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Permeability Characteristics of Sand-Bentonite Mixtures

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Abstract □ A series of permeability tests was performed on the mixtures with specific mixing rates of sand and bentonite using modified rigid-wall permeameter. Sand-bentonite mixtures were permeated by organics, ethanol and TCE. Permeability of bentonite with several mixing rates had a tendency to decrease up to initial one pore volume and permeability was thereafter converged to a constant value. When sand-bentonite mixtures was permeated by water, permeability was decreased at the beginning but it was thereafter converged to a constant. Among several mixing rates, permeability was greatly decreased at 15% of mixing rate. When sand-bentonite mixtures with 15% mixing rate was permeated by ethanol, permeability was about 10 times larger value than permeability of water. Peameability was shown greater values when permeated by TCE (TrichloroEthylene) followed by ethanol. Suitable mixing rate of sand-bentonite for a liner of waste landfills was detected.

Keywords □ sand-bentonite mixture, liner, permeants, waste landfills, diffuse double layer.

I. Introduction

Recently, waste sites and impoundments that contains waste were used the liner systems to prevent the groundwater and geosphere from concentration, if there is no good soil barrier underneath the waste sites. A natural clay layer and sand-bentonite mixture or synthetic materials are used to prevent the infiltration into and leaching of contaminants out of the waste site or potentially polluted area.

Sand-bentonite mixtures are comprised of two different soils in regards to grain size, permeability, chemical activity and strength. However the mixtures with small amount of bentonite possess strong load supporting framworks of sand that resist shrinkage due to dessication or osmotic consolidation.

If sand-bentonite mixture contains sufficient bentonite to fill their voids, it has a permeability characteristics by the permeability properties of bentonite and becomes an impermeable matrix. The mixture requires, therefore, both adequate content of bentonite and adequate distribution of bentonite within the mixtures to obtain a low-permeability.

Fluids and dissolved materials pass through soil barriers by processes of seepage and diffusion. Seepage is movement of fluid through soil caused by a hydraulic gradient. Diffusion is movement of dissolved matter through the pore fluid of the barrier caused by a chemical gradient. The fluid requirement of soil barrier is low permeability.

This research was focused on the permeability behaviers of sand-bentonite mixtures. The purpose of the study was to evalute the mechanism of permeability when selected chemicals were permeated through the layer of sand-bentonite mixtures

II. Previous Study

Interaction between chemicals and clay or sand-bentonite mixtures has been the subjects of several investigations.[6,11,13] The studies have shown that changes in permeability can be related to changes in the thickness of the diffuse double layer[12]. An increase in the thickness of the diffuse doube layer reduces permeability. Conversely shrinkage of the diffuse double layer tends to increase in permeability. The layer of water and absorbed ions that surrounds a clay particle is referred to as the diffuse double layer. In general, characteristics of permeant liquids that tend to shrink the diffuse double layer and, therfore, to cause an increase in permeability: (1) a low dielectric constant; (2) a high eletrolyte concentration; (3) a preponderance of multivalent cations. Studies dealing with the effect of chemicals on the

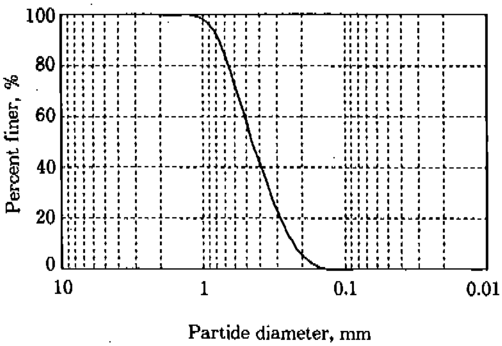

Fig. 1. Grain size distribution curves of Jumunjin sand

Table 1. Physical properties of sand and bentonite

Materials	Spec. gravity	Composition	Shape	Origin /Maker
Sand	2.65	Sand	Granular	Korea/ Jumunjin
Bentonite	2.88	Sodium-bentonite	Granular or Powder	USA /Volclay

permeability of bentonite mixtures were presented by Anderson et.al.[7]

