The Permeability Influence of Dune Sand Mixed with Bentonite

Dr. Jagdish Prasad[1], Dr. D.G.M. Purohit[2]

[1]Assistant Director, Directorate of Technical Education, Jodhpur, Rajasthan, India
[2]Professor, Department of Civil Engg., M.B.M. Engg. College, JNVU Jodhpur, Rajasthan, India

---***---

Abstract- *The permeability is property of a porous material which permits the seepage of water through its interconnecting voids. When suitable impervious soils are not available for containing the waste, form barriers constructed using dune sand mixed with bentonite are frequently adopting to contain the waste. A compacted mixture of bentonite with sand has been used to form barrier of fluids, in absence of impervious natural soils. This paper presents the laboratory experiments of permeability behavior of dune sand mixed with bentonite . Results of five different categories of laboratory experiments 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 2.5%, 5%, 7.5%, 10% and 12.5% bentonite content by dry weight in dune sand. The findings are that coefficient of consolidation decreases inversely proportional with lower bentonite and 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 of bentonite.The permeability investigated by falling head permeability test and one dimensional consolidation test are in good agreement.*

Key Words: Bentonite, Consolidation, Dune Sand, Laboratory Tests. Permeability.

1. INTRODUCTION

In the absence of natural impervious soils, compacted dune sand mixed with bentonite are frequently used for constructing barriers waste disposal projects. The waster water lagoons and mounted oil and gas storage tanks are typical design an economical application of sand mixed with bentonite. Permeability is the important parameter in the design and implementation of waste disposal facilities.The permeability for liner materials and caps i.e. moisture barrier is an important aspect. Generally clay is prominent among the materials usually considered for this purpose. But use of bentonite 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 themix. 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.

2. MATERIALS AND METHOD USED FOR STUDY

2.1 Dune Sand

Dune sand is a wind deposited, non-plastic, uniformly graded fine sandy soil. It is fine sand with no cohesion, and thus it has property of immense shifting nature, high permeability, low shear strength and poor bearing capacity. The Dune Sand used in the present study was brought from location near Sheo in Barmer district of Rajasthan where bentonite is also available. Geotechnical Properties of Dune Sand is listed in Table: 1

Table -1: Geotechnical Properties of Dune Sand

Sl. no.	Properties	Value
1.	Mean Diameter Size D_{60} (mm)	0.16
2.	Effective Particle Size D_{10} (mm)	0.12
3.	Specific Gravity	2.66
4.	Coefficient of Uniformity (C_u)	1.29
5.	Coefficient of Curvature (C_c)	0.97
6.	Fine Soil Fraction (-75 micron) in %	2
7.	Maximum dry density (gm/cc)	1.65
8.	Minimum dry density (gm/cc)	1.44
9.	Optimum Moisture content (%)	11
10.	Maximum voids ratio (e_{max})	0.93
11.	Minimum Voids ratio (e_{min})	0.50

2.2 Bentonite:

The bentonite used for present investigation is taken from Sheo in Barmer district of Rajathan. This Bentonite is expansive soils or Black cotton soils of western Rajasthan. The property of sample Bentonite is high swell due to the presence of imbalance electrical charge and cation exchange capacity produced by sodium-based Montmorillonite the expansive Bentonite soil swells. Replacing the sodium ions by inorganic compounds, which may produce such type of cation having less ion exchange capacity and also form a balanced electrical charge in soil structure, can reduce this expansion. Replacement of monovalent sodium by calcium ions may leads to a marked reduction in diffuse double layer thickness leading to decrease in liquid limit, plastics limits and swelling pressure. Chemical Composition of Bentonite and its Geotechnical properties are listed in Table: 2 and Table: 3.

