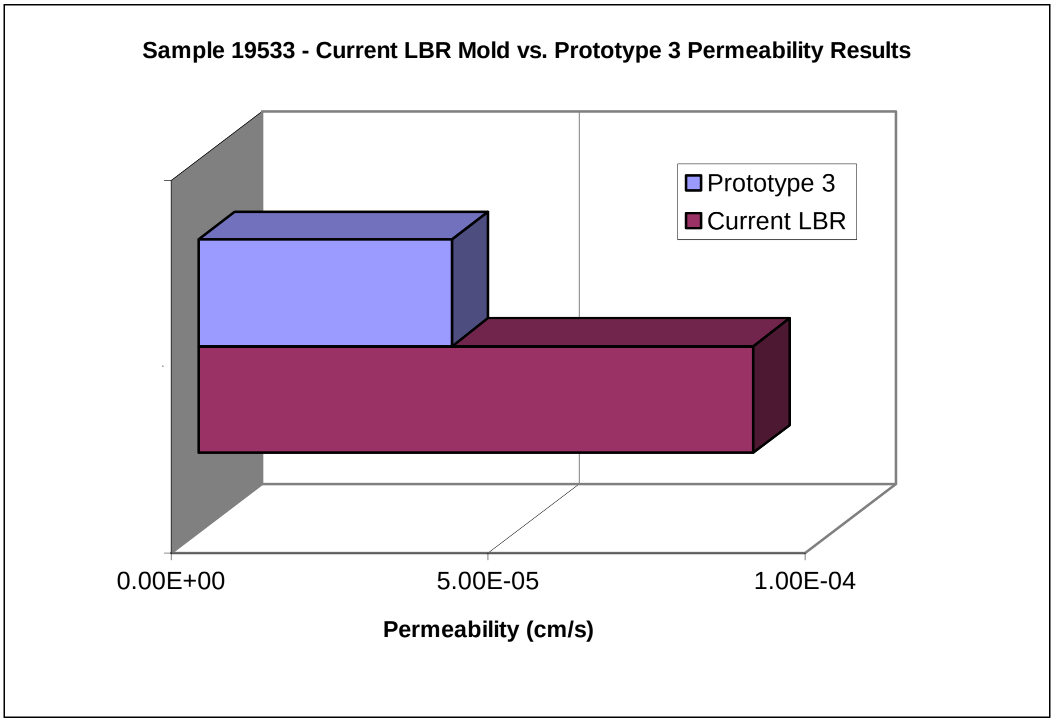


Figure 5.9. Permeability Results of Sample 19533

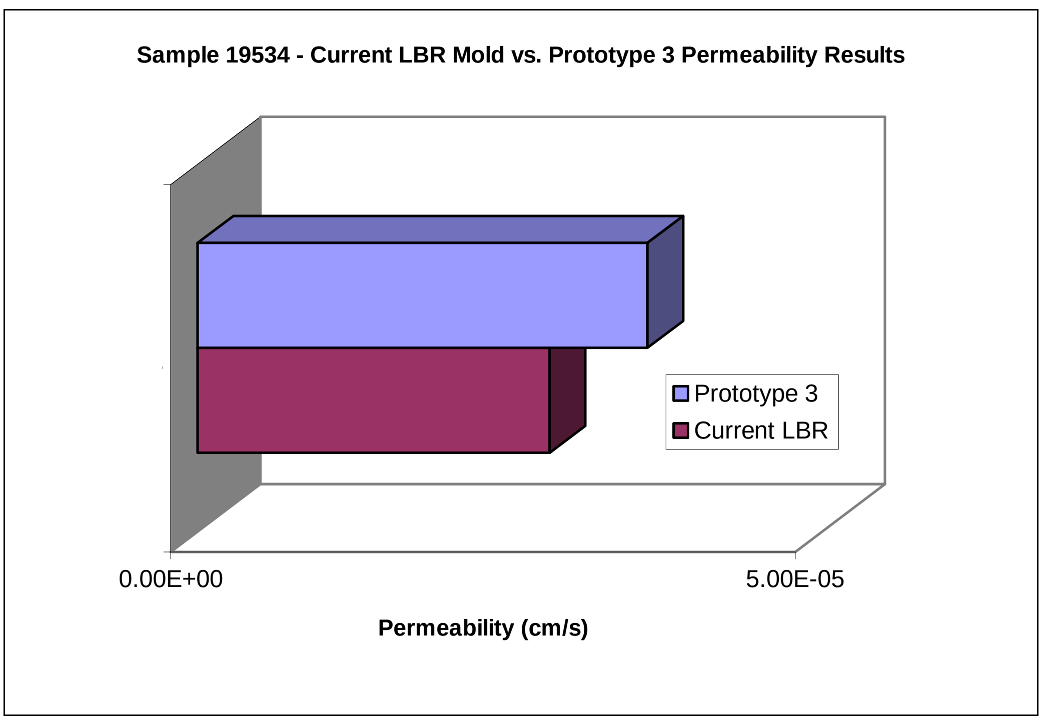


Figure 5.10. Permeability Results of Sample 19534

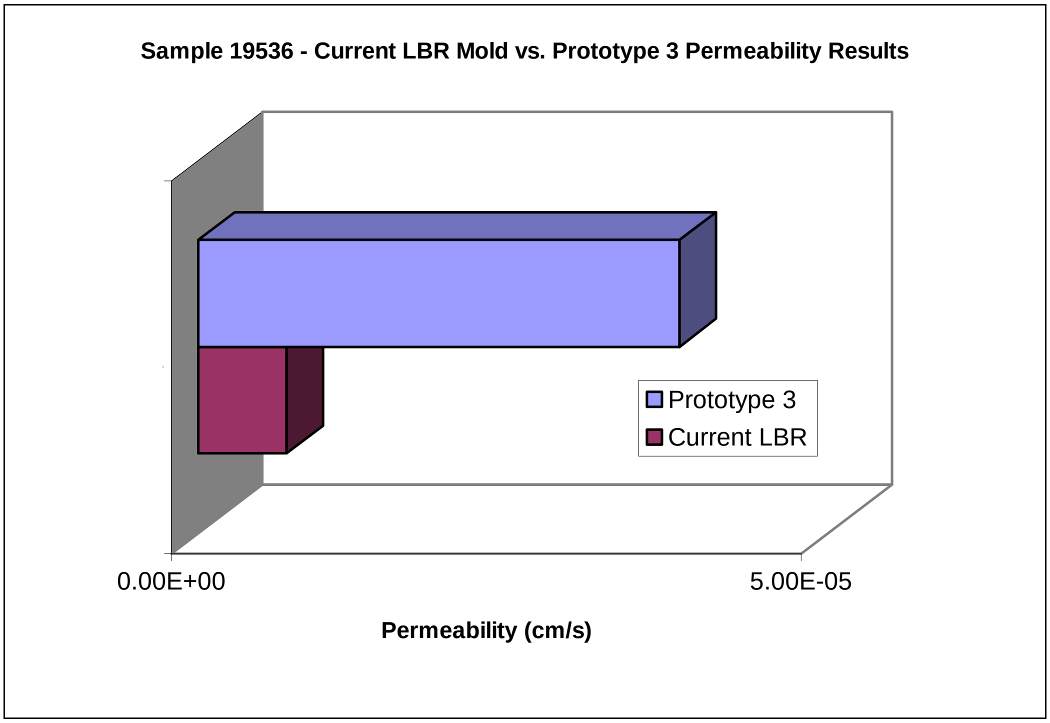


Figure 5.11. Permeability Results of Sample 19536

The data from the above tests does not provide a definitive indicator that the seepage rings of Prototype 3 are 100 % effective in reducing sidewall leakage. The technician who performed the testing believed that compaction and saturation difficulties caused problems in filling the grooves and therefore utilizing the prototype’s sidewall leakage interruption feature. Therefore additional permeability testing with better control over the sample preparation procedures was conducted in the saturation method comparison presented below and the parametric evaluation presented later in this report in order to better evaluate the reliability and feasibility of this prototype.

The results from the successful permeability tests using the Gainesville and Lake City saturation methods are summarized in Table 5.4. The Bartow saturation method was not used due to cracking of the sample during the vacuum saturation process. A graphical representation of the results is provided in Figure 5.12. When comparing the tests between the current LBR mold and Prototype 3, a reduction in permeability is apparent using Prototype 3 with both the Gainesville and the Lake City saturation methodology. Comparing results between both methods show higher permeability achieved by capillary rise, which might imply a more adequate saturation. A more detailed discussion is provided in a later section of this chapter and overall conclusions and recommendations are supplied in Chapter 6.

Table 5.4. Summary of Permeability Results with Comparison of Saturation Method

	Prototype 3		Current LBR	
Test	k (cm/s)	Dry Density (pcf)	k (cm/s)	Dry Density (pcf)
Gainesville #1	4.50E-06	108.5	3.60E-05	107.9
Gainesville #2	1.00E-05	107.6	3.75E-05	108.2
Gainesville #3	1.50E-05	109.1	4.25E-05	109.5
Gainesville #4	3.80E-05	108.2	4.50E-05	108.6
Lake City #1	2.50E-06	108.7	2.40E-05	109.2
Lake City #2	3.50E-06	107.7	N/A	N/A

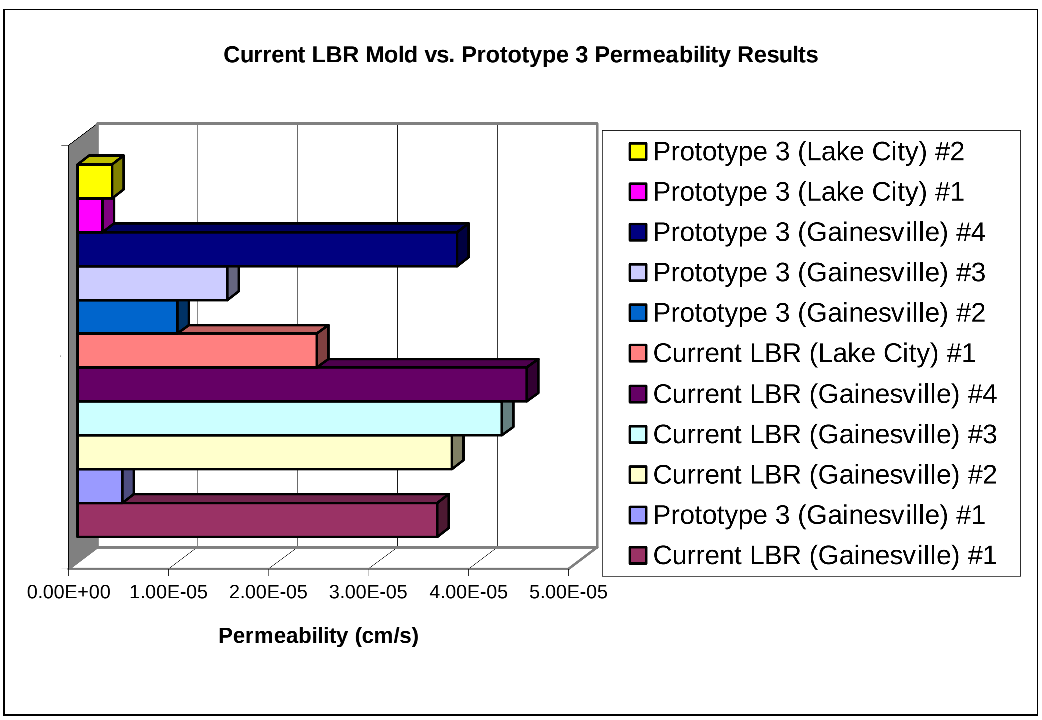


Figure 5.12. Comparison of Gainesville and Lake City Saturation Methods

5.2.2 Parametric Analysis of Prototype 3 versus Current LBR Mold

The types of tests that make-up the parametric evaluation, as described in Chapter 4, are reproduced in Table 4.3 for easy reference. The permeability results from the successful tests are summarized in Tables 5.5 and 5.6. The data for each trial from the permeability tests can be found in Appendix C. A graphical comparison of the results between Prototype 3 and the current LBR mold for each type of test is provided in Figures 5.13 – 5.28. Lower permeability values resulted when using Prototype 3, implying that piping had been reduced. A more detailed discussion is provided in a later section of this chapter and overall conclusions and recommendations are supplied in Chapter 6.

Table 4.3. Types of Sample Preparation Techniques

Test Code	Type of Sample Preparation
A	30 Minute Saturation Method, No Vacuum, and Top Steel Disk
B	30 Minute Saturation Method, No Vacuum, and Top Porous Stone
C	30 Minute Saturation Method, Vacuum, and Top Steel Disk
D	30 Minute Saturation Method, Vacuum, and Top Porous Stone
E	Overnight Saturation Method, No Vacuum, and Top Steel Disk
F	Overnight Saturation Method, No Vacuum, and Top Porous Stone
G	Overnight Saturation Method, Vacuum, and Top Steel Disk
H	Overnight Saturation Method, Vacuum, and Top Porous Stone

The results from the tests are plotted in Figures 5.29 – 5.32 grouped by the type of soil material and permeameter in order to compare the influence that each sample preparation parameter has on the determination of the coefficient of permeability. A more detailed discussion is provided in a later section of this chapter as well as a statistical analysis of the testing schemes. Overall conclusions and recommendations are supplied in Chapter 6.

Table 5.5. Summary of Prototype 3 vs. Current LBR Permeability Results (A-2-4 Soil)

	Current LBR		Prototype 3	
	k (cm/s)	Dry Density (pcf)	k (cm/s)	Dry Density (pcf)
A	1.94595E-04	108.3	1.17082E-04	109.2
B	3.31260E-04	107.5	2.37639E-04	108.3
C	3.67136E-04	109.2	2.36832E-04	108.9
D	3.57427E-04	108.5	2.73213E-04	107.7
E	2.10267E-04	107.6	1.59330E-04	108.2
F	2.51100E-04	107.9	1.35489E-04	108.6
G	4.10925E-04	108.7	3.72068E-04	109.8
H	4.28382E-04	109.1	2.70851E-04	109.4

Table 5.6. Summary of Prototype 3 vs. Current LBR Permeability Results (A-3 Soil)

	Current LBR		Prototype 3	
	k (cm/s)	Dry Density (pcf)	k (cm/s)	Dry Density (pcf)
A	1.75742E-04	109.4	1.17504E-04	108.4
B	2.05425E-04	108.5	1.07435E-04	109.2
C	2.81057E-04	108.9	1.84604E-04	108.1
D	3.45175E-04	107.7	1.45988E-04	107.9
E	1.31031E-04	108.5	1.13198E-04	108.1
F	1.72794E-04	108.3	1.10872E-04	109.6
G	3.57427E-04	109.6	2.61561E-04	108.7
H	4.15980E-04	109.5	2.86594E-04	107.9

