LINDA HALL LIBRARY
5109 CHERRY STREET
KANSAS CITY, MISSOURI
64110-2498
PHONE (816) 363-4600
FAX: (816) 926-8785

7/21/08 **DocServ #:** 509944 E

12:39

Shelved as: TD 511. G46 1987

Location:

SHIP TO:

Attn: Matthew Morales
Public Works, Landfill
211 West Aspen Avenue
Flagstaff AZ 86001

Fax:
Phone: 928-527-9843
Ariel:
Email: mmorales@ci.flagstaff.az.us

Title: Geotechnical Practice for Waste Disposal '87

Volume:

Issue:

Date:

Author: Dorairaja Raghu, Hsin-Neng Hsieh, Thomas Neilan, and Ching-Tzer Yih

Article Title: Water Treatment Plant Sludge as Landfill Liner

Pages: 744-758

Accept Non English? Yes

Regular

~~Fax~~ E

LHL

This request complies with 'Fair Use' X

Max Cost: © $19.00

Reference Number:

Account Number:
FEDEX Account Number:

Notes:
ASCE = PG

DOCSERV / WEB / PULL SLIP

15

Water Treatment Plant Sludge as Landfill Liner

Dorairaja Raghu,[1] M.ASCE, Hsin-Neng Hsieh,[2] A.M.ASCE, Thomas Neilan,[3] and Ching-Tzer Yih[4]

Chemical sludge is produced in large quantities during the water treatment processes. The present regulations pertaining to the disposal of solid wastes impose many constraints on any means of disposal. Thus, there exists a need for finding an acceptable use of water treatment sludge

In this study, an effort has been made to evaluate the feasibility of using this sludge as a liner for sanitary landfills. Sludge samples were collected from a water treatment plant and tested. Water was leached through the sludge samples and chemical analysis were made on the leachate. It was found that the concentrations of heavy metals and organic matter were too low to create any pollution problems.

From the geotechnical tests conducted, the sludge can be classified as silt. It was observed that the sludge compacted well under the hammer in the laboratory. This indicated that there will not be any serious problems associated with the placement and compaction of the sludge in the field. Consolidation tests on sludge compacted to a condition corresponding to 90 percent maximum modified proctor dry density were performed. From these tests, the coefficient of permeability was determined to be of the order of 10 cm/s. Sludge samples were soaked in leachate from a sanitary landfill for several days to determine whether the sludge liner would deteriorate as a result of the chemical reactions. Tests conducted on these samples indicated that the permeability was unaltered by soaking. Pinhole dispersion tests were performed and the sludge was determined to be nondispersive. From all of these tests it can be concluded that it is feasible to use water treatment plant sludge as a liner for sanitary landfills.

1. Associate Professor, Civil & Environmental Engineering, New Jersey Institute of Technology, Newark, N.J. 07102
2. Assistant Professor, Civil & Environmental Engineering, New Jersey Institute of Technology, Newark, N.J. 07102
3. Director, Jersey City Water Treatment Plant, Boonton, N.J. 07005
4. Graduate Student, Civil & Environmental Engineering, New Jersey Institute of Technology, Newark, N.J. 07102

Introduction

One area of great concern for water treatment plants is the disposal of sludge residues that are produced during the treatment process such as chemical coagulation, lime-soda softening, and filtration. Due to the large quantitites being generated and more stringent regulations concerning the handling and disposal of water treatment sludge, the utimate disposal of these sludges have become a national problem. The objective of this study is to investigate the use of water treatment plant sludge as a sanitary landfill liner.

Most landfills require at least one flexible membrane liner to be used for the primary lining system and an earth liner for backup. The most popular earth liner is clay, having been traditionally used as a liner for reservoirs, lagoons, and storage ponds due to its low permeability and high adsorption properties, but in some parts of the country, clay is not available and has to be transported from other states. In such cases, it will be necessary to find cheap locally avalable materials to substitute for clay. These materials should have the required physical properties and should possess low permeability. Water treatment plant sludge has been considered for this usage.

