Symposium on Energy Geotechnics
Accelerating the energy transition
3-5 October 2023, Delft, the Netherlands

Peer-reviewed Conference Contribution

Compressibility behavior of colemanite added bentonite under short and long-term high temperature

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Introduction

The increasing energy demand and the limited fossil fuel resources make searching for new sustainable clean energy sources. In this regard, it is vital to use energy geo-structures as a renewable and clean energy source. The geo-structures are in direct contact with the soil and cause temperature changes throughout the soil mass.

Bentonite is considered suitable as an engineering barrier in deep geological disposal repositories for spent nuclear fuel, mainly because of its favorable swelling properties and extremely low permeability [1]. It was reported by many researchers that the engineering properties of clayey soils change at high temperatures [2,3]. Therefore, there is a need for soil materials that can maintain their long-term engineering properties under high temperatures. Borates are naturally occurring minerals. They can be found mainly in sediments and sedimentary rocks. The most commercially important boron minerals are tincalconite, colemanite, and ulexite [4].

In the present study, it was tried to improve the compressibility behavior of bentonite by adding colemanite under high temperature. The oedometer tests were performed under a constant temperature (80 ºC) on the bentonite-colemanite mixtures. In this context, samples exposed to short and long-term high temperature (80 ºC) were used and the results were compared with the room temperature results.

Material Characterization and Methods

The Ca-bentonite sample used which is activated with sodium bicarbonate. Colemanite was added to bentonite at a rate of 10% of the bentonite by dry weight. In this context, B10C sample represents a 10% colemanite added bentonite mixture. The liquid limits of bentonite and colemanite are 270% and 37%, respectively. The samples (smaller than 75 µm) were obtained by mixing the mixture powder with tap water at a water content of 1.5 times the pre-determined liquid limit value of the mixtures. The slurries were consolidated under a vertical pressure of 12.5 kPa for 14 days. Samples 70 mm in diameter and 19 mm in height were obtained by trimming. The samples were placed in oedometers for tests at room and high temperature (80 ºC). The experimental system was modified for high-temperature tests. The modified system consists of a conventional apparatus, a heat ring, a thermostat, and a water tank. Thus, by heating the cell water, the temperature of the sample was indirectly increased to 80 °C. For long-term experiments, samples were placed in thermal pools in clamped molds (constant volume). These molds were kept in the thermal pools under a constant temperature of 80 °C for 6 months. Then, the consolidation tests of these samples were performed at 80 °C.

Results and Discussions

The result of the consolidation tests of bentonite mixtures at 80 °C after being kept in the thermal pool for 6 months is given in Figure 1. For comparison, the test results at room temperature and 80 °C are also shown. The compression amount of bentonite increased with the increase in temperature, while the swelling amount decreased. The total compression deformation of the bentonite sample, which showed 53% compression at room temperature, reached 65% when the temperature was increased to 80 °C. However, swelling deformation decreased from 7% to 3% when the temperature was increased. When the volumetric deformation behavior of bentonite (NC) is examined, thermal contraction behavior at high temperature (90 °C) was reported [2]. In other words, the

DOI: https://doi.org/10.59490/seg23.2023.634

vertical compression amount of NC bentonite increases at elevated temperatures. In addition, since the structure of the clay deteriorated at high temperature and the deformations were permanent, it was an expected result that the rebound (swelling) behavior would decrease at high temperature.

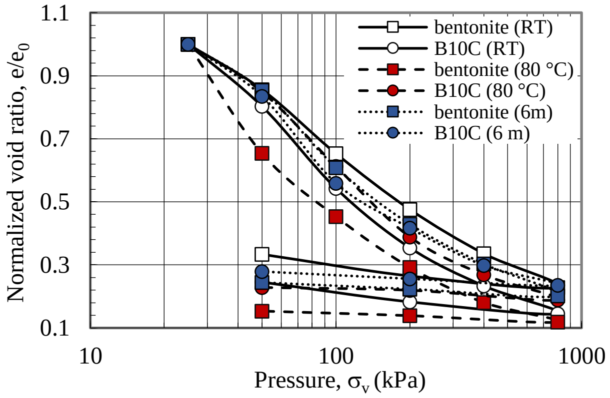

Figure 1: Void ratio-stress curves of colemanite-bentonite mixtures at room temperature and 80 °C.

There was a decrease in the amount of compression in the sample cured for 6 months, compared to 80 °C. However, although the compression amount of the 6-month cured sample decreased, the amount of compression still slightly increased compared to the room temperature. Compression-swelling deformation amounts of the samples cured for 6 months and tested at 80 °C are presented in Table 1 in detail. When the swelling behavior of additive-free bentonite was examined, increasing temperature decreased the rebound behavior of bentonite. In addition, the swelling amount of the sample cured for 6 months was determined to be almost the same as the sample at 80 °C. The reason for this was that the deformations that occurred at high temperatures were permanent.

Table 2: Total compression and swelling amounts of mixtures.

Sample	Room temperature				Short-term 80 °C			
	Compression (%)	Swelling (%)	Compression index (C_c)	Swelling index (C_s)	Compression (%)	Swelling (%)	Compression index (C_c)	Swelling index (C_s)
Ca-bentonite	53.27	7.24	2.46	1.92	65.36	2.89	2.16	0.25
B10C	42.02	4.93	1.65	0.30	53.27	2.67	2.23	0.35

Sample	Short-term 80 °C				Long-term 80 °C			
	Compression (%)	Swelling (%)	Compression index (C_c)	Swelling index (C_s)	Compression (%)	Swelling (%)	Compression index (C_c)	Swelling index (C_s)
Ca-bentonite	65.36	2.89	2.16	0.25	57.84	3.08	2.60	0.25
B10C	53.27	2.67	2.23	0.35	54.86	3.12	2.22	0.25

When the temperature of the colemanite-added bentonite mixtures was increased, the amount of deformation increased. However, the amount of deformation of additive-free bentonite decreased with the colemanite addition at 80 °C, and returned to its room temperature value (approximately 53%). In other words, the addition of colemanite had a positive effect by reducing the deformation amount of bentonite at both short and long term high temperatures. The short and long term effects of 80 °C temperature on colemanite added samples were almost the same.

Contributor statement

Sukran Gizem Alpaydin: Experimental investigation, Writing – original draft. Yusuf Batuge: Experimental investigation, Yeliz Yukselen-Aksoy: Methodology, Writing – review & editing, Funding acquisition, Project administration.

Acknowledgments

This study is supported by The Scientific and Technological Research Council of Turkey (TÜBİTAK) (Grant no. 120M470). The authors are grateful for this support.

References

[1] Yong, R.N., Boonsinsuk, P., & Wong, G. (1986). Formulation of backfill material for a nuclear fuel waste disposal vault. *Canadian Geotechnical Journal*, 23(2), 216-228
[2] Abuel-Naga, H.M., Bergado, D.T., Ramana, G.V., Grino, L., Rujivipat, P., & Thet, Y. (2006) Experimental evaluation of engineering behavior of soft Bangkok clay under elevated temperature. *Journal of Geotechnical and Geoenvironmental Engineering*, 132, 902–910
[3] Pusch, R., Karlnland, O., & Hokmark, H. (1990) *General Microstructural Model for Qualitative and Quantitative Studies of Smectite Clays*. SKB Technical Report 90-43, Stockholm, Sweden.
[4] Helvaci., C. (2005). Borates. *Encyclopedia Geology*, (2nd Ed., pp. 510–522)