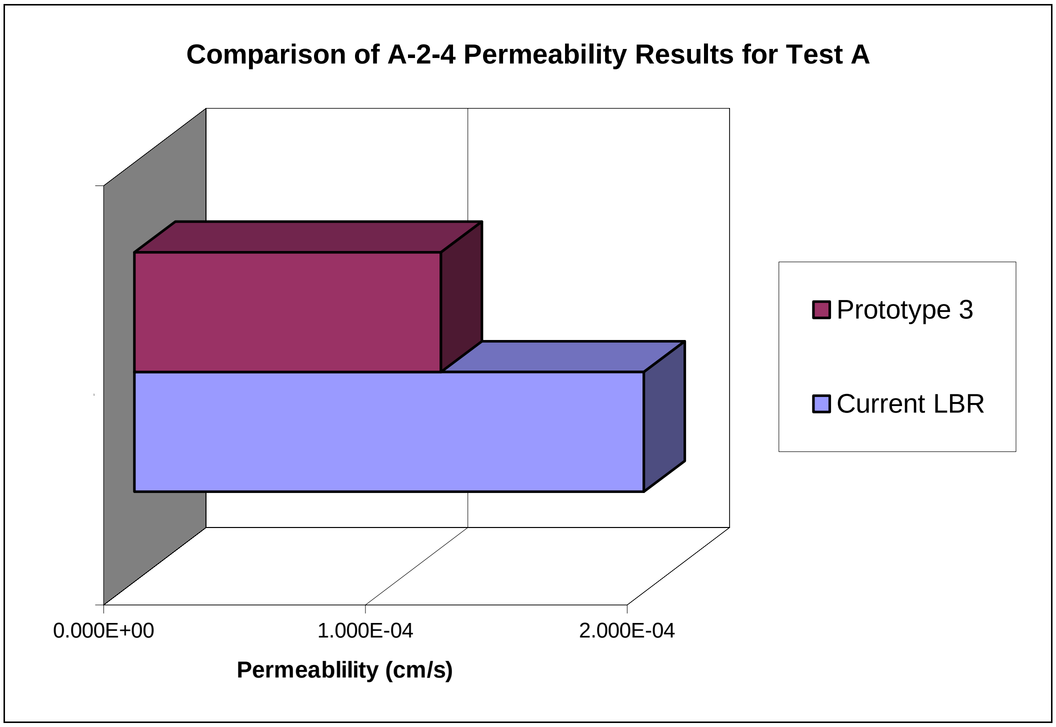


Figure 5.13. Comparison of Permeability Results for Test A on A-2-4 Soil

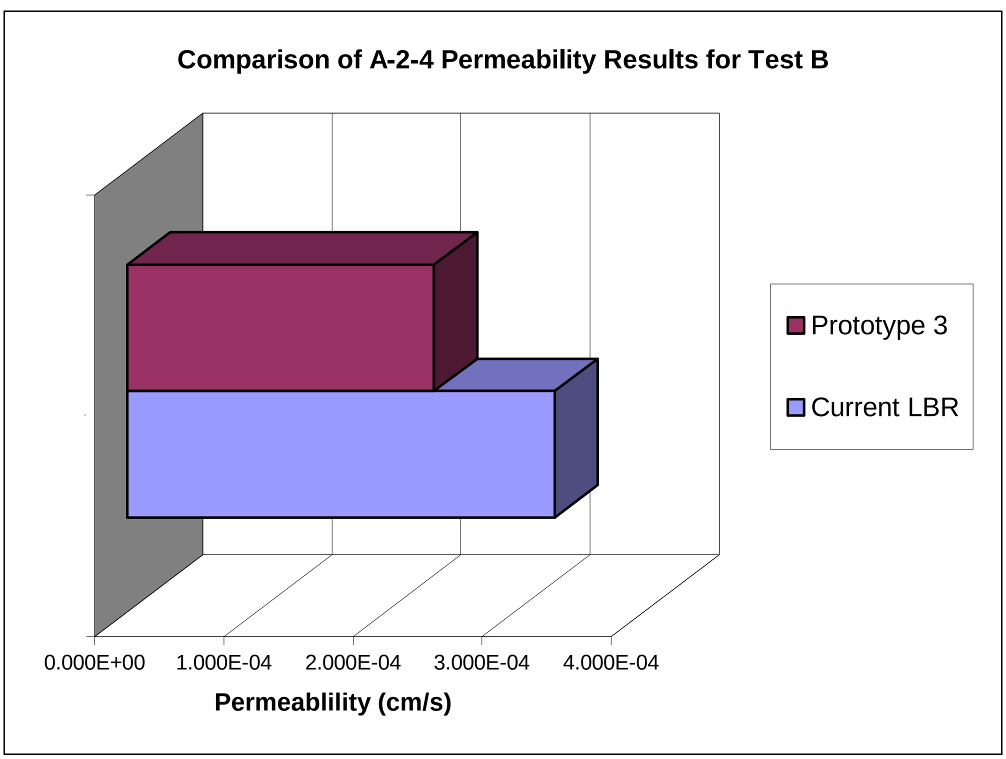


Figure 5.14. Comparison of Permeability Results for Test B on A-2-4 Soil

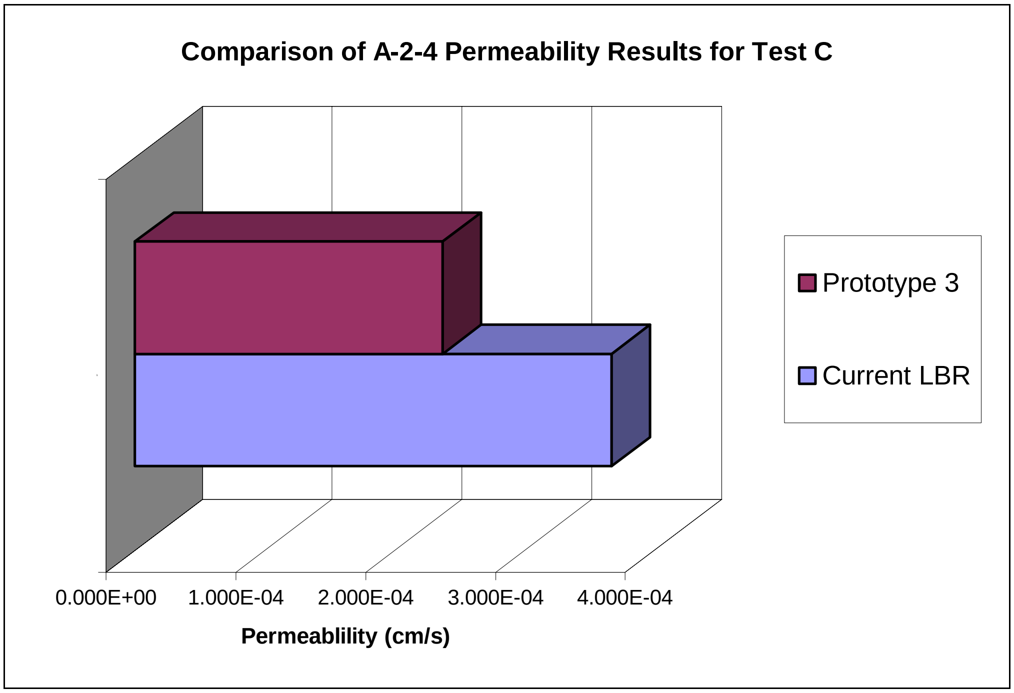


Figure 5.15. Comparison of Permeability Results for Test C on A-2-4 Soil

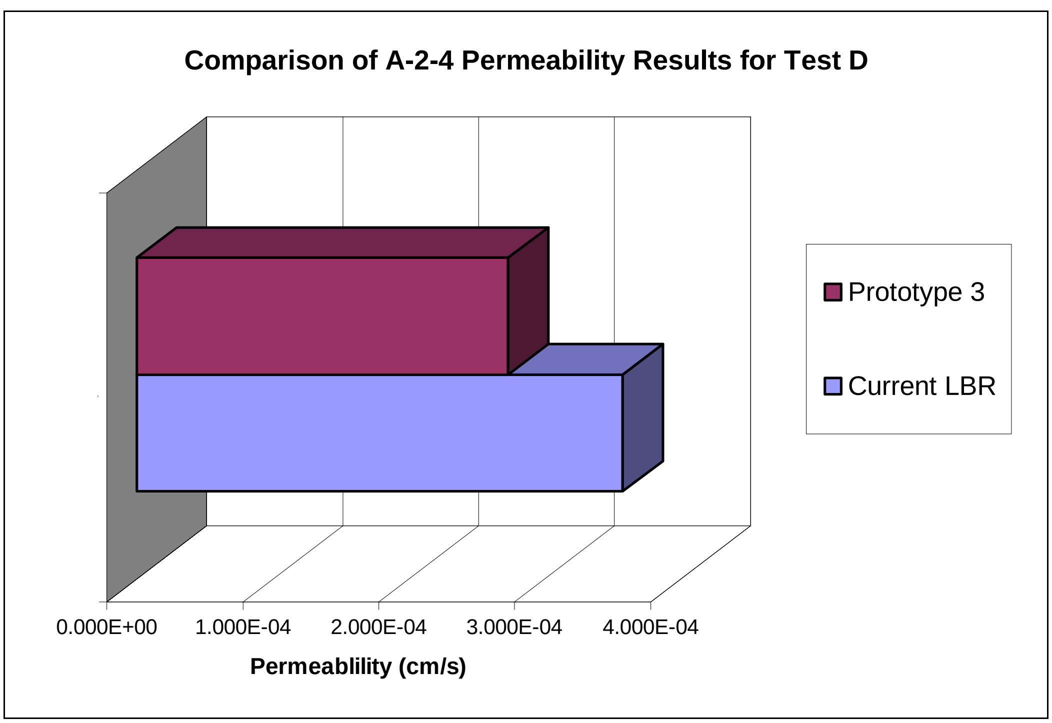


Figure 5.16. Comparison of Permeability Results for Test D on A-2-4 Soil

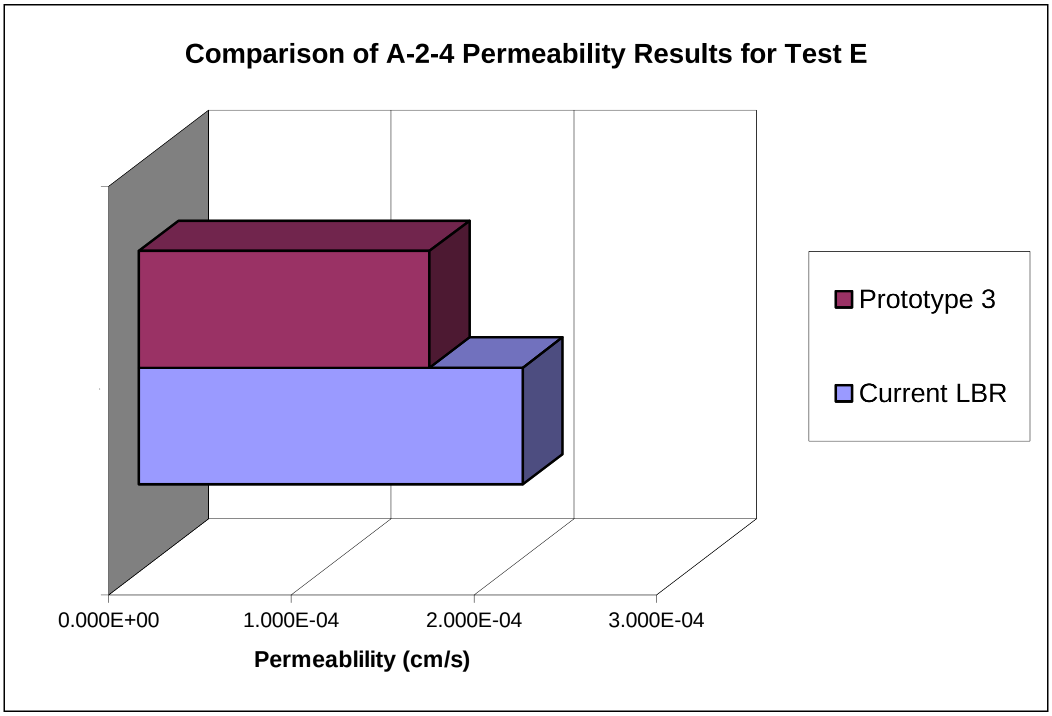


Figure 5.17. Comparison of Permeability Results for Test E on A-2-4 Soil

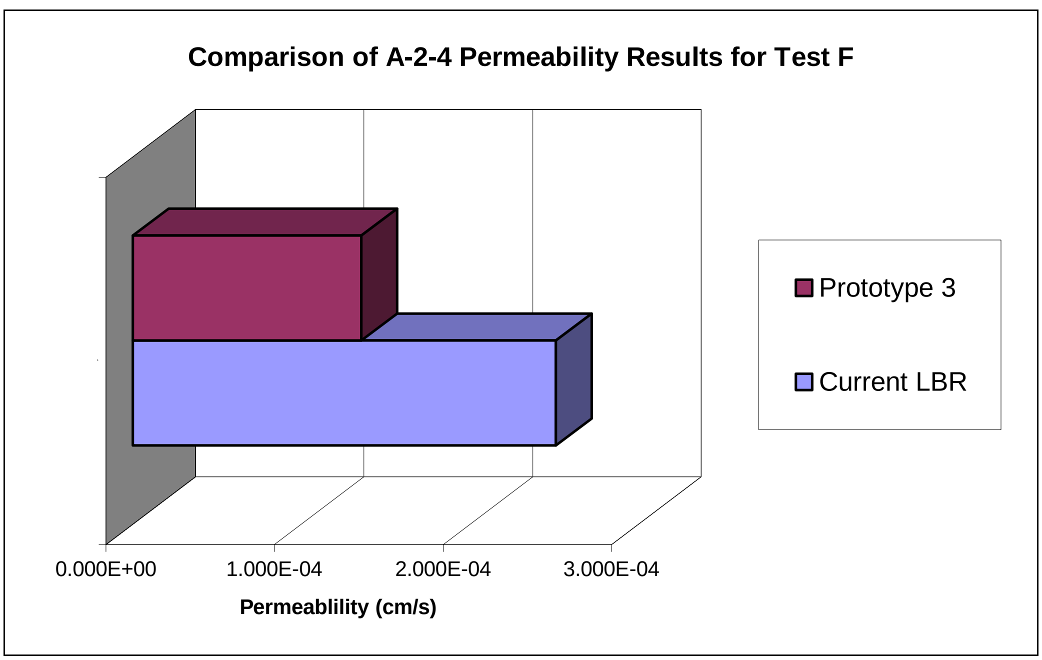


Figure 5.18. Comparison of Permeability Results for Test F on A-2-4 Soil

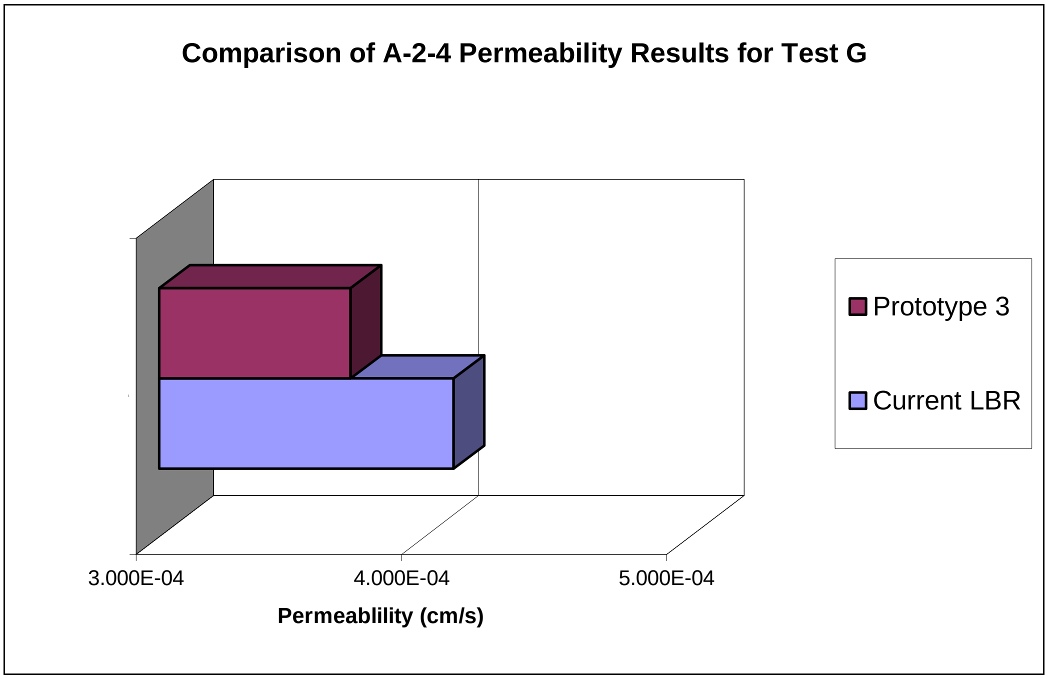


Figure 5.19. Comparison of Permeability Results for Test G on A-2-4 Soil

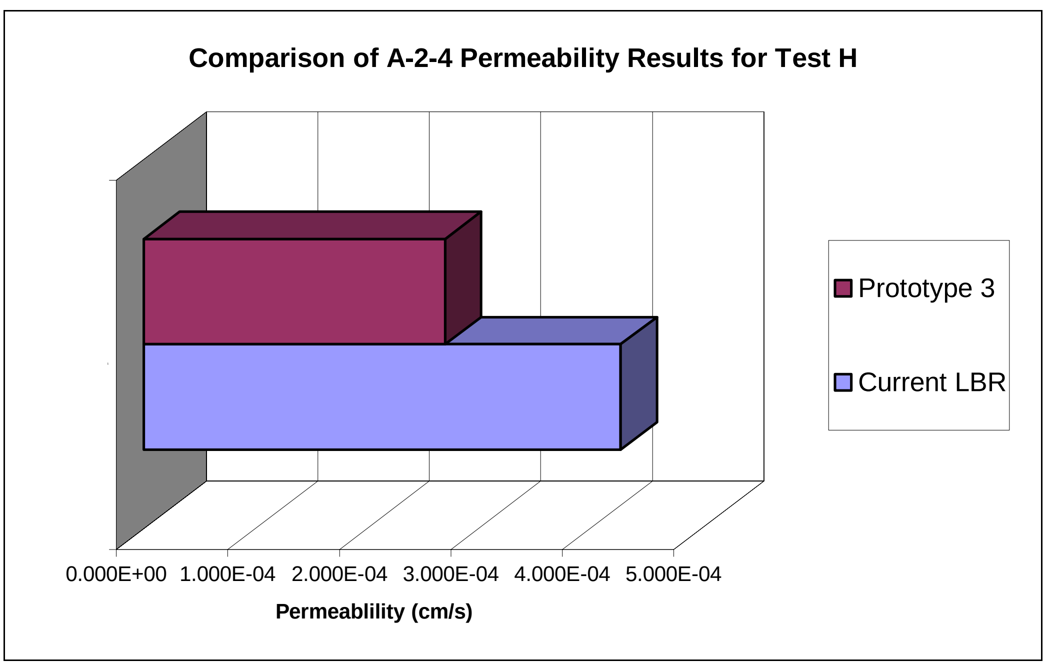


Figure 5.20. Comparison of Permeability Results for Test H on A-2-4 Soil

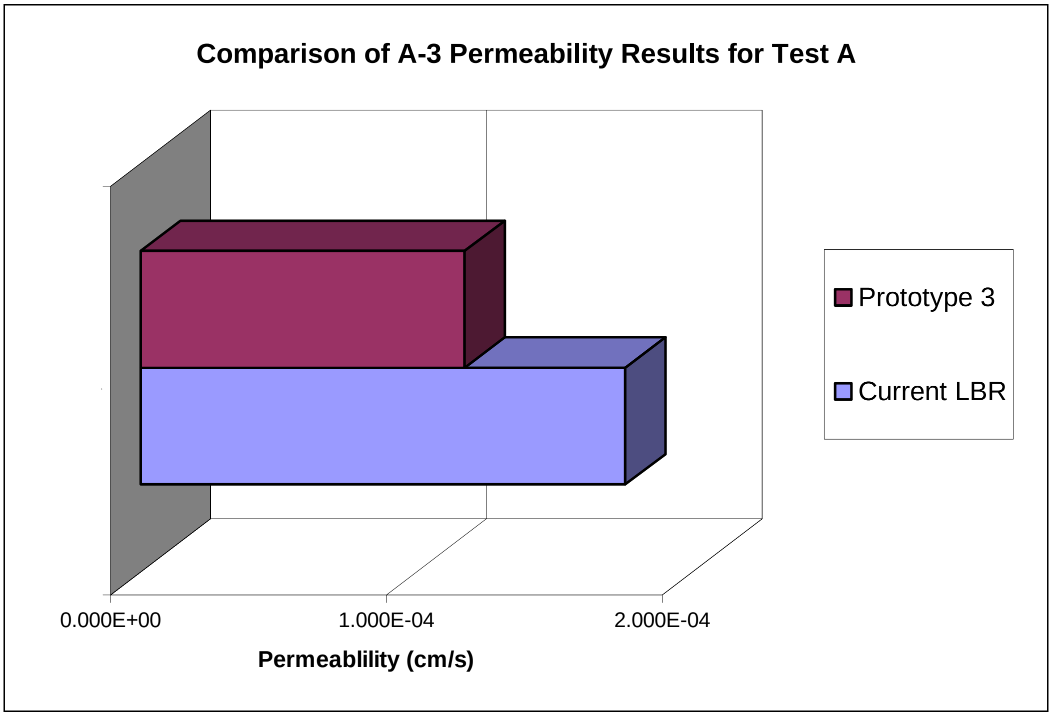


Figure 5.21. Comparison of Permeability Results for Test A on A-3 Soil

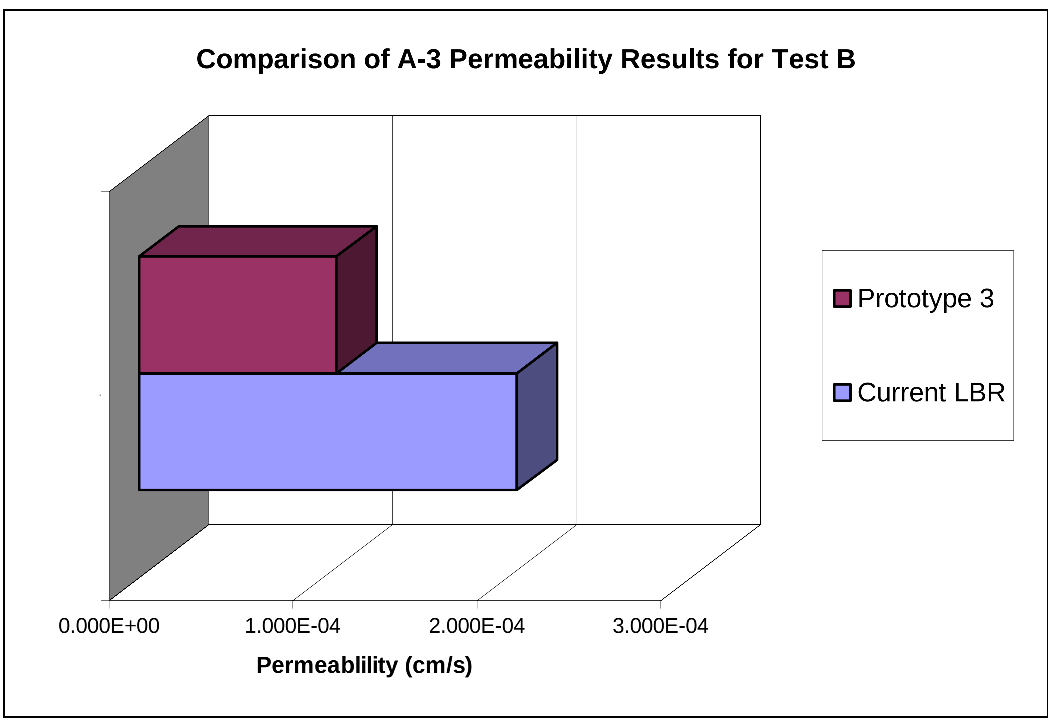


Figure 5.22. Comparison of Permeability Results for Test B on A-3 Soil

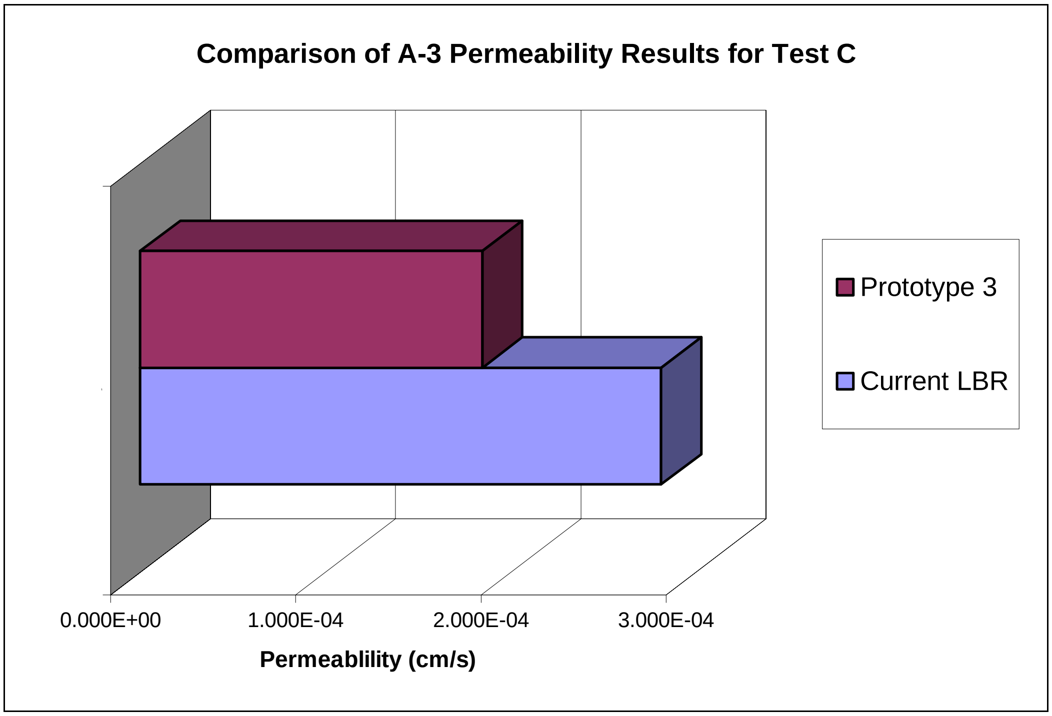


Figure 5.23. Comparison of Permeability Results for Test C on A-3 Soil

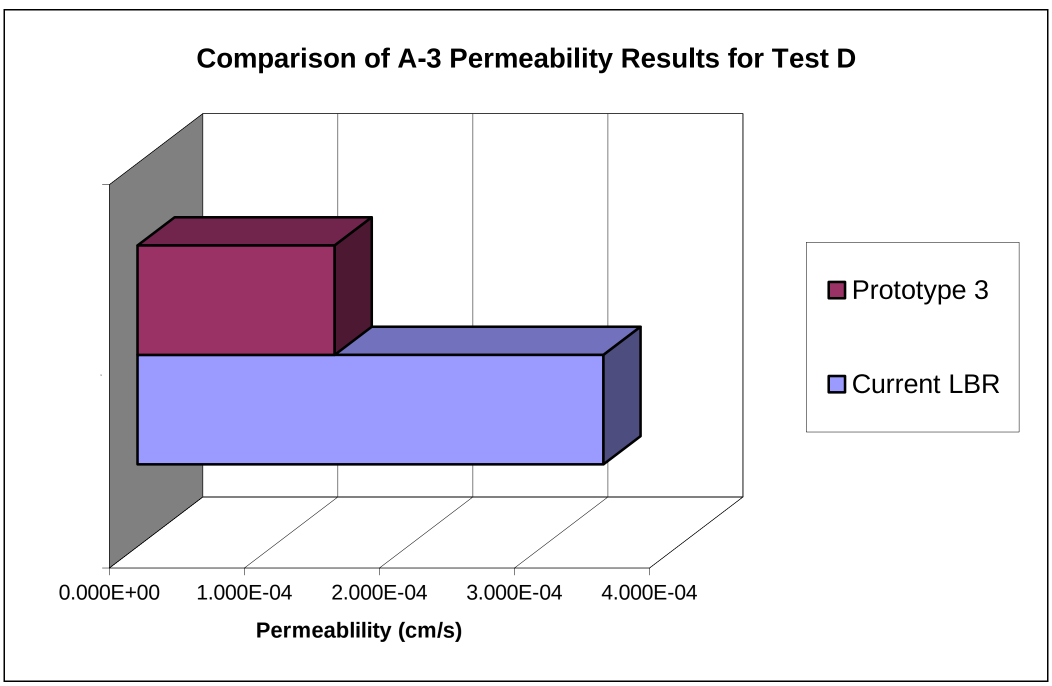


Figure 5.24. Comparison of Permeability Results for Test D on A-3 Soil

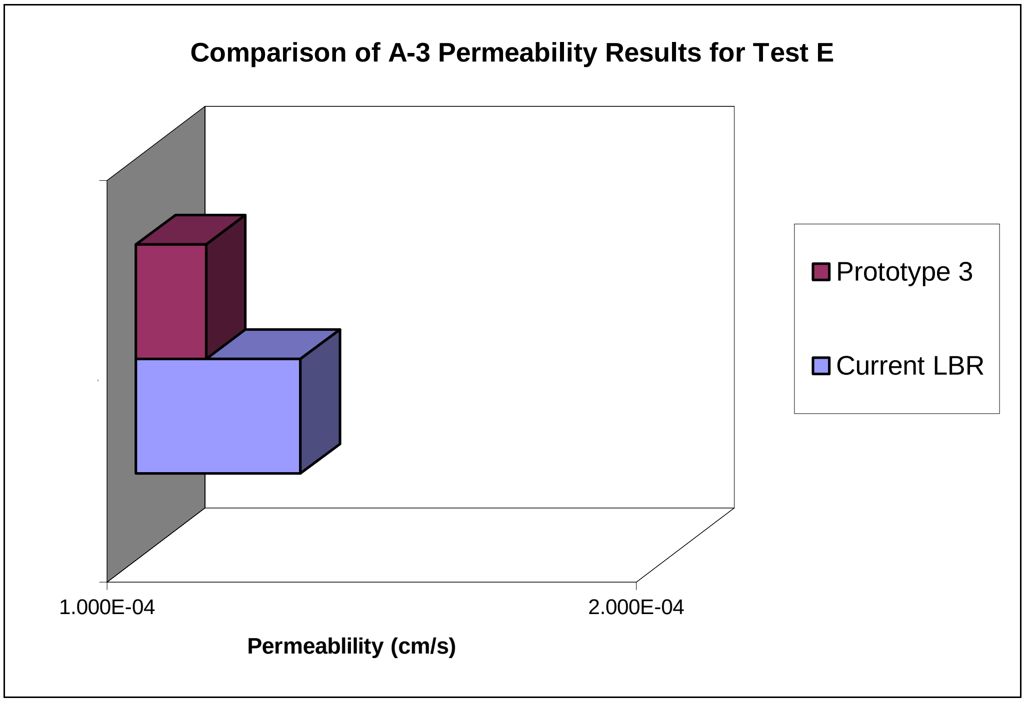


Figure 5.25. Comparison of Permeability Results for Test E on A-3 Soil

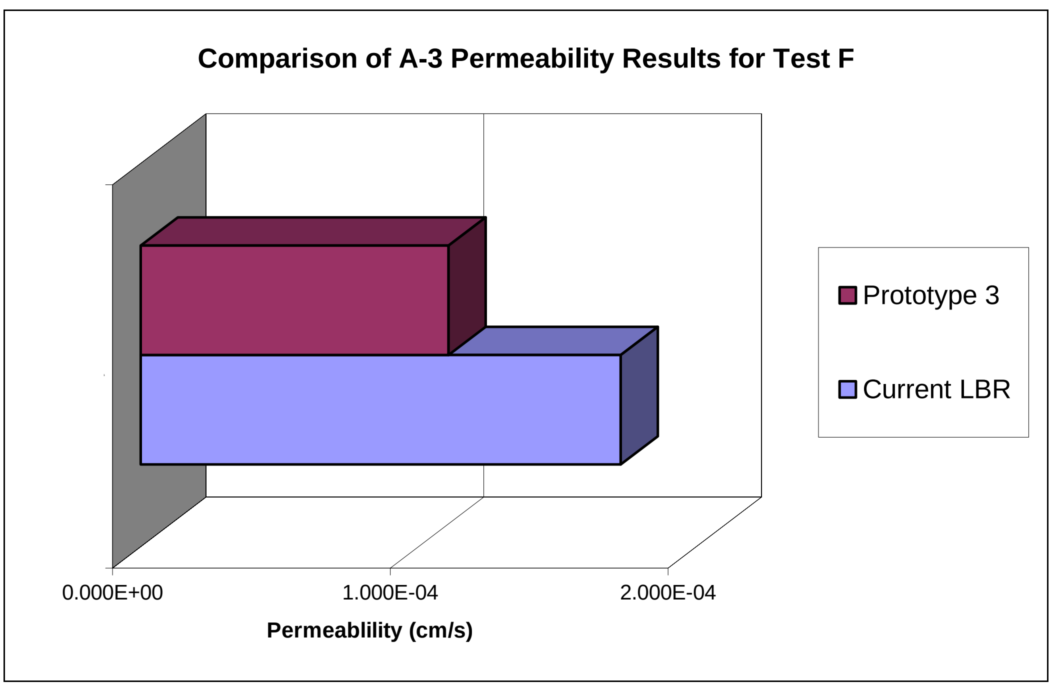


Figure 5.26. Comparison of Permeability Results for Test F on A-3 Soil

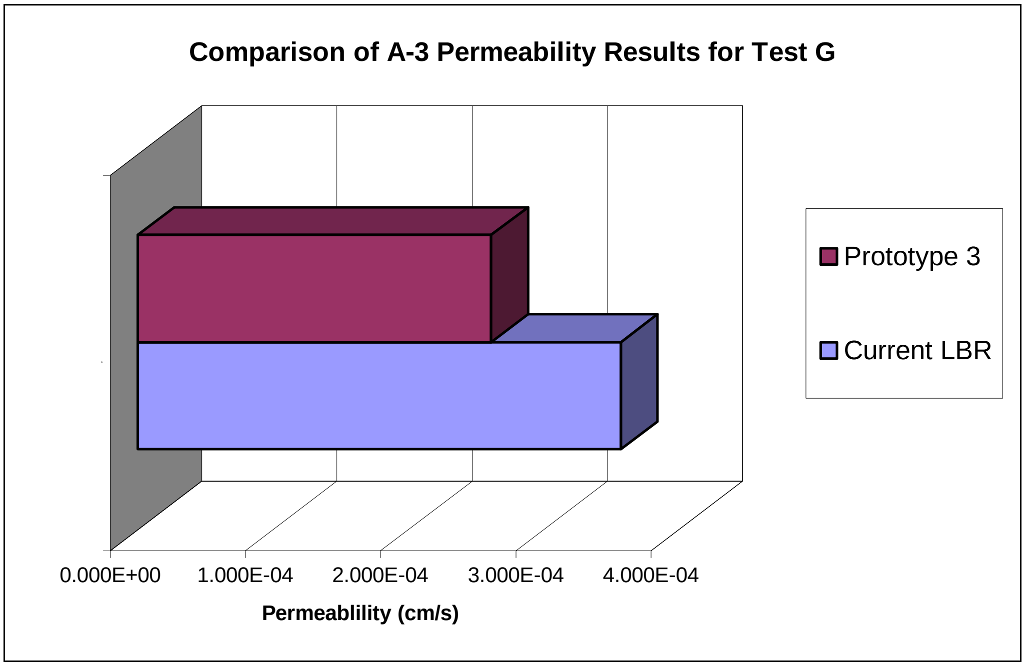


Figure 5.27. Comparison of Permeability Results for Test G on A-3 Soil

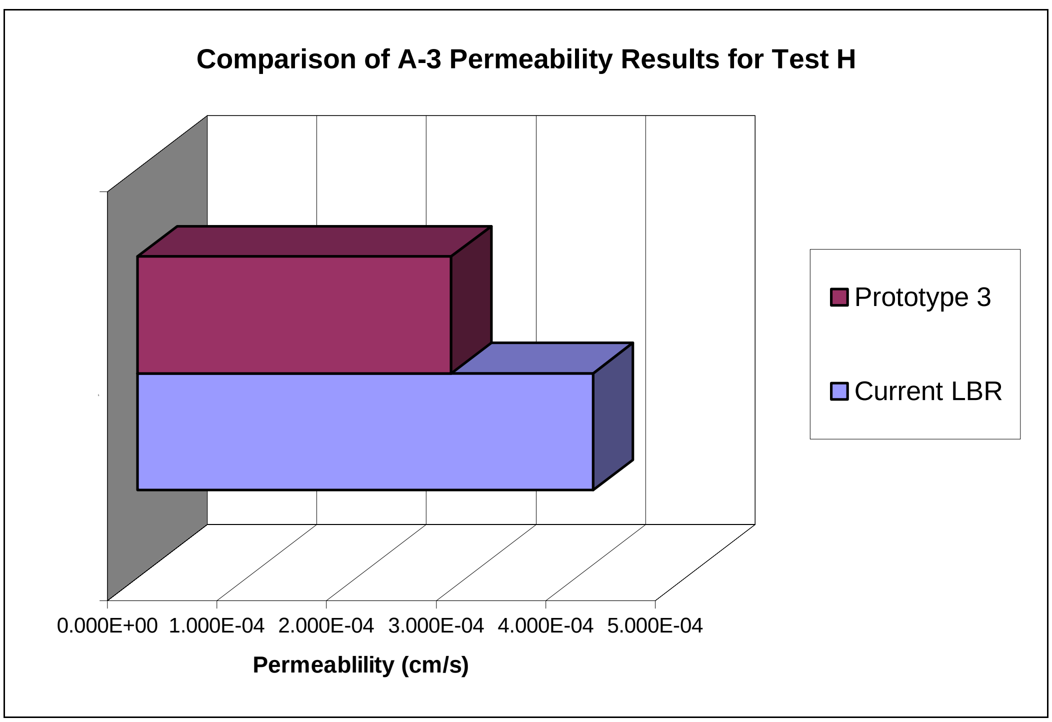


Figure 5.28. Comparison of Permeability Results for Test H on A-3 Soil

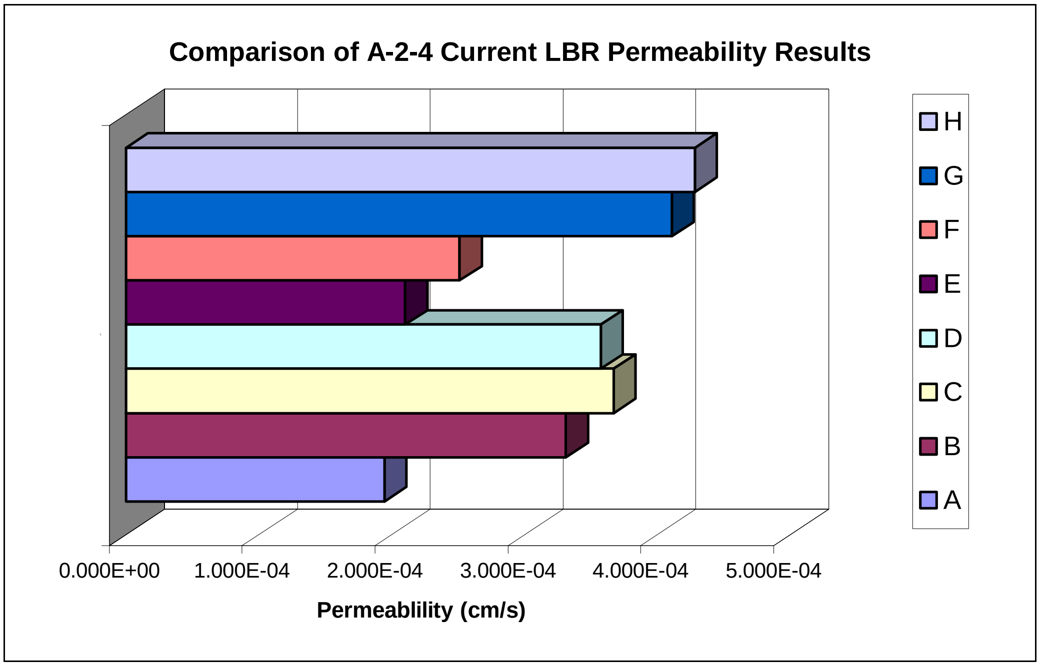


Figure 5.29. Comparison of Permeability Results for each Test Method using Current LBR Mold (A-2-4 Soil)

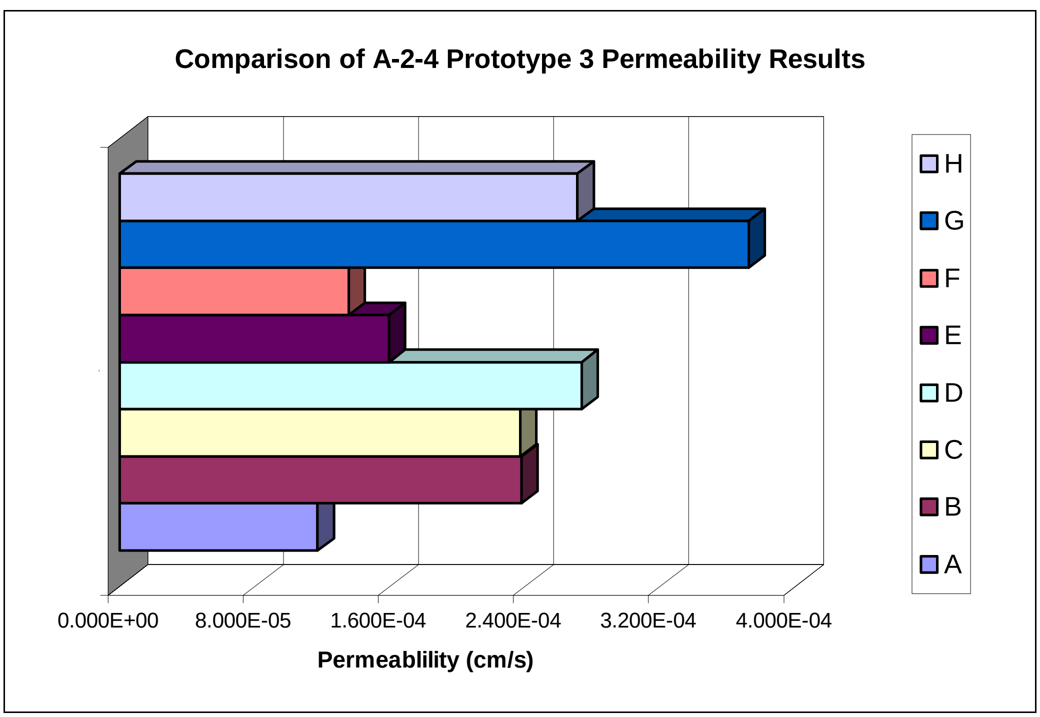


Figure 5.30. Comparison of Permeability Results for each Test Method using Prototype 3 (A-2-4 Soil)

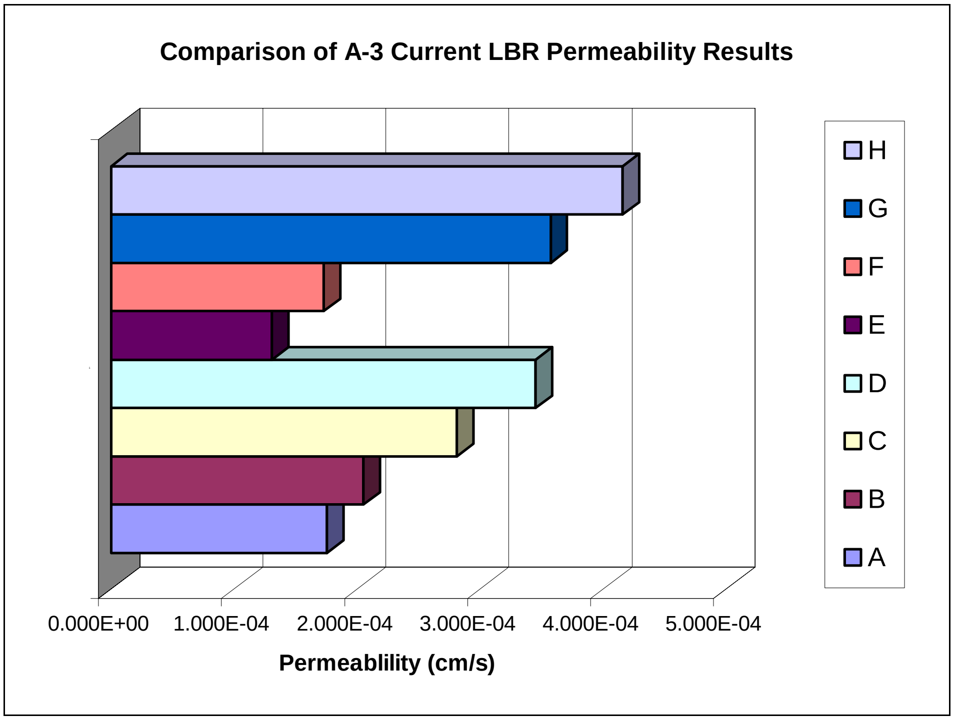


Figure 5.31. Comparison of Permeability Results for each Test Method using Current LBR Mold (A-3 Soil)

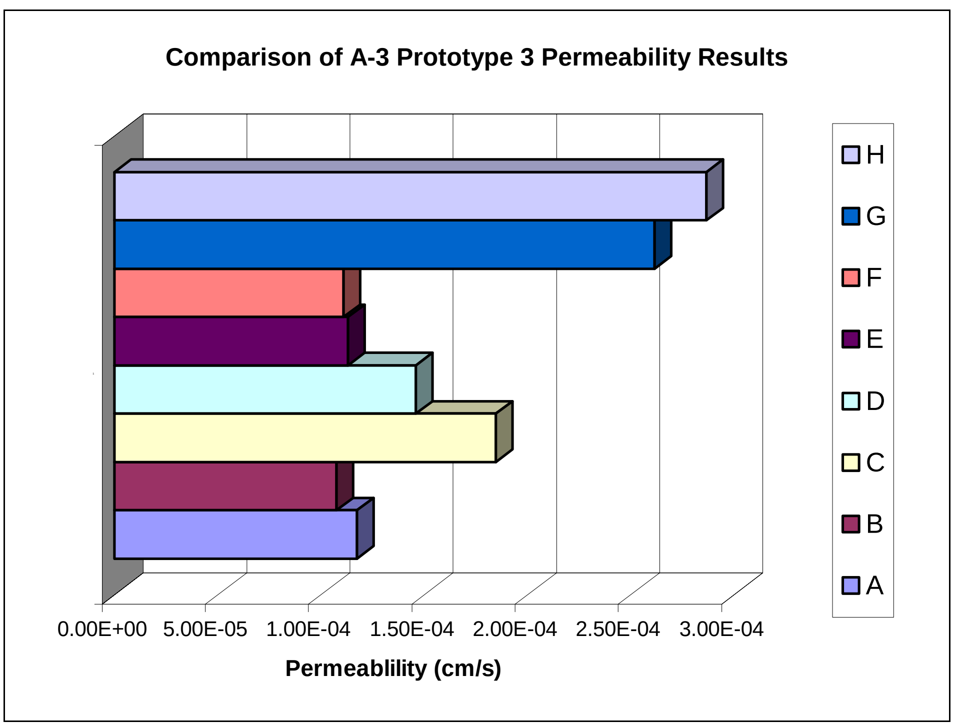


Figure 5.32. Comparison of Permeability Results for each Test Method using Prototype 3 (A-3 Soil)

The results of all the tests were averaged in order to demonstrate the overall effect that each test method had on the coefficient of permeability. The results from the parametric sensitivity study provide the following information about the magnitude of the coefficient of permeability that resulted from each type of test conducted:

- Test A - ↓↓
- Test B - ↓
- Test C - ↑
- Test D - ↑
- Test E - ↓↓
- Test F - ↓
- Test G - ↑
- Test H - ↑↑

The magnitude of the variability from each type of test is presented in the next section of this report.