Characteristics for Water Treatment Plant Sludge

The characteristics of water treatment plant sludge varies from one treatment to another. It depends on the raw water quality, the processes of water treatment, the amount of the metal ions, suspended solids, and colloidal materials removed, type of chemicals added, reactor mixing, and the method of sludge dewatering. The sludge may contain sand or silt, organics, ions, and other materials. The solid content of sludge varies widely - depending on the water treatment precesses. It has been reported in the literature that the dewatering characteristics of the sludge has been related to the calcium and magnesium molar ratio. A sludge with a ratio less than two will be difficult to dewater (A.W.W.A. Committee Report 1981). Studies have also shown that the size of the calcium carbonate particle formed during the chemical reaction also affects sludge thickening and dewatering (Judkins & Wynne, 1972). Softening sludge and chemical coagulation sludge tend to be thixotropic and the coagulation sludge is generally gelatinous (A.W.W.A. Committee Report, 1978).

Water treatment plant sludge used in this study was obtained from the Jersey City Water Treatment plant in Boonton, New Jersey. Sludge is being produced from the process of coagulation. Lime and alum are added as the coagulants. Polyamine is added as a coagulant aid. Sludge is formed in the mixing tank and it settles in the sedimentation tank. It is then removed from the sedimentation tank and dewatered prior to ultimate disposal. For this purpose, a filter press is utilized. Sludge is pumped into the space between a series of rectangular plates, recessed on both sides. A filter cloth is fitted over each plate. High pressure is applied. This forces the liquid out of the sludge. Lime is added in the sludge dewatering process as a chemical conditioner. After the dewatering, the solid content of sludge cake is 30 percent, whereas the solid content of raw sludge is about 3 percent. The amount of the sludge produced everyday is about 3180 kilograms and it occupies a volume of approximately 13 cubic meters. After the dewatering, the sludge cakes drop to a truck positioned underneath the filter press and are carried away to an open field. The sludge is then spread over the site and compacted by a bulldozer.

Leaching Test

Leaching tests for the determination of the chemicals released from the sludge are performed from time to time. Water was leached through the sludge and samples collected for analysis. Table 1 shows the results of this test. These data indicate that the concentration of heavy metals and pesticides in the sludge meet the New Jersey Surface Water Quality Criteria (N.J.A.C. 7.9 - 4.14). They also satisfy the U.S. Environmental Protection Agency Interim Drinking Water Standards set up in 1976 except for concentrations of four heavy metals, namely, mercury, cadmium, selenium and silver.

Table 1 Water Treatment Plant Sludge Leaching Test

Inorganic Chemicals (ppm)

Arsenic	< 0.05	Mercury	< 0.02
Barium	< 1.00	Selenium	< 0.05
Cadmium	< 0.05	Silver	< 0.05
Chromium	< 0.05	Cyanide	< 1.00
Lead	< 0.05	Sulfide	3.70

Organic Chemicals (ppb)

Lindane	< 4.00
Endrine	< 2.00
Methoxychlor	< 100.0
Toxaphene	< 5.0
2,4 - D	< 100.0
2,4,5, TP (Silvex)	< 10.0
PCB	< 1.0

Geotechnical Testing Done for this Investigation

New Jersey Institute of Technology was awarded a grant by Jersey City to study the feasibility of using water treatment plant sludge as a sanitary landfill liner. So a laboratory testing program was planned for this purpose. In this effort, the regulations of the New Jersey Department of Environmental Protection (N.J.A.C., 1986) regarding the clay liners were used as a guideline. According to these regulations, laboratory testing for classification, compaction, permeability, specific gravity and dispersion (pinhole tests) have to be conducted. These tests were performed on sludge samples.

For this study, samples of sludge were obtained from the filter press of the treatment facility. On these samples, tests were conducted to determine the relevant geotechnical and chemical properties. For the most part, the procedures adopted for these tests were the same as those specified in the applicable standards of A.S.T.M. Standard procedures are not available for such tests on sludge, therefore, sometimes it was necessary to modify the procedures in A.S.T.M. for testing sludge samples. In such instances, the deviations and the reasons for such deviations from standard procedures will be spelled out. For each type of test conducted, at least three tests were performed. It was observed that the results were reproducible. The results reported in this paper are the average of these tests.

