

Effect of Bentonite on Permeability of Dune Sand

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ABSTRACT

A compacted mixture of bentonite with sand has been used to form barrier of fluids, in absence of impervious natural soils. This paper focuses on the permeability behavior of dune sand/bentonite mixtures. Results of laboratory investigations are presented to show the influence of bentonite on permeability of dune sand. One dimensional consolidation and falling head permeability tests were conducted to evaluate permeability at 2%, 4%, 6%, 8% and 10% bentonite content by weight in dune sand. Some of the findings are: The coefficient of consolidation decreases inversely proportional with lower bentonite/dune sand ratios. The coefficient of volume change is more susceptible to changing stresses and is inversely related to it. The permeability of dune sand with bentonite is varied significantly and reduced significantly after addition bentonite. The permeability investigated by falling head permeability and one-dimensional consolidation test are in good agreement.

KEYWORDS: Mixture, Bentonite, Dune sand, Permeability, Laboratory study.

INTRODUCTION

Permeability is the dominant parameter in the design and implementation of waste disposal facilities. The permeability for liner materials & caps i.e. moisture barrier is an important aspect. Generally clay is prominent among the materials usually considered for this purpose. But use of clays is associated with the problem of cracking during period of desiccation. Hence instead of pure clays mixtures of clays with soils are becoming popular due to its not only economics but also strength properties. In Los Alamos, New Mexico, the prevailing stuff has the texture of sandy silt (Abrahams, 1963). Folk (1954) indicates that sandy silt is an unconsolidated sediment containing 10-50% sand and having a ratio of silt to clay greater than 2:1. This tuff mixed with bentonite appeared to give greatly decreasing hydraulic conductivity. The dune sand with low amounts of bentonite also appeared to be very promising in greatly decreasing hydraulic conductivity. Saturated sodium bentonite absorbs water up to 5 times its own mass to form a gel up to 15 times its own volume. A mix of dune sand and bentonite is less expensive and probably would not visibly crack when desiccated. Bentonite is contained within voids between sand particles and in presence of water, hydrates and swells. When the voids ratio of bentonite is less

than its free-swell capacity bentonite completely fills the spaces and presses lightly against the sand particles, thereby acting as a minor part of the load-bearing structure of the mixture. Ideal mixes which contain sufficient bentonite to fill all spaces and in which bentonite is uniformly distributed have their permeability controlled by the permeability of bentonite; and the sand particles are impervious inclusion in the matrix of hydrated bentonite. To obtain a low-permeability mixture requires adequate content of bentonite and adequate distribution of bentonite in the mix. Lundgren (1981), Chapuis(1981,1990),Kenny et al.(1992) and Abeele (1986) studied soil-bentonite mixes for liners. This study will lead us to know the influence of bentonite on permeability of dune sand for its possible use as a liner material for waste disposal.

MATERIALS USED FOR STUDY

The properties of materials used for investigations determined experimentally are as listed below.

Bentonite:

The bentonite used for present investigation is high swell sodium bentonite containing sodium montmorillonite and its properties are listed in Table 1.

Table 1: Properties of bentonite

S.N	Property	Value
1.	Specific gravity	2.24
2.	Liquid Limit	250 %
3.	Plastic Limit	47 %
4.	Maximum Dry Density	1.17 g/cm ³
5.	Optimum Moisture Content	46.70 %
6.	Swelling water absorbed per gm of oven dried bentonite in cc	7 to 8 times

Dune sand:

The grain size distribution of dune sand used for investigation is listed in Table 2. The coefficient of permeability of dune sand is 2.0×10^{-4} cm/s.

Table 2: Grain size distribution of dune sand

S.No.	Grain size (mm)	Frequency (% finer)
1.	2	99.9
2.	1	99.4
3.	0.6	98.1
4.	0.425	98.0
5.	0.30	97.3
6.	0.15	12.3
7.	0.075	2.0

Dune sand/Bentonite mixtures:

Dune sand/bentonite mixtures used for investigations are as listed below as Table 3.