5.3 Overall Comparison

This section of the report presents an overall comparison of the results from each analysis of the permeability tests that were conducted. A statistical analysis of the parametric evaluation is also provided in order to better understand the influence that sample preparation parameters can have on the coefficient of permeability.

5.3.1 Prototype Permeability Results

The results from each of the comparative and parametric analyses were evaluated in order to visualize the reduction in the permeability value that was seen between the use of the prototypes and the current LBR mold. Tables 5.7 – 5.12 present the data as a percentage decrease, it should be noted that negative values indicate an increase in permeability with the use of a prototype. The majority of the values indicate a reduction in the permeability using the prototypes; this is to be expected since the channeling effect along the mold/soil interface allows more flow to occur with the use of the current LBR mold.

Table 5.7. Reduction of Permeability using Prototype 1

Trial	Reduction (%)
1	5.91
2	32.05
3	28.99
4	26.37
5	31.32

Average
24.93

Table 5.8. Reduction of Permeability using Prototype 2

Trial	Reduction (%)
1	16.67
2	29.47
3	36.35
4	33.60
5	37.54

Average
30.73

Table 5.9. Reduction of Permeability using Prototype 3 (I-4 Soil Material)

Sample	Reduction (%)
19518	68.09
19519	-60.00
19522	54.41
19523	-312.50
19530	91.11
19531	58.11
19533	54.29
19534	-27.66
19536	-445.71

Table 5.10. Reduction of Permeability using Prototype 3 (I-4 Soil Material)

Test	Reduction (%)
Gainesville #1	87.50
Gainesville #2	73.33
Gainesville #3	64.71
Gainesville #4	15.56
Lake City #1	89.58
Lake City #2	N/A

Average
66.14

Table 5.11. Reduction of Permeability using Prototype 3 (A-2-4) (Parametric Evaluation)

	Reduction (%)
A	39.83
B	28.26
C	35.49
D	23.56
E	24.22
F	46.04
G	9.46
H	36.77

Average
30.46

Table 5.12. Reduction of Permeability using Prototype 3 (A-3) (Parametric Evaluation)

	Reduction (%)
A	33.14
B	47.70
C	34.32
D	57.71
E	13.61
F	35.84
G	26.82
H	31.10

Average
35.03

With the exception of the four tests conducted on the I-4 soil material, Prototype 3 had the highest average percentage decrease in soil permeability.

5.3.2 Statistical Analysis of Prototype 3 Parametric Results

The statistical analysis that was conducted as part of this investigation evaluated the standard deviation between each of the tests that were part of the parametric study. The results of the statistical analysis are provided in Tables 5.13 and 5.14. A graphical comparison of the standard deviations for each of the permeameters and soil type is given in Figures 33 – 36.

Table 5.13. Comparison of Standard Deviation for Parametric Evaluation (A-2-4 Soil)

	Current LBR	Prototype 3
A	2.62544E-05	1.99814E-05
B	3.23213E-05	3.50403E-05
C	3.79071E-05	9.14475E-06
D	3.6639E-05	3.11904E-05
E	3.36202E-05	2.80019E-05
F	3.58951E-05	3.0834E-05
G	8.71061E-05	3.82743E-05
H	8.58272E-05	4.10029E-05

Table 5.14. Comparison of Standard Deviation for Parametric Evaluation (A-3 Soil)

	Current LBR	Prototype 3
A	2.91215E-05	2.34056E-05
B	5.27066E-05	1.66213E-05
C	5.92697E-05	1.27968E-05
D	4.4257E-05	1.19633E-05
E	5.65089E-05	5.13858E-05
F	1.7324E-05	1.56513E-05
G	8.5809E-05	6.02443E-05
H	7.05364E-05	3.51156E-05

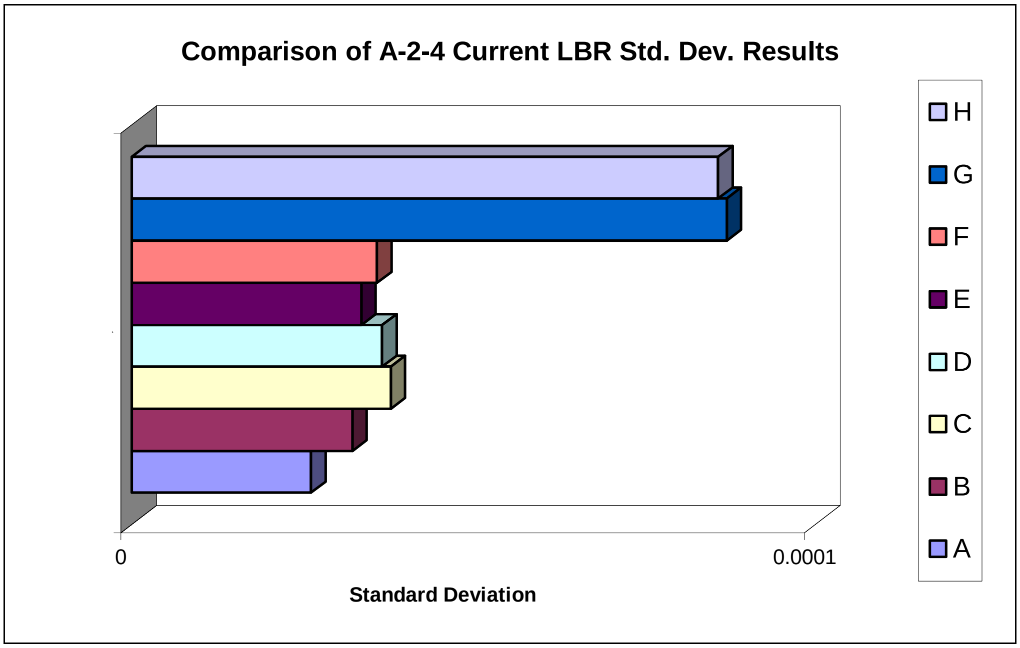


Figure 5.33. Comparison of Standard Deviation for Current LBR (A-2-4 Soil)

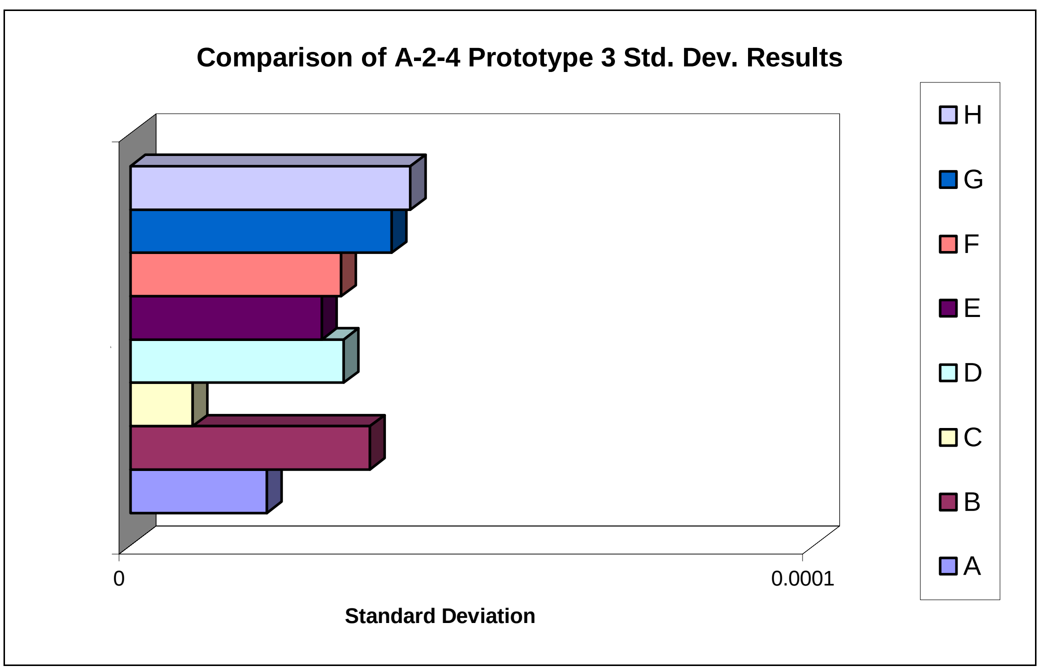


Figure 5.34. Comparison of Standard Deviation for Prototype 3 (A-2-4 Soil)

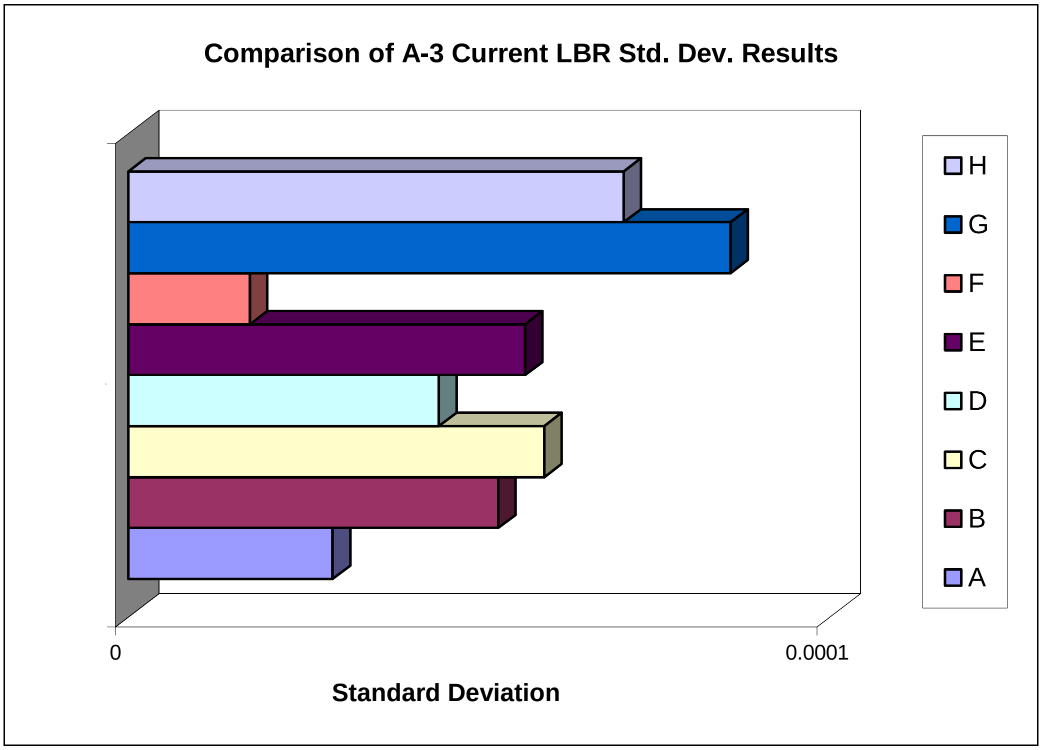


Figure 5.35. Comparison of Standard Deviation for Current LBR (A-3 Soil)

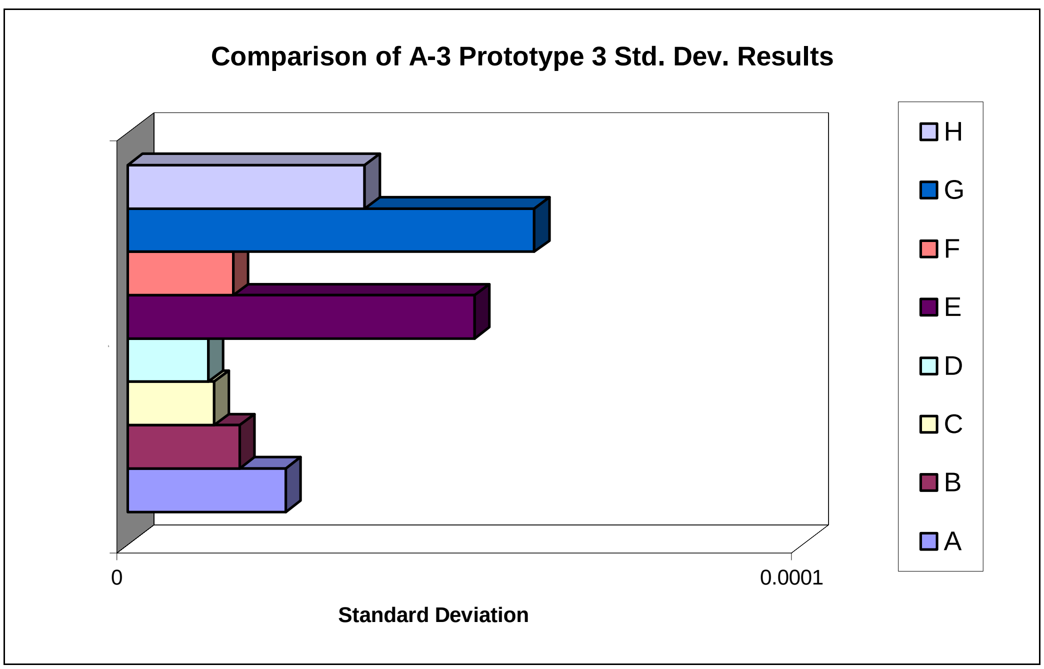


Figure 5.36. Comparison of Standard Deviation for Prototype 3 (A-3 Soil)

The results from the statistical analysis of the parametric sensitivity study provide the following information about the variability of the coefficient of permeability that resulted from each type of test conducted:

- Test A - ↓↓
- Test B - ↓
- Test C - ↓
- Test D - ↓↓
- Test E - ↑↑
- Test F - ↑
- Test G - ↑↑
- Test H - ↑

Prototype 3 had a lower standard deviation compared to that of the current LBR mold. Test method D had the lowest average standard deviation of the test methods. Overall conclusions and recommendations for limiting the variability in permeability testing methodology are supplied in Chapter 6.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

This chapter provides a discussion of the conclusions and recommendations that can be drawn from the analysis of the results from the permeability study.

6.1 Conclusions

The study shows that both a flexible-wall and grooved rigid-wall cylinder mold reduce the effect of sidewall leakage. On average, lower permeability values resulted when using the prototypes, implying that piping had been reduced. A comparison of the test methods used in the parametric evaluation demonstrated that a thirty-minute (30-min) saturation method with an applied full vacuum and the use of a saturated top porous stone produced the lowest standard deviation between testing trials.

6.2 Recommendations

Based on the negative design issues of the flexible-wall permeameters and discussions with Dr. Dave Horhota at the State Materials Office, the use of Prototypes 1 and 2 was not considered feasible. The complexities of the procedure as well as the leakage problems for the flexible-wall permeameter were considered greater problems than the potential benefits that it could offer. The use of seepage rings in Prototype 3 allowed for the continued use of the LBR mold with only slight modifications and was considered the best option for reducing the sidewall leakage of the current LBR mold. A recommendation is made to calibrate and test the automatic compaction equipment at the laboratory facilities statewide. Therefore the use of the current compaction procedures could be continued with greater reliability.

Vacuum saturation had previously been considered difficult due to the inability to maintain sample integrity. Downward saturation and air evacuation of samples can also have an effect on the density and permeability of the soil material, due to a loss of fines through the process. Appendix D is a study that was conducted which presents the effect that a loss of fines can have on typical Florida soil. Therefore, a modified saturation method is recommended to improve sample saturation. Increased degrees of saturation have been observed using reduced vacuum pressures of approximately 5-10 inches mercury applied at the top of the sample in the upward direction. A spring is recommended to apply a confining force of 5-10 pounds to the top porous stone and provide a higher degree of sample integrity.

In order to limit the variability seen in permeability results on similar soil samples from different test facilities, a more standardized sample preparation and permeability testing procedure is also recommended. An example of a proposed sample preparation and permeability testing procedure is provided in Appendix E.

It should be stated that these recommendations are based on limited testing of only a few types of soil materials. Additional testing is required in order to verify the results and to further examine the variability seen in permeability testing methodology.

APPENDIX A
CURRENT FLORIDA METHOD (FM 1-T 215)

Standard Method of Test
for

PERMEABILITY OF GRANULAR SOILS (CONSTANT HEAD)

AASHTO Designation: T 215-70 (1984)
(ASTM Designation: D 2434-68 (1974))

1. SCOPE

1.1 This method of test covers a procedure for determining the coefficient of permeability by a constant-head method for the laminar flow of water through granular soils. The procedure is intended to establish representative values of the coefficient of permeability of granular soils that may occur in natural deposits or as placed in embankments, or when used as base courses under pavements. In order to limit consolidation influences during testing, this procedure is limited to disturbed granular soils containing not more than 10 percent of non-plastic character passing the 0.075 mm (No. 200) sieve.

2. FUNDAMENTAL TEST CONDITIONS

2.1 The following ideal test conditions are prerequisites for the laminar flow of water through granular soils under constant-head conditions:

2.1.1 Continuity of flow with no soil volume changes during a test.

2.1.2 Flow with the soil voids saturated with water and no air bubbles in the soil voids.

2.1.3 Flow in the steady state with no changes in hydraulic gradient, and

2.1.4 Direct proportionality of velocity of flow with hydraulic gradients below certain critical values, where turbulent flow starts.

2.2 All other types of flow involving partial saturation of soil voids, turbulent flow, and unsteady state of flow are transient in character and yield variable and time-dependent coefficients of permeability; therefore, they require special test conditions and procedures.

3. APPARATUS

3.1 Permeameters, as shown in Fig. 1, shall have specimen cylinders with minimum diameters approximately 8 or 12 times the maximum particle size in accordance with Table 1. The permeameter should be fitted with: (1) a porous disk or suitable reinforced screen at the bottom with a permeability greater than that of the soil specimen, but with openings sufficiently small (not larger than 10 percent finer size) to prevent movement of particles; (2) manometer outlets for measuring the loss of head, h, over a length, 1, equivalent to at least the diameter of the cylinder;

(3) a porous disk or suitable reinforced screen with a spring attached to the top, or any other device, for applying a light spring pressure of 22 to 44N (5 to 10 lbf) total load, when the top plate is attached in place. This will hold the placement density and volume of soil without change during the saturation of the specimen and the permeability testing to satisfy the requirement prescribed in 2.1.1.

3.2 Constant Head Filter Tank, as shown in Fig. 1, to supply water and to remove most of the air from tap water, fitted with suitable control valves to maintain conditions described in 2.1.2.

Note 1: De-aired water may be used if preferred.

3.3 Large Funnels, fitted with special cylindrical spouts 25 mm (1 in.) in diameter for 9.5 mm (3/8 in.) maximum size particles and 12.7 (1/2 in.) in diameter for 2.00 mm (No. 10) maximum size particles. The length of the spout should be greater than the full length of the permeability chamber - at least 152 mm (6 in.).

3.4 Specimen Compaction Equipment - Compaction equipment as deemed desirable may be used. The following are suggested: a vibrating tamper fitted with a tamping foot 50 mm (2 in.) in diameter; a sliding-weight tamper consisting of a tamping foot 50 mm (2 in.) in diameter, and a rod for sliding weights of 100 g (0.22 lb) (for sands) to 1 kg (2.25 lb) (for soils with a large gravel content), having an adjustable height of drop to 100 mm (4 in.) for sands and 200 mm (8 in.) for soils with large gravel contents.

3.5 Vacuum Pump or Water Faucet Aspirator, for evacuating and for saturating soil specimens under full vacuum (see Fig. 2).

3.6 Manometer Tubes, with metric scales for measuring head of water.

3.7 Balance, conforming to the requirements of AASHTO M 231, Class G 5.

3.8 Scoop, with a capacity of about 100 g (0.22 lb) of soil.

3.9 Miscellaneous Apparatus - Thermometers, clock with sweep second hand, 250 ml graduate, quart jar, mixing pan, scoop, etc.

4. SAMPLE

4.1 A representative sample of air-dried granular soil, containing less than 10 percent nonplastic soil passing the 0.075 mm sieve and equal to an amount sufficient to satisfy the requirements prescribed in 4.2 and 4.3, shall be selected by the method of quartering.

4.2 A sieve analysis FM 1-T 088, Test for Particle Size Analysis of Soils, shall be made on a representative sample of the complete soil prior to the permeability test. Any particles larger than 19.0 mm (3/4 in.) shall be separated out by sieving. This oversize material shall not be used for the permeability test, but the percentage of the oversize material shall be recorded.

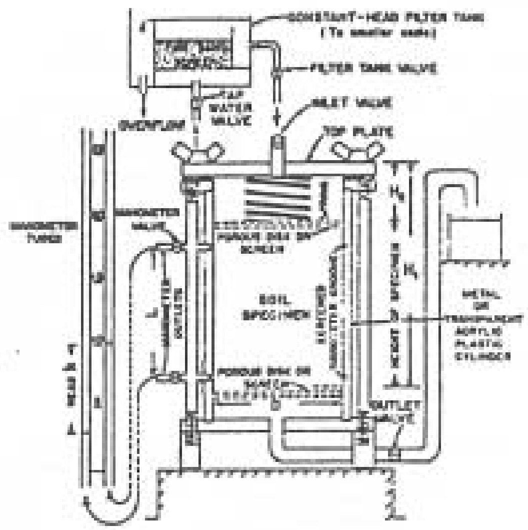


FIGURE 1 Constant Head Permeameter

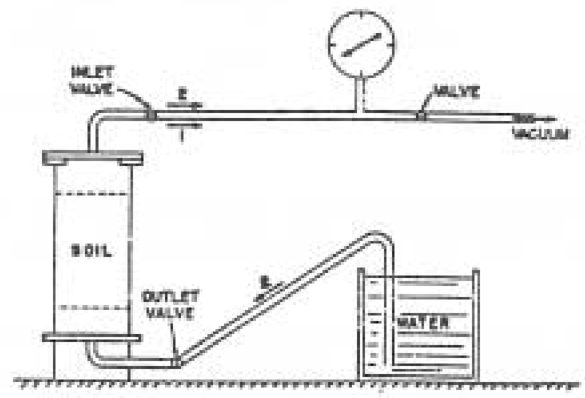


FIGURE 2 Device for Evacuating and Saturating Specimen

Note 2: In order to establish values of coefficients of permeabilities for the range that may exist in the situation being investigated, samples of the finer, average, and coarser soils should be obtained for testing.

4.3 From the material from which the oversize has been removed (see 4.2), select by the method of quartering, a sample for testing equal to an amount approximately twice that required for filling the permeameter chamber.

5. PREPARATION OF SPECIMENS

5.1 The size of permeameter to be used shall be as prescribed in Table 1.

5.2 Make the following initial measurements in millimeters or square millimeters and record on the test data sheet (Fig. 3); the inside diameter, D, of the permeameter; the length, L, between manometer outlets; the depth, H_1, measured at four symmetrically spaced points from the upper surface of the top plate of permeability cylinder to the top of the upper porous stone or screen temporarily placed on the lower porous plate or screen. This automatically deducts the thickness of the upper porous plate or screen from the height measurements used to determine the volume of soil placed in the permeability cylinder. A duplicate top plate containing four large symmetrically spaced openings through which the necessary measurements can be made shall be employed to determine the average value for H_1. Calculate the cross sectional area, A, of the specimen.

TABLE 1 Cylinder Diameter

	Minimum Cylinder Diameter			
	More than 35 percent of Total Soil Retained on Sieve Opening		Less than 35 percent of Total Soil Retained on Sieve Opening	
Maximum Particle Size Lies Between Sieve Openings	2.00-mm (No. 10)	9.5-mm (⅜-in.)	2.00-mm (No. 10)	9.5-mm (⅜-in.)
2.00-mm (No. 10) and 9.5-mm (⅜-in.)	75 mm (3 in.)	—	115 mm (4.5 in.)	—
9.5-mm (⅜-in.) and 19-mm (¾-in.)	—	150 mm (6 in.)	—	230 mm (9 in.)

5.3 A small portion of the sample selected as prescribed in 4.2 shall be taken for water content determinations. Record the mass of the remaining air-dried sample (see 4.3), W_1, for density determinations.

5.4 Place the prepared soil by one of the following procedures in uniform thin layers approximately equal in thickness after compaction to the maximum size of particle, but not less than approximately 15 mm (0.60 in.).

5.4.1 For soils having a maximum size of 9.5 mm (3/8 in.) or less, place the appropriate size of funnel, as prescribed in 3.3, in the permeability device with the spout in contact with the lower porous plate or screen, or previously formed layer, and fill the funnel with sufficient soil to form a layer, taking soil from different areas of the sample in the pan. Lift the funnel by 15 mm (0.60 in.), or approximately the unconsolidated layer thickness to be formed, and spread the soil with slow spiral motion, working from the perimeter of the device toward the center, so that a uniform layer is formed. Remix the soil in the pan for each successive layer to reduce segregation caused by taking soil from the pan.

5.4.2 For soils with a maximum size greater than 9.5 mm (3/8 in.), spread the soil from a scoop. Uniform spreading can be obtained by sliding a scoopful of soil in a nearly horizontal position down along the inside surface of the device to the bottom or to the formed layer, then tilting the scoop and drawing it toward the center with a single slow motion; this allows the soil to run smoothly from the scoop in a windrow without segregation. Turn the permeability cylinder sufficiently for the next scoopful, thus progressing around the inside perimeter to form a uniform compacted layer of a thickness equal to the maximum particle size.

5.5 Compact successive layers of soil to the desired relative density by appropriate procedures, as follows, to a height of about 20 mm (0.8 in.) above the upper manometer outlet.

5.5.1 Minimum Density (0 Percent Relative Density)[1] - Continue placing layers of soil in succession by one of the procedures described in 5.4.1 or 5.4.2 until the device is filled to the proper level.

5.5.2 Maximum Density (100 percent Relative Density)[1]:

5.5.2.1 Compacting by Vibrating Tamper - Compact each layer of soil thoroughly with the vibrating tamper, distributing the light tamping action uniformly over the surface of the layer in a regular pattern. The pressure of contact and the length of time of the vibrating action at each spot should not cause soil to escape from beneath the edges of the tamping foot, thus tending to loosen the layer. Make a sufficient number of coverages to produce maximum density, as evidenced by practically no visible motion of surface particles adjacent to the edges of the tamping foot.

5.5.2.2 Compaction by Sliding Weight Tamper - Compact each layer of soil thoroughly by tamping blows uniformly distributed over the surface of the layer. Adjust the height of drop and give sufficient coverages to produce maximum density, depending on the coarseness and gravel content of the soil.

5.5.2.3 Compaction by Other Methods - Compaction may be accomplished by other approved methods, such as by vibratory packer equipment, where care is taken to obtain a uniform specimen without segregation of particle sizes.

5.5.3 Relative Density[1] Intermediate Between 0 and 100 Percent - By trial in a separate container of the same diameter as the permeability cylinder, adjust the compaction to obtain reproducible values of relative density. Compact the soil in the permeability cylinder by these procedures in thin layers to a height about 20 mm (0.80 in.) above the upper manometer outlet.