Table- 2 : Chemical Composition of Bentonite

Sl. no.	Chemical Composition	Chemical Composition (%)
1.	SiO_2	56.8
2.	Al_2O_3	16.52
3.	Fe_2O_3	9.25
4.	CaO	1.84
5.	MgO	4.25
6.	Na_2O	1.58
7.	TiO_2	0.86
8.	K_2O	0.12
9.	P_2O_5	0.18
10.	SO_3	0.045
11.	Loss on ignition	8.555

Table- 3: Geotechnical Properties of Bentonite

Sl. no.	Properties	Value
1.	Liquid Limit %	254.0
2.	Plastic Limit %	48.0
3.	Plasticity Index	206.0
4.	Maximum dry Density	1.18
5.	% Passing 75 Micro Sieve	99.0
6.	Silt Percentage	27.0
7.	Clay %	71.0
8.	Specific Gravity	2.28
9.	OMC	20.4 to 24.8%
10.	Free Swell Index	745%
11.	Soil Group	CH

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

Table- 4 : Grain Size Distribution of Dune Sand

Sl. no.	Sieve Size mm	Weight Retained (gm)	% Weight Retained	Cumulative % Weight Retained	Cumulative % Weight Passing	% Finer
1.	4.75	1.5	0.15	0.15	99.85	99.85
2.	2.36	2.0	0.20	0.35	99.65	99.65
3.	1.18	1.5	0.15	0.50	99.50	99.50
4.	0.60	2.5	0.25	0.70	99.30	99.30
5.	0.425	1.5	0.15	0.90	99.10	99.10
6.	0.300	2.5	0.25	1.15	98.85	98.85
7.	0.150	905.5	90.55	91.70	8.30	8.30
8.	0.075	81.0	8.10	99.80	0.20	0.20
9.	Pan	2.0	0.20	100	0.00	0.00

2.3 Dune Sand mixed With Bentonite:

For liquid limit and plastic limit, bentonite was mixed with distilled water, forming a thick paste and allowed to hydrate for about 24 h. For higher bentonite contents, considering the active nature of bentonite type used in the present study, hydration duration of 24 h was adopted to maintain uniformity among all bentonite contents. In this study five categories of sand mixed with bentonite were used with bentonite content varies from 2.5%,5%,7.5%,10% and 12.5% as shown in Table 5.

Table- 5: Dune Sand mixed with Bentonite used for Study

Sl. no.	Symbol	Bentonite (%)	Dune Sand (%)	Maximum Dry Density (gm/cc)	Optimum Moisture Content (%)
1.	SB-1	2.5	97.5	1.72	15.18
2.	SB-2	5.0	95.0	1.75	15.95
3.	SB-3	7.5	92.5	1.82	14.16
4.	SB-4	10.0	90.0	1.80	15.21
5.	SB-5	12.5	87.5	1.79	15.81

3. 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 dune soil mixed with 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 (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.

$$k = c_v \times m_v \times Y_w$$

where c_v = coefficient of consolidation, m_v = volume of compressibility of the soil and

Y_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 0.5, 1.0, 2.0, 4.0 and 8.0 kg/cm^2 . 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 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 6.

Table-6: Permeability by One Dimension Consolidation Test at Various Pressure Increments

Pressure (kg/ cm^2)	SB-1	SB-2	SB-3	SB-4	SB-5
0.50	1.05×10^{-5}	8.71×10^{-6}	2.65×10^{-6}	2.94×10^{-7}	6.35×10^{-8}
1.0	5.68×10^{-6}	5.14×10^{-6}	2.11×10^{-6}	1.21×10^{-7}	5.15×10^{-8}
2.0	3.28×10^{-6}	2.32×10^{-6}	1.29×10^{-6}	1.14×10^{-7}	3.64×10^{-8}
4.0	2.24×10^{-6}	1.55×10^{-6}	8.51×10^{-7}	8.36×10^{-8}	2.65×10^{-8}
8.0	1.14×10^{-6}	8.75×10^{-7}	6.28×10^{-7}	6.75×10^{-8}	1.64×10^{-8}

The coefficient of permeability for various bentonite contents varying from 2.5% to 12.5% , SB-1 to SB-5 are shown in Figure 1 against various pressure increments. The coefficient of consolidation c_v is decreasing for lower bentonite contents, whereas at higher bentonite contents the variation is little and for 5% to 7.5% the variation is haphazard as shown in Figure 2. The coefficient of volume change m_v is decreasing with pressure increments for all bentonite contents in Figure 3.