III. Materials and Test Procedures

Jumunjin sand used in the tests was ranged in grain size from 0.2 to 1.2 mm. Its grain size distribution curve was shown in Fig. 1. Physical properties of sodium bentonite from Volclay Company, U.S.A. was shown in le 1. Table 2 was shown chemical properties of organic permeants used in the test. A modified rigid-wall permeameter was used to perform permeability tests on specimens whose dimensions were 45mm in diameter and 30 mm in height as shown in Fig. 2.

Sand and bentonite were mixed by hand until the mixtures became visibly and texturally homogenous and mixing continued in

Table 2. Chemical properties of organic permeants

Permeants	Formula	D	γ	μ	DM	MW	SBL
Water	H_2O	80.1	0.998	1.02	1.87	18.0	-
Ethanol	C_2HCL_3	25.0	0.792	1.19	1.69	46.1	∞
TCE	C_2HCL_3	3.4	1.470	0.58	0	131.4	1

D : Dielectric constant(20℃), γ : Unit weight(kg/m^3) (20℃), μ : Viscosity(centipoise) (20℃), DM : Dipole moment(debyes), MW : Molecular weight, SBL : Water solubility(mg/ℓ at 25℃), TCE : TrichloroEthylene.

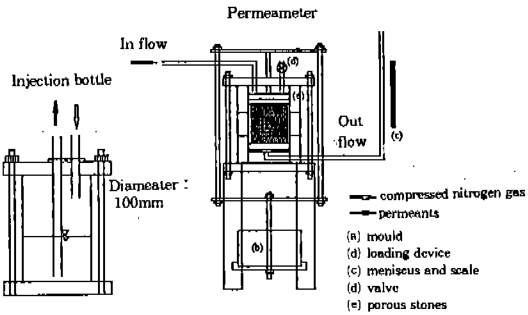

Fig. 2. Schematic views of permeameter and setup

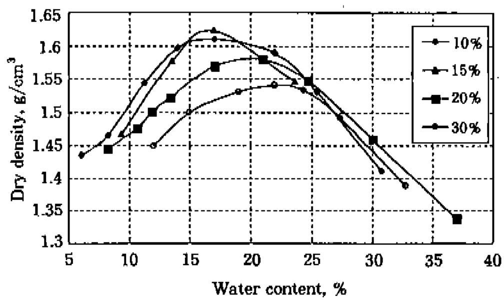

Fig. 3. Compaction curves of sand-bentonite mixutres

additon of water. Sand-bentonite mixtures were allowed to hydrate for at least 24 hours prior to being compacted.

Compactions having several differnt sand-bentonite rates on tap water were performed with 5.625kg·cm/cm^3 of compaction energy