Moisture Content

Environmental engineers define moisture content as the ratio of the weight of water to the total weight of sample expressed as a percentage. Geotechnical engineers define moisture content as the ratio of the weight of water to the weight of dry sample expressed as a percentage. For the purpose of this paper, the definition employed by geotechnical engineers will be used. At first, the sludge samples were dried in an oven at 110 degrees celsius, as called for in the testing techniques for soils. Erratic and inconsistent results were obtained. This is probably due to the thermal reactions that took place resulting in loss of volatile solids present in the sludge. Hence a modified procedure was adopted to determine water content.

The sludge samples were dried in the oven at 35 degrees celsius over a period of time. Another set of samples were air dried in the laboratory. The weights of both sets of samples were determined daily and the results are plotted in Figure 1. From these data, it can be concluded that it is necessary to oven-dry the sludge at 35 degrees celsius to determine the moisture content. This could also be accomplished by air-drying for 21 days. For

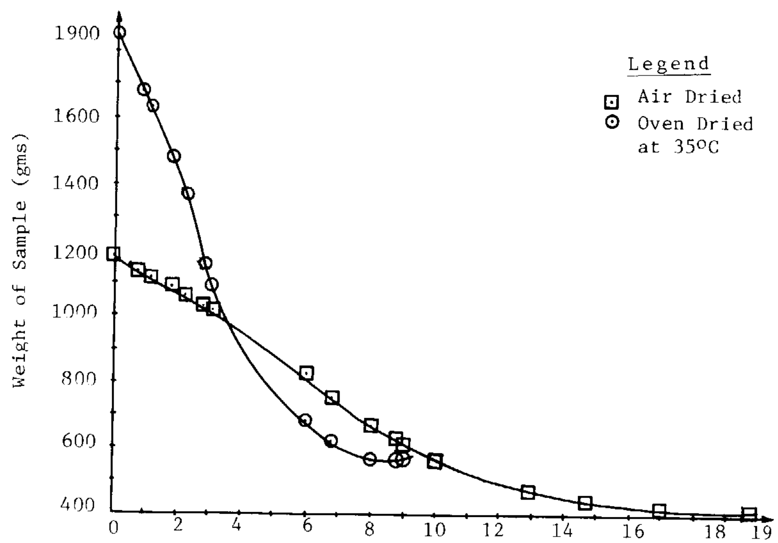

Figure 1 Weight of Sample vs. Time Plot

this study, it was decided to oven-dry the samples. The natural moisture content of sludge was determined to be 226 percent employing this drying process.

Specific Gravity of Soil Solids

The A.S.T.M. procedure relevant for this test calls for either one of two techniques for removing air from the sample. They are heating and applying vacuum. Since heating may initiate thermal and/or chemical reactions, it was decided to employ the vacuum method to remove the air. The specific gravity of soil solids was determined to be 1.9.

Grain Size Analysis

In order to determine the grain size distribution of sludge samples, combined analyses consisting of both sieve analyses and hydrometer analyses were conducted. A typical grain size distribution curve is shown in Figure 2. It is noted from this plot that the sludge is composed of particles 40 percent of which have the grain size of silt and the remainder sand. The sludge can be classified as SM.

Atterberg Limits

Tests were conducted to determine the plasticity charcteristics of sludge samples. During these tests, it was noted that the samples could not be rolled into threads of 0.125 inches diameter, therefore it was not possible to determine the plastic limit of sludge. Efforts to conduct liquid limit tests proved to be futile. Under any condition of placement, the number of drops of the cup in the liquid limit apparatus required to bring together the two sides of the sample was always less than 15. This made it impossible to determine the liquid limit of the sample. Similar observations were made by Knocke and Wakeland (1983). Hence, no significant conclusions based on these tests as to the plasticity of the sludge samples could be reached. However, based on the workability of sludge samples, it can be speculated that the samples possessed slight to little plasticity.