Note 3: In order to bracket, systematically and representatively, the relative density conditions that may govern in natural deposits or in compacted embankments, a series of permeability tests should be made to bracket the range of field relative densities.

5.6 Preparation of Specimens for Permeability Test:

[1] ASTM Designation: D 2049, Standard Method of Test for Relative Density of Cohesionless Soils.

5.6.1 Level the upper surface of the soil by placing the upper porous plate or screen in position and by rotating it gently back and forth.

5.6.2 Measure and record: The final height of specimen, H_1-H_2, by measuring the depth, H_2, from the upper surface of the perforated top plate employed to measure H_1 to the top of the upper porous plate or screen at four symmetrically spaced points after compressing the spring lightly to seat the porous plate or screen during the measurements; the final mass of air-dried soil used in the test (W_1-W_2) by weighing the remainder of soil, W_2, left in the pan. Compute and record the densities, void ratio, and relative density of the test specimen.

5.6.3 With its gasket in place, press down the top plate against the spring and attach it securely to the top of the permeameter cylinder, making an airtight seal. This satisfies the condition described in 2.1.1 of holding the initial density without significant volume change during the test.

5.6.4 Using a vacuum pump or suitable aspirator, evacuate the specimen under 500 mm (20 in.) mercury minimum for 15 min to remove air adhering to soil particles and from the voids. Follow the evacuation by a slow saturation of the specimen from the bottom upward (Fig. 2) under full vacuum in order to free any remaining air in the specimen. Continued saturation of the specimen can be maintained more adequately by the use of (1) deaired water, or (2) water maintained at an in-flow temperature sufficiently high to cause a decreasing temperature gradient in the specimen during the test. Native water or water of low mineral content should be used for the test, but in any case the fluid should be described on the report form (Fig. 3). This satisfies the conditions described in 2.1.2 for saturation of soil voids.

Note 4: Native water is the water occurring in the rock or soil in situ. It should be used if possible, but it (as well as de-aired water) may be a refinement not ordinarily feasible for large-scale production testing.

5.6.5 After the specimen has been saturated and the permeameter is full of water, close the bottom valve on the outlet tube (Fig. 2) and disconnect the vacuum. Care should be taken to ensure that the permeability flow system and the manometer system are free of air and are working satisfactorily. Fill the inlet tube with water from the constant-head tank by slightly opening the filter tank valve. Then connect the inlet tube to the top of the permeameter, open the inlet valve slightly and open the manometer outlet cocks, slightly, to allow water to flow, thus freeing them of air. Connect the water manometer tubes to the manometer outlets and fill with water to remove the air. Close the inlet valve and open the outlet valve to allow the water in the manometer tubes to reach their stable water level under zero head.

6. PROCEDURE

6.1 Open the inlet valve from the filter tank slightly for the first run to conditions described in 2.1.3, delay measurements of quantity of flow and head until a stable head condition without appreciable drift in water manometer levels is attained. Measure and record the time, t, head, h (the difference in level in the manometers), quantity of flow, Q, and water temperature, T.

PERMEABILITY TEST ON GRANULAR SOIL

Test No.
Location of Sample — Date Sampled
Boring— Sample— Depth—

Date of Test
Report

(a) Description of Soil ______________________________

____

Materials Used: ______________________________

(b) Unit Weight Determination:

Diameter, D cm
Area, A, sq cm
Length, L, cm

Height Before, H_1
Height After, H_2
Height Net, cm

Weight Before, W_1
Weight After, W_2
Weight Net, g

Moisture Content (air-dried) ________

W(max)
W (min)

Dry Unit Density, pcf W ________
Void Ratio, e ________
Relative Density, RD ________

(c) Permeability Test (Degrees of Compactness)

Test No.	Manometers		Head h	Q cm³	t (sec)	Q/At	h/L	Temperature (deg C)	k (cm k/sec)
	H_1	H_2							
1									
2									
3									
4									
5									
6									

FIGURE 3 Permeability Test Data Sheet

6.2 Repeat test runs at heads increasing by 5 mm in order to establish accurately the region of lamin flow with velocity, v, (where v = Q/At) directly proportional to hydraulic gradient, i (where i = hL). When departures from the linear relation become apparent, indicating the initiation of turbulent flow conditions, 10 mm intervals of head may be used to carry the test run sufficiently along in the region of turbulent flow to define this region if it is significant for field conditions.

Note 5: Much lower values of hydraulic gradient, h/L, are required than generally recognized, in orde to insure laminar flow conditions. The following values are suggested: Loose compactness ratings h/L from 0.2 to 0.3, and dense compactness ratings h/L from 0.3 to 0.5, the lower values of h/L applying to coarser soils and the higher values to finer soils.

6.3 At the completion of the permeability test, drain the specimen and inspect it to establish whether it was essentially homogeneous and isotropic in character. Any light and dark alternating horizontal streaks or layers are evidence of segregation of fines.

7. CALCULATIONS

7.1 Calculate the coefficient of permeability, k, as follows:

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

Where:
k = coefficient of permeability,
Q = quantity of water discharged,
L = distance between manometers,
A = cross-sectional area of specimen,
t = total time of discharge,
h = difference in head on manometers.

7.2 Correct the permeability to that for 20°C (68°F) by multiplying k (7.1) by the ratio of the viscosity of water at test temperature to the viscosity of water at 20°C (68°F).

8. REPORT

8.1 The report of permeability test shall include the following information:

8.1.1 Project, dates, sample number, location, depth, and any other pertinent information.

8.1.2 Grain size analysis, classification, maximum particle size, and percentage of any oversize material not used.

8.1.3 Dry density, void ratio, relative density as placed, and maximum and minimum densities.

8.1.4 A statement of any departures from these test conditions, so the results can be evaluated and used.

8.1.5 Complete test data, as indicated in the laboratory form for test data (see Fig. 3) and

8.1.6 Test curves plotting velocity, Q/At, versus hydraulic gradient, h/L, covering the ranges of soil identifications and of relative densities.

APPENDIX B
SOIL PROPERTY DATA

LAB. NO. 020143 PROJ 19106618101

REPORTED

CARBONATES OF CALCIUM AND MAGNESIUM

MAX DEN (M) 110 LBS/CF/KG/CM ORGANIC MATTER

OPT. MOIST 10 PERCENT THIS SAMPLE PASSED SPECIFICATION

LBR- 280

PASS 3.5" SIEVE JOB CONTROL RESULTS

PASS #4 SIEVE MAX DEN ( ) LBS/CF

PASS #200 SIEVE OPT. MOIST PER CENT.

LIQUID LIMIT - NP

PLASTIC INDEX - NP

Pass #40 Sieve = 94 %

Perm. = 3.594×10^{-4} Pass #60 Sieve = 76 %

Pass #200 Sieve = 12 %

Class = A-2-4

TESTED BY Greer / Harvey DATE

20143-3

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

FORM 675-050-04 MATERIALS - 08/99

PROJECT ID:

MATERIAL NO. PAY ITEM NO.

DATE SAMPLED 032901 SAMPLE NO. 4

STA TO STA FROM

RDWAY SIDE OFFSET DISTANCE SAMP FROM

REFERENCE LINE OFFSET DIRECTION MAINLINE

PLANT OR PIT NO. W.H. QUANT REP

INTENDED USE OR PART OF STRUCTURE PLACED Subgrade Embankment

ROAD NO. DISTRICT NO.

CONTRACT COUNTY SECTION

MATERIAL DESC. SAND SAMPLED BY

MANUFACTURER OR PRODUCER (NOT JOBBER)

SOURCE (PLACE FROM WHICH SHIPMENT WAS MADE)

GRADE

LOT NO. LAB NO. 020143

SLUMP DESIGN MIX NO.

% AIR

PRODUCERS: CMT. F.A. C.A.

RETARDANT FLY ASH

REMARKS

T-180, LBR, CLASSIFICATION

SUBMITTED BY R. Venick PHONE 955-6379

ADDRESS

RECYCLED PAPER

CONSTANT HEAD PERMEABILITY

roject No. ____________ Sta. ____________ Lab No. 20143-5

ample Height(cm) 11.66 Sample diameter(cm) 15.24 Area(cm^2) 182.41

ested by Harvey Date 24-05-01

Perm

Mold No.	Test	W%	Yd(pcf)	h(cm)	t(sec)	Q(cm^3)	T°c	Kt	K20°c
#100				82	120	64	20.8°C	4.158×10^{-4}	4.078×10^{-4}
				82	120	63	20.8°C	4.093×10^{-4}	4.014×10^{-4}
				82	120	63	20.8°C	4.093×10^{-4}	4.014×10^{-4}
				82	120	63	20.8°C	4.093×10^{-4}	4.014×10^{-4}
				82	120	63	20.8°C	4.093×10^{-4}	4.014×10^{-4}
				82	180	93	20.8°C	4.028×10^{-4}	3.95×10^{-4}
				82	120	64	20.8°C	4.158×10^{-4}	4.078×10^{-4}
				82	120	64	20.8°C	4.158×10^{-4}	4.078×10^{-4}
				82	120	63	20.8°C	4.093×10^{-4}	4.014×10^{-4}
				82	120	64	20.8°C	4.158×10^{-4}	4.078×10^{-4}
				82	120	63	20.8°C	4.093×10^{-4}	4.014×10^{-4}
				82	120	64	20.8°C	4.158×10^{-4}	4.078×10^{-4}
				82	120	63	20.8°C	4.093×10^{-4}	4.014×10^{-4}
				82	120	63	20.8°C	4.093×10^{-4}	4.014×10^{-4}
				82	120	63	20.8°C	4.093×10^{-4}	4.014×10^{-4}
				82				AVG =	4.031×10^{-4}
				82					
				82					
				82					
				82					

$$KT = \frac{QL}{tha}$$

$$K20° = \left(\frac{UT}{U20°c}\right) K_T$$

Where Kt = coefficient of permeability at T temperature
Q = discharge (cm^3)
L = length of soil sample
t = time in seconds
h = total head
A = Cross-sectional Area

Where UT = Viscosity of water at T temperature
U20°c = Viscosity of water at 20° centigrade

CONSTANT HEAD PERMEABILITY

roject No. ______ Sta. ______ Lab No. 20143-S

ample Height(cm) 11.66 Sample diameter(cm) 15.24 Area(cm²) 182.41

ested by Harvey Date 04-05-01

Mold No.	Test	W%	Yd(pcf)	h(cm)	t(sec)	Q(cm³)	T°c	Kt	K20°c
111				82	120	32.5	20.8°c	2.149×10^{-4}	2.110×10^{-4}
				82	120	33	20.8°c	2.149×10^{-4}	2.110×10^{-4}
				82	120	33	20.8°c	2.149×10^{-4}	2.110×10^{-4}
				82	120	33	20.8°c	2.149×10^{-4}	2.110×10^{-4}
				82	120	33	20.8°c	2.149×10^{-4}	2.110×10^{-4}
				82	180	51	20.8°c	2.221×10^{-4}	2.166×10^{-4}
				82	120	38	20.8c	2.469×10^{-4}	2.421×10^{-4}
				82	120	38	20.8°	2.469×10^{-4}	2.421×10^{-4}
				82	120	37	20.8°c	2.404×10^{-4}	2.358×10^{-4}
				82	120	37	20.8°c	2.404×10^{-4}	2.358×10^{-4}
				82	120	38	20.8°c	2.469×10^{-4}	2.421×10^{-4}
				82	120	37	20.8°c	2.404×10^{-4}	2.358×10^{-4}
				82	120	37	20.8°c	2.404×10^{-4}	2.358×10^{-4}
				82	120	37	20.8°c	2.404×10^{-4}	2.358×10^{-4}
				82	120	37	20.8°c	2.404×10^{-4}	2.358×10^{-4}
				82	120	37	20.8°c	2.404×10^{-4}	2.358×10^{-4}
				82				AVG=	2.280×10^{-4}
				82					
				82	Perm# 100 + Perm# 111			AVE=	3.19×10^{-4}
				82	mold	mold			

$$KT = \frac{QL}{tha}$$

$$K20° = \left(\frac{UT}{U20°c}\right) K_T$$

Where Kt = coefficient of permeability at T temperature
Q = discharge (cm³)
L = length of soil sample
t = time in seconds
h = total head
A = Cross-sectional Area

Where UT = Viscosity of water at T temperature
U20°c = Viscosity of water at 20° centigrade

TESTED BY JH

DATE TESTED 104050

Perm

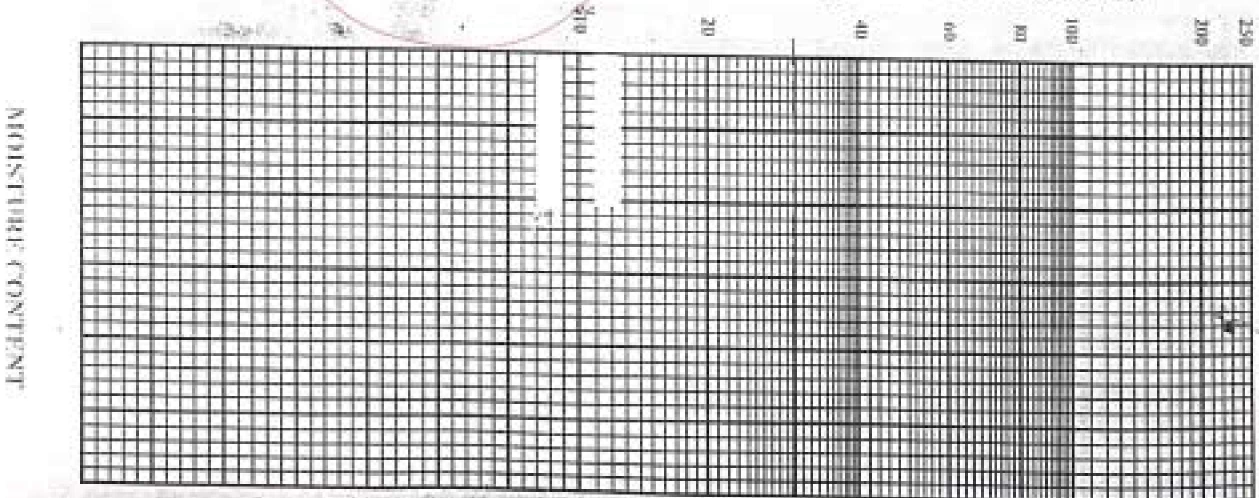
MOLD NO.	100	111					PASS/RET.	
[illegible]	11.3%	11.3%					1 1/2"	
WT. + MOLD (GM)	11294.8	11410.2					1 1/2" 1"	
WT. + MOLD (LBS)	24.90	25.15					1" 3/4"	
WT. OF MOLD (LBS)	15.79	16.12					3/4" #4	
WET WT. (LBS)	9.11	9.03					#4	
WET UNIT WT. (LBS/C.F.)	121.4	120.4						
DRY UNIT WT. (LBS/C.F.)	109.2	107.8						
L.B.R.								
BEGIN SOAK								
END SOAK								
TIME OF TEST								

MOISTURE DETERMINATION

CAN NO.	B-5	F						
CAN + WET SOIL (GM)	526.10	593.80						
CAN + DRY SOIL (GM)	480.60	539.60						
WT. WATER (GM)	45.50	54.20						
WT. CAN (GM)	75.80	76.60						
WT. DRY SOIL (GM)	404.80	463.00						
MOISTURE CONTENT (%)	11.2%	11.7%						

DRY UNIT WT (P.C.F)

L.B.R. @ 0.1" PENATRATION



Project No. ____________

Lab No. 20143-5

Sample No. 5-4

Date 04-04-01

Tested By Harvey

Sample Description ____________

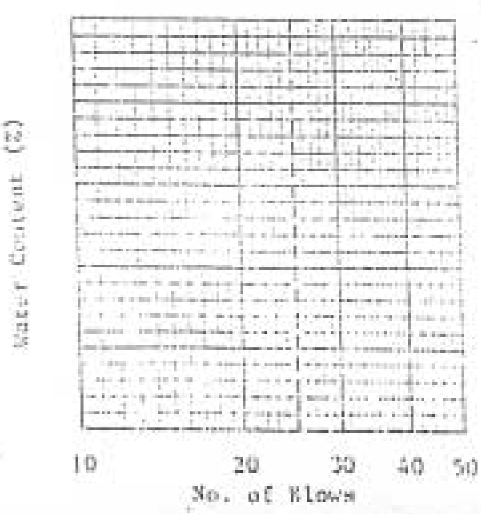
____

Liquid Limit

Tare No.	Wet Wt. + Tare (gm)	Dry Wt. + Tare (gm)	Wt. Water (gm)	Tare Wt. (gm)	Dry Wt. (gm)	Water Content (%)	No. of Blows
		N.P.			N.P.		

Plastic Limit

Tare No.	Wet Wt. + Tare (gm)	Dry Wt. + Tare (gm)	Wt. Water (gm)	Tare Wt. (gm)	Dry Wt. (gm)	Water Content (%)



Summary

Liquid Limit, LL ________ %

Plastic Limit, PL ________ %

Plasticity Index, P.I. ________ %

Remarks ____________

____

DEPARTMENT OF TRANSPORTATION

PARTICLE SIZE ANALYSIS
WORK SHEET

UMBER ______ LINE ITEM NO. ______ MATERIAL NO. ______

LE NO. 3-4 LAB NO. 20,143-3 TESTED BY TH PASSED ______ FAILED ______

INED BY Class. A-2-4 DATE TESTED 949291

D. ______ W. Grade

FIC GRAVITY ______

INAL SAMPLE ______ GM MINUS #10 MAT. ______ GM = ______ %

VE ANALYSIS

E SIZE	3"	2"	1"	#4	#10	#40	#60	#100	#200
RETAINED (GM)						8.18	33.86		125.10
ETAINED						5.73	23.71		87.59
NER						94.27	76.29		12.41
NER (TOTAL)					100	94	76		12

HYGROSCOPIC MOISTURE

TARE NO.	2
TARE + AIR DRY SOIL (GM)	121.11
TARE + OVEN DRY SOIL (GM)	121.09
WT. WATER (GM)	0.02
TARE WT. (GM)	95.38
OVEN DRY SOIL (GM)	25.71
HYGROSCOPIC MOISTURE, W (%)	0.078
CORRECTION FACTOR 100/(100 + W)	0.9992

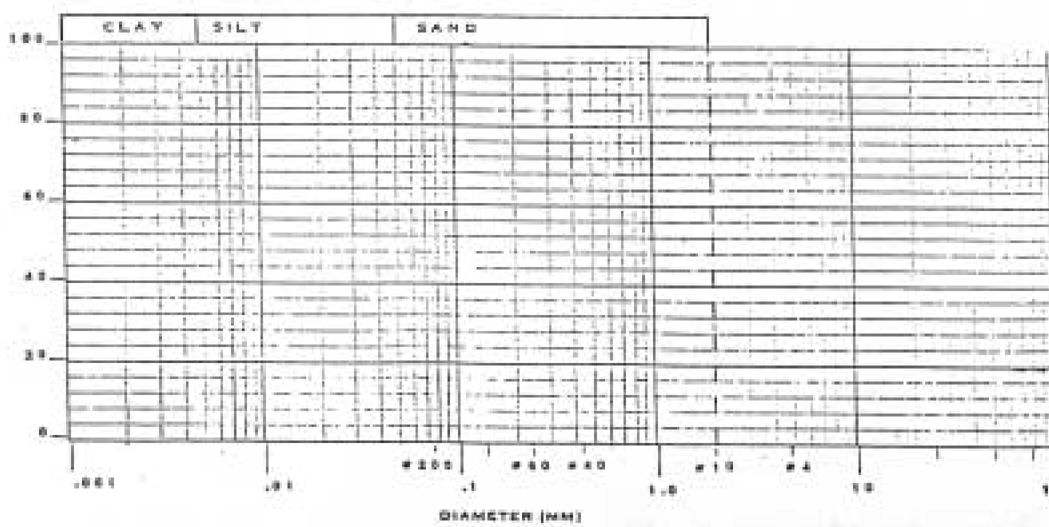
ROMETER ANALYSIS TIME START ______

R HYDROMETER (152H)

ASPED TIME (MIN.)	2	5	15	30	60	250	1440
IPERATURE (°F)							
DROMETER READING							
MPOSITE CORRECTION							
RRECTED READING, R							
AIN DIAMETER (MM)							
INER = $\frac{RA}{W} \times 100$							
INER (TOTAL)							

MINUS #10 MATERIAL

PERCENTAGE (%)	
TARE + AIR DRY (GM)	241.50
TARE NO. 110 (GM)	98.56
AIR DRY WT. (GM)	142.94
OVEN DRY, W (GM)	142.83



CLAY ______ % SILT ______ % SAND ______ %

COMPACTION TEST (~~STANDARD~~/MODIFIED) & LBR WORKSHEET ✓ 120

SAMPLE NO. 5-4 LAB NO. 2011435 TESTED BY PASSED FAILED

SAMPLED BY Test Pit DATE TESTED

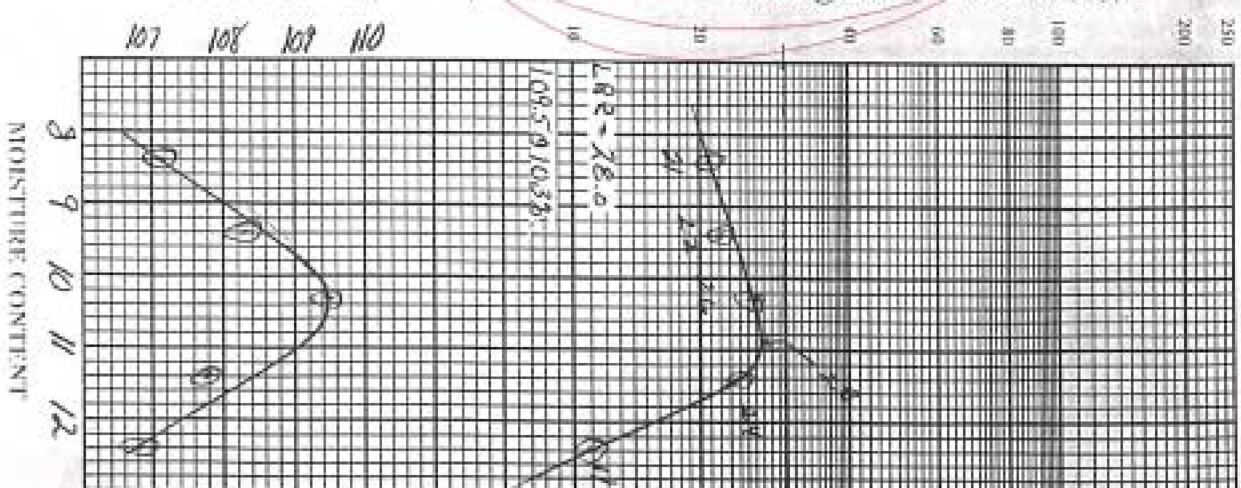
I NO. 15 4SC Lt Brown Sand

DATE COMPACTED 4-2-01

MOLD VOLUME (1/30) or (1/13.33) C.F.

							PASS/RET.	%
MOLD NO.		177	55	19	218	198		
WATER (ADDED)		8%	9%	10%	11%	12%	3 1/2" --	
WET WT. + MOLD (GM)		11190	11275	11370	11193	11239	3 1/2 3"	
WET WT. + MOLD (LBS)		25.67	24.86	25.07	24.68	24.78	2" 3/4"	
WT. OF MOLD (LBS)		15.96	15.97	16.01	15.67	15.76	3/4" #4	
NET WT. (LBS)		8.71	8.89	9.06	9.01	9.02	#4 ---	
WET UNIT WT. (LBS/C.F.)		116.1	118.5	120.9	1201	120.2		
DRY UNIT WT. (LBS/C.F.)		107.1	108.3	109.5	107.9	106.9		
L.B.R.		21.0	22.0	26.0	24.0	11.0		
BEGIN SOAK					—			
END SOAK		7	6	5	4	3		
TIME OF TEST				Damp	Damp	Wet		
MOISTURE DETERMINATION								
CAN NO.		C-9	2-4	13	23	H-6		
CAN + WET SOIL (GM)		722.5	710.7	710.8	714.5	723.4		
CAN + DRY SOIL (GM)		672.6	656.0	651.6	649.4	652.0		
WT. WATER (GM)		49.9	54.7	59.2	65.1	71.4		
WT. CAN (GM)		75.8	75.6	76.2	77.2	77.1		
WT. DRY SOIL (GM)		596.8	580.4	575.4	572.2	574.9		
MOISTURE CONTENT (%)		8.9	9.4	10.3	11.4	12.4		

DRY UNIT WT (P.C.F) L.B.R. @ 0.1" PENATRATION



LAB. NO. 020145 PROJ 19106618101

REPORTED

CARBONATES OF CALCIUM AND MAGNESIUM

MAX DEN (M) 113 LBS/CF/KG/CM ORGANIC MATTER

OPT. MOIST 12 PERCENT THIS SAMPLE PASSED SPECIFICATION

LBR- 32.0

PASS 3.5" SIEVE JOB CONTROL RESULTS

PASS #4 SIEVE MAX DEN ( ) LBS/CF

PASS #200 SIEVE OPT. MOIST PER CENT

LIQUID LIMIT - NP

PLASTIC INDEX - NP

Class = A-3

Ave Perm = 6.228 X 10^-4

TESTED BY Green / Harvey DATE

20145-S

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

MAR 2 9 2001

FORM 675-030-04 MATERIALS - 00/00

PROJECT ID 1910661 B1 01 PAY ITEM NO.

MATERIAL NO. SAMPLE NO. 1

DATE SAMPLED 03/29/01 STA FROM

STA TO SAMP FROM

RDWAY SIDE OFFSET DISTANCE OFFSET DIRECTION MAINLINE

REFERENCE LINE

PLANT OR PIT NO. QUANT REP

INTENDED USE OR PART OF STRUCTURE PLACED EMBANKMENT

ROAD NO. DISTRICT NO. COUNTY Alachua SECTION

CONTRACT SAMPLED BY Lewis

MATERIAL DESC. Sand

MANUFACTURER OR PRODUCER (NOT JOBBER) V G Whitehurst

SOURCE (PLACE FROM WHICH SHIPMENT WAS MADE) Starveation Hill

GRADE BATCH NO.

LOT NO. LAB NO. DESIGN MIX NO.

SLUMP % AIR

PRODUCERS: CMT. F.A. C.A.

RETARDANT FLY ASH

REMARKS T-180-LBR, WASH GRAD

SUBMITTED BY R.C. Lewis PHONE

ADDRESS RECYCLED PAPER

CONSTANT HEAD PERMEABILITY

ject No. ______________ Sta. ______________ Lab No. 20145-S #1

ple Height(cm) 11.66 Sample diameter(cm) 15.24 Area(cm^2) 182.41

ted by Harvey Date 04-04-01

Perms

ld No.	Test	W%	Yd(pcf)	h(cm)	t(sec)	Q(cm^3)	T°c	Kt	K20°c
109				82	90	78	23.0°c	6.756×10^{-4}	6.290×10^{-4}
				82	90	78	23.0°c	6.756×10^{-4}	6.290×10^{-4}
				82	90	76	23.0°c	6.588×10^{-4}	6.129×10^{-4}
				82	90	75	23.0°c	6.496×10^{-4}	6.049×10^{-4}
				82	89	75	23.0°c	6.496×10^{-4}	6.049×10^{-4}
				82	89	75	23.0°c	6.496×10^{-4}	6.049×10^{-4}
				82	88	75	22.0°c	6.644×10^{-4}	6.190×10^{-4}
				82	88	75	23.0°c	6.496×10^{-4}	6.049×10^{-4}
				82	88	75	23.0°c	6.496×10^{-4}	6.049×10^{-4}
								AVG =	6.127×10^{-4}
113				82	85	79	22.0°c	7.245×10^{-4}	6.905×10^{-4}
				82	90	72	22.0°c	6.609×10^{-4}	6.293×10^{-4}
				82	86	73	22.0°c	6.695×10^{-4}	6.381×10^{-4}
				82	86	72	22.0°c	6.609×10^{-4}	6.293×10^{-4}
				82	86	72	22.0°c	6.603×10^{-4}	6.293×10^{-4}
				82	86	73	22.0°c	6.695×10^{-4}	6.381×10^{-4}
				82	86	71	22.0°c	6.511×10^{-4}	6.246×10^{-4}
				82	85	71	22.0°c	6.571×10^{-4}	6.206×10^{-4}
				82	85	70	22.0°c	6.420×10^{-4}	6.119×10^{-4}
				82	85	71	22.0°c	6.511×10^{-4}	6.206×10^{-4}
								AVG =	6.328×10^{-4}

$KT = \frac{QL}{tha}$ Mold #109 + Mold #113 results AVG = 6.228×10^{-4} $K20° = \left(\frac{UT}{U20°c}\right) K_T$

Where Kt = coefficient of permeability at T temperature
Q = discharge (cm^3)
L = length of soil sample
t = time in seconds
h = total head
A = Cross-sectional Area

Where UT = Viscosity of water at T temperature

U20°c = Viscosity of water at 20° centigrade

#1

20145-5

TH

04 04 01

Per 111

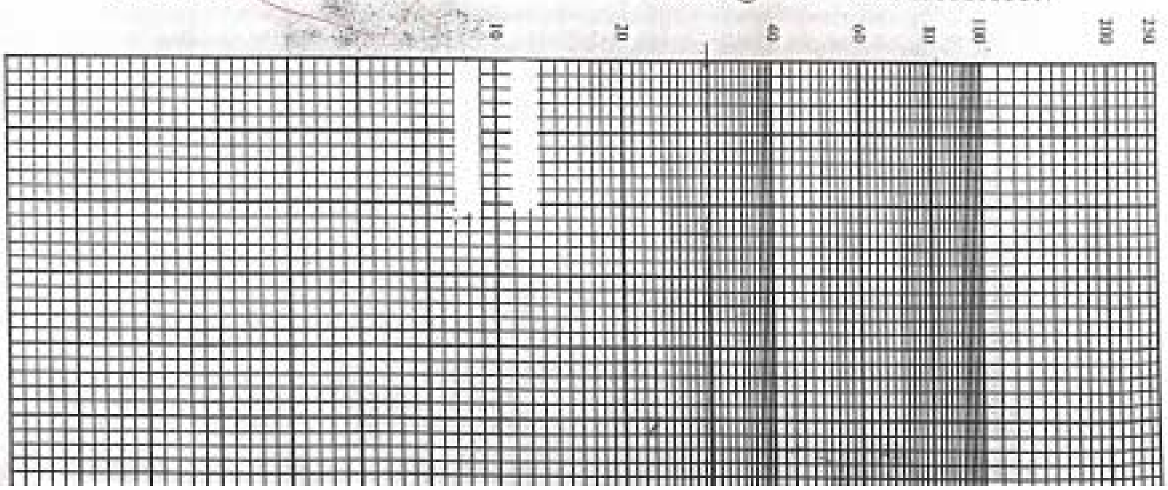
OLD NO.	109	113				
ATER (ADDED)	10.3%	10.3%				
ET WT. + MOLD (GM)	11456.1	11269.1				
ET WT. + MOLD (LBS)	25.26	24.84				
T. OF MOLD (LBS)	16.20	15.72				
ET WT. (LBS)	9.06	9.12				
ET UNIT WT. (LBS/C.F.)	120.8	121.6				
RY UNIT WT. (LBS/C.F.)	109.7	109.8				
.B.R.						
EGIN SOAK						
ND SOAK						
TIME OF TEST						

MOISTURE DETERMINATION

CAN NO.	G-10	D-5				
CAN + WET SOIL (GM)	578.50	624.45				
CAN + DRY SOIL (GM)	532.50	571.20				
WT. WATER (GM)	46.00	53.25				
WT. CAN (GM)	76.20	74.30				
WT. DRY SOIL (GM)	456.30	496.90				
MOISTURE CONTENT (%)	10.1%	10.7%				

DRY UNIT WT (P.C.F.) L.B.R. @ 0.1" : PENATRATION

MOISTURE CONTENT



[illegible]

Project No. ____________

Lab No. 20145-S

Sample No. #1

Date 04-04-01

Tested by Harvey

Sample Description ____________

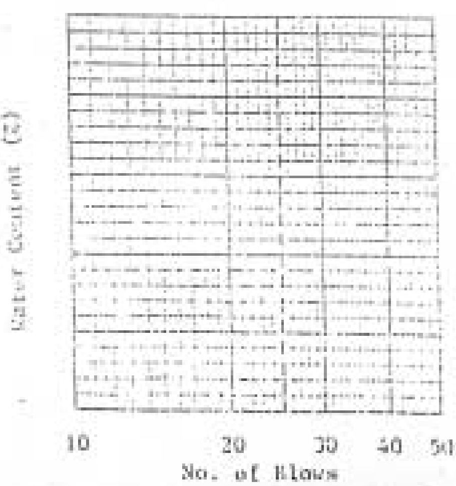
____

Liquid Limit

Tare No.	Wet Wt. + Tare (gm)	Dry Wt. + Tare (gm)	Wt. Water (gm)	Tare Wt. (gm)	Dry Wt. (gm)	Water Content (%)	No. of Blows
	N.P.		N.P.				