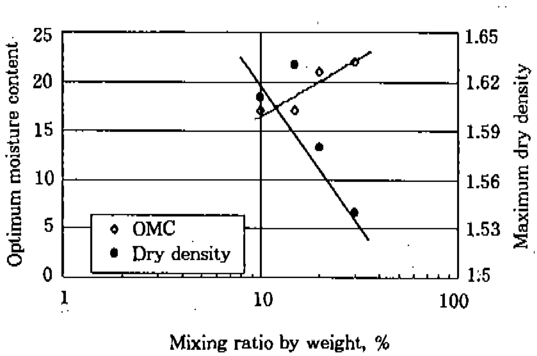

Fig. 4. Relationship between mixing rate and maximum dry density, OMC

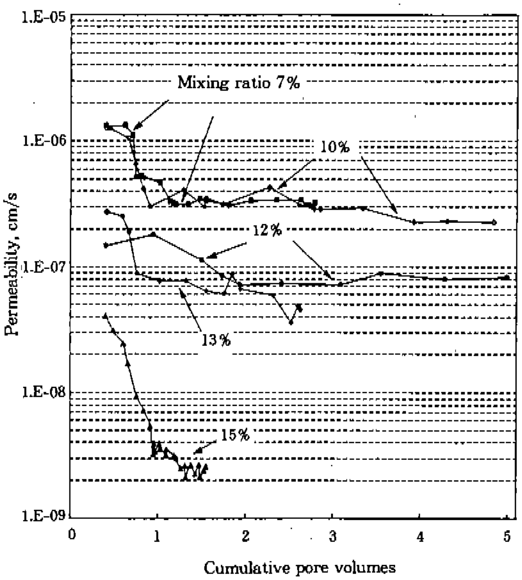

Fig. 5. Permeabilities of sand-bentonite mixtures

as specified in Standard Proctor Compaction Test. Optimum moisture contents of specimens were typically 17 to 21 %, and maximum dry density were 1.54 to 1.63g/cm^3 as shown in Table 3. The specimens were stabilized in humid area for 24 hours before running tests. Permeability tests were performed with a confining pressure of 1.3t/m^3 and with a constant hydrulic gradient. For some

Table 3. Sand-bentonite mixing ratio and results

Mixing ratio(%)	Max. dry density(g/cm^3)	OMC*(%)
10	1.61	17
15	1.63	17
20	1.58	21
30	1.54	21

*OMC : Optimum Moisture Content.

Table 4. Summary of initial conditions of sand-bentonite(S/B) mixtures used in tests

S/B mixing rate(%)	Dry density (g/cm^3)	Void ratio (e)	Deg. of saturation (%)	Deg. of compaction (%)	1 pore volume (cm^3)	Remarks
7	1.567	0.70	68	96	19.7	matured
10	1.577	0.72	70	98	20.0	matured
12	1.544	0.73	72.6	96	20.1	matured
13	1.569	0.70	79.5	98	19.7	matured
15	1.571	0.70	83.2	99	19.6	matured

tests with ethanol, the specimens were, at first, permeated with tap water, and then the permeant was changed to ethanol. For further tests with TCE, the permeant TCE was followed by ethanol.

The initial condition of sand-bentonite specimens used in the test were shown in Table 4.

IV. Results and discussions

Since permeability of sand-bentonite mixtures was dependent upon texture of bentonite, mixing ratio, mixing methods and permeant. Sand-bentonite mixtures were compacted to get an optimum mixing rates with various mixing rates of 7, 10, 12, and 15% of bentonite by weight. In Fig. 6 were plotted relationships between permeability and mixing rates and their numerical data were shown in Table 5. As shown in the figure, permeability was exponentially decreased as mixing rate

Table 5. Summary of mixing rates and permeability

Mixing ratio(%)	7	10	12	13	15
Permeability (cm/s)	3.31×10^{-7}	3.05×10^{-7}	12.7×10^{-8}	6.21×10^{-8}	2.82×10^{-9}

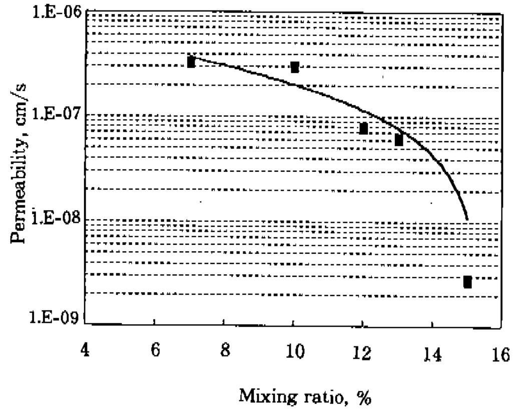

Fig. 6. Relationship between mixing rates and permeability

of bentonite was increased up to 15%. Permeability of the mixing rate over 12% exhibited 1.0×10^{7}cm/s or less which is a permeability requirement for a liner of waste site currently. Permeability of 15% or more mixing ratio seemed to be appropriate but strength requirements could not be met for a liner.