Compaction Tests

Modified Proctor Compaction Tests (A.S.T.M. D1553 Method B) were conducted with sludge samples to determine the moisture-density characteristics. Another purpose of these tests was to determine whether there would be any difficulties associated with the placement and compaction of sludge in the field. In order to determine the range of moisture content for which compaction testing is to be performed to obtain a well-defined moisture-density plot,

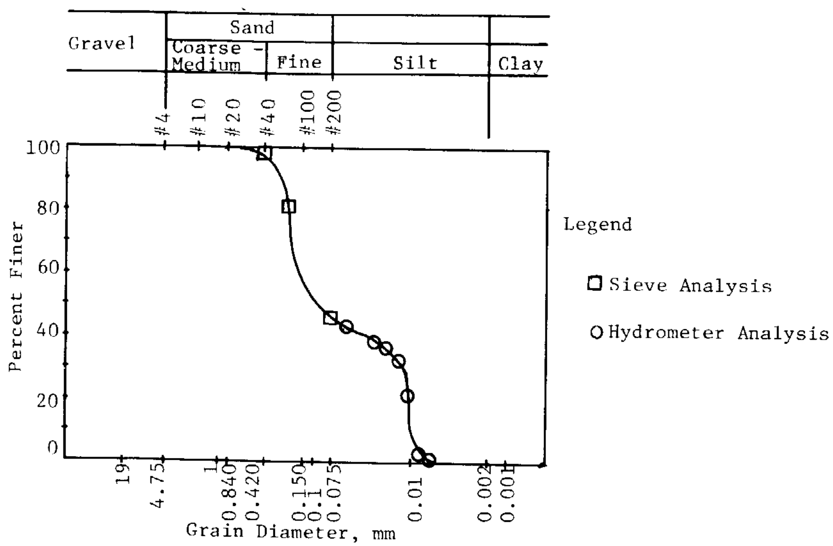

Figure 2 Grain Size Distribution Curve for Sludge

prior knowledge or an estimate of the optimum moisture content of the sample will be helpful. For soils, this information can be obtained from several sources, but no such information is available for sludge at present. So, to obtain an estimate of optimum moisture content, several sludge samples at predetermined moisture content were prepared. The behavior of these samples during rolling and squeezing was noted in the laboratory. Based on these observations, the optimum moisture content of sludge was estimated to be 70 percent.

Three compaction tests were conducted. A typical moisture-density plot of these tests is shown in Figure 3. The optimum moisture content was about 68 percent and the maximum dry density was about 51 pounds per cubic foot. During these tests, it was observed that the sludge compacted well under the hammer in the laboratory. On this basis, it is expected that there will not be any serious problems associated with the placement and compaction of the sludge in the field. This has been verified by the field tests that are currently underway provided the placement moisture content is controlled.

Permeability Tests

Compaction of samples on the wet side of optimum is required to obtain low permeabilities (Daniel, 1984). In this investigation, permeability tests were conducted on samples compacted to 90 percent of maximum modified proctor dry densities. In a prior study (Zargarelahi, 1984) conducted on sludge samples, permeability determinations were made based on falling head tests. These tests indicated that the sludge material was impervious. In order to determine the permeability characteristics of sludge more accurately, either triaxial or consolidation tests have to be conducted. According to a recent study, (Daniel, et al. 1985), either one of these tests is suitable. In this study, since samples are to be placed and compacted in the apparatus, consolidation tests were performed on sludge samples.

Three such tests were conducted. A typical void ratio-logarithm of pressure plot and a time-settlement curve are shown respectively in Figures 4 and 5. Another plot showing the variation of logarithm of coefficient of permeability is presented in Figure 6. The values of the coefficients of permeability obtained from these tests are on the order of 10^{-7} cm/second. This confirms the findings of the previous study regarding the impervious nature of the sludge material.

