

FIELD PERMEABILITY TESTING
FOR A RCRA LANDFILL FINAL COVER

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ABSTRACT

A Quality Assurance - Quality Control (QA/QC) Program developed for use at the BKK Corporation Landfill in Southern California involves a unique approach for permeability testing of the Landfill final cover. The program contains five major elements: (i) in-situ, field permeability testing of the compacted cover material as it is being placed, (ii) laboratory permeameter testing of soil cores, (iii) intensive field permeability testing in designated test control areas of the cover; and (iv) comparative field infiltration and permeability testing on a separate test fill.

This multi-pronged approach generates a complimentary mix of permeability data encompassing short and long term field and laboratory tests on samples obtained from the final cover and special field areas. Such a program was designed, to alleviate questions which might arise from any one of the individual test methods employed.

Results generated by this program have demonstrated the viability of employing multiple permeability testing methods for providing a continuous input into the decision making process for geotechnical design and construction. It is expected that this or similar types of permeability testing for covers and liners could be generally employed to fulfill local, state and federal regulatory requirements, as part of the design and closure plans for RCRA and other waste disposal facilities.

INTRODUCTION

The BKK Landfill is a 5B3 acre facility located in West Covina, California. Disposal of non-hazardous waste began at the site in 1963. In 1969, BKK was granted an unconditional use permit allowing for the disposal of hazardous waste. Disposal of hazardous material began in 1972 in a limited 40 acre area of the site. In 1975, the Los Angeles Regional Water Quality Control Board approved the expansion of the Class I disposal operation to 100 acres (Figure 1). BKK Corporation voluntarily ceased accepting hazardous wastes on November 1, 1984. The disposal of non-hazardous waste will continue in the previous hazardous waste disposal area until July 1, 1987.

Following the cessation of hazardous waste disposal in 1984, BKK was required under federal law to file a detailed Closure Plan. This plan, originally submitted in December 1984, was reviewed by the regulatory agencies and revised several times. Following a public hearing on November 19, 1986, the EPA, the State Department of Health Services, and the Los Angeles Regional Water Quality Control Board approved the Closure Plan with modifications on December 23, 1986.

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The requirements set by federal and state agencies which form the basis of the Final Closure Plan are found in:

- Title 40 CFR, Parts 264 and 265, which establish performance standards and minimum technology requirements for hazardous waste landfills.
- Title 23 CAC, Chapter 3, Subchapter 15, Articles 4 and 8, which set construction standards and requirements for closure activities.

One of the most critical aspects of the Closure Plan is the final cover design. The purposes of the final cover are to:

- Prevent infiltration of runoff and excess irrigation water.
- Control the venting of gas generated in the facility;
- Isolate the wastes from the surface environment;
- Accommodate settlement and subsidence to maintain cover integrity; and
- Promote drainage and minimize erosion or abrasion of the cover.

After evaluating the site geometry and probable soils conditions it became apparent that a multi-layered system (as normally required by federal and state guidelines) was not suitable for the BKK Landfill cover. BKK's Chief Consulting Engineers, Bryan A. Stirrat and Associates, (BAS), authors of the Closure Plan, proposed instead the installation of a single, five foot thick, horizontally placed layer of low permeability silt and clay. This would cover the required Class I area in its entirety and a majority of the contiguous Class II area. The closure plan entails placement and testing of more than 1.8 million cubic yards of cover material and will require more than 18 months to complete. To provide assurances that satisfactory materials and sound engineering practices are employed, in completing the cover, a detailed construction plan; including quality control and assurance procedures, was developed by geologists from Moore and Taber and the BKK Corporation and included in the Final Closure Plan.

Due to the critical time schedules being faced while the Closure Plan was under agency review, BKK and the agencies designated portions of the proposed cover as "test control areas". BKK also constructed a separate test -fill in area outside of 'the proposed Closure area using the same construction techniques employed elsewhere. Although this fill was built specifically for testing a sealed double-ring infiltrometer, as-required by the "agencies, it also provided an area where comparative permeability testing could be conducted.