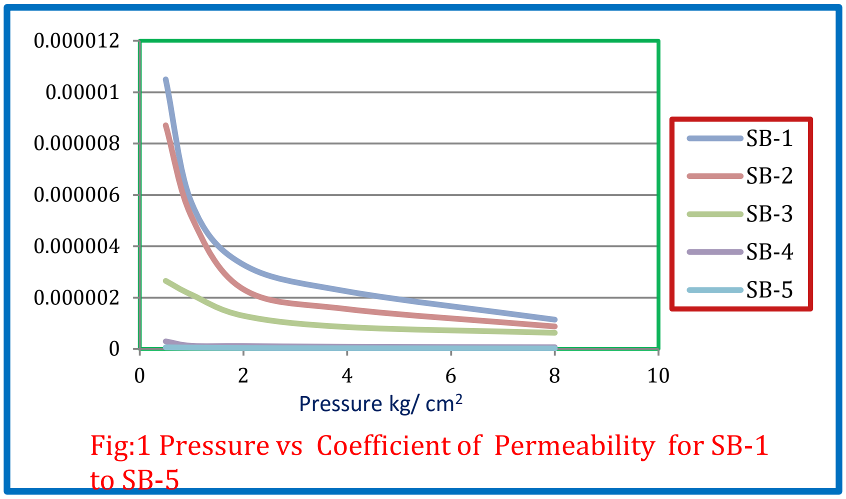

Figure 1: Pressure vs Coefficient of Permeability for SB-1 to SB-5

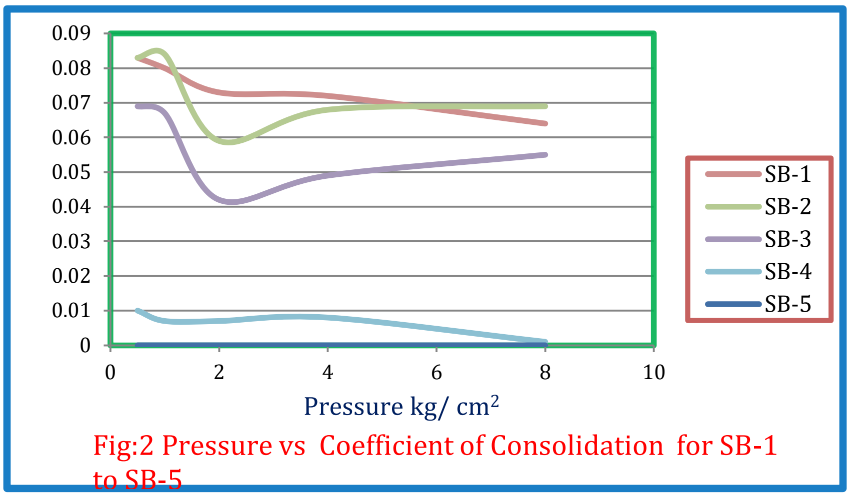

Figure 2: Pressure vs Coefficient of Consolidation for SB-1 to SB-5

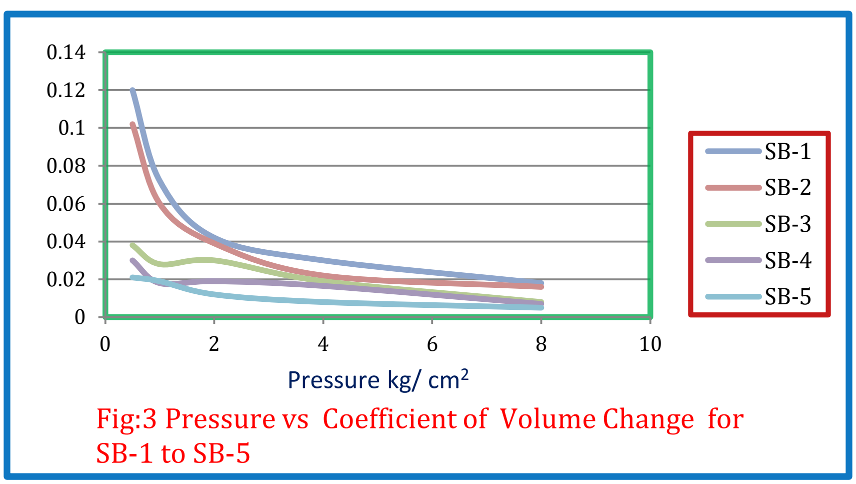

Figure 3: Pressure vs Coefficient of Volume Change for SB-1 to SB-5

For estimating permeability, conventional falling head permeability test were also conducted by using standard permeameter. Soil samples for these tests SB-1 to SB-5 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 7.

Table- 7: Permeability by Falling Head Test

Sl. no.	Sample	Permeability by Falling Head Test (cm / sec)
1.	SB-1	1.64×10^{-5}
2.	SB-2	4.25×10^{-6}
3.	SB-3	7.85×10^{-7}
4.	SB-4	2.21×10^{-7}
5.	SB-5	6.95×10^{-8}

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

4. CONCLUSIONS

Based on the analysis and interpretation of experimental investigation on dune sand mixed with bentonite, the following conclusions are made:

1. The investigations were carried out with the view of exploring the possibilities of effect of Bentonite on permeability of dune sand . The various experiments were performed on mix compositions of dune sand with Bentonite have been studied. Maximum dry density is higher for higher comp active efforts and optimum water content is lower.

2. 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 5% to 7.5%.

3. 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 and dune sand mixes.However, results obtained using falling head method are in good agreement with the same.

4. The permeability is greatly affected by adding bentonite and reported reduced from 10 cm/s after addition of 12.5% Bentonite with compaction at maximum dry density at optimum moisture content.