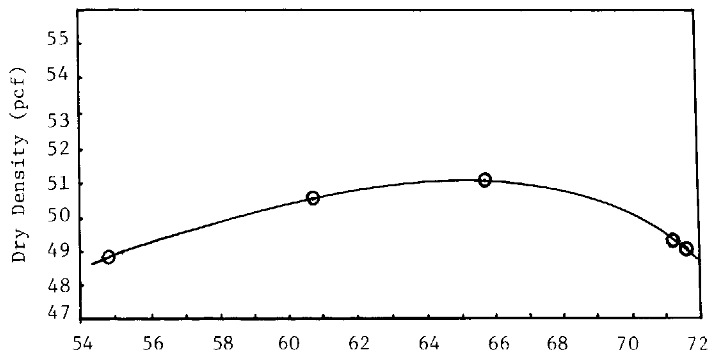

Figure 3 Moisture-Density Curve for Sludge

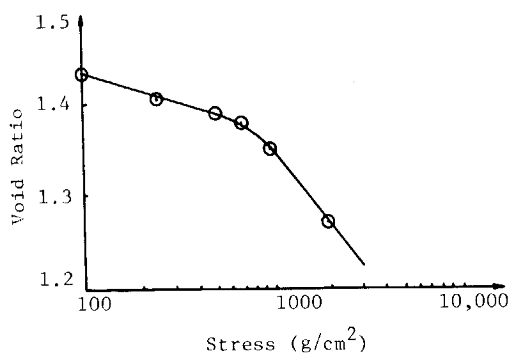

Figure 4 e - Log p Curve

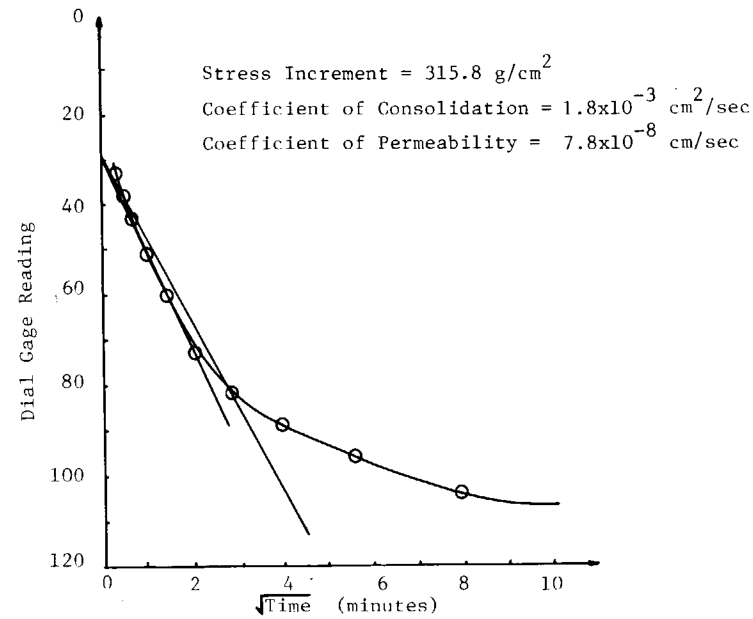

Figure 5 Time-Settlement Curve Before Soaking

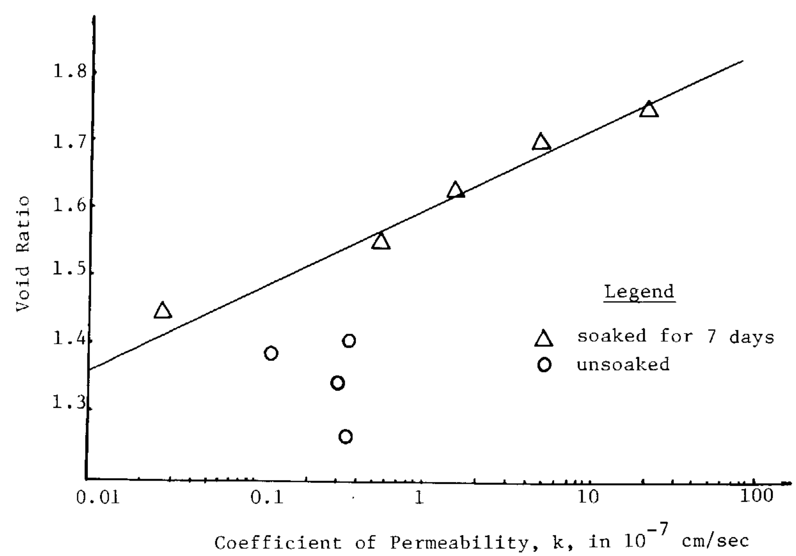

Figure 6 Relationship between Void Ratio and Permeability

Effect of Landfill Leachate on Permeability

The properties of the liner material are to be chemically compatible with the leachate. In other words, the liner should not deteriorate as a result of the chemical reactions between the leachate and the liner. This was investigated in this study by conducting tests on samples soaked in a tank filled with leachate collected from a nearby sanitary landfill for seven, fourteen, and twenty-eight days, respectively. Under these conditions, the time taken for a quantity of water equal to three times the pore volume of the sludge sample was computed to be seven days. The characteristics of the leachate are shown in Table 2. Before the soaking the pH value of the sludge was found to be 10.8. It was noted that the pH values of sludge samples were unaffected by soaking. The sludge samples remained structurally intact, without any holes or deformation after soaking. These data seem to indicate that the properties of sludge materials such as permeability and structural integrity would not change due to leachate from sanitary landfill.

Table 2 Characteristics of Leachate from Landfill

Total Dissolved Solids	10800 mg/l
COD	1750 mg/l
BOD, 5 day	91 mg/l
Ammonia	711 mg/l
Nitrate	1.38 mg/l
Nitrite	0.54 mg/l
Sulfide	70 mg/l
Cadmium	0.078 mg/l
Chromium	1.002 mg/l
Copper	3.655 mg/l
Iron	41.26 mg/l
Lead	1.078 mg/l
Manganese	1.160 mg/l
Nickel	0.518 mg/l
Zinc	6.120 mg/l
pH	7.7