QUALITY ASSURANCE / QUALITY CONTROL PROGRAM

The Quality Assurance (OA) program is designed to provide both the owner of the facility and the overseeing agencies with an evaluation of whether the in-place cover meets the project specifications. Although OA testing could be performed on the completed cover, this can prove to be both inefficient and impractical since compacted fill is continually becoming a finished product throughout construction. The OA program at BKK is administered by Bryan A. Stirrat, (BAS), the registered engineer responsible for the final certification of the Closure Plan. The U.S. Army Corps of Engineers under contract to the U.S. Environmental Protection Agency reviews final cover activities regularly and may request additional testing.

The Quality Control (QC) program should provide the owner and constructor with timely information about the quality of the cover being placed. Continual Quality Control testing is vital, as late observation of substandard construction can have a severe economic and practical impact on operations. The geotechnical engineering firm of Moore & Taber has responsibility for geotechnical QC during cover construction at BKK.

Since the OA and QC programs for this project are similar in both intent and procedure, they are both included within a single plan. Due to the unique cover design and the

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numerous regulatory requirements, BKK proposed a multi-pronged permeability testing approach to quality control and quality assurance.

Permeability Testing Approach

The QA/QC program at BKK was designed to achieve its goals and minimize questions which could result from anyone of the individual test methods. The BKK Landfill Final Cover QA/QC program includes four major activities generating comparative data on the permeability characteristics of the final cover. These encompass both field and laboratory tests, as-built and special test facilities, and short and long term tests. Particular emphasis is placed on measurements of in-situ permeability, the most critical parameter to proper performance. The four QA/QC permeability evaluation methods are:

- 1) In-situ, field permeability testing of the compacted cover material as it is being placed. These tests are used as an indicator of ongoing construction quality control;
- 2) Laboratory permeameter testing of "undisturbed" soil cores from both
- 3) Intensive field permeability testing in two' designated test control areas of the cover (Figure 1). This activity was intended to verify the adequacy of the material, design and construction procedures using full scale compaction and earth moving equipment, to generate data comparing the various test methods, and to provide a basis for establishing performance specifications; and
- 4) Comparative field infiltration and permeability testing on a separate test fill. The test fill provides a means to perform tests which would otherwise interfere with construction operations

Performance Specifications

In order to evaluate the permeability characteristic of the compacted cover, the tests listed in Table I are being utilized. The permeability limits for acceptable cover material were set after analysis of intensive permeability testing (activity iii), and are summarized in Table II. They are based on the observed variability of test results and methods and are intended to maintain a maximum average permeability, plus 2σ of less than 1×10^{-6} cm/s.

Table I. Permeability Test Methods and Frequency of Use.

Parameter	Test method	Location	
		Normal cover	Test areas
Permeability	SDRI	@	1 test
	Shelby Tube	@	6,000 yds ³
	4" Remolded	@	15,000 yds ³
	BAT Permeameter	5,000 yds ³	2,500 yds ³
	4" Drive Ring	20,000 yds ³	2,500 yds ³

@ not applicable.

Should any of the permeability tests indicate that a portion of the cover does not meet the performance specifications, confirmation of the unacceptable result is required. This is done using two additional tests of the same type, performed in the immediate vicinity of the failing test. If either of these "check" tests fails, that portion of the cover will be considered inadequate, and will be removed or reworked until the required performance is attained. In order to determine the cause of failing tests, soils deemed unacceptable are excavated and examined in both the field and the lab.

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Table II. Performance Specifications.

Parameter	method	Location	
		Side slopes	Decks
Permeability	BAT Permeameter 4" Drive Ring	7 x 10 ⁻⁷ cm/s 9 x 10 ⁻⁷ cm/s	4 x 10 ⁻⁷ cm/s 8 x 10 ⁻⁷ cm/s

DESCRIPTION OF TEST METHODS

As mentioned above, the test methods encompass field permeability testing, laboratory permeability testing and field infiltration testing.