Table 3: Dune sand/bentonite mixtures used for study

S.N.	Symbol	% Bentonite	%Dune sand	*MDD (g/cc)	#OMC (%)
1	M1	2	98	1.71	15.21
2	M2	4	96	1.74	16.00
3	M3	6	94	1.79	14.15
4	M4	8	92	1.80	15.20
5	M5	10	90	1.78	15.74

* MDD is Maximum dry density and #OMC is optimum moisture content.

LABORTARY PERMEABILITY TESTS

The permeability tests are performed in the laboratory for selection of materials to be made. These tests are done to determine for the selected soil and bentonite mix, the degree of imperviousness provided by the bentonite content. The required hydraulic conductivity is frequently $k < 10^{-6}$ to 10^{-8} cm/s for various projects and a decision is made as to whether long term tests are to required to verify the physiochemical stability of the optimized mix. Laboratory permeability test can be done by falling head permeability or one-dimensional consolidation, both of which have their advantages and disadvantages.

One dimensional consolidation test is an indirect evaluation of soil permeability. The coefficient of consolidation of soil sample under stress is related to its permeability (e.g., Olson and Daniel, 1981). Evaluation of permeability from consolidation tests has the advantage of being more rapid than that derived from standard permeability tests. Terzaghi's theory, used in the interpretation of consolidation rates in terms of permeability, is based on some assumptions that do not necessarily fit the actual soil behavior exactly. But assuming the requirement being fulfilled, the permeability may be derived from the one-dimensional consolidation equation.

$$k = c_v m_v \gamma_w$$

where

c_v = coefficient of consolidation,

m_v = volume of compressibility of the soil

and γ_w = unit weight of water.

A specimen of 60 mm dia. and 20 mm high was held in a metal ring and loading pressures selected as 0.25, 0.5, 1.0, 2.0, 4.0 and 8.0 kg/cm². Each pressure was maintained for 24 hrs. The specimen consolidates with free drainage occurring from both the top and bottom faces. The permeability of the soil is determined by Terzaghi's one-dimensional consolidation theory. c_v can be obtained by Taylor's method or Casagrande's method. Olson R.E (1986) has shown that the estimated permeability values are always less than the measured values. The permeability values estimated from Taylor's method are more close to the measured values than the values obtained from the Casagrande.

In the present study for estimating c_v , Taylor's method has been used. The results are reported in Table 4.

Table 4: Permeability by one dimensional consolidation test at various pressures increments

Pressure (kg/cm ²)	M1	M2	M3	M4	M5
0.50	$1.02 \cdot 10^{-5}$	$8.69 \cdot 10^{-6}$	$2.62 \cdot 10^{-6}$	$2.91 \cdot 10^{-7}$	$6.36 \cdot 10^{-8}$
1.0	$5.67 \cdot 10^{-6}$	$5.13 \cdot 10^{-6}$	$2.04 \cdot 10^{-6}$	$1.20 \cdot 10^{-7}$	$5.16 \cdot 10^{-8}$
2.0	$3.29 \cdot 10^{-6}$	$2.32 \cdot 10^{-6}$	$1.28 \cdot 10^{-6}$	$1.05 \cdot 10^{-7}$	$3.58 \cdot 10^{-8}$
4.0	$2.23 \cdot 10^{-6}$	$1.55 \cdot 10^{-6}$	$8.5 \cdot 10^{-7}$	$8.33 \cdot 10^{-8}$	$2.27 \cdot 10^{-8}$
8.0	$1.14 \cdot 10^{-6}$	$8.74 \cdot 10^{-6}$	$6.25 \cdot 10^{-7}$	$6.77 \cdot 10^{-8}$	$1.61 \cdot 10^{-8}$

The coefficient of permeability for various bentonite contents varying from 2% to 10% i.e. M1 to M5 are shown in Figure 1 against various pressure increments.