Plastic Limit

Tare No.	Wet Wt. + Tare (gm)	Dry Wt. + Tare (gm)	Wt. Water (gm)	Tare Wt. (gm)	Dry Wt. (gm)	Water Content (%)



Summary

Liquid Limit, LL ________ %

Plastic Limit, PL ________ %

Plasticity Index, P.I. ________ %

Remarks ____________

____

DEPARTMENT OF TRANSPORTATION

PARTICLE SIZE ANALYSIS WORK SHEET

NUMBER: ______ LINE ITEM NO. ______ MATERIAL NO. ______

FILE NO. 41 LAB NO. 20/45 TESTED BY ______ PASSED ______ FAILED ______

SAMPLED BY ______ DATE TESTED ______

NO. = H-3

SPECIFIC GRAVITY ______

ORIGINAL SAMPLE ______ GM MINUS #10 MAT. ______ GM = ______ %

SIEVE ANALYSIS

SIEVE SIZE	3"	2"	1"	#4	#10	#20	#40	#100	#200
WT. RETAINED (GM)						19.00	62.78		105.16
% RETAINED						16.91	56.75		93.57
% FINER						83.09	43.25		6.43
% FINER (TOTAL)					100	83	43		6

HYGROSCOPIC MOISTURE

TARE NO.	71
TARE + AIR DRY SOIL (GM)	140.37
TARE + OVEN DRY SOIL (GM)	140.29
WT. WATER (GM)	0.08
TARE WT. (GM)	101.66
OVEN DRY SOIL (GM)	38.63
HYGROSCOPIC MOISTURE, W (%)	0.207
CORRECTION FACTOR 100/(100 + W)	.9979

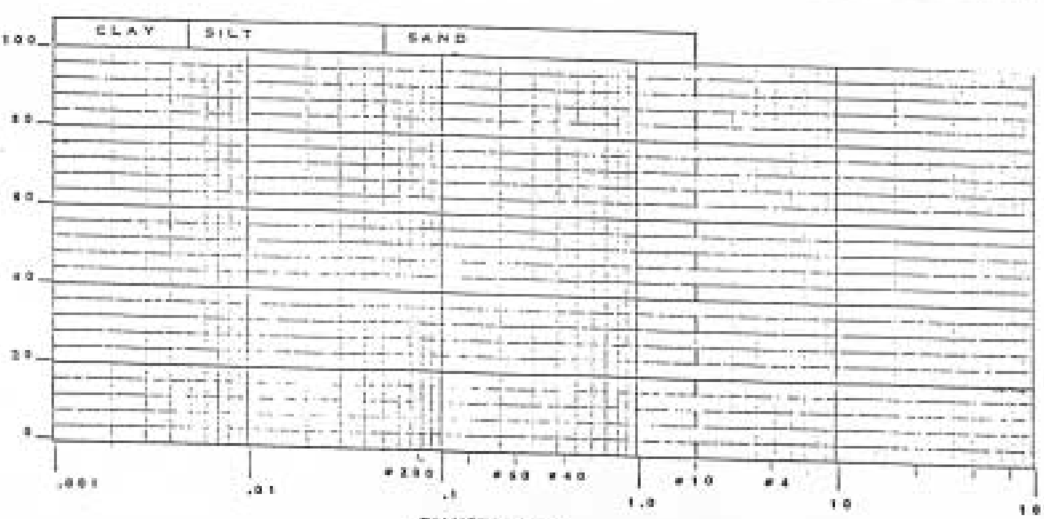
HYDROMETER ANALYSIS

TIME START ______

ELAPSED TIME (MIN.)	2	5	15	30	60	250	1440
TEMPERATURE (°F)							
HYDROMETER READING							
COMPOSITE CORRECTION							
CORRECTED READING, R							
GRAIN DIAMETER (MM)							
% FINER = $\frac{RA}{W} \times 100$							
% FINER (TOTAL)							

MINUS #10 MATERIAL

PERCENTAGE (%)	
TARE + AIR DRY (GM)	212.00
TARE NO. 15 (GM)	99.38
AIR DRY WT. (GM)	112.62
OVEN DRY, W (GM)	112.39



CLAY ______ % SILT ______ % SAND ______ %

COMPACTION TEST (STANDARD/SOIL/FIELD) & LBR WORKSHEET

NUMBER | LINE ITEM NO. | MATERIAL NO.

HOLE NO. 1 | LAB NO. 201455 | TESTED BY | P-ITEM | ROLLED

SOURCE BY: Test Pit | DATE TESTED

T NO. 15 #SC Brown Sand

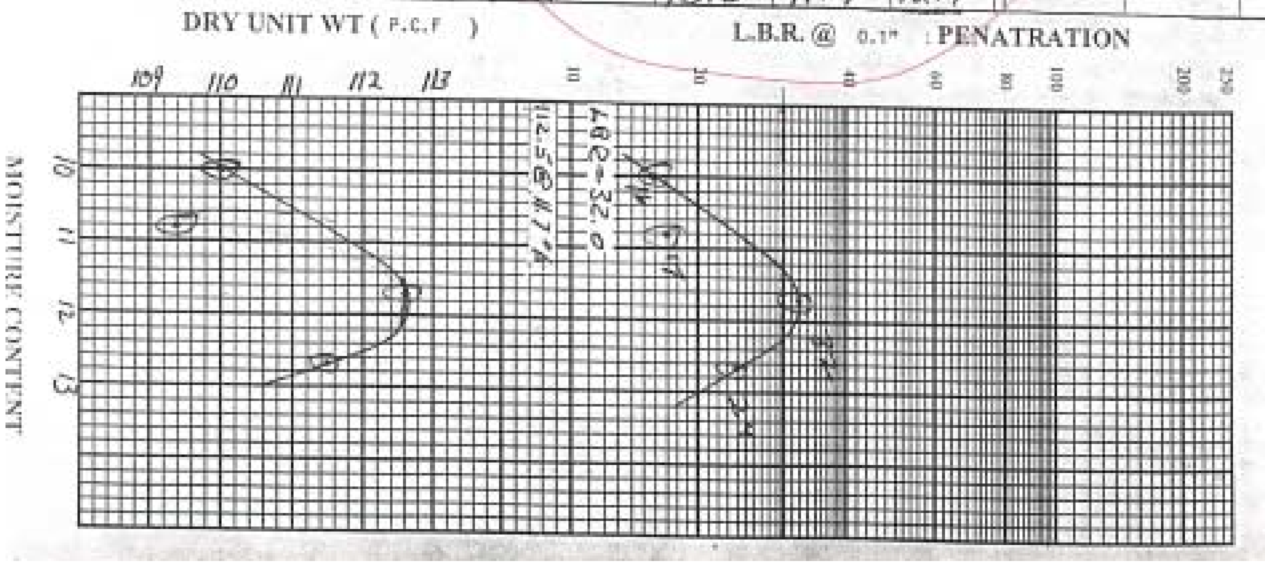
DATE COMPACTED 4-2-01

MOLD NO.			59	115	182	170	PASS/RET.	
WATER (ADDED)			9%	10%	11%	12%	1 1/2"	
WET WT. + MOLD (GM)			11355	11421	11350	11513	1 1/2" 1"	
WET WT. + MOLD (LBS)			25.03	25.18	26.02	25.38	1" 3/4"	
WT. OF MOLD (LBS)			15.95	16.09	16.59	15.95	3/4" #4	
WET WT. (LBS)			9.08	9.09	9.43	9.43		
WET UNIT WT. (LBS/C.F.)			121.0	121.2	125.7	125.7		
DRY UNIT WT. (LBS/C.F.)			110.0	109.4	112.5	111.5		
L.B.R.			16.0	17.0	32.0	24.0		
BEGIN SOAK								
END SOAK			11	10	9	8		
TIME OF TEST					[illegible]	[illegible]		

MOLD VOLUME 1/30 or 1/13.33 C.F.

MOISTURE DETERMINATION

CAN NO.			F	B-5	D-5	16		
CAN + WET SOIL (GM)			732.7	727.9	708.2	711.1		
CAN + DRY SOIL (GM)			673.0	664.6	692.1	639.3		
WT. WATER (GM)			59.7	63.3	66.1	71.8		
WT. CAN (GM)			76.6	75.8	74.8	75.6		
WT. DRY SOIL (GM)			594.4	588.8	567.3	563.7		
MOISTURE CONTENT (%)			10.0	10.8	11.7	12.7		



APPENDIX C
PERMEABILITY RESULTS DATA

Current LBR Permeability Results

Soil Type	*A-2-4*

A) 30 Minute Saturation Method, No Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	21	60	24.0	2.237E-04	2.040E-04	0.9097	0.0019	8.576
2	22	60	24.0	2.344E-04	2.137E-04	0.9097	0.0020	8.576
3	22	60	24.0	2.344E-04	2.137E-04	0.9097	0.0020	8.576
4	23	60	24.0	2.450E-04	2.234E-04	0.9097	0.0021	8.576
5	23	60	24.0	2.450E-04	2.234E-04	0.9097	0.0021	8.576
				2.365E-04	2.157E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	44	120	23.8	2.344E-04	2.147E-04	0.914	0.0020	8.576
2	45	120	23.8	2.397E-04	2.196E-04	0.914	0.0021	8.576
3	44.5	120	23.8	2.370E-04	2.172E-04	0.914	0.0020	8.576
4	24	120	23.8	1.278E-04	1.171E-04	0.914	0.0011	8.576
5	44.5	120	23.8	2.370E-04	2.172E-04	0.914	0.0020	8.576
				2.152E-04	1.971E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	60	24.2	2.131E-04	1.938E-04	0.9055	0.0018	8.576
2	19	60	24.2	2.024E-04	1.841E-04	0.9055	0.0017	8.576
3	21	60	24.2	2.237E-04	2.035E-04	0.9055	0.0019	8.576
4	20	60	24.2	2.131E-04	1.938E-04	0.9055	0.0018	8.576
5	20	60	24.2	2.131E-04	1.938E-04	0.9055	0.0018	8.576
				2.131E-04	1.938E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	22	60	25.0	2.344E-04	2.132E-04	0.8887	0.0020	8.576
2	23	60	25.0	2.450E-04	2.229E-04	0.8887	0.0021	8.576
3	22	60	25.0	2.344E-04	2.132E-04	0.8887	0.0020	8.576
4	22	60	25.0	2.344E-04	2.132E-04	0.8887	0.0020	8.576
5	22	60	25.0	2.344E-04	2.132E-04	0.8887	0.0020	8.576
				2.365E-04	2.152E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	16	60	24.7	1.705E-04	1.551E-04	0.895	0.0015	8.576
2	16	60	24.7	1.705E-04	1.551E-04	0.895	0.0015	8.576
3	15	60	24.7	1.598E-04	1.454E-04	0.895	0.0014	8.576
4	15	60	24.7	1.598E-04	1.454E-04	0.895	0.0014	8.576
5	16	60	24.7	1.705E-04	1.551E-04	0.895	0.0015	8.576
				1.662E-04	1.512E-04			

Avg Perm	1.946E-04	cm/s

B) 30 Minute Saturation Method, No Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	34	60	24.8	3.622E-04	3.295E-04	0.8929	0.0031	8.576
2	34	60	24.8	3.622E-04	3.295E-04	0.8929	0.0031	8.576
3	34	60	24.8	3.622E-04	3.295E-04	0.8929	0.0031	8.576
4	65	120	24.8	3.462E-04	3.150E-04	0.8929	0.0030	8.576
5	34	60	24.8	3.622E-04	3.295E-04	0.8929	0.0031	8.576
				3.590E-04	3.266E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	32	60	25.1	3.409E-04	3.101E-04	0.8866	0.0029	8.576
2	33	60	25.1	3.516E-04	3.198E-04	0.8866	0.0030	8.576
3	33	60	25.1	3.516E-04	3.198E-04	0.8866	0.0030	8.576
4	32	60	25.1	3.409E-04	3.101E-04	0.8866	0.0029	8.576
5	32	60	25.1	3.409E-04	3.101E-04	0.8866	0.0029	8.576
				3.452E-04	3.140E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	39	60	24.3	4.155E-04	3.780E-04	0.9034	0.0036	8.576
2	39	60	24.3	4.155E-04	3.780E-04	0.9034	0.0036	8.576
3	38	60	24.3	4.048E-04	3.683E-04	0.9034	0.0035	8.576
4	40	60	24.3	4.261E-04	3.877E-04	0.9034	0.0037	8.576
5	39	60	24.3	4.155E-04	3.780E-04	0.9034	0.0036	8.576
				4.155E-04	3.780E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	30	60	25.3	3.196E-04	2.907E-04	0.8824	0.0027	8.576
2	31	60	25.3	3.303E-04	3.004E-04	0.8824	0.0028	8.576
3	30	60	25.3	3.196E-04	2.907E-04	0.8824	0.0027	8.576
4	30	60	25.3	3.196E-04	2.907E-04	0.8824	0.0027	8.576
5	30	60	25.3	3.196E-04	2.907E-04	0.8824	0.0027	8.576
				3.217E-04	2.927E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	35	60	24.9	3.729E-04	3.392E-04	0.8908	0.0032	8.576
2	35	60	24.9	3.729E-04	3.392E-04	0.8908	0.0032	8.576
3	36	60	24.9	3.835E-04	3.489E-04	0.8908	0.0033	8.576
4	36	60	24.9	3.835E-04	3.489E-04	0.8908	0.0033	8.576
5	36	60	24.9	3.835E-04	3.489E-04	0.8908	0.0033	8.576
				3.793E-04	3.450E-04			

Avg Perm	3.313E-04	cm/s

C) 30 Minute Saturation Method, Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	35	60	25.3	3.729E-04	3.392E-04	0.8824	0.0032	8.576
2	36	60	25.3	3.835E-04	3.489E-04	0.8824	0.0033	8.576
3	35	60	25.3	3.729E-04	3.392E-04	0.8824	0.0032	8.576
4	34	60	25.3	3.622E-04	3.295E-04	0.8824	0.0031	8.576
5	35	60	25.3	3.729E-04	3.392E-04	0.8824	0.0032	8.576
				3.729E-04	3.392E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	32	60	24.9	3.409E-04	3.101E-04	0.8908	0.0029	8.576
2	33	60	24.9	3.516E-04	3.198E-04	0.8908	0.0030	8.576
3	33	60	24.9	3.516E-04	3.198E-04	0.8908	0.0030	8.576
4	35	60	24.9	3.729E-04	3.392E-04	0.8908	0.0032	8.576
5	34	60	24.9	3.622E-04	3.295E-04	0.8908	0.0031	8.576
				3.558E-04	3.237E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	42	60	22.5	4.475E-04	4.225E-04	0.9421	0.0038	8.576
2	41	60	22.5	4.368E-04	4.125E-04	0.9421	0.0037	8.576
3	42	60	22.5	4.475E-04	4.225E-04	0.9421	0.0038	8.576
4	42	60	22.5	4.475E-04	4.225E-04	0.9421	0.0038	8.576
5	42	60	22.5	4.475E-04	4.225E-04	0.9421	0.0038	8.576
				4.453E-04	4.205E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	38	60	25.1	4.048E-04	3.683E-04	0.8866	0.0035	8.576
2	38	60	25.1	4.048E-04	3.683E-04	0.8866	0.0035	8.576
3	39	60	25.1	4.155E-04	3.780E-04	0.8866	0.0036	8.576
4	38	60	25.1	4.048E-04	3.683E-04	0.8866	0.0035	8.576
5	38	60	25.1	4.048E-04	3.683E-04	0.8866	0.0035	8.576
				4.070E-04	3.702E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	39	60	23.2	4.155E-04	3.860E-04	0.9268	0.0036	8.576
2	38	60	23.2	4.048E-04	3.761E-04	0.9268	0.0035	8.576
3	39	60	23.2	4.155E-04	3.860E-04	0.9268	0.0036	8.576
4	39	60	23.2	4.155E-04	3.860E-04	0.9268	0.0036	8.576
5	38	60	23.2	4.048E-04	3.761E-04	0.9268	0.0035	8.576
				4.112E-04	3.820E-04			

Avg Perm	3.671E-04	cm/s

D) 30 Minute Saturation Method, Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	38	60	24.8	4.048E-04	3.683E-04	0.8929	0.0035	8.576
2	39	60	24.8	4.155E-04	3.780E-04	0.8929	0.0036	8.576
3	40	60	24.8	4.261E-04	3.877E-04	0.8929	0.0037	8.576
4	39	60	24.8	4.155E-04	3.780E-04	0.8929	0.0036	8.576
5	39	60	24.8	4.155E-04	3.780E-04	0.8929	0.0036	8.576
				4.155E-04	3.780E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	42	60	25.2	4.475E-04	4.070E-04	0.8845	0.0038	8.576
2	41	60	25.2	4.368E-04	3.974E-04	0.8845	0.0037	8.576
3	42	60	25.2	4.475E-04	4.070E-04	0.8845	0.0038	8.576
4	42	60	25.2	4.475E-04	4.070E-04	0.8845	0.0038	8.576
5	42	60	25.2	4.475E-04	4.070E-04	0.8845	0.0038	8.576
				4.453E-04	4.051E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	37	60	24.3	3.942E-04	3.586E-04	0.9034	0.0034	8.576
2	37	60	24.3	3.942E-04	3.586E-04	0.9034	0.0034	8.576
3	38	60	24.3	4.048E-04	3.683E-04	0.9034	0.0035	8.576
4	37	60	24.3	3.942E-04	3.586E-04	0.9034	0.0034	8.576
5	37	60	24.3	3.942E-04	3.586E-04	0.9034	0.0034	8.576
				3.963E-04	3.605E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	32	60	24.9	3.409E-04	3.101E-04	0.8908	0.0029	8.576
2	32	60	24.9	3.409E-04	3.101E-04	0.8908	0.0029	8.576
3	33	60	24.9	3.516E-04	3.198E-04	0.8908	0.0030	8.576
4	32	60	24.9	3.409E-04	3.101E-04	0.8908	0.0029	8.576
5	33	60	24.9	3.516E-04	3.198E-04	0.8908	0.0030	8.576
				3.452E-04	3.140E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	35	60	24.8	3.729E-04	3.392E-04	0.8929	0.0032	8.576
2	34	60	24.8	3.622E-04	3.295E-04	0.8929	0.0031	8.576
3	33	60	24.8	3.516E-04	3.198E-04	0.8929	0.0030	8.576
4	34	60	24.8	3.622E-04	3.295E-04	0.8929	0.0031	8.576
5	34	60	24.8	3.622E-04	3.295E-04	0.8929	0.0031	8.576
				3.622E-04	3.295E-04			

Avg Perm	3.574E-04	cm/s

E) Overnight Saturation Method, No Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	21	60	25.5	2.237E-04	2.035E-04	0.8782	0.0019	8.576
2	20	60	25.5	2.131E-04	1.938E-04	0.8782	0.0018	8.576
3	20	60	25.5	2.131E-04	1.938E-04	0.8782	0.0018	8.576
4	21	60	25.5	2.237E-04	2.035E-04	0.8782	0.0019	8.576
5	20	60	25.5	2.131E-04	1.938E-04	0.8782	0.0018	8.576
				2.173E-04	1.977E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	22	60	25.8	2.344E-04	2.132E-04	0.8719	0.0020	8.576
2	22	60	25.8	2.344E-04	2.132E-04	0.8719	0.0020	8.576
3	21	60	25.8	2.237E-04	2.035E-04	0.8719	0.0019	8.576
4	22	60	25.8	2.344E-04	2.132E-04	0.8719	0.0020	8.576
5	22	60	25.8	2.344E-04	2.132E-04	0.8719	0.0020	8.576
				2.322E-04	2.113E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	18	120	23.9	9.588E-05	8.764E-05	0.9118	0.0008	8.576
2	18	60	23.9	1.918E-04	1.753E-04	0.9118	0.0016	8.576
3	19	60	23.9	2.024E-04	1.850E-04	0.9118	0.0017	8.576
4	19	60	23.9	2.024E-04	1.850E-04	0.9118	0.0017	8.576
5	18	60	23.9	1.918E-04	1.753E-04	0.9118	0.0016	8.576
				1.769E-04	1.616E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	24	60	24.2	2.557E-04	2.326E-04	0.9055	0.0022	8.576
2	23	60	24.2	2.450E-04	2.229E-04	0.9055	0.0021	8.576
3	24	60	24.2	2.557E-04	2.326E-04	0.9055	0.0022	8.576
4	24	60	24.2	2.557E-04	2.326E-04	0.9055	0.0022	8.576
5	24	60	24.2	2.557E-04	2.326E-04	0.9055	0.0022	8.576
				2.536E-04	2.307E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	25	60	24.7	2.663E-04	2.423E-04	0.895	0.0023	8.576
2	25	60	24.7	2.663E-04	2.423E-04	0.895	0.0023	8.576
3	26	60	24.7	2.770E-04	2.520E-04	0.895	0.0024	8.576
4	26	60	24.7	2.770E-04	2.520E-04	0.895	0.0024	8.576
5	27	60	24.7	2.876E-04	2.617E-04	0.895	0.0025	8.576
				2.749E-04	2.500E-04			

Avg Perm	2.103E-04	cm/s

F) Overnight Saturation Method, No Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	27	60	25.8	2.876E-04	2.617E-04	0.8719	0.0025	8.576
2	28	60	25.8	2.983E-04	2.714E-04	0.8719	0.0026	8.576
3	28	60	25.8	2.983E-04	2.714E-04	0.8719	0.0026	8.576
4	28	60	25.8	2.983E-04	2.714E-04	0.8719	0.0026	8.576
5	28	60	25.8	2.983E-04	2.714E-04	0.8719	0.0026	8.576
				2.962E-04	2.694E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	23	60	24.8	2.450E-04	2.229E-04	0.8929	0.0021	8.576
2	23	60	24.8	2.450E-04	2.229E-04	0.8929	0.0021	8.576
3	23	60	24.8	2.450E-04	2.229E-04	0.8929	0.0021	8.576
4	23	60	24.8	2.450E-04	2.229E-04	0.8929	0.0021	8.576
5	24	60	24.8	2.557E-04	2.326E-04	0.8929	0.0022	8.576
				2.472E-04	2.248E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	27	60	25.3	2.876E-04	2.617E-04	0.8824	0.0025	8.576
2	26	60	25.3	2.770E-04	2.520E-04	0.8824	0.0024	8.576
3	26	60	25.3	2.770E-04	2.520E-04	0.8824	0.0024	8.576
4	27	60	25.3	2.876E-04	2.617E-04	0.8824	0.0025	8.576
5	26	60	25.3	2.770E-04	2.520E-04	0.8824	0.0024	8.576
				2.813E-04	2.559E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	60	24.7	2.131E-04	1.938E-04	0.895	0.0018	8.576
2	21	60	24.7	2.237E-04	2.035E-04	0.895	0.0019	8.576
3	22	60	24.7	2.344E-04	2.132E-04	0.895	0.0020	8.576
4	22	60	24.7	2.344E-04	2.132E-04	0.895	0.0020	8.576
5	22	60	24.7	2.344E-04	2.132E-04	0.895	0.0020	8.576
				2.280E-04	2.074E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	30	60	23.9	3.196E-04	2.921E-04	0.9118	0.0027	8.576
2	30	60	23.9	3.196E-04	2.921E-04	0.9118	0.0027	8.576
3	31	60	23.9	3.303E-04	3.019E-04	0.9118	0.0028	8.576
4	31	60	23.9	3.303E-04	3.019E-04	0.9118	0.0028	8.576
5	31	60	23.9	3.303E-04	3.019E-04	0.9118	0.0028	8.576
				3.260E-04	2.980E-04			

Avg Perm	2.511E-04	cm/s

G) Overnight Saturation Method, Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	48	60	25.9	5.114E-04	4.652E-04	0.8698	0.0044	8.576
2	48	60	25.9	5.114E-04	4.652E-04	0.8698	0.0044	8.576
3	47	60	25.9	5.007E-04	4.555E-04	0.8698	0.0043	8.576
4	48	60	25.9	5.114E-04	4.652E-04	0.8698	0.0044	8.576
5	48	60	25.9	5.114E-04	4.652E-04	0.8698	0.0044	8.576
				5.092E-04	4.633E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	51	60	25.8	5.433E-04	4.943E-04	0.8719	0.0047	8.576
2	50	60	25.8	5.327E-04	4.846E-04	0.8719	0.0046	8.576
3	50	60	25.8	5.327E-04	4.846E-04	0.8719	0.0046	8.576
4	50	60	25.8	5.327E-04	4.846E-04	0.8719	0.0046	8.576
5	50	60	25.8	5.327E-04	4.846E-04	0.8719	0.0046	8.576
				5.348E-04	4.865E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	33	60	24.1	3.516E-04	3.198E-04	0.9076	0.0030	8.576
2	32	60	24.1	3.409E-04	3.101E-04	0.9076	0.0029	8.576
3	33	60	24.1	3.516E-04	3.198E-04	0.9076	0.0030	8.576
4	33	60	24.1	3.516E-04	3.198E-04	0.9076	0.0030	8.576
5	33	60	24.1	3.516E-04	3.198E-04	0.9076	0.0030	8.576
				3.494E-04	3.179E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	49	60	24.6	5.220E-04	4.749E-04	0.8971	0.0045	8.576
2	48	60	24.6	5.114E-04	4.652E-04	0.8971	0.0044	8.576
3	49	60	24.6	5.220E-04	4.749E-04	0.8971	0.0045	8.576
4	49	60	24.6	5.220E-04	4.749E-04	0.8971	0.0045	8.576
5	49	60	24.6	5.220E-04	4.749E-04	0.8971	0.0045	8.576
				5.199E-04	4.730E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	33	60	24.3	3.516E-04	3.198E-04	0.9034	0.0030	8.576
2	33	60	24.3	3.516E-04	3.198E-04	0.9034	0.0030	8.576
3	33	60	24.3	3.516E-04	3.198E-04	0.9034	0.0030	8.576
4	31	60	24.3	3.303E-04	3.004E-04	0.9034	0.0028	8.576
5	32	60	24.3	3.409E-04	3.101E-04	0.9034	0.0029	8.576
				3.452E-04	3.140E-04			