Field Permeability Testing

One of the two primary indicators for permeability are results generated by the BAT Permeameter (Torstensson 1984, Petsonk 1984). This tool was selected because it performs fast, in-situ measurements. A BAT test in a soil having a permeability of 1 x 10⁻⁷ cm/s can normally be performed in as little as one day. It therefore entails only minimal interference with construction activities, while providing vital QA/QC data in essentially real time.

The test procedure requires that a saturated 8A7 filter tip be installed in a preaugered hole, about 24 hours prior to testing. The permeameter is then attached to the tip (Figure 2). It functions by injecting water under an elevated, falling head into the soil matrix. A SAT test is considered complete when a stable value is attained for the calculated, permeability after a minimum liquid volume has been injected. A typical BAT test result is shown in Figure 3.

A BAT test primarily measures horizontal permeability, which should provide a conservative estimate in horizontally compacted clay soils. The equipment is capable of measuring very small flow rates (+1 x 10⁻⁹ cm/s).

Laboratory Permeability Testing

The second primary permeability indicator is the 4" drive ring laboratory permeameter. Turn-around time for these tests is usually three to seven days.

The primary tool for sample retrieval and measurement is Moore & Taber's 4" drive ring (Figure 4). This ring is driven into the fill using a slide hammer, and then removed by manual excavation. The sample is transported in a sealed bag to the lab, where it is visually inspected. If significant sample disturbance or isolated large pieces of rock are found in the sample a new sample is obtained. After preliminary inspection, the samples are trimmed and saturated. The sample is then extruded from the drive ring, inserted into the test cylinder and flat, porous stones, the same diameter as the cylinder, are used to immobilize the sample. - The edges of the sample and porous stones are then sealed by paraffin and clay to prevent sidewall leakage. Permeability is measured using a constant head test.

During development of the QA/QC plan, Shelby tube and remolded 4" permeability tests were conducted using the same permeameter as described above.

Field Infiltration Testing

In addition to the primary permeability testing methods described above, a sealed, double-ring infiltrometer (SDRI) is being used on the separate test fill. This device

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(Daniel & Trautwein 1986, Daniel 1987), uses a water-filled, flexible bag to measure the vertical infiltration rate of water from the open bottom of a square, sealed container, the sides of which are imbedded in the soil. The container is submerged under a constant head of water in a square pool, the sides of which are also imbedded deep in the soil (Figure 5). Tensiometers, installed at various depths in the annular space between the rings, are used to estimate the progress of the wetting -front, and to provide soil suction data for permeability calculations.

The developers of the SDRI estimate that it can be used to measure infiltration rates down to 1×10^{-7} cm/s. Using various theoretical assumptions, it is possible to compute permeability from the infiltration rate. SDRI procedures must take in to account factors such as evaporation, temperature changes, etc.

The SDRI was developed specifically for use on clay liners, to detect possible differences between micro- or matrix permeability on the one hand, and macro- or secondary permeability on the other hand. The test fill, which was specifically prepared for the SDRI, has been constructed like a liner, with an underlying drainage layer. It therefore differs in at least one significant respect from the actual cover.

No performance specifications for use with the SDRI have been established; however, its use on the test fill has been mandated by the State of California. SDRI tests normally take several months to complete, due to the large soil volume being tested, and the long time period required to reach steady-state conditions. The SDRI was installed at BKK on 10/14/86. As of 3/15/87, the wetting front is approaching 12 inches in depth, indicating a permeability value significantly less than 1×10^{-7} cm/s.

TEST RESULTS

The results presented here represent data from the two test control areas and the test fill. With regard to permeability, the combined results show an overall arithmetic mean of 1.1×10^{-6} cm/s, with a standard deviation of 6.8×10^{-6} cm/s. However, it is more proper to examine the data individually, as field and laboratory measurements often tend to exhibit different variabilities. In addition, different methods of compaction were used in each of the test areas, due to mechanical access constraints on the equipment. Finally, the above value also includes results from tests on soil which was deemed unacceptable and removed (see below), or were considered anomalous (eg. performed adjacent to siltstone clasts). Table III summarizes the arithmetic mean and standard deviation of acceptable test values.

