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Effect of temperature on the compressibility behavior of glass fiber-bentonite mixture

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Storage of nuclear wastes in deep geological disposals is an important concept in terms of energy geotechnics. With its low permeability and high swelling potential, bentonite clay is preferred in high level waste (HLW) repositories. The long-term heat released by nuclear waste causes changes in the structure of the buffer material bentonite clay. Hence, it is critical to determine and improve the short and long term engineering parameters of bentonite clay under high temperature. Various fiber materials are used to improve the mechanical properties of the clayey soils [1,2]. In this study, it was investigated short-term and long-term compressibility behavior of bentonite with glass fiber additive under high temperature.

The bentonite used in the study was activated Ca-bentonite. Bentonite was in powder form and all of its particles were smaller than 75 µm. The liquid and plastic limit values of the Ca-bentonite is 270% and 63%, respectively. The specific gravity is 2.60 and the natural water content is 7%. Glass fiber is a silica-based material obtained by melting glass, passing it through thin wires and cutting it. It has high tensile strength and modulus of elasticity and is resistant to heat. The glass fibers used in this study were3 mm long, 13 microns in diameter, and have a specific gravity of 2.60. To examine the compressibility behavior, one-dimensional consolidation tests were conducted on the samples according to ASTM D2435 (2020). Glass fiber was added corresponding to 1% by dry weight of bentonite. The liquid limit value of the bentonite-glass fiber mixture was found to be 265%. Bentonite and bentonite-glass fiber mixtures were prepared at a water content of 1.5 times their liquid limit values. Tap water was used in the tests. For a uniform moisture distribution, the samples were kept for 24 h in a closed container. All samples were placed in a cell made of plexiglass with a height of 3 cm on a rigid steel ring with a diameter of 7 cm and a height of 1.9 cm and kept under seating pressure of 12.25 kPa for 14 days. At the end of 14 days, the sample in the steel ring was placed in the oedometer cell. The oedometer cell modified for high temperature. The heat coil, thermostat probe and thermocouple placed inside the oedometer cell in order to maintain constant 80 °C temperature inside the cell. The temperature was increased by 5 °C per hour to prevent excess pore water formation. For long-term behavior, after the samples were subjected to seating pressure for 14 days, samples were cured for 6 months in thermal water pools at 80 °C. Samples were kept in a clamped mold inside the thermal pool to avoid any volume change.The tests were performed under three different thermal conditions; under room temperature, high temperature (80 °C) and curing in a heat pool at constant temperature of 80 °C for 6 months.

The stress-strain graphs of the samples are shown in Figure 1. Since the e-logp graphs of high plasticity clays are non-linear, different compression index and swell index values of each loading level occur. Compression and swelling moduli values obtained from the stress-strain plot were used to explain the compressibility behavior. Based on the initial conditions, all samples are fully saturated. Initial dry densities of all samples varied between 2.64-2.94 kN/m3. Initial and final void ratio values for additive-free bentonite samples were found to be 7.68 to 2.00 for the room temperature sample, 8.02 to 1.15 for the short term 80 °C sample, and 8.49 to 1.68 for the long term 80 °C sample. In bentonite-glass fiber mixtures, 8.78 and 2.83 in the room temperature sample, 8.01 and 2.40 in the short-term 80 °C sample, 7.33 and 1.68 in the long-term 80 °C sample.The compression deformation moduli were determined when the applied stress is increased from 24.5 to 784.5 kPa and the swelling deformation moduli were determined when

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the stress was decreased from 784.5 to 49 kPa. Compression and swelling moduli values for each experiment are presented in Table-1. In the presence of 80 °C, the compressibility of additive-free bentonite increased while swelling (rebound) decreased. This result is in agreement with the literature [3]. When the long-term and short-term behavior of bentonite were compared, an improvement was observed in both compressibility and rebound behavior. Decrease in the rebound behavior of bentonite under high temperature can be explained by the decrease in water retention capacity and weakening of the bonds of water molecules with clay minerals. In the presence of 1% glass fiber, it was observed that the plastic deformation increased in different thermal conditions. In the presence of 1% glass fiber, it was observed that the plastic deformation increased in three different thermal conditions. Since glass fiber occupies less space than bentonite particles in terms of volume, it increased the compressibility. However, it was seen an improvement in total rebound behavior by reducing the permanent deformation of bentonite.

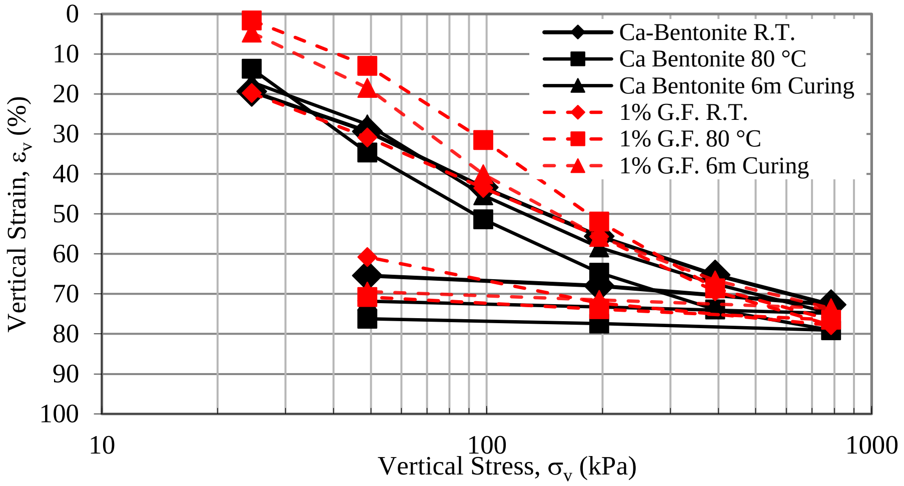

Figure 1. Stress-strain graphs of the samples (RT:Room Temperature, GF: Glass Fiber)

Table 1:The results of the tests

	Room Temperature		Short-Term High Temperature (80 °C)		Long-Term High Temperature (80 °C)	
	Compression moduli (%)	Swelling moduli (%)	Compression moduli (%)	Swelling moduli (%)	Compression moduli (%)	Swelling moduli (%)
Bentonite	53.28	7.24	65.36	2.89	57.84	3.08
1% Glass -Bentonite	58.03	17.03	74.90	5.70	68.93	4.18

Contributor Statement

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

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