Sand-bentonite mixtures were permeated with water at first and then with the chemical solutions such as ethanol and TCE. Permeability of the mixtures was generally attained as shown in Figs 7 and 8. Permeability of sand-bentonite mixtures were 2.1×10^{-9}cm/s when permeated with water, but the permeability typically increased to 4.0 $\times10^{-8}$cm/s when ethanol was introduced and thereafter converged to 2.0×10^{-8}cm/s as shown in Fig. 7. As expected, ethanol and

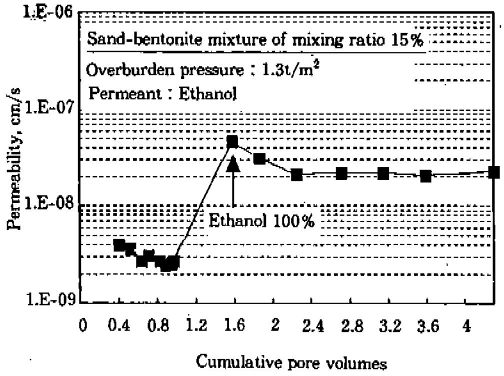

Fig. 7. Permeabilities of sand-bentonite mixture with mixing rate 15% and permeant 100% ethanol

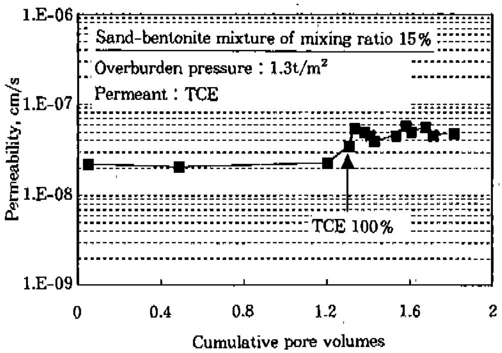

Fig. 8. Permeabilities of sand-bentonite mixture with mixing rate 15% and permeant TCE

TCE caused a significant increase in permeability of the samples.

For tests with TCE, the specimens were permeated with tap water at the beginning, and the permeant was then changed to ethanol. Further tests was continued with TCE. Based on the test results in the Fig. 8, permeability was initally 2.0×10^{-8}cm/s when permeated by ethanol. As TCE was introduced permeability was increased and stabilized to 5×10^{-8}cm/s which was 2~2.5 times greater values when permeated by TCE (TrichloroEthylene) followed by ethanol.

As expected, TCE caused less significant increase than ethanol in permeability of the mixtures. Shrinkage of the diffuse double layer helped to increase in permeability for both ethanol and TCE. This fact confirmed that an increase in the thickness of the diffuse doube layer reduces permeability. Conversely shrinkage of the diffuse double layer tends to increase in permeability.[12]

V. Conclusion

A series of permeability tests was performed on the mixtures with specific mixing rates of sand and bentonite using modified rigid-wall permeameter to study on the permeability characteristics of sand-bentonite mixtures permeated by organics, ethanol and TCE.

Results of the study are as follows : Permeability of sand-bentonite mixtures at 7, 10, 12, 13, 15% mixing rates had a tendency to decrease up to initial one pore volume and permeability was thereafter converged to a constant value. When sand-bentonite mixtures was permeated by water, permeability was decreased at first but it was thereafter converged to a constant. Among several mixing rates, permeability was greatly decreased at 15% of mixing rate. When sand-bentonite mixtures of 15% mixing rate was permeated by ethanol, permeability was converged to 2.1 $\times10^{-8}$cm/s. It was about 10 times larger value than permeability of water. Peameability was converged to 5×10^{-8}cm/s which was 2~2.5 times greater values when permeated by TCE (TrichloroEthylene) followed by ethanol. A suitable mixing rate of sand-bentonite liner of waste landfills was 12 ~15%

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