Unacceptable Material

It is important that unacceptable materials be discovered as early as possible, so that remedial action does not become overly time consuming or costly. The BAT system has provided a means to accomplish this.

In one of the test areas, two BAT tests failed to meet the permeability requirements. In accordance with the QA/QC procedure, two additional tests were run for each failed test. Only one of these retests passed, indicating that material had to be removed. The lateral boundaries of the failed material were dictated by the location of the nearest passing tests at a similar elevation. The soil was excavated vertically to the elevation of the last passing test and another test run as a check on the bottom material. The area was then backfilled, recompacted and retested. Normal fill operations resumed when the new tests passed.

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Table III. Average Permeabilities (10^{-6} cm/s). (excludes failing and anomalous test results)

Test type	Test bench Y		Test bench P		Test fill		Combined		Number of tests
BAT	8.9	+ 17.3	2.8	+ 3.0	8.0	+ 7.5	6.4	+ 12.8	33
4" drive ring	4.5	+ 4.6	2.3	±2.1	1.2	+ 0.2	3.0	+ 3.6	28
4" remolded	3.3	#	4.9	#		-	4.1	+ 1.6	4
Shelby tube	3.2	± 3.1	1.2	+ 0.5		-	2.0	± 2.2	10
SDRI *					6.5	#	6.5	#	1
ALL tests	6.3	+ 12.5	2.4	+ 2.4	4.8	+ 6.0	4.5	+ 9.0	76

n.n + mm.m → arithmetic mean permeability $n.n \times 10^{-8}$ cm/s,

- standard deviation $mm.m \times 10^{-8}$ cm/s.

→ no tests performed using this type of test.

→ too few tests for statistical purposes.

* → infiltration rate; test still in progress.

To determine the cause of the failure, the soil around the BAT tips was inspected. Although grain size analyses, indicated that the material was suitable for placement, it appeared from visual observations that it had been insufficiently processed. This led to modifications of the QA/QC plan, including use of thinner lifts, better mixing and curing of borrow materials, and modified HAT installation and use procedures.

Data Analysis

During installation of the final cover material, conventional geotechnical soils test, (e.g. compaction) were conducted in addition to the permeability test. Tests, especially those in the failed area, indicate that acceptable materials and proper processing and placement are all necessary to achieve the desired permeability.

Analysis of the available permeability test data reveals several important points:

- a) Due to the inherent variability of the cover material the individual test values can be quite different. However, the average values for the various permeability tests do correlate with each other, clearly demonstrating the in-place cover permeability. This validates the use multiple permeability test methods as an effective means for construction quality control.
- b) The different compaction methods used for the various test areas have not resulted in major differences in permeability. This confirms the validity of using performance rather than method specifications.
- c) Although the differences are not statistically significant, permeabilities measured in-situ are in general higher than those measured using laboratory methods. In addition, the field data exhibit a significantly larger variability than do those measured in the laboratory.
- d) The single SDRI test does not indicate any significant secondary permeability in the test fill area. In fact, the test values obtained to date are in agreement with and validate the results of the other permeability tests.
- e) Cover areas which have received inadequately processed materials are readily observed by use of the BAT and 4" drive ring tests. If the soil is removed or reworked, these values should not be included in any statistical analysis of the completed cover.

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CONCLUSIONS

It is evident from the above discussion that the varying demands placed on a Quality Assurance/Quality Control program for landfill covers can entail use of a variety of test methods. The program developed and implemented for the BKK Landfill has enhanced data quality and quantity, while minimizing interference with normal construction activities. Results from the studies described herein were incorporated into the final OA/QC document, and served as the basis for the performance standards set by the regulatory agencies. It is therefore thought that this or similar types of OA/QC programs for covers and liners can be generally employed to fulfill local, state and federal regulatory requirements for RCRA and other waste disposal facilities.