Another simple test was conducted to study the effect of chemicals on sludge. In this test, 25 ml of sludge was placed in a column buret. The height of sludge sample in the buret was 9 inches. A liquid column of hydrocholoric acid with a concentration of 5% and 3 inches in height was placed over the top of the sludge. After three months, it was noted that the acid did not pass through the sludge at all. The top one inch of sludge was discolored indicating that the acid penetration into the sludge was insignificant. Additional research to investigate this aspect is in progress at the New Jersey Institute of Technology.

Consolidation tests were conducted on samples of sludge soaked in the leachate respectively for seven, fourteen and twenty-eight days. A typical time-settlement curve for these series of tests is shown in Figure 7. It was noted from these test results that the coefficient of permeability was still of the order of 10^{-7} cm/second. This points out that the imperviousness of sludge is virtually unaffected by soaking in leachate, confirming the earlier inference drawn on the basis of pH tests. Laboratory and field model testing at New Jersey Institute of Technology to verify that these findings already underway is part of another project funded by Jersey City.

Dispersion Tests

Fine grained materials consisting of fine sands and silts have a tendency to be washed out by pore fluids. Such soils are termed dispersive. Tests were conducted to investigate the dispersive nature of sludge in the laboratories at Woodward Clyde Associates in Clifton, New Jersey. Pinhole dispersion tests (Sherard, et al. 1976) were conducted on sludge samples compacted to 90 percent maximum modified proctor densities on the wet side of optimum moisture content. The results of these tests indicate that the sludge is non-dispersive.

Conclusions

Based on the laboratory tests conducted, the following conclusions have been drawn:

1. The sludge material has sand and silt size grains. It can be classified based on grain size as SM according to the Unified Classification System.

2. Sludge compacted to 90 percent maximum modified proctor dry density wet of optimum is of low permeability. It meets the standards prescribed for liners by the New Jersey Department of Environmental Protection as far as the coefficient of permeability is concerned.

