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Effect of Leachate Presence on Shear Strength Parameters of Bentonite-Amended Zeolite Soil

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Abstract**—**Over recent years, due to increased population and increased waste production, groundwater protection has become more important, therefore, designing engineered barrier systems such as landfill liners to prevent the entry of leachate into groundwater should be done with greater accuracy. These measures generally involve the application of low permeability soils such as clays. Bentonite is a natural clay with low permeability which makes it a suitable soil for using in liners. Also zeolite with high cation exchange capacity can help to reduce of hazardous materials risk. Bentonite expands when wet, absorbing as much as several times its dry mass in water. This property may effect on some structural properties of soil such as shear strength. In present study, shear strength parameters are determined by both leachates polluted and not polluted bentonite-amended zeolite soil with mixing rates (B/Z) of 5%-10% and 20% with unconfined compression test to obtain the differences. It is shown that leachate presence causes reduction in resistance in general.

Keywords**—**Bentonite, zeolite, leachate, shear strength parameters, unconfined compression tests.

I. INTRODUCTION

ADDRESSING environmental issues has become increasingly important nowadays. The importance of this issue is increasing day by day due to population growth and natural resource depletion. Underground waters are undoubtedly one of the most important natural resources, and ground water contamination can put human life and other creatures at serious risk. One of the most important factors that can cause groundwater pollution is the transmission of pollution trough the landfill sites in the cities, which requires engineering design to achieve the goals of appropriate layer of liners. The main requirements of liners are to ensure the minimization of pollutant migration, low swelling and shrinkage and resistance to shearing [1]. The use of compacted clay soils has long been considered due to properties such as low permeability and high absorption capacity of cations for use in liner layers; in this regard, [2] has proposed the use of bentonite-amended zeolite instead of using clay to achieve a lower thickness of the liners and reduce the risk of leachate. Bentonites are preferred because of its fine particle size and high surface charges which possesses low hydraulic conductivity and high absorption capacity [3]. Also in order to reduce the hazards associated with aqueous wastes, clinoptinolite, a natural zeolite, is considered to be one of the most viable options [4]. Zeolites are crystalline, hydrated alluminosilicate of alkali and alkaline earth cations possessing an infinite, open three-dimensional structure [5]. Also this liner should be efficient for future structures [6]. Hence, compacted soils used for waste contaminant liners must have adequate strength for stability. Waste materials exert compressive stress on liner system. The compressive stress depends on the height of the landfill and the unit weight of waste. Thus, to date, the minimum required strength of soil used for compacted soil liners is not specified. Daniel and Wu [7] arbitrarily selected them, to support the maximum compressive stress in a landfill. They mentioned that soil used for liners should have a minimum unconfined compression strength of 200 kPa.

Due to the fact that materials with different chemical properties have different effect on soil resistance, in the present study, the unconfined compression strength of soil containing bentonite and zeolite with 5%-10% and 20% mixing rate (B/Z), in two conditions, compacted with optimum humidity by water and leachate, has been compared.

II. MATERIAL PROPERTIES

Three types of materials were used in this study, including commercial bentonite powder with the specification given in Table I, clinoptinolite zeolite with the specification given in Table II, and also the leachate of Kahrizak, Tehran (the largest landfill site in Iran) with specification presented in Table III.

III. TEST PROCEDURE AND APPARATUS

A. Atterberg Limits Test

Liquid limit and plastic limit tests were conducted according to ASTM D 4318. These tests were repeated three times for each (B/Z) 5%-10% and 20% combination of mixtures.

B. Compaction Test

Compaction parameters of mixtures such as the maximum dry density and the optimum moisture content were obtained by Standard Proctor tests (ASTM D 698). To determine the compaction parameters, each different admixture was evaluated at four different water concentrations in three steps.

C. Unconfined Compression Test

The unconfined compressive strength values of samples were determined according to ASTM 2166. The unconfined compression test is widely used as a quick, economical way of obtaining the approximate compressive strength of cohesive

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soils. In this laboratory work one cylindrical mold with a length (70 mm)/diameter (35 mm) ratio of 2 was used to prepare 12 samples. These 12 samples consist of 6 compacted samples (90% density) with optimum water-based moisture and 6 compacted samples (90% density) with optimum moisture content applied by the leachate, which 6 samples (3 compacted with water and 3 compacted with leachate) were tested after 7 days and 6 other specimens after 28 days.