The parameter considered most important for soil-based covers and liners by owners, operators, constructors and agencies is permeability. It is clear from the results presented here that in-situ methods such as BAT and drive ring tests can be used as primary, real-time indicators to test quality control with regard to permeability. Use of such tests in conjunction with conventional geotechnical soils testing can provide a sound statistical basis for describing and analyzing the finished product. Due to the wide variation in field conditions, and the costs associated with soil removal or reworking, unacceptable test results should be confirmed using additional tests.

REFERENCES

1. Bryan A. Stirrat and Associates, Final Closure Plan or the Hazardous Waste Management Area of the BKK Landfill, West Covina, California, September 1986
2. United States of America, Code of Federal Regulations Title 40, US Government Printing Office, Washington, D.C., 1986.
3. State of California, California Administrative Code, Title 23, Chapter 3, Subchapter 15, Sacramento, California, 1986.
4. Bryan A. Stirrat and Associates, QA/QC for the Placement of Final Cover on the Hazardous Waste Management Area of the BKK Landfill, Final Closure Plan for the Hazardous Waste Management Area of the BKK Landfill, Approval Modifications, Volume VIII, West Covina, California, January 1987.
5. American Society for Testing and Materials (ASTM), Annual Book of ASTM Standards, Volume 04.06, Philadelphia, Pennsylvania, 1986
6. Torstensson, B-A , A New System for Ground Water Monitoring , Ground Water Monitoring Review, vol. 4 no. 4, 1984, pp. 131-138.
7. Petsonk, A.M., The BAT Method for In-situ measurement of Hydraulic Conductivity in Saturated Soils, Thesis in Hydrogeology, University of Uppsala, Sweden, 1984, 54 pp.
8. Daniel, D.E., and Trautwein, S.J., Field Permeability Test for Earthen Liners, Proceedings of In-situ '86, ASCE specialty conference, Blacks burg, Virginia, June 23-25, 1986, pp. 146-160.
9. Daniel, D.E., Hydraulic Conductivity Tests for Clay Liners,. Proceedings of Ninth Annual Symposium on Geotechnical and Geohydrological Aspects of Waste Management, D.J.A. van Zyl et al., Eds., Lewis Publishers, Inc., Chelsea, Michigan, 1987, pp. 15-34.