Avg Perm	4.109E-04	cm/s

H) Overnight Saturation Method, Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	32.5	60	25.7	3.462E-04	3.150E-04	0.874	0.0030	8.576
2	32	60	25.7	3.409E-04	3.101E-04	0.874	0.0029	8.576
3	32	60	25.7	3.409E-04	3.101E-04	0.874	0.0029	8.576
4	32	60	25.7	3.409E-04	3.101E-04	0.874	0.0029	8.576
5	32	60	25.7	3.409E-04	3.101E-04	0.874	0.0029	8.576
				3.420E-04	3.111E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	53	60	23.5	5.646E-04	5.209E-04	0.9204	0.0048	8.576
2	52	60	23.5	5.540E-04	5.111E-04	0.9204	0.0048	8.576
3	53	60	23.5	5.646E-04	5.209E-04	0.9204	0.0048	8.576
4	53	60	23.5	5.646E-04	5.209E-04	0.9204	0.0048	8.576
5	53	60	23.5	5.646E-04	5.209E-04	0.9204	0.0048	8.576
				5.625E-04	5.189E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	45	60	25.1	4.794E-04	4.361E-04	0.8866	0.0041	8.576
2	45	60	25.1	4.794E-04	4.361E-04	0.8866	0.0041	8.576
3	46	60	25.1	4.901E-04	4.458E-04	0.8866	0.0042	8.576
4	45	60	25.1	4.794E-04	4.361E-04	0.8866	0.0041	8.576
5	46	60	25.1	4.901E-04	4.458E-04	0.8866	0.0042	8.576
				4.837E-04	4.400E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	39	60	23.7	4.155E-04	3.815E-04	0.9161	0.0036	8.576
2	39	60	23.7	4.155E-04	3.815E-04	0.9161	0.0036	8.576
3	38	60	23.7	4.048E-04	3.718E-04	0.9161	0.0035	8.576
4	38	60	23.7	4.048E-04	3.718E-04	0.9161	0.0035	8.576
5	38	60	23.7	4.048E-04	3.718E-04	0.9161	0.0035	8.576
				4.091E-04	3.757E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	51	60	24.1	5.433E-04	4.943E-04	0.9076	0.0047	8.576
2	52	60	24.1	5.540E-04	5.040E-04	0.9076	0.0048	8.576
3	51	60	24.1	5.433E-04	4.943E-04	0.9076	0.0047	8.576
4	51	60	24.1	5.433E-04	4.943E-04	0.9076	0.0047	8.576
5	51	60	24.1	5.433E-04	4.943E-04	0.9076	0.0047	8.576
				5.455E-04	4.962E-04			

Avg Perm	4.284E-04	cm/s

Prototype 3 Permeability Results

Soil Type	*A-2-4*

A) 30 Minute Saturation Method, No Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	120	23.8	1.065E-04	9.760E-05	0.914	0.0009	8.576
2	10	60	23.8	1.065E-04	9.760E-05	0.914	0.0009	8.576
3	12	60	23.8	1.278E-04	1.171E-04	0.914	0.0011	8.576
4	12	60	23.8	1.278E-04	1.171E-04	0.914	0.0011	8.576
5	12	60	23.8	1.278E-04	1.171E-04	0.914	0.0011	8.576
				1.193E-04	1.093E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	12	60	24.2	1.278E-04	1.163E-04	0.9055	0.0011	8.576
2	12	60	24.2	1.278E-04	1.163E-04	0.9055	0.0011	8.576
3	11	60	24.2	1.172E-04	1.066E-04	0.9055	0.0010	8.576
4	11	60	24.2	1.172E-04	1.066E-04	0.9055	0.0010	8.576
5	12	60	24.2	1.278E-04	1.163E-04	0.9055	0.0011	8.576
				1.236E-04	1.124E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	13	60	23.7	1.385E-04	1.272E-04	0.9161	0.0012	8.576
2	14	60	23.7	1.492E-04	1.370E-04	0.9161	0.0013	8.576
3	13	60	23.7	1.385E-04	1.272E-04	0.9161	0.0012	8.576
4	13	60	23.7	1.385E-04	1.272E-04	0.9161	0.0012	8.576
5	13	60	23.7	1.385E-04	1.272E-04	0.9161	0.0012	8.576
				1.406E-04	1.291E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	9	60	24.1	9.588E-05	8.722E-05	0.9076	0.0008	8.576
2	9	60	24.1	9.588E-05	8.722E-05	0.9076	0.0008	8.576
3	10	60	24.1	1.065E-04	9.692E-05	0.9076	0.0009	8.576
4	9	60	24.1	9.588E-05	8.722E-05	0.9076	0.0008	8.576
5	10	60	24.1	1.065E-04	9.692E-05	0.9076	0.0009	8.576
				1.001E-04	9.110E-05			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	15	60	24.5	1.598E-04	1.454E-04	0.8992	0.0014	8.576
2	15	60	24.5	1.598E-04	1.454E-04	0.8992	0.0014	8.576
3	14	60	24.5	1.492E-04	1.357E-04	0.8992	0.0013	8.576
4	15	60	24.5	1.598E-04	1.454E-04	0.8992	0.0014	8.576
5	15	60	24.5	1.598E-04	1.454E-04	0.8992	0.0014	8.576
				1.577E-04	1.434E-04			

Avg Perm	1.171E-04	cm/s

B) 30 Minute Saturation Method, No Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	25	60	24.8	2.663E-04	2.423E-04	0.8929	0.0023	8.576
2	14	30	24.8	2.983E-04	2.714E-04	0.8929	0.0026	8.576
3	13	30	24.8	2.770E-04	2.520E-04	0.8929	0.0024	8.576
4	23	60	24.8	2.450E-04	2.229E-04	0.8929	0.0021	8.576
5	24	60	24.8	2.557E-04	2.326E-04	0.8929	0.0022	8.576
				2.685E-04	2.442E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	60	25.4	2.131E-04	1.938E-04	0.8803	0.0018	8.576
2	18	60	25.4	1.918E-04	1.744E-04	0.8803	0.0016	8.576
3	19	60	25.4	2.024E-04	1.841E-04	0.8803	0.0017	8.576
4	21	60	25.4	2.237E-04	2.035E-04	0.8803	0.0019	8.576
5	20	60	25.4	2.131E-04	1.938E-04	0.8803	0.0018	8.576
				2.088E-04	1.900E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	60	24.1	2.131E-04	1.938E-04	0.9076	0.0018	8.576
2	21	30	24.1	4.475E-04	4.070E-04	0.9076	0.0038	8.576
3	20	30	24.1	4.261E-04	3.877E-04	0.9076	0.0037	8.576
4	20	60	24.1	2.131E-04	1.938E-04	0.9076	0.0018	8.576
5	20	60	24.1	2.131E-04	1.938E-04	0.9076	0.0018	8.576
				3.026E-04	2.752E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	27	60	25.3	2.876E-04	2.617E-04	0.8824	0.0025	8.576
2	27	60	25.3	2.876E-04	2.617E-04	0.8824	0.0025	8.576
3	28	60	25.3	2.983E-04	2.714E-04	0.8824	0.0026	8.576
4	27	60	25.3	2.876E-04	2.617E-04	0.8824	0.0025	8.576
5	27	60	25.3	2.876E-04	2.617E-04	0.8824	0.0025	8.576
				2.898E-04	2.636E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	22	60	25.1	2.344E-04	2.132E-04	0.8866	0.0020	8.576
2	22	60	25.1	2.344E-04	2.132E-04	0.8866	0.0020	8.576
3	23	60	25.1	2.450E-04	2.229E-04	0.8866	0.0021	8.576
4	22	60	25.1	2.344E-04	2.132E-04	0.8866	0.0020	8.576
5	22	60	25.1	2.344E-04	2.132E-04	0.8866	0.0020	8.576
				2.365E-04	2.152E-04			

Avg Perm	2.376E-04	cm/s

C) 30 Minute Saturation Method, Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	51	120	24.8	2.717E-04	2.471E-04	0.8929	0.0023	8.576
2	50	120	24.8	2.663E-04	2.423E-04	0.8929	0.0023	8.576
3	52	120	24.8	2.770E-04	2.520E-04	0.8929	0.0024	8.576
4	52	120	24.8	2.770E-04	2.520E-04	0.8929	0.0024	8.576
5	52	120	24.8	2.770E-04	2.520E-04	0.8929	0.0024	8.576
				2.738E-04	2.491E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	49	120	24.3	2.610E-04	2.374E-04	0.9034	0.0022	8.576
2	49	120	24.3	2.610E-04	2.374E-04	0.9034	0.0022	8.576
3	48	120	24.3	2.557E-04	2.326E-04	0.9034	0.0022	8.576
4	49	120	24.3	2.610E-04	2.374E-04	0.9034	0.0022	8.576
5	49	120	24.3	2.610E-04	2.374E-04	0.9034	0.0022	8.576
				2.599E-04	2.365E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	23	60	23.0	2.450E-04	2.287E-04	0.9311	0.0021	8.576
2	22	60	23.0	2.344E-04	2.187E-04	0.9311	0.0020	8.576
3	23	60	23.0	2.450E-04	2.287E-04	0.9311	0.0021	8.576
4	23	60	23.0	2.450E-04	2.287E-04	0.9311	0.0021	8.576
5	23	60	23.0	2.450E-04	2.287E-04	0.9311	0.0021	8.576
				2.429E-04	2.267E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	26	60	24.5	2.770E-04	2.520E-04	0.8992	0.0024	8.576
2	24	60	24.5	2.557E-04	2.326E-04	0.8992	0.0022	8.576
3	25	60	24.5	2.663E-04	2.423E-04	0.8992	0.0023	8.576
4	25	60	24.5	2.663E-04	2.423E-04	0.8992	0.0023	8.576
5	25	60	24.5	2.663E-04	2.423E-04	0.8992	0.0023	8.576
				2.663E-04	2.423E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	24	60	23.2	2.557E-04	2.375E-04	0.9268	0.0022	8.576
2	24	60	23.2	2.557E-04	2.375E-04	0.9268	0.0022	8.576
3	23	60	23.2	2.450E-04	2.276E-04	0.9268	0.0021	8.576
4	22	60	23.2	2.344E-04	2.177E-04	0.9268	0.0020	8.576
5	23	60	23.2	2.450E-04	2.276E-04	0.9268	0.0021	8.576
				2.472E-04	2.296E-04			

Avg Perm	2.368E-04	cm/s

D) 30 Minute Saturation Method, Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	27	60	24.3	2.876E-04	2.617E-04	0.9034	0.0025	8.576
2	28	60	24.3	2.983E-04	2.714E-04	0.9034	0.0026	8.576
3	28	60	24.3	2.983E-04	2.714E-04	0.9034	0.0026	8.576
4	27	60	24.3	2.876E-04	2.617E-04	0.9034	0.0025	8.576
5	27	60	24.3	2.876E-04	2.617E-04	0.9034	0.0025	8.576
				2.919E-04	2.656E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	30	60	25.6	3.196E-04	2.907E-04	0.8761	0.0027	8.576
2	31	60	25.6	3.303E-04	3.004E-04	0.8761	0.0028	8.576
3	30	60	25.6	3.196E-04	2.907E-04	0.8761	0.0027	8.576
4	30	60	25.6	3.196E-04	2.907E-04	0.8761	0.0027	8.576
5	31	60	25.6	3.303E-04	3.004E-04	0.8761	0.0028	8.576
				3.239E-04	2.946E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	25	60	24.9	2.663E-04	2.423E-04	0.8908	0.0023	8.576
2	24	60	24.9	2.557E-04	2.326E-04	0.8908	0.0022	8.576
3	25	60	24.9	2.663E-04	2.423E-04	0.8908	0.0023	8.576
4	26	60	24.9	2.770E-04	2.520E-04	0.8908	0.0024	8.576
5	25	60	24.9	2.663E-04	2.423E-04	0.8908	0.0023	8.576
				2.663E-04	2.423E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	32	60	23.9	3.409E-04	3.116E-04	0.9118	0.0029	8.576
2	32	60	23.9	3.409E-04	3.116E-04	0.9118	0.0029	8.576
3	33	60	23.9	3.516E-04	3.213E-04	0.9118	0.0030	8.576
4	32	60	23.9	3.409E-04	3.116E-04	0.9118	0.0029	8.576
5	33	60	23.9	3.516E-04	3.213E-04	0.9118	0.0030	8.576
				3.452E-04	3.155E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	25	60	24.6	2.663E-04	2.423E-04	0.8971	0.0023	8.576
2	26	60	24.6	2.770E-04	2.520E-04	0.8971	0.0024	8.576
3	25	60	24.6	2.663E-04	2.423E-04	0.8971	0.0023	8.576
4	26	60	24.6	2.770E-04	2.520E-04	0.8971	0.0024	8.576
5	26	60	24.6	2.770E-04	2.520E-04	0.8971	0.0024	8.576
				2.727E-04	2.481E-04			

Avg Perm	2.732E-04	cm/s

E) Overnight Saturation Method, No Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	16	60	26.3	1.705E-04	1.551E-04	0.8614	0.0015	8.576
2	16	60	26.3	1.705E-04	1.551E-04	0.8614	0.0015	8.576
3	16	60	26.3	1.705E-04	1.551E-04	0.8614	0.0015	8.576
4	15	60	26.3	1.598E-04	1.454E-04	0.8614	0.0014	8.576
5	15	60	26.3	1.598E-04	1.454E-04	0.8614	0.0014	8.576
				1.662E-04	1.512E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	18	60	25.8	1.918E-04	1.744E-04	0.8719	0.0016	8.576
2	19	60	25.8	2.024E-04	1.841E-04	0.8719	0.0017	8.576
3	18	60	25.8	1.918E-04	1.744E-04	0.8719	0.0016	8.576
4	18	60	25.8	1.918E-04	1.744E-04	0.8719	0.0016	8.576
5	18	60	25.8	1.918E-04	1.744E-04	0.8719	0.0016	8.576
				1.939E-04	1.764E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	60	25.2	2.131E-04	1.938E-04	0.8845	0.0018	8.576
2	21	60	25.2	2.237E-04	2.035E-04	0.8845	0.0019	8.576
3	20	60	25.2	2.131E-04	1.938E-04	0.8845	0.0018	8.576
4	20	60	25.2	2.131E-04	1.938E-04	0.8845	0.0018	8.576
5	20	60	25.2	2.131E-04	1.938E-04	0.8845	0.0018	8.576
				2.152E-04	1.958E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	15	60	24.7	1.598E-04	1.454E-04	0.895	0.0014	8.576
2	15	60	24.7	1.598E-04	1.454E-04	0.895	0.0014	8.576
3	16	60	24.7	1.705E-04	1.551E-04	0.895	0.0015	8.576
4	16	60	24.7	1.705E-04	1.551E-04	0.895	0.0015	8.576
5	16	60	24.7	1.705E-04	1.551E-04	0.895	0.0015	8.576
				1.662E-04	1.512E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	13	60	24.6	1.385E-04	1.260E-04	0.8971	0.0012	8.576
2	12	60	24.6	1.278E-04	1.163E-04	0.8971	0.0011	8.576
3	12	60	24.6	1.278E-04	1.163E-04	0.8971	0.0011	8.576
4	13	60	24.6	1.385E-04	1.260E-04	0.8971	0.0012	8.576
5	13	60	24.6	1.385E-04	1.260E-04	0.8971	0.0012	8.576
				1.342E-04	1.221E-04			

Avg Perm	1.593E-04	cm/s

F) Overnight Saturation Method, No Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	10.5	60	26.3	1.119E-04	1.018E-04	0.8614	0.0010	8.576
2	10	60	26.3	1.065E-04	9.692E-05	0.8614	0.0009	8.576
3	10	60	26.3	1.065E-04	9.692E-05	0.8614	0.0009	8.576
4	10	60	26.3	1.065E-04	9.692E-05	0.8614	0.0009	8.576
5	11	60	26.3	1.172E-04	1.066E-04	0.8614	0.0010	8.576
				1.097E-04	9.982E-05			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	60	25.8	2.131E-04	1.938E-04	0.8719	0.0018	8.576
2	18	60	25.8	1.918E-04	1.744E-04	0.8719	0.0016	8.576
3	18	60	25.8	1.918E-04	1.744E-04	0.8719	0.0016	8.576
4	18	60	25.8	1.918E-04	1.744E-04	0.8719	0.0016	8.576
5	18	60	25.8	1.918E-04	1.744E-04	0.8719	0.0016	8.576
				1.960E-04	1.783E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	15	60	26.0	1.598E-04	1.454E-04	0.8677	0.0014	8.576
2	16	60	26.0	1.705E-04	1.551E-04	0.8677	0.0015	8.576
3	16	60	26.0	1.705E-04	1.551E-04	0.8677	0.0015	8.576
4	15	60	26.0	1.598E-04	1.454E-04	0.8677	0.0014	8.576
5	16	60	26.0	1.705E-04	1.551E-04	0.8677	0.0015	8.576
				1.662E-04	1.512E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	12	60	25.3	1.278E-04	1.163E-04	0.8824	0.0011	8.576
2	12	60	25.3	1.278E-04	1.163E-04	0.8824	0.0011	8.576
3	12	60	25.3	1.278E-04	1.163E-04	0.8824	0.0011	8.576
4	11	60	25.3	1.172E-04	1.066E-04	0.8824	0.0010	8.576
5	12	60	25.3	1.278E-04	1.163E-04	0.8824	0.0011	8.576
				1.257E-04	1.144E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	13	60	25.6	1.385E-04	1.260E-04	0.8761	0.0012	8.576
2	14	60	25.6	1.492E-04	1.357E-04	0.8761	0.0013	8.576
3	15	60	25.6	1.598E-04	1.454E-04	0.8761	0.0014	8.576
4	13	60	25.6	1.385E-04	1.260E-04	0.8761	0.0012	8.576
5	14	60	25.6	1.492E-04	1.357E-04	0.8761	0.0013	8.576
				1.470E-04	1.337E-04			

Avg Perm	1.355E-04	cm/s

G) Overnight Saturation Method, Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	39	60	25.9	4.155E-04	3.780E-04	0.8698	0.0036	8.576
2	38	60	25.9	4.048E-04	3.683E-04	0.8698	0.0035	8.576
3	39	60	25.9	4.155E-04	3.780E-04	0.8698	0.0036	8.576
4	39	60	25.9	4.155E-04	3.780E-04	0.8698	0.0036	8.576
5	39	60	25.9	4.155E-04	3.780E-04	0.8698	0.0036	8.576
				4.134E-04	3.760E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	41	60	25.8	4.368E-04	3.974E-04	0.8719	0.0037	8.576
2	42	60	25.8	4.475E-04	4.070E-04	0.8719	0.0038	8.576
3	41	60	25.8	4.368E-04	3.974E-04	0.8719	0.0037	8.576
4	41	60	25.8	4.368E-04	3.974E-04	0.8719	0.0037	8.576
5	41	60	25.8	4.368E-04	3.974E-04	0.8719	0.0037	8.576
				4.389E-04	3.993E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	37	60	24.2	3.942E-04	3.586E-04	0.9055	0.0034	8.576
2	37	60	24.2	3.942E-04	3.586E-04	0.9055	0.0034	8.576
3	36	60	24.2	3.835E-04	3.489E-04	0.9055	0.0033	8.576
4	37	60	24.2	3.942E-04	3.586E-04	0.9055	0.0034	8.576
5	37	60	24.2	3.942E-04	3.586E-04	0.9055	0.0034	8.576
				3.921E-04	3.567E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	33	60	23.9	3.516E-04	3.213E-04	0.9118	0.0030	8.576
2	32	60	23.9	3.409E-04	3.116E-04	0.9118	0.0029	8.576
3	33	60	23.9	3.516E-04	3.213E-04	0.9118	0.0030	8.576
4	32	60	23.9	3.409E-04	3.116E-04	0.9118	0.0029	8.576
5	32	60	23.9	3.409E-04	3.116E-04	0.9118	0.0029	8.576
				3.452E-04	3.155E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	42	60	25.1	4.475E-04	4.070E-04	0.8866	0.0038	8.576
2	43	60	25.1	4.581E-04	4.167E-04	0.8866	0.0039	8.576
3	42	60	25.1	4.475E-04	4.070E-04	0.8866	0.0038	8.576
4	43	60	25.1	4.581E-04	4.167E-04	0.8866	0.0039	8.576
5	43	60	25.1	4.581E-04	4.167E-04	0.8866	0.0039	8.576
				4.538E-04	4.129E-04			

Avg Perm	3.721E-04	cm/s

H) Overnight Saturation Method, Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	22	60	25.9	2.344E-04	2.132E-04	0.8698	0.0020	8.576
2	22	60	25.9	2.344E-04	2.132E-04	0.8698	0.0020	8.576
3	22	60	25.9	2.344E-04	2.132E-04	0.8698	0.0020	8.576
4	21	60	25.9	2.237E-04	2.035E-04	0.8698	0.0019	8.576
5	22	60	25.9	2.344E-04	2.132E-04	0.8698	0.0020	8.576
				2.322E-04	2.113E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	28	60	23.5	2.983E-04	2.752E-04	0.9204	0.0026	8.576
2	28	60	23.5	2.983E-04	2.752E-04	0.9204	0.0026	8.576
3	29	60	23.5	3.090E-04	2.850E-04	0.9204	0.0026	8.576
4	29	60	23.5	3.090E-04	2.850E-04	0.9204	0.0026	8.576
5	28	60	23.5	2.983E-04	2.752E-04	0.9204	0.0026	8.576
				3.026E-04	2.791E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	31	60	25.3	3.303E-04	3.004E-04	0.8824	0.0028	8.576
2	32	60	25.3	3.409E-04	3.101E-04	0.8824	0.0029	8.576
3	31	60	25.3	3.303E-04	3.004E-04	0.8824	0.0028	8.576
4	32	60	25.3	3.409E-04	3.101E-04	0.8824	0.0029	8.576
5	32	60	25.3	3.409E-04	3.101E-04	0.8824	0.0029	8.576
				3.367E-04	3.063E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	25	60	23.2	2.663E-04	2.474E-04	0.9268	0.0023	8.576
2	25	60	23.2	2.663E-04	2.474E-04	0.9268	0.0023	8.576
3	26	60	23.2	2.770E-04	2.573E-04	0.9268	0.0024	8.576
4	25	60	23.2	2.663E-04	2.474E-04	0.9268	0.0023	8.576
5	25	60	23.2	2.663E-04	2.474E-04	0.9268	0.0023	8.576
				2.685E-04	2.494E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	32	60	24.1	3.409E-04	3.101E-04	0.9076	0.0029	8.576
2	32	60	24.1	3.409E-04	3.101E-04	0.9076	0.0029	8.576
3	32	60	24.1	3.409E-04	3.101E-04	0.9076	0.0029	8.576
4	31	60	24.1	3.303E-04	3.004E-04	0.9076	0.0028	8.576
5	32	60	24.1	3.409E-04	3.101E-04	0.9076	0.0029	8.576
				3.388E-04	3.082E-04			

Avg Perm	2.709E-04	cm/s

Current LBR Permeability Results

Soil Type	*A-3*

A) 30 Minute Saturation Method, No Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	51	180	24.5	1.811E-04	1.648E-04	0.8992	0.0016	8.576
2	52	180	24.5	1.847E-04	1.680E-04	0.8992	0.0016	8.576
3	48	180	24.5	1.705E-04	1.551E-04	0.8992	0.0015	8.576
4	49	180	24.5	1.740E-04	1.583E-04	0.8992	0.0015	8.576
5	49	180	24.5	1.740E-04	1.583E-04	0.8992	0.0015	8.576
				1.769E-04	1.609E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	49	180	24.5	1.740E-04	1.583E-04	0.8992	0.0015	8.576
2	48	180	24.5	1.705E-04	1.551E-04	0.8992	0.0015	8.576
3	50	180	24.5	1.776E-04	1.615E-04	0.8992	0.0015	8.576
4	48	180	24.5	1.705E-04	1.551E-04	0.8992	0.0015	8.576
5	49	180	24.5	1.740E-04	1.583E-04	0.8992	0.0015	8.576
				1.733E-04	1.577E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	60	25.5	2.131E-04	1.938E-04	0.8782	0.0018	8.576
2	21	60	25.5	2.237E-04	2.035E-04	0.8782	0.0019	8.576
3	20	60	25.5	2.131E-04	1.938E-04	0.8782	0.0018	8.576
4	20	60	25.5	2.131E-04	1.938E-04	0.8782	0.0018	8.576
5	21	60	25.5	2.237E-04	2.035E-04	0.8782	0.0019	8.576
				2.173E-04	1.977E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	22	60	25.0	2.344E-04	2.132E-04	0.8887	0.0020	8.576
2	23	60	25.0	2.450E-04	2.229E-04	0.8887	0.0021	8.576
3	22	60	25.0	2.344E-04	2.132E-04	0.8887	0.0020	8.576
4	22	60	25.0	2.344E-04	2.132E-04	0.8887	0.0020	8.576
5	22	60	25.0	2.344E-04	2.132E-04	0.8887	0.0020	8.576
				2.365E-04	2.152E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	30	120	24.5	1.598E-04	1.454E-04	0.8992	0.0014	8.576
2	30	120	24.5	1.598E-04	1.454E-04	0.8992	0.0014	8.576
3	30	120	24.5	1.598E-04	1.454E-04	0.8992	0.0014	8.576
4	31	120	24.5	1.651E-04	1.502E-04	0.8992	0.0014	8.576
5	31	120	24.5	1.651E-04	1.502E-04	0.8992	0.0014	8.576
				1.619E-04	1.473E-04			

Avg Perm	1.757E-04	cm/s

B) 30 Minute Saturation Method, No Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	27	60	24.0	2.876E-04	2.623E-04	0.9097	0.0025	8.576
2	24	60	24.0	2.557E-04	2.331E-04	0.9097	0.0022	8.576
3	28	60	24.0	2.983E-04	2.720E-04	0.9097	0.0026	8.576
4	27	60	24.0	2.876E-04	2.623E-04	0.9097	0.0025	8.576
5	28	60	24.0	2.983E-04	2.720E-04	0.9097	0.0026	8.576
				2.855E-04	2.603E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	15	60	26.0	1.598E-04	1.454E-04	0.8677	0.0014	8.576
2	40	180	26.0	1.420E-04	1.292E-04	0.8677	0.0012	8.576
3	28	120	26.0	1.492E-04	1.357E-04	0.8677	0.0013	8.576
4	15	60	26.0	1.598E-04	1.454E-04	0.8677	0.0014	8.576
5	15	60	26.0	1.598E-04	1.454E-04	0.8677	0.0014	8.576
				1.541E-04	1.402E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	22	60	24.0	2.344E-04	2.137E-04	0.9097	0.0020	8.576
2	23	60	24.0	2.450E-04	2.234E-04	0.9097	0.0021	8.576
3	22	60	24.0	2.344E-04	2.137E-04	0.9097	0.0020	8.576
4	22	60	24.0	2.344E-04	2.137E-04	0.9097	0.0020	8.576
5	24	60	24.0	2.557E-04	2.331E-04	0.9097	0.0022	8.576
				2.408E-04	2.195E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	33	120	25.0	1.758E-04	1.599E-04	0.8887	0.0015	8.576
2	33	120	25.0	1.758E-04	1.599E-04	0.8887	0.0015	8.576
3	34	120	25.0	1.811E-04	1.648E-04	0.8887	0.0016	8.576
4	32	120	25.0	1.705E-04	1.551E-04	0.8887	0.0015	8.576
5	34	120	25.0	1.811E-04	1.648E-04	0.8887	0.0016	8.576
				1.769E-04	1.609E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	25	60	24.6	2.663E-04	2.423E-04	0.8971	0.0023	8.576
2	25	60	24.6	2.663E-04	2.423E-04	0.8971	0.0023	8.576
3	25	60	24.6	2.663E-04	2.423E-04	0.8971	0.0023	8.576
4	26	60	24.6	2.770E-04	2.520E-04	0.8971	0.0024	8.576
5	26	60	24.6	2.770E-04	2.520E-04	0.8971	0.0024	8.576
				2.706E-04	2.462E-04			

Avg Perm	2.054E-04	cm/s

C) 30 Minute Saturation Method, Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	25	60	25.3	2.663E-04	2.423E-04	0.8824	0.0023	8.576
2	26	60	25.3	2.770E-04	2.520E-04	0.8824	0.0024	8.576
3	26	60	25.3	2.770E-04	2.520E-04	0.8824	0.0024	8.576
4	23	60	25.3	2.450E-04	2.229E-04	0.8824	0.0021	8.576
5	25	60	25.3	2.663E-04	2.423E-04	0.8824	0.0023	8.576
				2.663E-04	2.423E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	23	60	24.9	2.450E-04	2.229E-04	0.8908	0.0021	8.576
2	24	60	24.9	2.557E-04	2.326E-04	0.8908	0.0022	8.576
3	23	60	24.9	2.450E-04	2.229E-04	0.8908	0.0021	8.576
4	23	60	24.9	2.450E-04	2.229E-04	0.8908	0.0021	8.576
5	23	60	24.9	2.450E-04	2.229E-04	0.8908	0.0021	8.576
				2.472E-04	2.248E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	30	60	25.0	3.196E-04	2.907E-04	0.8887	0.0027	8.576
2	31	60	25.0	3.303E-04	3.004E-04	0.8887	0.0028	8.576
3	31	60	25.0	3.303E-04	3.004E-04	0.8887	0.0028	8.576
4	30	60	25.0	3.196E-04	2.907E-04	0.8887	0.0027	8.576
5	30	60	25.0	3.196E-04	2.907E-04	0.8887	0.0027	8.576
				3.239E-04	2.946E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	38	60	24.7	4.048E-04	3.683E-04	0.895	0.0035	8.576
2	39	60	24.7	4.155E-04	3.780E-04	0.895	0.0036	8.576
3	40	60	24.7	4.261E-04	3.877E-04	0.895	0.0037	8.576
4	39	60	24.7	4.155E-04	3.780E-04	0.895	0.0036	8.576
5	38	60	24.7	4.048E-04	3.683E-04	0.895	0.0035	8.576
				4.134E-04	3.760E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	27	60	25.2	2.876E-04	2.617E-04	0.8845	0.0025	8.576
2	27	60	25.2	2.876E-04	2.617E-04	0.8845	0.0025	8.576
3	29	60	25.2	3.090E-04	2.811E-04	0.8845	0.0026	8.576
4	28	60	25.2	2.983E-04	2.714E-04	0.8845	0.0026	8.576
5	27	60	25.2	2.876E-04	2.617E-04	0.8845	0.0025	8.576
				2.940E-04	2.675E-04			