TABLE I
BENTONITE CHEMICAL PROPERTIES

Chemical compound	Weight percentage
Na_2O	2.55
SO_3	0.23
Fe_2O_3	1.32
MgO	1.93
CL	0.55
L.O.I	10.01
Al_2O_3	14.32
K_2O	0.21
La&Lu	<1
SiO_2	68.25
CaO	0.63
PH	7.91

TABLE II
ZEOLITE CHEMICAL PROPERTIES

Major phase: clinoptilolitre (KNa_2Ca_2(Si29AAL7)O72.24H_2O Specific gravity=1.62	
Chemical compound	Weight percentage
Na_2O	0.95
SO_3	0.068
Fe_2O_3	0.97
MgO	0.79
L.O.I	10.64
Al_2O_3	11.14
K_2O	0.95
SiO_2	68.95
CaO	4.83

TABLE III
KAHRIZAK LEACHATE PROPERTIES

Chemical compound	Meq/L
Zn	8.5
Fe	16.5
P	121
So_4^{2-}	48
Hco^{3-}	55
Cl^-	223
Mg^{2+}	22
K^+	68
Na^+	197

IV. RESULT AND DISCUSSION

A. Atterberg Limits

The consistency limits of variation mixing rates which are shown in Table IV and compared in Fig. 1, show that, increasing the amount of bentonite in the mixture leads to decreasing and increasing in the plastic limit and liquid limit, respectively.

B. Compaction Test Results

The standard proctor test was done for mixing percentages (B/Z) 5%-10% and 20% and the result indicated that increasing the amount of bentonite in the mixture of soils increases the optimum moisture content. It was also observed that the dry density of soil of the optimum moisture content in the specimens with 10% of mixing rate (B/Z) was higher than the other specimens (shown in Table V and Figs. 2, 3).

TABLE IV
ATTERBERG LIMITS RESULTS FOR DIFFERENT MIXING RATES

B/Z (%)	Plastic limit (%)	Liquid limit (%)
5%	49.76	48.42
10%	47.76	53.66
20%	43.97	60.75

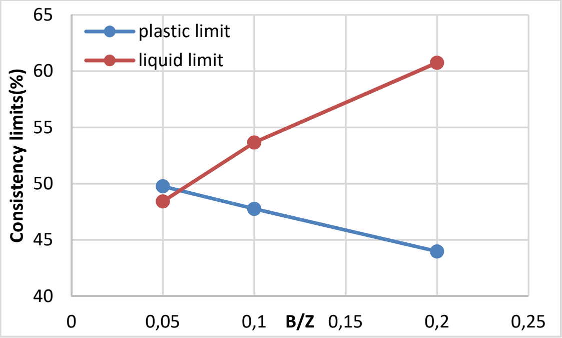

Fig. 1 Atterberg limits test results

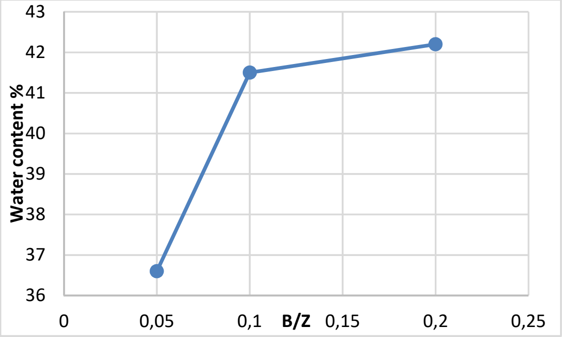

Fig. 2 Optimum moisture content variation based on B/Z mixing rate

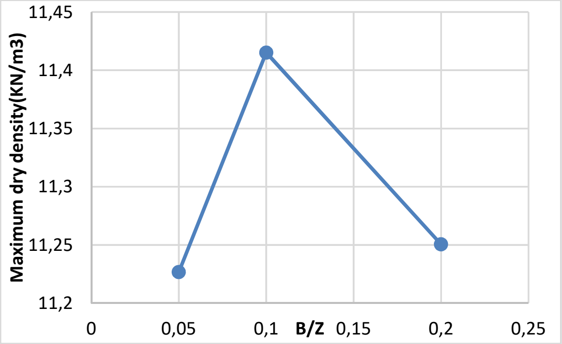

Fig. 3 Maximum dry density variation based on B/Z mixing rate

TABLE V
COMPACTION RESULTS FOR DIFFERENT MIXING RATES

B/Z (%)	Optimum water content (%)	Maximum dry density (KN/m^3)
5%	36.6	11.22
10%	41.5	11.42
20%	42.2	11.25

C. Unconfined Compression Test Results

The unconfined compressive strength of samples, compacted with water and leachate moisture, was obtained by unconfined compression test, which is evident in Figs. 4-6 and Table VI. Compared to the samples of each of the groups compacted with water and leachate, by increasing the amount of bentonite in the soil mixture, resistance is generally increased except for the specimens which had been compacted with water and had 7-day aging time which showed highest resistance at the mixing rate of 10. Also all 28-day specimens show greater resistance to their 7-day resistance as shown in Figs. 7 and 8. However, in comparison with leachate and water containing samples, the presence of leachate reduced the compressive strength of the samples. But noteworthy point is the sudden resistance increase in 28-day sample with 20% mixing rate of B/Z which compacted by optimum moisture content with leachate by about 1.5 times greater than the similar sample which had been compacted with water.