The coefficient of consolidation is decreasing for lower bentonite contents, whereas at higher bentonite contents the variation is little and for 4% to 6% the variation is haphazard as shown in Figure 2.

The coefficient of volume change is decreasing with pressure increments for all bentonite contents (Figure 3).

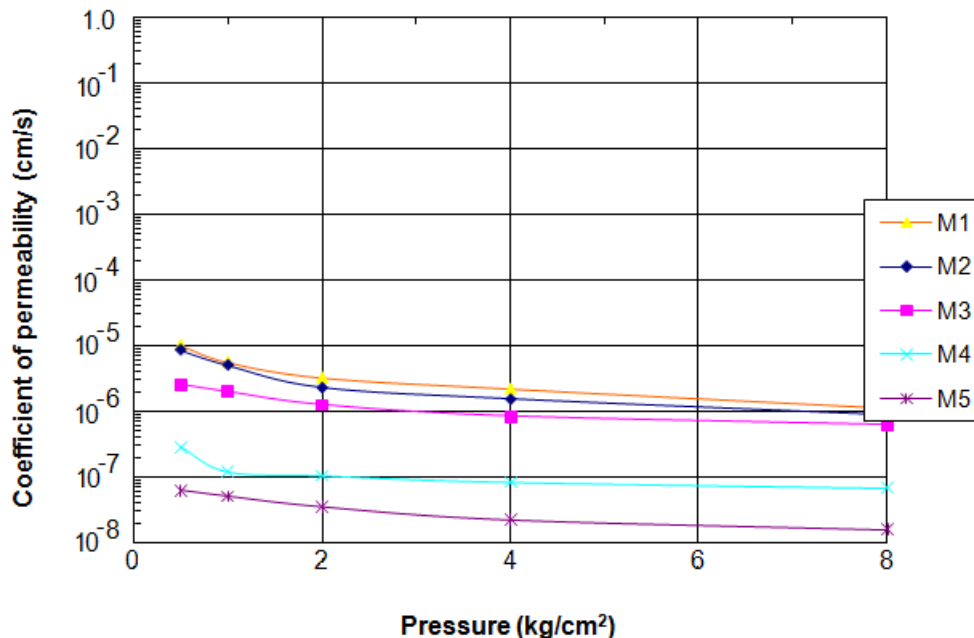


Figure 1: Pressure vs Coefficient of permeability for M1 to M5

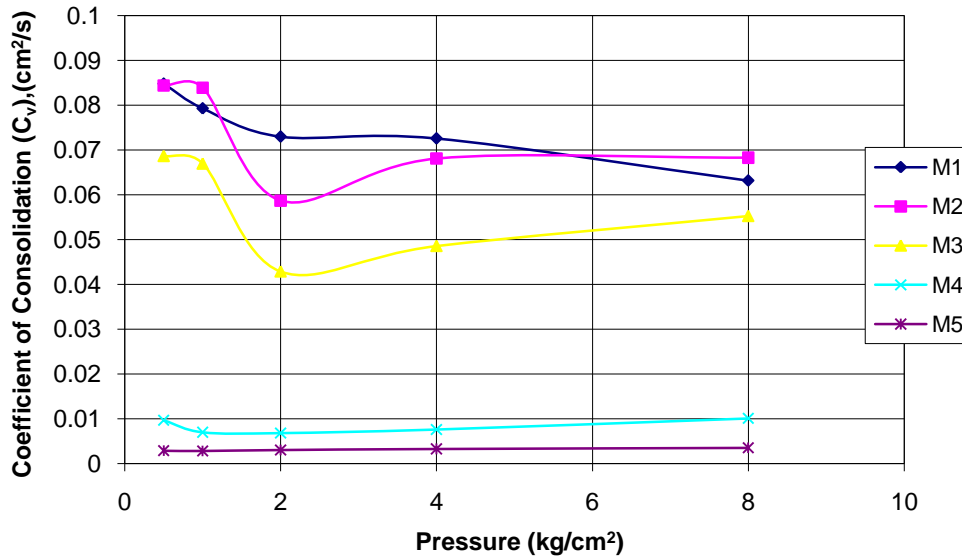


Figure 2: Pressure vs coefficient of consolidation (c_v) for M1 to M5

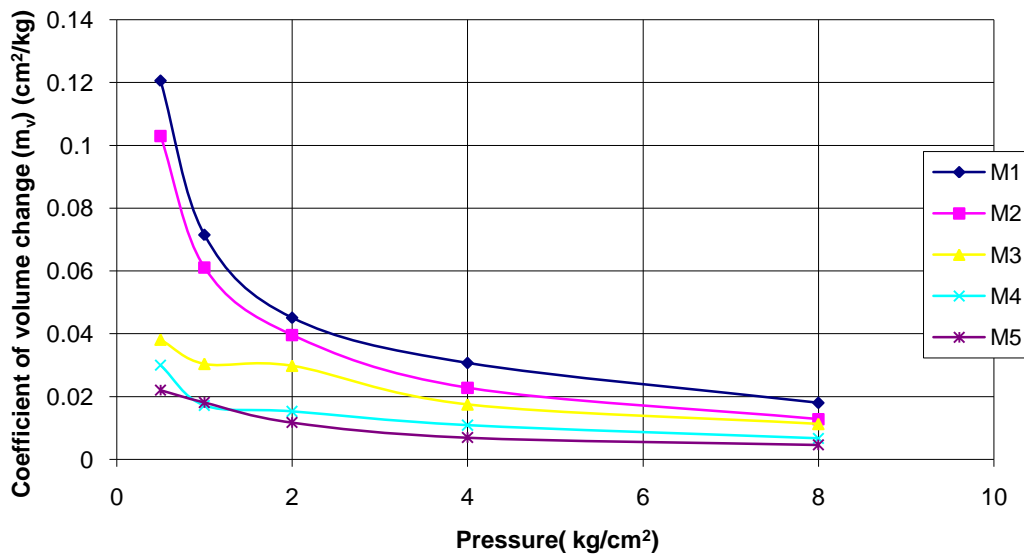


Figure 3: Pressure vs coefficient of volume change (m_v) for M1 to M5.

For estimating permeability, conventional falling head permeability test were also conducted by using standard permeameter. Soil samples for these tests M1 to M5 were prepared in rigid moulds by compacting the soils at maximum dry density and optimum moisture content. Samples were kept for saturation for about 24 hrs to one week and later connected to water column. After

completion of the test it was observed that the degree of saturation varied from 97 to 100% for different samples. The obtained permeability values are represented in the Table 5.

Table 5: Permeability by falling head test

S.N.	Sample	Permeability by falling head test (cm/s)
1	M1	1.65×10^{-5}
2	M2	4.23×10^{-6}
3	M3	7.82×10^{-7}
4	M4	2.18×10^{-7}
5	M5	6.94×10^{-8}

The permeability values of dune sand/bentonite mixture obtained by falling head permeability are in good agreements with the results of one dimensional consolidation test.

CONCLUSIONS

The coefficient of consolidation at varying pressure, shown decrease for lower bentonite content and little variation in higher bentonite content i.e. 8 to 10% and shown mixed trend for bentonite content 4 to 6%.

The coefficient of volume change is more susceptible to changing stresses and is inversely related to it.

Several indication lead to believe in the eventual inadequacy of Terzaghi's method for deriving hydraulic conductivity when applied to bentonite/dune sand mixes. However, results obtained using falling head method are in good agreement with the same.

The permeability is greatly affected by adding bentonite and reported reduced from 10^{-04} cm/s to 10^{-08} cm/s after addition of 10% bentonite with compaction at maximum dry density at optimum moisture content.

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