ACKNOWLEDGEMENT

The author is grateful to Dr. D.G.M. Purohit, Professor, Department of Civil Engineering, M.B.M. Engineering College, J.N.V. University Jodhpur, Rajasthan, India research guide for his keen interest, sincere and valuable guidance, moral support and inexhaustible encouragement and timely suggestion were useful in the preparation of my this paper. Finally a word of thanks is in store especially for Dear Most Mrs. Indu Bala Chaudhary and Mr. Mohit Inaniyan.

REFERENCES

1. Abeele, W.V. (1986) "The influence of bentonite on the permeability of sandy silts" Nuclear and chemical waste management Vol. 6: 81-88.

2. Abraham, Jr., J.H. (1963) “Physical properties of and movement of water in the Bandelier Tuff, Los Alamos and Santa Fe Counties,” N.M. US department of the interior geological survey, Albuquerque, New Mexico.

3. Chapuis,R.P. (1981) “Permeability testing of soil-bentonite mixtures,” Proceedings, 10 th International conference on Soil Mechanics and Foundation engineering, Stockholm, Vol.4, 744-745.

4. Chapuis, R.P (1990) “Sand-bentonite liners: predicting permeability from laboratory tests” Can. GTech. J. 27, 47-57.

5. Kenny, T.C., W.A. Van Veen, M.A. Swallow and M.A. Sungaila (1992) “Hydraulic conductivity of compacted bentonite-sand mixtures,” Can. Geotech. J. 29, 264-374.

6. Holtz W. G. and Gibbs H. J., Engg. Properties of expansive clays. Transactions of ASCE, 1956, 121, 641-663.

7. Katti, R.K. (1979) "Search for Solutions to Problems in Black Cotton Soils". IG Journal, LG.S. Vol. 9, No. 1

8. Sridharan A. and Prakash K. Classification Procedures for expansive soils, Proc. Instn. Civ. Engrs Geo tech. Engg, 2000, 143, Oct., 235-240.