Avg Perm	2.811E-04	cm/s

D) 30 Minute Saturation Method, Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	34	60	23.6	3.622E-04	3.334E-04	0.9183	0.0031	8.576
2	35	60	23.6	3.729E-04	3.432E-04	0.9183	0.0032	8.576
3	35	60	23.6	3.729E-04	3.432E-04	0.9183	0.0032	8.576
4	35	60	23.6	3.729E-04	3.432E-04	0.9183	0.0032	8.576
5	34	60	23.6	3.622E-04	3.334E-04	0.9183	0.0031	8.576
				3.686E-04	3.393E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	33	60	23.8	3.516E-04	3.221E-04	0.914	0.0030	8.576
2	34	60	23.8	3.622E-04	3.318E-04	0.914	0.0031	8.576
3	33	60	23.8	3.516E-04	3.221E-04	0.914	0.0030	8.576
4	32	60	23.8	3.409E-04	3.123E-04	0.914	0.0029	8.576
5	34	60	23.8	3.622E-04	3.318E-04	0.914	0.0031	8.576
				3.537E-04	3.240E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	39	60	23.7	4.155E-04	3.815E-04	0.9161	0.0036	8.576
2	40	60	23.7	4.261E-04	3.913E-04	0.9161	0.0037	8.576
3	38	60	23.7	4.048E-04	3.718E-04	0.9161	0.0035	8.576
4	40	60	23.7	4.261E-04	3.913E-04	0.9161	0.0037	8.576
5	39	60	23.7	4.155E-04	3.815E-04	0.9161	0.0036	8.576
				4.176E-04	3.835E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	29	60	24.0	3.090E-04	2.817E-04	0.9097	0.0026	8.576
2	30	60	24.0	3.196E-04	2.914E-04	0.9097	0.0027	8.576
3	29	60	24.0	3.090E-04	2.817E-04	0.9097	0.0026	8.576
4	29	60	24.0	3.090E-04	2.817E-04	0.9097	0.0026	8.576
5	30	60	24.0	3.196E-04	2.914E-04	0.9097	0.0027	8.576
				3.132E-04	2.856E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	42	60	24.2	4.475E-04	4.070E-04	0.9055	0.0038	8.576
2	40	60	24.2	4.261E-04	3.877E-04	0.9055	0.0037	8.576
3	41	60	24.2	4.368E-04	3.974E-04	0.9055	0.0037	8.576
4	40	60	24.2	4.261E-04	3.877E-04	0.9055	0.0037	8.576
5	40	60	24.2	4.261E-04	3.877E-04	0.9055	0.0037	8.576
				4.325E-04	3.935E-04			

Avg Perm	3.452E-04	cm/s

E) Overnight Saturation Method, No Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	11	120	25.5	5.860E-05	5.330E-05	0.8782	0.0005	8.576
2	7	60	25.5	7.458E-05	6.784E-05	0.8782	0.0006	8.576
3	7	60	25.5	7.458E-05	6.784E-05	0.8782	0.0006	8.576
4	7	60	25.5	7.458E-05	6.784E-05	0.8782	0.0006	8.576
5	7	60	25.5	7.458E-05	6.784E-05	0.8782	0.0006	8.576
				7.138E-05	6.493E-05			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	60	24.3	2.131E-04	1.938E-04	0.9034	0.0018	8.576
2	18	60	24.3	1.918E-04	1.744E-04	0.9034	0.0016	8.576
3	18	60	24.3	1.918E-04	1.744E-04	0.9034	0.0016	8.576
4	18	60	24.3	1.918E-04	1.744E-04	0.9034	0.0016	8.576
5	18	60	24.3	1.918E-04	1.744E-04	0.9034	0.0016	8.576
				1.960E-04	1.783E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	18	120	25.0	9.588E-05	8.722E-05	0.8887	0.0008	8.576
2	18	120	25.0	9.588E-05	8.722E-05	0.8887	0.0008	8.576
3	19	120	25.0	1.012E-04	9.207E-05	0.8887	0.0009	8.576
4	19	120	25.0	1.012E-04	9.207E-05	0.8887	0.0009	8.576
5	19	120	25.0	1.012E-04	9.207E-05	0.8887	0.0009	8.576
				9.908E-05	9.013E-05			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	26	120	24.8	1.385E-04	1.260E-04	0.8929	0.0012	8.576
2	25	120	24.8	1.332E-04	1.211E-04	0.8929	0.0011	8.576
3	26	120	24.8	1.385E-04	1.260E-04	0.8929	0.0012	8.576
4	26	120	24.8	1.385E-04	1.260E-04	0.8929	0.0012	8.576
5	25	120	24.8	1.332E-04	1.211E-04	0.8929	0.0011	8.576
				1.364E-04	1.241E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	60	25.2	2.131E-04	1.938E-04	0.8845	0.0018	8.576
2	20	60	25.2	2.131E-04	1.938E-04	0.8845	0.0018	8.576
3	21	60	25.2	2.237E-04	2.035E-04	0.8845	0.0019	8.576
4	21	60	25.2	2.237E-04	2.035E-04	0.8845	0.0019	8.576
5	20	60	25.2	2.131E-04	1.938E-04	0.8845	0.0018	8.576
				2.173E-04	1.977E-04			

Avg Perm	1.310E-04	cm/s

F) Overnight Saturation Method, No Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	46	180	25.0	1.634E-04	1.486E-04	0.8887	0.0014	8.576
2	32	120	25.0	1.705E-04	1.551E-04	0.8887	0.0015	8.576
3	17	60	25.0	1.811E-04	1.648E-04	0.8887	0.0016	8.576
4	17	60	25.0	1.811E-04	1.648E-04	0.8887	0.0016	8.576
5	17	60	25.0	1.811E-04	1.648E-04	0.8887	0.0016	8.576
				1.754E-04	1.596E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	18	60	24.8	1.918E-04	1.744E-04	0.8929	0.0016	8.576
2	19	60	24.8	2.024E-04	1.841E-04	0.8929	0.0017	8.576
3	18	60	24.8	1.918E-04	1.744E-04	0.8929	0.0016	8.576
4	18	60	24.8	1.918E-04	1.744E-04	0.8929	0.0016	8.576
5	18	60	24.8	1.918E-04	1.744E-04	0.8929	0.0016	8.576
				1.939E-04	1.764E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	50	180	25.3	1.776E-04	1.615E-04	0.8824	0.0015	8.576
2	51	180	25.3	1.811E-04	1.648E-04	0.8824	0.0016	8.576
3	50	180	25.3	1.776E-04	1.615E-04	0.8824	0.0015	8.576
4	51	180	25.3	1.811E-04	1.648E-04	0.8824	0.0016	8.576
5	50	180	25.3	1.776E-04	1.615E-04	0.8824	0.0015	8.576
				1.790E-04	1.628E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	60	24.7	2.131E-04	1.938E-04	0.895	0.0018	8.576
2	21	60	24.7	2.237E-04	2.035E-04	0.895	0.0019	8.576
3	21	60	24.7	2.237E-04	2.035E-04	0.895	0.0019	8.576
4	22	60	24.7	2.344E-04	2.132E-04	0.895	0.0020	8.576
5	20	60	24.7	2.131E-04	1.938E-04	0.895	0.0018	8.576
				2.216E-04	2.016E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	34	120	23.9	1.811E-04	1.655E-04	0.9118	0.0016	8.576
2	33	120	23.9	1.758E-04	1.607E-04	0.9118	0.0015	8.576
3	34	120	23.9	1.811E-04	1.655E-04	0.9118	0.0016	8.576
4	34	120	23.9	1.811E-04	1.655E-04	0.9118	0.0016	8.576
5	33	120	23.9	1.758E-04	1.607E-04	0.9118	0.0015	8.576
				1.790E-04	1.636E-04			

Avg Perm	1.728E-04	cm/s

G) Overnight Saturation Method, Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	48	60	25.5	5.114E-04	4.652E-04	0.8782	0.0044	8.576
2	48	60	25.5	5.114E-04	4.652E-04	0.8782	0.0044	8.576
3	49	60	25.5	5.220E-04	4.749E-04	0.8782	0.0045	8.576
4	49	60	25.5	5.220E-04	4.749E-04	0.8782	0.0045	8.576
5	49	60	25.5	5.220E-04	4.749E-04	0.8782	0.0045	8.576
				5.178E-04	4.710E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	30	60	25.3	3.196E-04	2.907E-04	0.8824	0.0027	8.576
2	31	60	25.3	3.303E-04	3.004E-04	0.8824	0.0028	8.576
3	30	60	25.3	3.196E-04	2.907E-04	0.8824	0.0027	8.576
4	30	60	25.3	3.196E-04	2.907E-04	0.8824	0.0027	8.576
5	30	60	25.3	3.196E-04	2.907E-04	0.8824	0.0027	8.576
				3.217E-04	2.927E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	55	120	24.9	2.930E-04	2.665E-04	0.8908	0.0025	8.576
2	50	120	24.9	2.663E-04	2.423E-04	0.8908	0.0023	8.576
3	52	120	24.9	2.770E-04	2.520E-04	0.8908	0.0024	8.576
4	52	120	24.9	2.770E-04	2.520E-04	0.8908	0.0024	8.576
5	53	120	24.9	2.823E-04	2.568E-04	0.8908	0.0024	8.576
				2.791E-04	2.539E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	40	60	25.1	4.261E-04	3.877E-04	0.8866	0.0037	8.576
2	42	60	25.1	4.475E-04	4.070E-04	0.8866	0.0038	8.576
3	40	60	25.1	4.261E-04	3.877E-04	0.8866	0.0037	8.576
4	41	60	25.1	4.368E-04	3.974E-04	0.8866	0.0037	8.576
5	40	60	25.1	4.261E-04	3.877E-04	0.8866	0.0037	8.576
				4.325E-04	3.935E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	39	60	24.7	4.155E-04	3.780E-04	0.895	0.0036	8.576
2	38	60	24.7	4.048E-04	3.683E-04	0.895	0.0035	8.576
3	39	60	24.7	4.155E-04	3.780E-04	0.895	0.0036	8.576
4	39	60	24.7	4.155E-04	3.780E-04	0.895	0.0036	8.576
5	39	60	24.7	4.155E-04	3.780E-04	0.895	0.0036	8.576
				4.134E-04	3.760E-04			

Avg Perm	3.574E-04	cm/s

H) Overnight Saturation Method, Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	35	60	24.7	3.729E-04	3.392E-04	0.895	0.0032	8.576
2	37	60	24.7	3.942E-04	3.586E-04	0.895	0.0034	8.576
3	34	60	24.7	3.622E-04	3.295E-04	0.895	0.0031	8.576
4	35	60	24.7	3.729E-04	3.392E-04	0.895	0.0032	8.576
5	35	60	24.7	3.729E-04	3.392E-04	0.895	0.0032	8.576
				3.750E-04	3.411E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	35	60	22.3	3.729E-04	3.537E-04	0.9465	0.0032	8.576
2	33	60	22.3	3.516E-04	3.335E-04	0.9465	0.0030	8.576
3	35	60	22.3	3.729E-04	3.537E-04	0.9465	0.0032	8.576
4	35	60	22.3	3.729E-04	3.537E-04	0.9465	0.0032	8.576
5	35	60	22.3	3.729E-04	3.537E-04	0.9465	0.0032	8.576
				3.686E-04	3.497E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	50	60	24.3	5.327E-04	4.846E-04	0.9034	0.0046	8.576
2	51	60	24.3	5.433E-04	4.943E-04	0.9034	0.0047	8.576
3	52	60	24.3	5.540E-04	5.040E-04	0.9034	0.0048	8.576
4	50	60	24.3	5.327E-04	4.846E-04	0.9034	0.0046	8.576
5	50	60	24.3	5.327E-04	4.846E-04	0.9034	0.0046	8.576
				5.391E-04	4.904E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	42	60	22.7	4.475E-04	4.206E-04	0.9377	0.0038	8.576
2	42	60	22.7	4.475E-04	4.206E-04	0.9377	0.0038	8.576
3	41	60	22.7	4.368E-04	4.105E-04	0.9377	0.0037	8.576
4	42	60	22.7	4.475E-04	4.206E-04	0.9377	0.0038	8.576
5	41	60	22.7	4.368E-04	4.105E-04	0.9377	0.0037	8.576
				4.432E-04	4.166E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	48	60	23.1	5.114E-04	4.761E-04	0.929	0.0044	8.576
2	48	60	23.1	5.114E-04	4.761E-04	0.929	0.0044	8.576
3	49	60	23.1	5.220E-04	4.861E-04	0.929	0.0045	8.576
4	49	60	23.1	5.220E-04	4.861E-04	0.929	0.0045	8.576
5	49	60	23.1	5.220E-04	4.861E-04	0.929	0.0045	8.576
				5.178E-04	4.821E-04			

Avg Perm	4.160E-04	cm/s

Prototype 3 Permeability Results

Soil Type	A-3

A) 30 Minute Saturation Method, No Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	24	150	24.5	1.023E-04	9.304E-05	0.8992	0.0009	8.576
2	25	150	24.5	1.065E-04	9.692E-05	0.8992	0.0009	8.576
3	41	240	24.5	1.092E-04	9.934E-05	0.8992	0.0009	8.576
4	24	150	24.5	1.023E-04	9.304E-05	0.8992	0.0009	8.576
5	24	150	24.5	1.023E-04	9.304E-05	0.8992	0.0009	8.576
				1.045E-04	*9.507E-05*			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	36	190	24.5	1.211E-04	1.102E-04	0.8992	0.0010	8.576
2	38	200	24.5	1.215E-04	1.105E-04	0.8992	0.0010	8.576
3	28	150	24.5	1.193E-04	1.085E-04	0.8992	0.0010	8.576
4	33	180	24.5	1.172E-04	1.066E-04	0.8992	0.0010	8.576
5	36	195	24.5	1.180E-04	1.074E-04	0.8992	0.0010	8.576
				1.194E-04	1.086E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	12	60	23.5	1.278E-04	1.179E-04	0.9204	0.0011	8.576
2	12	60	23.5	1.278E-04	1.179E-04	0.9204	0.0011	8.576
3	12	60	23.5	1.278E-04	1.179E-04	0.9204	0.0011	8.576
4	14	60	23.5	1.492E-04	1.376E-04	0.9204	0.0013	8.576
5	13	60	23.5	1.385E-04	1.278E-04	0.9204	0.0012	8.576
				1.342E-04	1.238E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	10	60	24.0	1.065E-04	9.714E-05	0.9097	0.0009	8.576
2	11	60	24.0	1.172E-04	1.069E-04	0.9097	0.0010	8.576
3	11	60	24.0	1.172E-04	1.069E-04	0.9097	0.0010	8.576
4	12	60	24.0	1.278E-04	1.166E-04	0.9097	0.0011	8.576
5	10	60	24.0	1.065E-04	9.714E-05	0.9097	0.0009	8.576
				1.151E-04	1.049E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	15	60	24.5	1.598E-04	1.454E-04	0.8992	0.0014	8.576
2	16	60	24.5	1.705E-04	1.551E-04	0.8992	0.0015	8.576
3	16	60	24.5	1.705E-04	1.551E-04	0.8992	0.0015	8.576
4	16	60	24.5	1.705E-04	1.551E-04	0.8992	0.0015	8.576
5	17	60	24.5	1.811E-04	1.648E-04	0.8992	0.0016	8.576
				1.705E-04	1.551E-04			

Avg Perm	1.175E-04	cm/s

B) 30 Minute Saturation Method, No Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	24	120	25.0	1.278E-04	1.163E-04	0.8887	0.0011	8.576
2	49	240	25.0	1.305E-04	1.187E-04	0.8887	0.0011	8.576
3	23	120	25.0	1.225E-04	1.115E-04	0.8887	0.0011	8.576
4	24	120	25.0	1.278E-04	1.163E-04	0.8887	0.0011	8.576
5	24	120	25.0	1.278E-04	1.163E-04	0.8887	0.0011	8.576
				1.273E-04	1.158E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	24	120	24.8	1.278E-04	1.163E-04	0.8929	0.0011	8.576
2	48	240	24.8	1.278E-04	1.163E-04	0.8929	0.0011	8.576
3	16	150	24.8	6.818E-05	6.203E-05	0.8929	0.0006	8.576
4	18	150	24.8	7.671E-05	6.978E-05	0.8929	0.0007	8.576
5	18	150	24.8	7.671E-05	6.978E-05	0.8929	0.0007	8.576
				9.546E-05	8.684E-05			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	13	60	24.7	1.385E-04	1.260E-04	0.895	0.0012	8.576
2	15	60	24.7	1.598E-04	1.454E-04	0.895	0.0014	8.576
3	12	60	24.7	1.278E-04	1.163E-04	0.895	0.0011	8.576
4	13	60	24.7	1.385E-04	1.260E-04	0.895	0.0012	8.576
5	14	60	24.7	1.492E-04	1.357E-04	0.895	0.0013	8.576
				1.428E-04	1.299E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	120	23.6	1.065E-04	9.806E-05	0.9183	0.0009	8.576
2	19	120	23.6	1.012E-04	9.315E-05	0.9183	0.0009	8.576
3	19	120	23.6	1.012E-04	9.315E-05	0.9183	0.0009	8.576
4	21	120	23.6	1.119E-04	1.030E-04	0.9183	0.0010	8.576
5	20	120	23.6	1.065E-04	9.806E-05	0.9183	0.0009	8.576
				1.055E-04	9.708E-05			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	22	120	24.2	1.172E-04	1.066E-04	0.9055	0.0010	8.576
2	22	120	24.2	1.172E-04	1.066E-04	0.9055	0.0010	8.576
3	22	120	24.2	1.172E-04	1.066E-04	0.9055	0.0010	8.576
4	23	120	24.2	1.225E-04	1.115E-04	0.9055	0.0011	8.576
5	22	120	24.2	1.172E-04	1.066E-04	0.9055	0.0010	8.576
				1.183E-04	1.076E-04			

Avg Perm	1.074E-04	cm/s

C) 30 Minute Saturation Method, Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	60	24.8	2.131E-04	1.938E-04	0.8929	0.0018	8.576
2	19	60	24.8	2.024E-04	1.841E-04	0.8929	0.0017	8.576
3	18	60	24.8	1.918E-04	1.744E-04	0.8929	0.0016	8.576
4	20	60	24.8	2.131E-04	1.938E-04	0.8929	0.0018	8.576
5	21	60	24.8	2.237E-04	2.035E-04	0.8929	0.0019	8.576
				2.088E-04	1.900E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	36	120	24.5	1.918E-04	1.744E-04	0.8992	0.0016	8.576
2	35	120	24.5	1.864E-04	1.696E-04	0.8992	0.0016	8.576
3	34	120	24.5	1.811E-04	1.648E-04	0.8992	0.0016	8.576
4	36	120	24.5	1.918E-04	1.744E-04	0.8992	0.0016	8.576
5	35	120	24.5	1.864E-04	1.696E-04	0.8992	0.0016	8.576
				1.875E-04	1.706E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	18	60	25.0	1.918E-04	1.744E-04	0.8887	0.0016	8.576
2	19	60	25.0	2.024E-04	1.841E-04	0.8887	0.0017	8.576
3	21	60	25.0	2.237E-04	2.035E-04	0.8887	0.0019	8.576
4	20	60	25.0	2.131E-04	1.938E-04	0.8887	0.0018	8.576
5	21	60	25.0	2.237E-04	2.035E-04	0.8887	0.0019	8.576
				2.109E-04	1.919E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	40	120	23.4	2.131E-04	1.970E-04	0.9225	0.0018	8.576
2	41	120	23.4	2.184E-04	2.020E-04	0.9225	0.0019	8.576
3	41	120	23.4	2.184E-04	2.020E-04	0.9225	0.0019	8.576
4	40	120	23.4	2.131E-04	1.970E-04	0.9225	0.0018	8.576
5	40	120	23.4	2.131E-04	1.970E-04	0.9225	0.0018	8.576
				2.152E-04	1.990E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	35	120	23.6	1.864E-04	1.716E-04	0.9183	0.0016	8.576
2	35	120	23.6	1.864E-04	1.716E-04	0.9183	0.0016	8.576
3	36	120	23.6	1.918E-04	1.765E-04	0.9183	0.0016	8.576
4	35	120	23.6	1.864E-04	1.716E-04	0.9183	0.0016	8.576
5	34	120	23.6	1.811E-04	1.667E-04	0.9183	0.0016	8.576
				1.864E-04	1.716E-04			

Avg Perm	1.846E-04	cm/s

D) 30 Minute Saturation Method, Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	30	120	25.0	1.598E-04	1.454E-04	0.8887	0.0014	8.576
2	30	120	25.0	1.598E-04	1.454E-04	0.8887	0.0014	8.576
3	44	180	25.0	1.563E-04	1.421E-04	0.8887	0.0013	8.576
4	99	420	25.0	1.507E-04	1.371E-04	0.8887	0.0013	8.576
5	30	120	25.0	1.598E-04	1.454E-04	0.8887	0.0014	8.576
				1.573E-04	1.431E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	15	60	22.8	1.598E-04	1.498E-04	0.9355	0.0014	8.576
2	15	60	22.8	1.598E-04	1.498E-04	0.9355	0.0014	8.576
3	26	120	22.8	1.385E-04	1.299E-04	0.9355	0.0012	8.576
4	25	120	22.8	1.332E-04	1.249E-04	0.9355	0.0011	8.576
5	25	120	22.8	1.332E-04	1.249E-04	0.9355	0.0011	8.576
				1.449E-04	1.359E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	18	60	25.2	1.918E-04	1.744E-04	0.8845	0.0016	8.576
2	17	60	25.2	1.811E-04	1.648E-04	0.8845	0.0016	8.576
3	17	60	25.2	1.811E-04	1.648E-04	0.8845	0.0016	8.576
4	16	60	25.2	1.705E-04	1.551E-04	0.8845	0.0015	8.576
5	18	60	25.2	1.918E-04	1.744E-04	0.8845	0.0016	8.576
				1.832E-04	1.667E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	30	120	24.3	1.598E-04	1.454E-04	0.9034	0.0014	8.576
2	29	120	24.3	1.545E-04	1.405E-04	0.9034	0.0013	8.576
3	28	120	24.3	1.492E-04	1.357E-04	0.9034	0.0013	8.576
4	30	120	24.3	1.598E-04	1.454E-04	0.9034	0.0014	8.576
5	31	120	24.3	1.651E-04	1.502E-04	0.9034	0.0014	8.576
				1.577E-04	1.434E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	13	60	23.7	1.385E-04	1.272E-04	0.9161	0.0012	8.576
2	15	60	23.7	1.598E-04	1.467E-04	0.9161	0.0014	8.576
3	14	60	23.7	1.492E-04	1.370E-04	0.9161	0.0013	8.576
4	15	60	23.7	1.598E-04	1.467E-04	0.9161	0.0014	8.576
5	15	60	23.7	1.598E-04	1.467E-04	0.9161	0.0014	8.576
				1.534E-04	1.409E-04			

Avg Perm	1.460E-04	cm/s

E) Overnight Saturation Method, No Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	5	60	25.5	5.327E-05	4.846E-05	0.8782	0.0005	8.576
2	5	60	25.5	5.327E-05	4.846E-05	0.8782	0.0005	8.576
3	5	60	25.5	5.327E-05	4.846E-05	0.8782	0.0005	8.576
4	5	60	25.5	5.327E-05	4.846E-05	0.8782	0.0005	8.576
5	5	60	25.5	5.327E-05	4.846E-05	0.8782	0.0005	8.576
				5.327E-05	4.846E-05			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	10	60	25.8	1.065E-04	9.692E-05	0.8719	0.0009	8.576
2	11	60	25.8	1.172E-04	1.066E-04	0.8719	0.0010	8.576
3	10	60	25.8	1.065E-04	9.692E-05	0.8719	0.0009	8.576
4	10	60	25.8	1.065E-04	9.692E-05	0.8719	0.0009	8.576
5	10	60	25.8	1.065E-04	9.692E-05	0.8719	0.0009	8.576
				1.087E-04	9.885E-05			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	18	60	26.0	1.918E-04	1.744E-04	0.8677	0.0016	8.576
2	18	60	26.0	1.918E-04	1.744E-04	0.8677	0.0016	8.576
3	18	60	26.0	1.918E-04	1.744E-04	0.8677	0.0016	8.576
4	19	60	26.0	2.024E-04	1.841E-04	0.8677	0.0017	8.576
5	18	60	26.0	1.918E-04	1.744E-04	0.8677	0.0016	8.576
				1.939E-04	1.764E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	15	60	25.3	1.598E-04	1.454E-04	0.8824	0.0014	8.576
2	16	60	25.3	1.705E-04	1.551E-04	0.8824	0.0015	8.576
3	18	60	25.3	1.918E-04	1.744E-04	0.8824	0.0016	8.576
4	15	60	25.3	1.598E-04	1.454E-04	0.8824	0.0014	8.576
5	15	60	25.3	1.598E-04	1.454E-04	0.8824	0.0014	8.576
				1.683E-04	1.531E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	9	60	25.2	9.588E-05	8.722E-05	0.8845	0.0008	8.576
2	9	60	25.2	9.588E-05	8.722E-05	0.8845	0.0008	8.576
3	10	60	25.2	1.065E-04	9.692E-05	0.8845	0.0009	8.576
4	9	60	25.2	9.588E-05	8.722E-05	0.8845	0.0008	8.576
5	9	60	25.2	9.588E-05	8.722E-05	0.8845	0.0008	8.576
				9.801E-05	8.916E-05			

Avg Perm	1.132E-04	cm/s

F) Overnight Saturation Method, No Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	24	120	26.0	1.278E-04	1.163E-04	0.8677	0.0011	8.576
2	22	120	26.0	1.172E-04	1.066E-04	0.8677	0.0010	8.576
3	22	120	26.0	1.172E-04	1.066E-04	0.8677	0.0010	8.576
4	22	120	26.0	1.172E-04	1.066E-04	0.8677	0.0010	8.576
5	22	120	26.0	1.172E-04	1.066E-04	0.8677	0.0010	8.576
				1.193E-04	1.085E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	12	60	25.6	1.278E-04	1.163E-04	0.8761	0.0011	8.576
2	13	60	25.6	1.385E-04	1.260E-04	0.8761	0.0012	8.576
3	12	60	25.6	1.278E-04	1.163E-04	0.8761	0.0011	8.576
4	12	60	25.6	1.278E-04	1.163E-04	0.8761	0.0011	8.576
5	12	60	25.6	1.278E-04	1.163E-04	0.8761	0.0011	8.576
				1.300E-04	1.182E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	27	120	25.6	1.438E-04	1.308E-04	0.8761	0.0012	8.576
2	28	120	25.6	1.492E-04	1.357E-04	0.8761	0.0013	8.576
3	28	120	25.6	1.492E-04	1.357E-04	0.8761	0.0013	8.576
4	28	120	25.6	1.492E-04	1.357E-04	0.8761	0.0013	8.576
5	27	120	25.6	1.438E-04	1.308E-04	0.8761	0.0012	8.576
				1.470E-04	1.337E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	10	60	24.9	1.065E-04	9.692E-05	0.8908	0.0009	8.576
2	10	60	24.9	1.065E-04	9.692E-05	0.8908	0.0009	8.576
3	11	60	24.9	1.172E-04	1.066E-04	0.8908	0.0010	8.576
4	10	60	24.9	1.065E-04	9.692E-05	0.8908	0.0009	8.576
5	10	60	24.9	1.065E-04	9.692E-05	0.8908	0.0009	8.576
				1.087E-04	9.885E-05			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	9	60	24.7	9.588E-05	8.722E-05	0.895	0.0008	8.576
2	10	60	24.7	1.065E-04	9.692E-05	0.895	0.0009	8.576
3	10	60	24.7	1.065E-04	9.692E-05	0.895	0.0009	8.576
4	9	60	24.7	9.588E-05	8.722E-05	0.895	0.0008	8.576
5	11	60	24.7	1.172E-04	1.066E-04	0.895	0.0010	8.576
				1.044E-04	9.498E-05			

Avg Perm	1.109E-04	cm/s

G) Overnight Saturation Method, Vacuum, and Top Steel Disk

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	35	60	25.1	3.729E-04	3.392E-04	0.8866	0.0032	8.576
2	35	60	25.1	3.729E-04	3.392E-04	0.8866	0.0032	8.576
3	34	60	25.1	3.622E-04	3.295E-04	0.8866	0.0031	8.576
4	35	60	25.1	3.729E-04	3.392E-04	0.8866	0.0032	8.576
5	35	60	25.1	3.729E-04	3.392E-04	0.8866	0.0032	8.576
				3.707E-04	3.373E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	33	60	25.8	3.516E-04	3.198E-04	0.8719	0.0030	8.576
2	32	60	25.8	3.409E-04	3.101E-04	0.8719	0.0029	8.576
3	30	60	25.8	3.196E-04	2.907E-04	0.8719	0.0027	8.576
4	33	60	25.8	3.516E-04	3.198E-04	0.8719	0.0030	8.576
5	33	60	25.8	3.516E-04	3.198E-04	0.8719	0.0030	8.576
				3.430E-04	3.121E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	25	60	24.9	2.663E-04	2.423E-04	0.8908	0.0023	8.576
2	26	60	24.9	2.770E-04	2.520E-04	0.8908	0.0024	8.576
3	25	60	24.9	2.663E-04	2.423E-04	0.8908	0.0023	8.576
4	25	60	24.9	2.663E-04	2.423E-04	0.8908	0.0023	8.576
5	25	60	24.9	2.663E-04	2.423E-04	0.8908	0.0023	8.576
				2.685E-04	2.442E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	22	60	23.8	2.344E-04	2.147E-04	0.914	0.0020	8.576
2	20	60	23.8	2.131E-04	1.952E-04	0.914	0.0018	8.576
3	21	60	23.8	2.237E-04	2.050E-04	0.914	0.0019	8.576
4	22	60	23.8	2.344E-04	2.147E-04	0.914	0.0020	8.576
5	22	60	23.8	2.344E-04	2.147E-04	0.914	0.0020	8.576
				2.280E-04	2.089E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	20	60	23.3	2.131E-04	1.975E-04	0.9247	0.0018	8.576
2	20	60	23.3	2.131E-04	1.975E-04	0.9247	0.0018	8.576
3	21	60	23.3	2.237E-04	2.073E-04	0.9247	0.0019	8.576
4	21	60	23.3	2.237E-04	2.073E-04	0.9247	0.0019	8.576
5	22	60	23.3	2.344E-04	2.172E-04	0.9247	0.0020	8.576
				2.216E-04	2.054E-04			

Avg Perm	2.616E-04	cm/s

H) Overnight Saturation Method, Vacuum, and Top Porous Stone

Trial 1

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	23	60	22.6	2.450E-04	2.308E-04	0.9399	0.0021	8.576
2	23	60	22.6	2.450E-04	2.308E-04	0.9399	0.0021	8.576
3	23	60	22.6	2.450E-04	2.308E-04	0.9399	0.0021	8.576
4	12	30	22.6	2.557E-04	2.409E-04	0.9399	0.0022	8.576
5	23	60	22.6	2.450E-04	2.308E-04	0.9399	0.0021	8.576
				2.472E-04	2.329E-04			

Trial 2

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	28	60	23.5	2.983E-04	2.752E-04	0.9204	0.0026	8.576
2	28	60	23.5	2.983E-04	2.752E-04	0.9204	0.0026	8.576
3	29	60	23.5	3.090E-04	2.850E-04	0.9204	0.0026	8.576
4	29	60	23.5	3.090E-04	2.850E-04	0.9204	0.0026	8.576
5	28	60	23.5	2.983E-04	2.752E-04	0.9204	0.0026	8.576
				3.026E-04	2.791E-04			

Trial 3

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	33	60	24.1	3.516E-04	3.198E-04	0.9076	0.0030	8.576
2	32	60	24.1	3.409E-04	3.101E-04	0.9076	0.0029	8.576
3	33	60	24.1	3.516E-04	3.198E-04	0.9076	0.0030	8.576
4	33	60	24.1	3.516E-04	3.198E-04	0.9076	0.0030	8.576
5	32	60	24.1	3.409E-04	3.101E-04	0.9076	0.0029	8.576
				3.473E-04	3.159E-04			

Trial 4

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	32	60	23.8	3.409E-04	3.123E-04	0.914	0.0029	8.576
2	33	60	23.8	3.516E-04	3.221E-04	0.914	0.0030	8.576
3	33	60	23.8	3.516E-04	3.221E-04	0.914	0.0030	8.576
4	33	60	23.8	3.516E-04	3.221E-04	0.914	0.0030	8.576
5	33	60	23.8	3.516E-04	3.221E-04	0.914	0.0030	8.576
				3.494E-04	3.201E-04			

Trial 5

Reading	Q (cm^3)	t (sec)	Temp (°C)	k (cm/s)	k_{20} (cm/s)	Temp Factor	Velocity (cm/s)	Hyd Gradient
1	30	60	24.1	3.196E-04	2.907E-04	0.9076	0.0027	8.576
2	29	60	24.1	3.090E-04	2.811E-04	0.9076	0.0026	8.576
3	29	60	24.1	3.090E-04	2.811E-04	0.9076	0.0026	8.576
4	29	60	24.1	3.090E-04	2.811E-04	0.9076	0.0026	8.576
5	30	60	24.1	3.196E-04	2.907E-04	0.9076	0.0027	8.576
				3.132E-04	2.849E-04			

Avg Perm	2.866E-04	cm/s

APPENDIX D
EFFECT OF FINES ON PERMEABILITY AND DENSITY VALUES

This appendix is provided to study the effect of fines on permeability and density values of typical Florida soils. The soil samples used in this study were provided by the FDOT from various sites. The collected soil samples represent typical subbase materials used in conjunction with rigid pavements. Essential lab tests were performed to obtain basic soil properties.

