The Effect of Colemanite and Ulexite Additives on the Shear Strength Behavior of Sand-Bentonite Mixtures Under High Temperature

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Introduction

The fossil fuels are expensive and contaminant for environment. For that reason, nuclear energy, energy piles and geothermal energy become more important in last decades. Energy structures directly connect to the soil and cause thermal heat changes on the underlying soils. Furthermore, there are thermal cyclics occur at soils which underlying under the heat storage systems, buried high voltage cables, CO2 sequestration plants. For that reason, the number of studies on the thermal behavior of soils under high temperatures and thermal cycles in-crease. These studies show that thermal cycles and high temperatures affect the hydraulic conductivity, volume change (compressibility-swelling) and shear strength properties of soils (Pusch et al. 1990, Abuel-Naga et al. 2006). The number of these studies are limited and generally focused on the one type of soil (clay, silt). Howev-er, generally bentonite-sand mixtures are used in landfill liners.

Boron is ranked 51st among the elements commonly found in the earth crust. Boron never appears as a free element in nature. Almost 230 types of boron minerals are known to be present in nature. Natural borates are used to define concentrated boron ores such as; tincal, colemanite, and ulexite. Boron is used in the industry for high temperature resistance, flexibility, lightness, power and ease of production. It increases the resistance to thermal shocks. Boron has an important role in the production of heat-resistant glassware and high-quality glass for use in electronics and space research as it significantly reduces heat expansion of the glasses, protects the glass against acid and scratches. Previous studies on the reaction of boron with clay structure have shown that the boron is held strongly by the aluminum or silicon tetrahedron portion in the clay structure (Gillott, 1987).

There is a need for thermally resistive and durable soil layers at the nuclear waste landfills and under the energy structure systems. In this study, it was tried to develop thermally resistive and more durable sand-bentonite mixtures by adding ulexite and colemanite. These boron admixtures are more expensive than sand, for that reason they were added to soil mixtures by 5 and 10%. The direct shear tests were conducted under the con-stant temperature (90□C) on the bentonite-sand-boron mixtures and the results were compared with the room temperature results.

Material Characterization and Methods

The bentonite samples were gathered from Eczacıbaşı Esan Company and it is Na-bentonite. The bentonite samples were oven dried (105°C), crushed and sieved through 0.425 mm. Grain size distribution, specific gravity, liquid and plastic limit of the samples were determined according to ASTM standards. According to the results the specific gravity and clay fraction values 2.73 and 79%, respectively. The liquid and plastic limit values of the samples were determined as 427% and 60.6%, respectively. The compaction characteristics of the sam-ples were determined according to ASTM standards and Standard Proctor effort was applied.

The direct shear test system was modified with silicone heat tapes in order to maintain constant heat during the tests. The bentonite-sand mixtures were compacted at their maximum dry unit weight and optimum water contents. The water in the box was heated and the water and sample temperature were controlled and recorded during the tests. The shear velocity was 0.25 mm/min. The results were compared with the test results which were performed under the room temperature.

Results and Discussions

The direct shear tests were performed under the room temperature and 90□C and the results were compared. The shear failure envelopes of the samples under room tempretaure and 90°C are given in Figure 1. The obtained internal friction angles and cohesion values were given in Table 1.

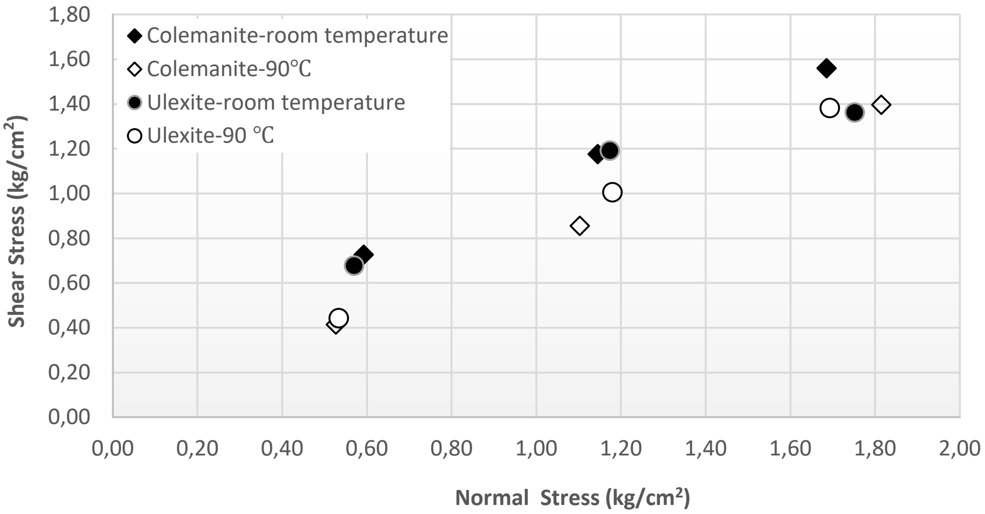

Figure 1: The shear failure envelopes in the presence of ulexite and colemanite

Table 1: The direct shear test results in the presence of ulexite and colemanite under room temperature and 90°C

Sample	Boron amount (%)	Boron type	Room Temperature		90℃ Temperature	
			ϕ (°)	c (kPa)	ϕ (°)	c (kPa)
10% bentonite	0	-	37.2	28.8	36.4	28.4
	5	Ulexite	38.2	22.8	37.2	5.7
		Colemanite	34.9	32.4	35.0	16.0
	10	Ulexite	30.2	39.3	39.1	2.1
		Colemanite	39.6	26.5	37.3	1.4
20% bentonite	0	-	36.2	34.3	34.9	45.3
	5	Ulexite	28.4	58.1	35.4	41.2
		Colemanite	32.2	41.0	39.1	25.1
	10	Ulexite	34.6	40.2	36.9	22.2
		Colemanite	35.2	32.6	33.6	46.8

The internal friction angle values and cohesion values were determined of the 10% and 20% bentonite-sand mixtures without ulexite and colemanite. The results have shown that, the ulexite and colemanite addition decreases the internal friction angles of the both 10% and 20% bentonite mixtures under the room temperature. However, when the temperature was increased to 90°C boron additives the internal friction angles were higher when compared with room temperature. Generally, the cohesion values were higher in the presence of ulexite and colemanite under room temperature. However, as temperature was increased to 90°C the cohesion values decreased for 10% bentonite while it increased for 20% bentonite mixtures. Generally, %10 addition of the ulexite and colemanite is more effective than 5% under high temperature. The boron addition increased the shear strength of bentonite-sand mixtures under high temperatures. It can be concluded that ulexite and cole-manite can be used as a temperature resistance increasing admixtures.

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