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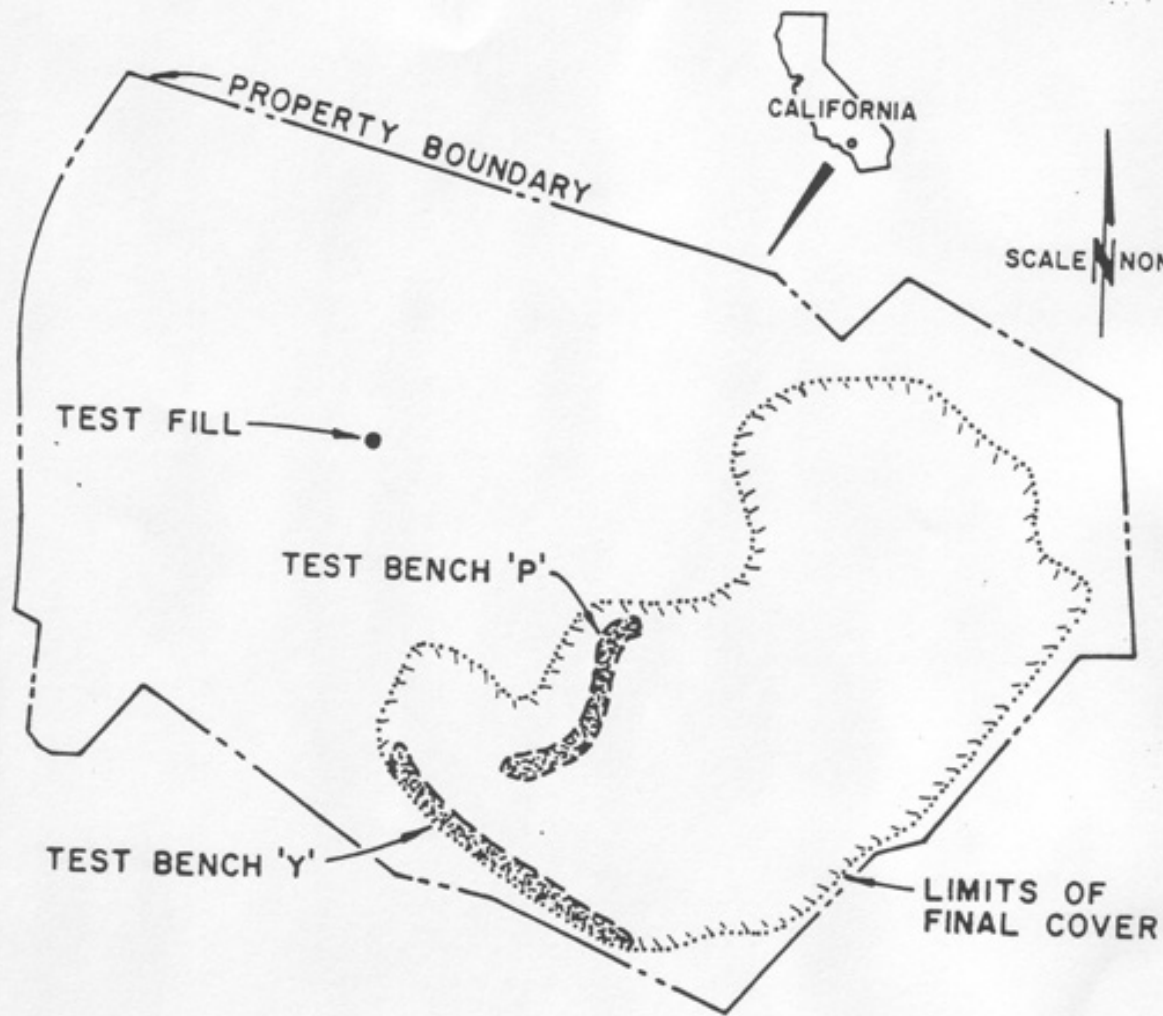


Figure 1. Map of BKK Corporation Landfill
Showing Extent of Final Cover & Test Areas

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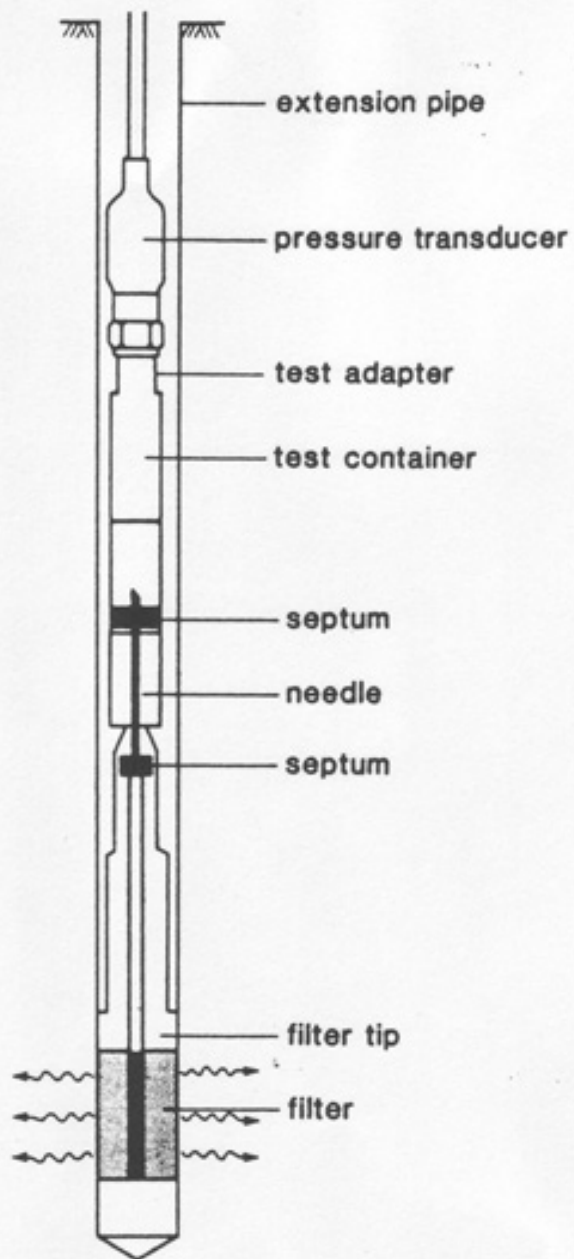