3. Based on the tests conducted on samples of sludge soaked in leachate, it appears that the properties of the sludge material are not affected by soaking in landfill leachate.

4. The sludge material is non-dispersive.

It can be concluded based on these findings, that the sludge meets all the criteria imposed by the New Jersey Department of Environmental Protection for use as sanitary landfill liners (N.J.A.C.,1986). Therefore, it is feasible to use the sludge material as a liner for sanitary landfills.

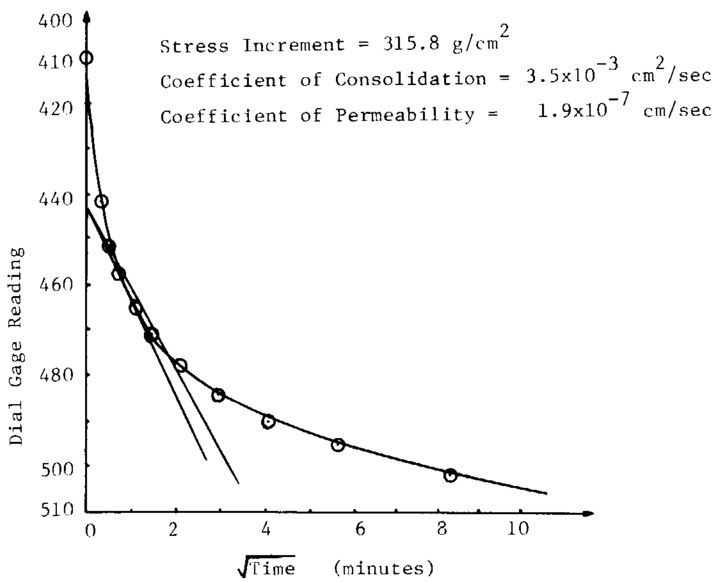

Figure 7 Time-Settlement Curve After Soaking

Acknowledgement

The results reported herein were developed from a study funded by the City of Jersey City. The assistance provided by Jersey City is gratefully acknowledged.

APPENDIX I

References

1. Daniel, D.E., "Predicting Hydraulic Conductivity of Clay Liners," Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, Vol. 110, No. GT2, February 1984, pages 285-300.

2. Daniel, D.E., Anderson, D.C., and Boynton, S.S., "Fixed vs. Flexible Wall Permeameters," A.S.T.M., S.T.P. 84, 1985.

3. Judkins, J.F., Jr. and Wynne, R.H., Jr., "Crystal-Seed Conditioning of Lime-Softening Sludge," Journal of American Water Works Association, Vol. 64, May 1972, pages 306-309.

4. Knocke, W.R., and Wakeland, D.L., "Fundamental Characteristics of Water Treatment Plant Sludges," Journal of American Water Works Association, Vol. 75 75, Oct. 1983, pages 485-540.

5. "Lime Softening Sludge Treatment and Disposal," Committee Report, Journal of the American Water Works Association, Vol. 73, Nov. 1981, pages 600-608.

6. Proposed New Rule N.J.A.C., (New Jersey Administrative Code), 7.26, 1986.

7. Sherard, James L., Dunnigan, Lorn P., Decker, Roy S., and Steele, Edgar F., "Pinhole Test for Identifying Dispersive Soils," Journal of the Geotechnical Engineering Division, Proceedings of the American Society of Civil Engineers, Volume 102, No. GTl, January 1976, pages 69-86.

8. "Water Treatment Plant Sludges - An Update of the State of the Art: Part 1," Committee Report, Journal of the American Water Works Association, Vol. 70, Sept. 1978, pages 498-503.

9. Zargarelahi, Mohson, "Feasibility of Water Treatment Plant Sludge as Construction Material," Project Report submitted in partial fulfillment of the requirments for the degree of Master of Science in Civil Engineering, Civil and Environmental Engineering Department, New Jersey Institute of Technology, Newark, New Jersey, April 1984.

APPENDIX II

Conversion of Units

$1 g/cm^2$	=	98 Pa
1 cm	=	0.01 M
1 pcf	=	$0.157 kN/M^3$