TABLE VI
UNCONFINED COMPRESSION RESULTS (U C= UNCONFINED COMPRESSION)

B/Z (%)	U C (Water) (Kpa)		U C (Leachate) (Kpa)	
	7-day	28-day	7-day	28-day
5%	195.24	291.21	61.52	143.66
10%	229.83	230.2	136.68	206.9
20%	150.92	303.71	234.77	492.4

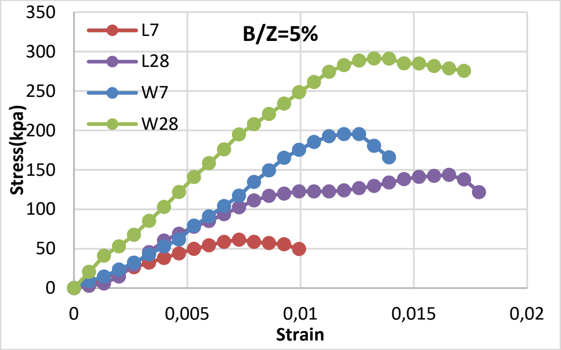

Fig. 4 Unconfined compression of B/Z=5% after 7 and 28 days

V. CONCLUSION

In this study, 12 samples were prepared to compare the effect of leachate presence on the unconfined compressive strength of soils containing bentonite and zeolite with the mixing rates of B/Z 5%-10% and 20%. Half of these specimens were compacted with optimum moisture content applied by water and the other half by leachate. The samples were all tested after 7-day and 28-day aging time.

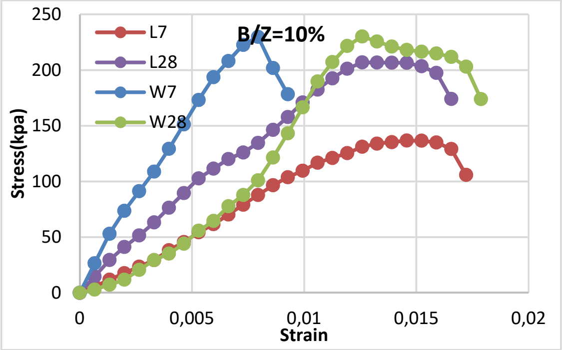

Fig. 5 Unconfined compression of B/Z=10% after 7 and 28 days

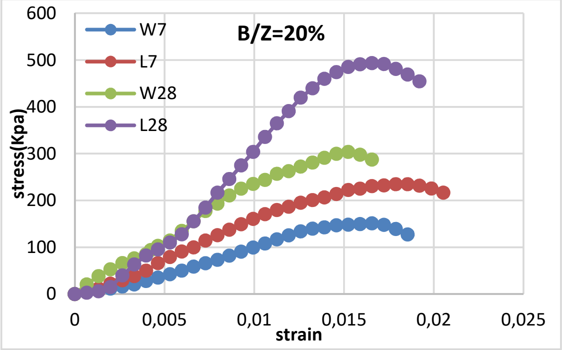

Fig. 6 Unconfined compression of B/Z=20% after 7 and 28 days

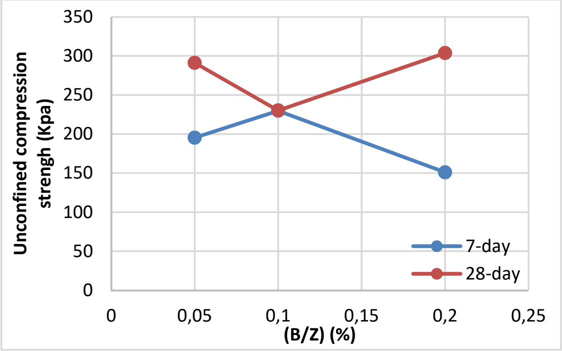

Fig. 7 Unconfined compression of variation mixing rates compacted with water

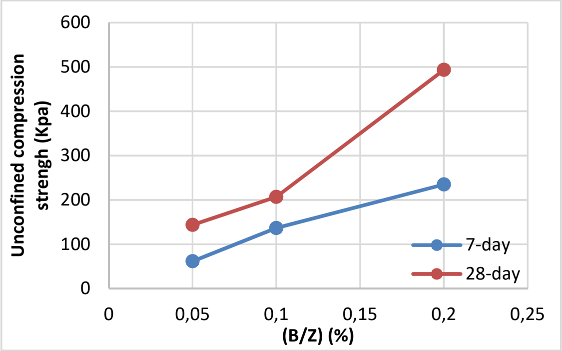

Fig. 8 Unconfined compression of variation mixing rates compacted with leachate

In general, the presence of leachate reduces the compressive strength of the specimens with the exception of the B/Z = 20% 28-day leachate compacted sample. Considering that under the contract, the minimum compressive strength of the layers of landfill liners is 200 kPa, all samples which compacted with water, after 28 days, show a good resistance and are reliable. But about samples compacted with leachate, the mixing rates B/Z of 10% and 20% can satisfy this minimum resistance after 28-day aging times.

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