D.1 Soil Samples

The soil samples from the six different sources represent the typical subbase material for constructing rigid pavements in Florida. The FDOT also provided some basic properties of the samples as shown in Table D.1.

Table D.1. Descriptions of obtained samples

Soil #	Description	FDOT Permeability (cm/s)	% Passing # 200 (% Fines)	Modified Proctor Dry Density		Opt. Water Content (%)
				(pcf)	(g/cm^3)	
1	72280-3424 004H	N/A	9.82	106.61	1.709	9.31
2	Test Pit Tan Sand	6.1375×10^{-4}	4	108.7	1.743	10.9
3	Beck Pit Subgrade	3.278×10^{-3}	2	104.5	1.675	13.6
4	Goldhead	4.317×10^{-4}	6	108.2	1.735	9.2
5	GrovePark / Whitehurst	2.804×10^{-5}	13	119.2	1.911	9.2
6	Middleburg-Clay Co.	4.873×10^{-5}	9	109.9	1.762	11.2

D.1.1 Basic Properties

This section describes the basic properties of the soil material based on an independent evaluation of laboratory testing by the University of Florida.

D.1.1.1 Grain Size Distribution Analysis

Sieve analyses were performed on the six soil samples using U.S. standard sieves. The procedure followed ASTM D422.

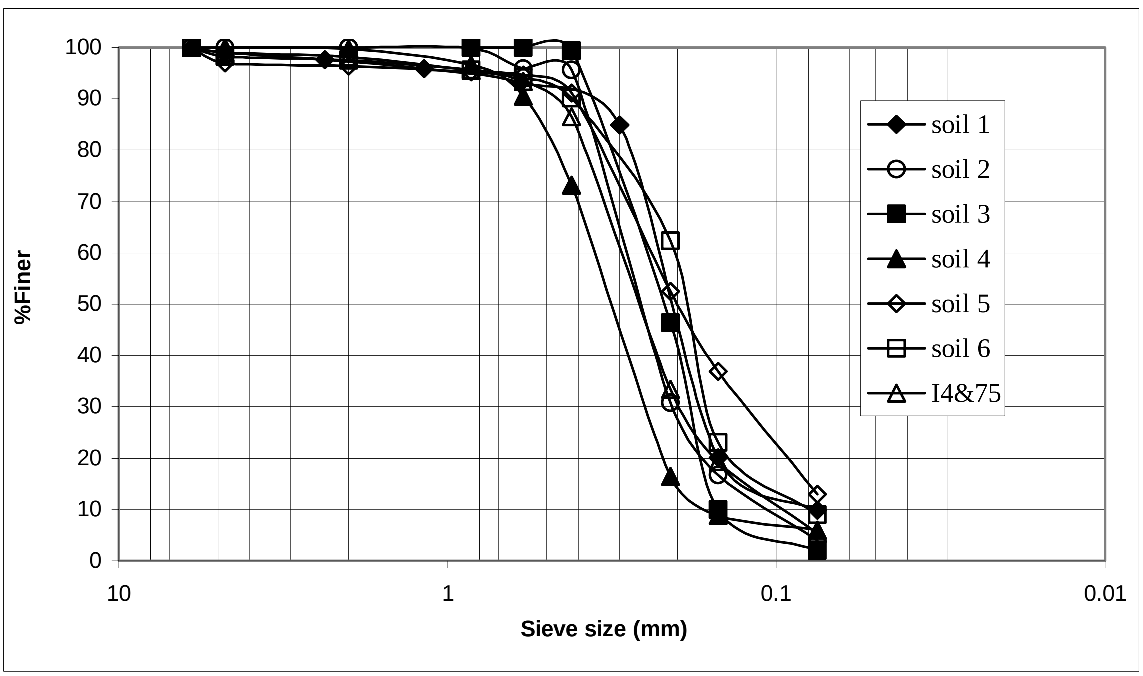


Figure D.1. Grain size distribution curves of six Florida soil samples.

D.2 Variation of Permeability and Density with % fines Sensitivity

The coefficient of permeability of a saturated granular soil is primarily a function of the grain-size distribution, the void ratio and the roughness of the mineral particles. An empirical equation cannot accurately estimate the permeability of a soil simply by using the given grain size distribution plot. To examine the effect of % fines on the permeability of various materials, permeability tests were performed on samples of each soil type. Particles passing through the #200 sieve were separated from each sample, producing material lacking particles smaller than 0.075mm. Subsequently, a pre-determined amount of #200 material was added to each same sample to obtain samples with fixed amount of fines. The designated % fines used for studying fine particle effects were 0%, 5%, 10%, 15% and 20%. Each prepared sample was compacted in an ASTM permeability device using a hand-tamper and a vacuum was applied to remove the air from the sample. Because the six samples were classified as medium to fine sands, constant head tests were performed for permeability, following the ASTM D2434 standard procedure. Test data of the samples was input into a prepared spreadsheet to calculate the dry density and the permeability of each sample. The summary of the results can be seen in Figures D.2 through D.8.

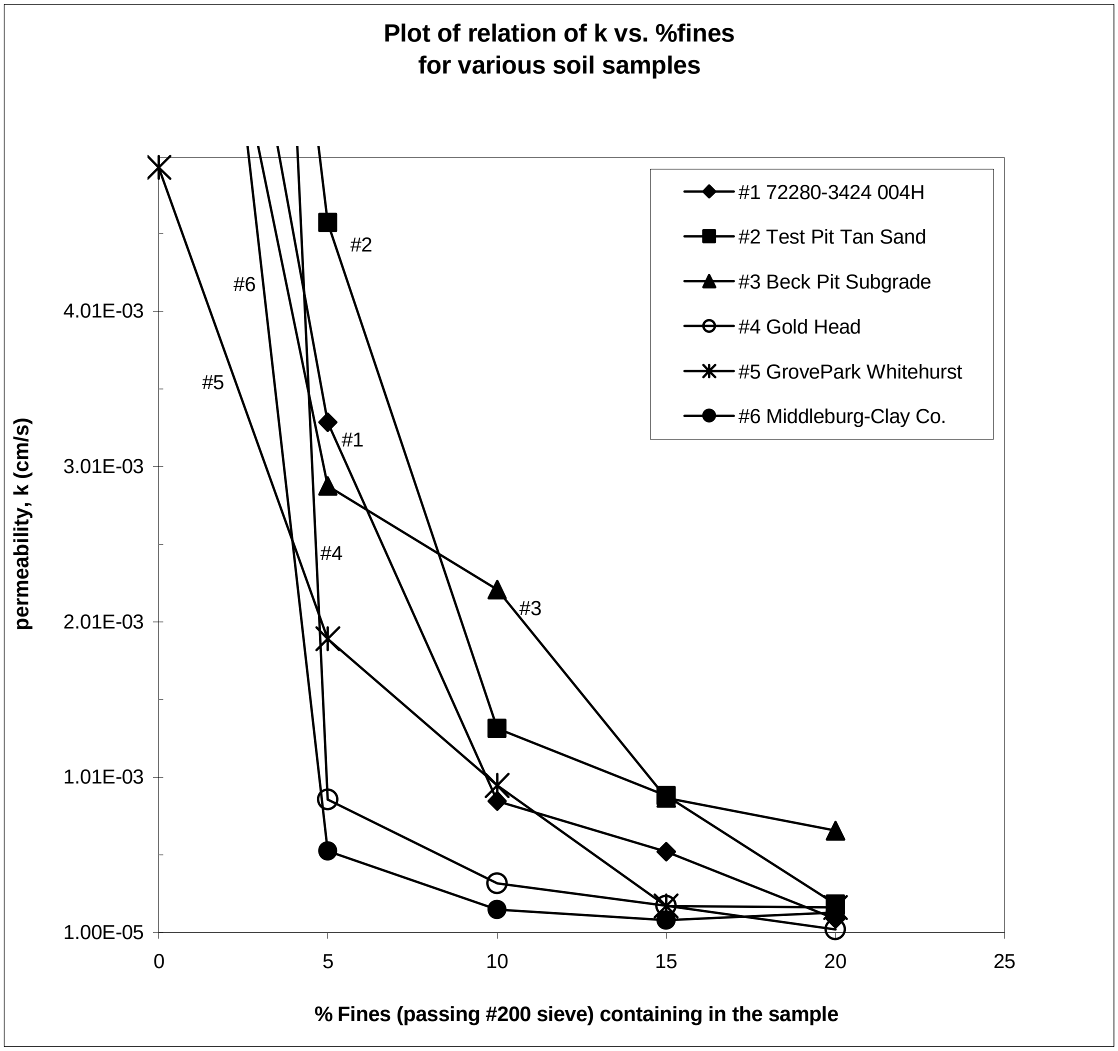


Figure D.2. Permeability values from test results of samples with various % fines.

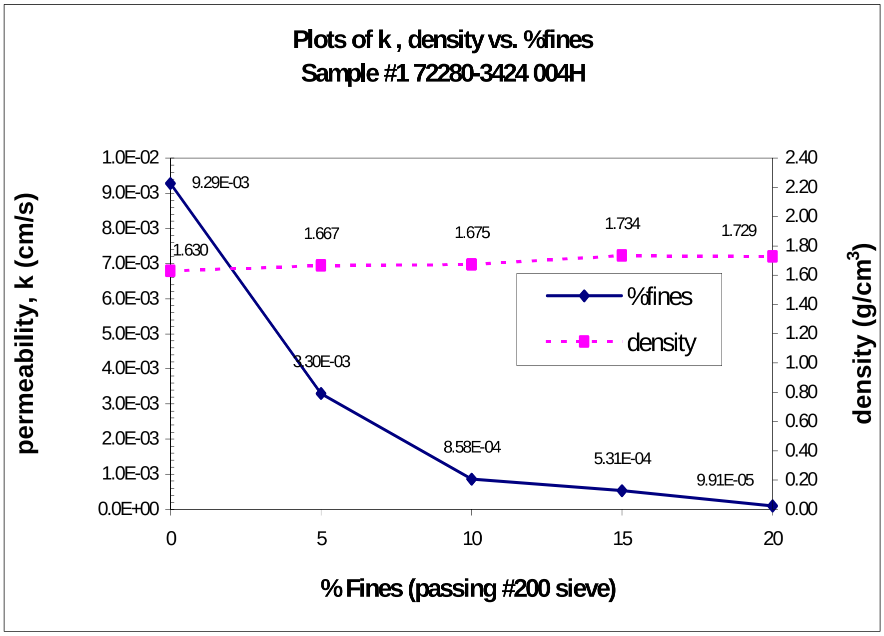


Figure D.3. Permeability and density values for sample # 1.

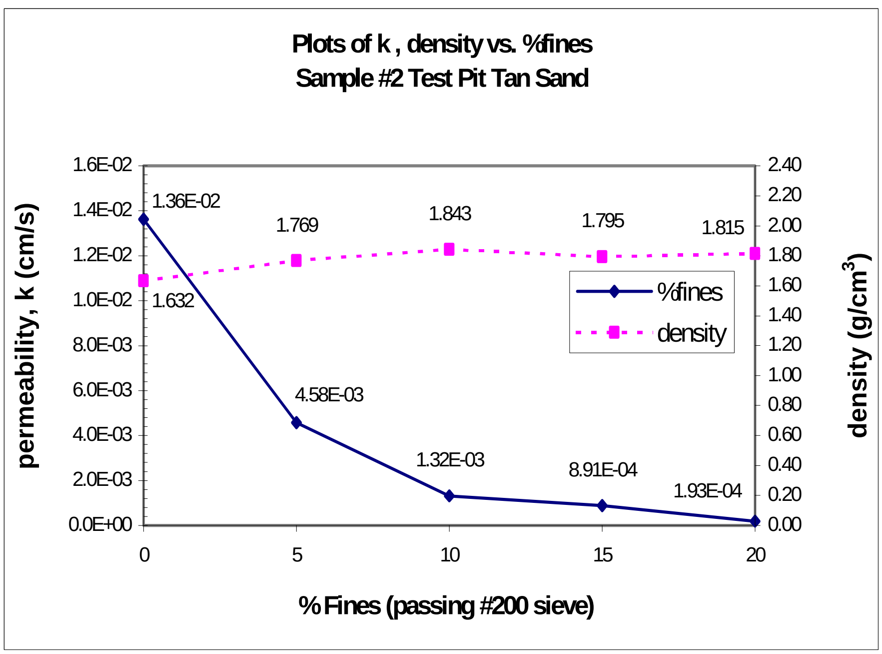


Figure D.4. Permeability and density values for sample # 2.

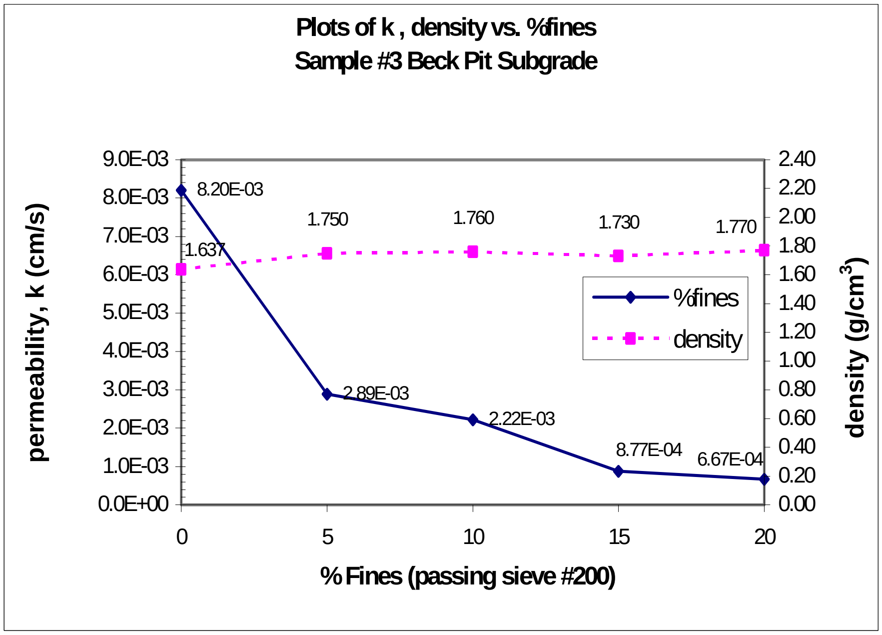


Figure D.5. Permeability and density values for sample # 3.

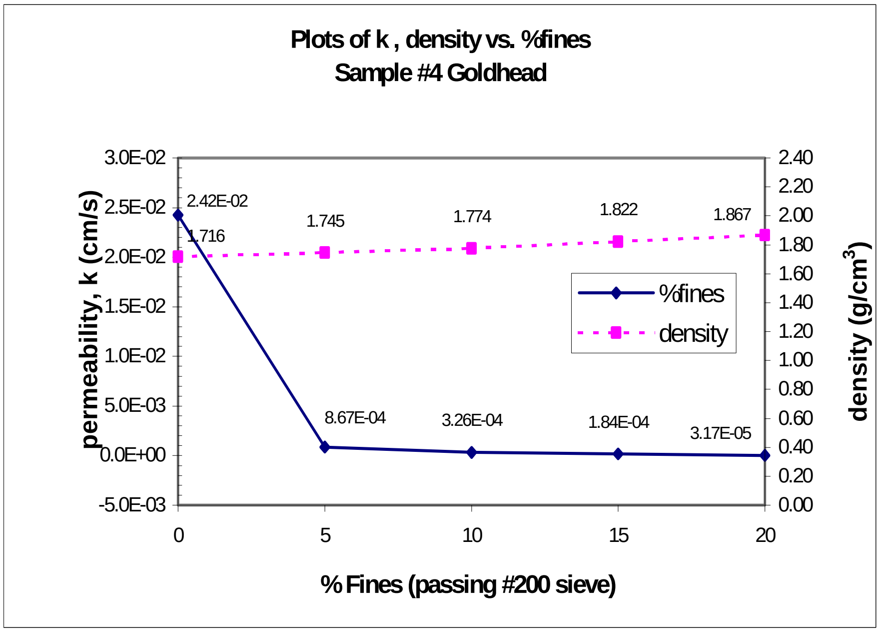


Figure D.6. Permeability and density values for sample # 4.

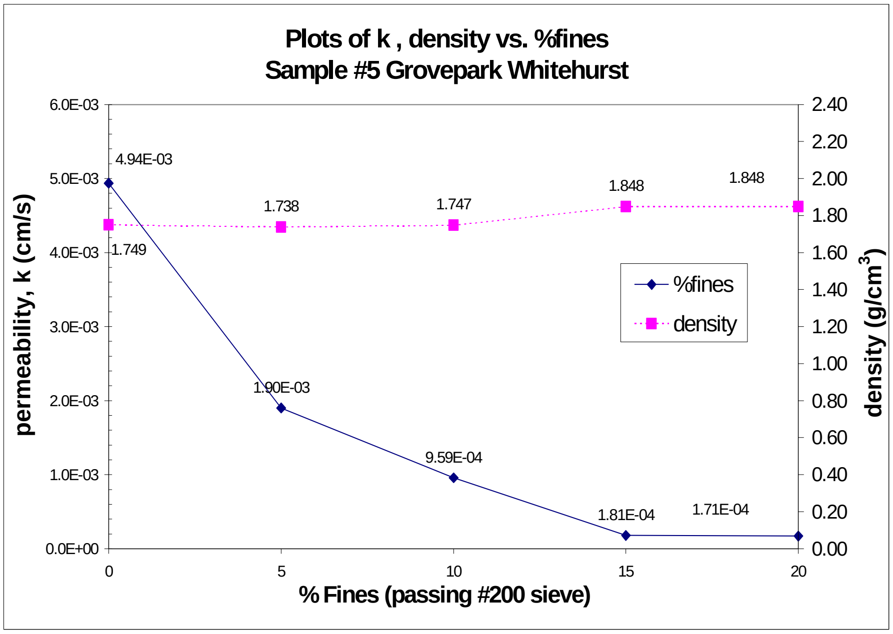


Figure D.7. Permeability and density values for sample # 5.

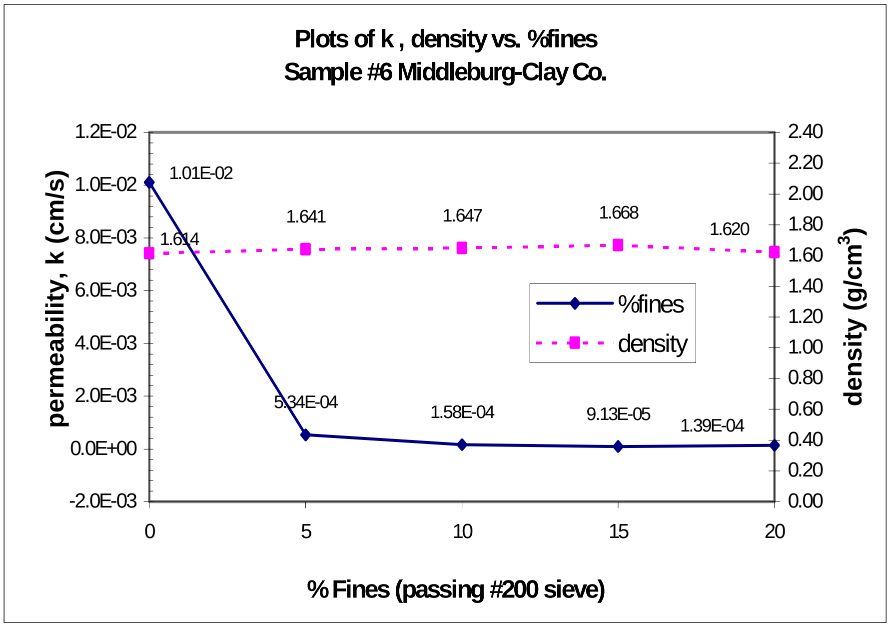


Figure D.8. Permeability and density values for sample # 6.

D.3 Overall Comparison of Permeability and Density and versus %Fines

This section provides a summary and comparison of the permeability and density values that resulted based on the six samples and the variation in the percentage of fines.

D.3.1 The effect of % fines on permeability

The addition of fine material to the samples increased their densities, thus reducing the effective pore volumes. As a result, a reduction in permeability was observed. In the '% fines vs. permeability' plots for the six samples, the permeability declines rapidly as the % fines increased from 0% to 5%. However, further reduction is minor between 5% to 20% fines. Therefore, for the soils tested, once 5% fines content is reached, further reduction in k appears minimal.

D.3.2 The effect of % fines on dry density

The six samples were compacted in the cylinder containers using hand-tamping efforts. The density of the samples prepared by hand effort [Figs. D.3 – D.8] is within the 98% of the density of the samples in Table D.1 (spec requirement). The energy of the compaction effort, however, varied slightly for each sample, thus affecting the dry density. Considering the relationship between the %fines and the dry density (γ_d) of each sample, the density tends to increase slightly as the %fines increase. This is true because the fine particles fill the voids between the larger particles, resulting in greater sample densities.

The average permeability values, density values, and standard deviations of the six samples are summarized in Table 2-2 and Fig. 2-5.

Table D.2. Avg permeability and density of soil samples and their standard deviations.

% Fines	0		5		10		15	
	AVG.	STDEV.	AVG.	STDEV.	AVG.	STDEV.	AVG.	STDEV.
γ dry, (g/cm^3)	1.663	0.055	1.719	0.051	1.741	0.071	1.766	0.067
k (cm/s)	1.25E-02	7.53E-03	2.45E-03	1.62E-03	1.02E-03	7.84E-04	4.82E-04	3.81E-04

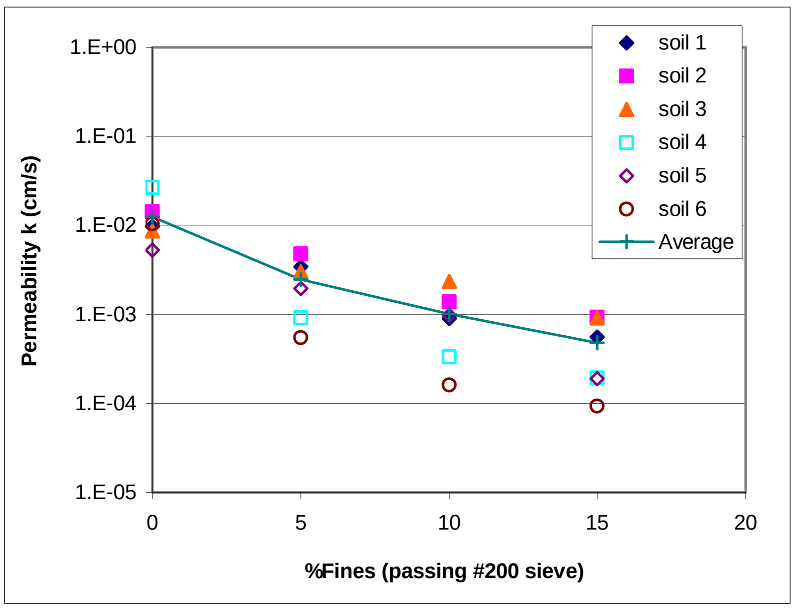


Figure D.9. Average permeability of the six samples vs. % fines content.

APPENDIX E
SAMPLE PREPARATION AND PERMEABILITY TESTING PROCEDURES

This appendix provides the detailed procedures of sample preaparation and permeability testing propsed for more consistentcy in statewide permeability testing methodology.

E.1 Sample Preparation Procedure

E.1.1 Natural Moisture and Compaction Procedure

1. Weigh out approximately 13 lb of soil.
2. Add optimum moisture content to soil sample based on Modified Proctor results.
3. Weigh the compaction mold and base plate without spacer or soil using a mass balance and record mass.
4. Setup compaction mold with spacer (hole on spacer should face down).
5. Place a pre-cut circular aluminum foil sample separator on top of the spacer.
6. Place circular filter paper on top of the aluminum foil sample separator.
7. Add the extension ring to the top of the compaction mold.
8. Compact the soil sample using five (5) lifts with the automatic compaction machine.
9. Take the extension ring off the top of the compaction mold and screet the excess soil off in order to make the soil flush with the top of the mold.
10. Place circular filter paper on top of the soil sample.

11. Place another spacer (hole side down) to the side of the compaction mold.
12. Undo the securing wing nuts and gently take the mold out of the base plate.
13. Gently flip the mold over and place on top of the spacer located to the side of the mold.
14. Gently remove the circular aluminum foil sample separator, leaving the circular filter paper.
15. Weigh the compaction mold, base plate, and soil sample without spacer using a mass balance and record mass.

E.1.2 Permeameter Setup, Air Evacuation, and Saturation Procedure

1. Setup the constant head device and tubing for the permeability testing apparatus.
2. Setup the permeability testing apparatus by placing a porous stone, a circular filter paper, and an o-ring on the bottom of the permeability testing apparatus.
3. Gently remove the mold with the soil sample from the compaction base plate and place in the permeability testing apparatus with the gap on the top.
4. Place the plate with holes on top of the sample with a spring-loaded spacer.
5. Place an o-ring on the top of the mold.
6. Attach the lid for the permeability testing apparatus, maintaining a good seal with the o-ring.
7. Tighten the wing nuts and check the sealing of the apparatus.
8. Open the valve on the top of the mold and connect the tubing for the vacuum (Note: Top chamber should be filled with water).

9. Slowly apply 5-10 inches mercury pressure to the sample and evacuate the air from the specimen for a minimum of fifteen minutes.
10. Connect the constant head tubing to the valve on the bottom of the mold.
11. With a constant head of water in the tubing, slowly open the bottom valve and allow a slow and steady upward flow through the sample until the sample is saturated.
12. Once saturated, close the top and bottom valves on the permeameter.
13. Connect the constant head tubing to the valve on the top of the mold.

E.2 Permeability Testing Procedure

1. With a constant head of water in the tubing, slowly open the top valve and ensure the top chamber of the permeameter is filled.
2. Slowly open the bottom valve on the permeameter and allow a slow and steady downward flow through the sample.
3. Once water starts to come out of the bottom valve, check for any leakage.
4. Adjust the water in the constant head device until the water level remains steady.
5. Leave the sample for approximately 30 minutes until the outflow from the discharge has steadied.
6. Place a measuring device under the discharge outlet and begin taking readings.

REFERENCES

Daniel, D.E., Anderson, D.C., and Boynton, S.S., "Fixed-Wall Versus Flexible-Wall Permeameters," *Hydraulic Barriers in Soil and Rock, ASTM STP 874*, A.I.

Johnson, R.K. Frobel, N.J. Cavalli, and C.B. Pettersson, Eds., American Society for Testing and Materials, Philadelphia, 1985, pp. 107-126