Figure 2. BAT Permeability System

IN SITU PERMEABILITY TEST CALIFORNIA LANDFILL NO. 121

1986-09-29

07:40

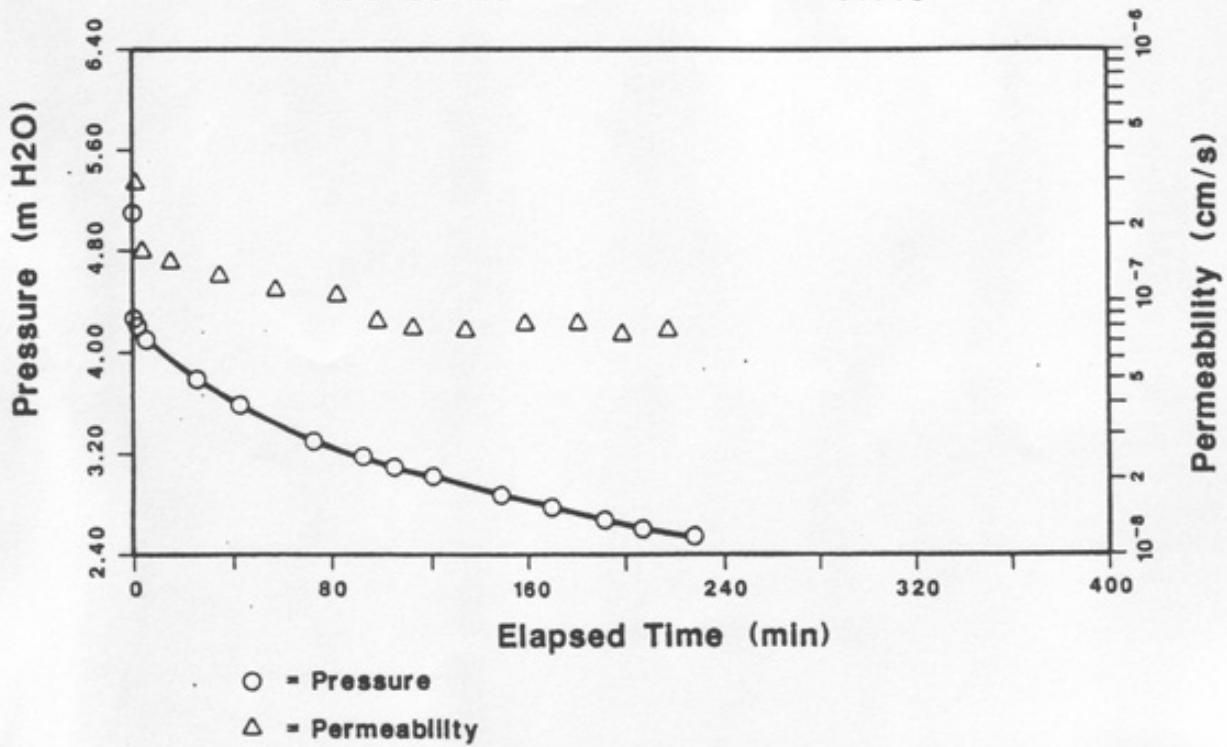


Figure 3. Result of Typical BAT Test

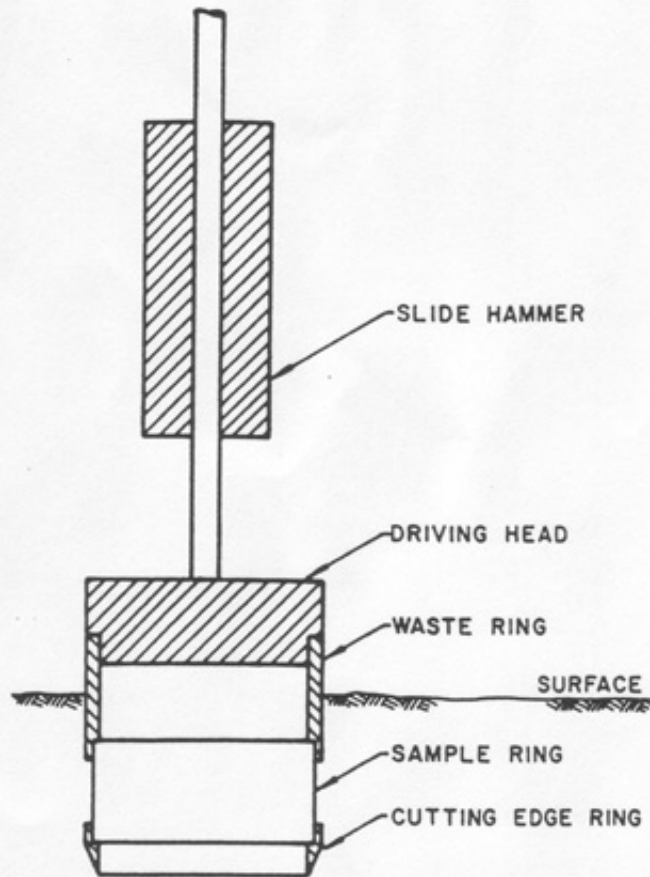


Figure 4. Moore & Taber 4" Drive Ring

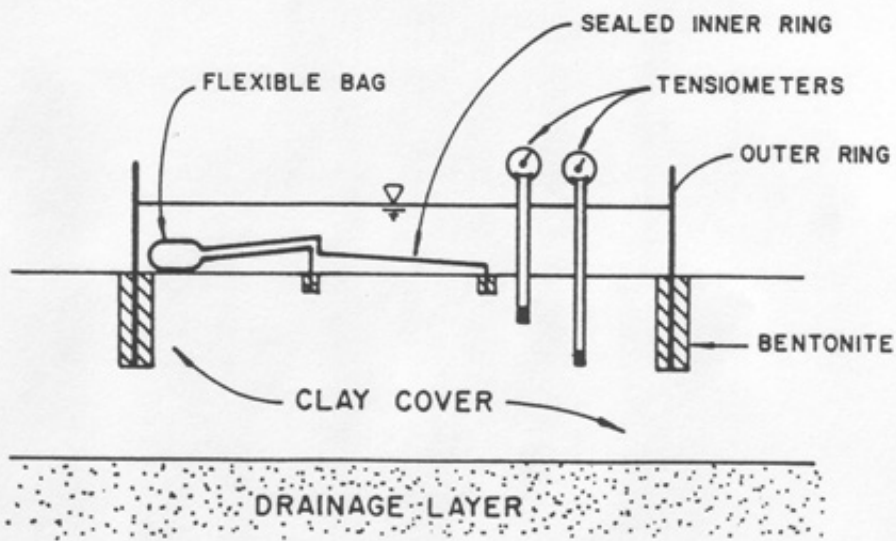


Figure 5. Sealed Double-Ring Infiltrometer (SDRI)
(After Daniel, 1987)

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