Time-Dependent Effects and Microscopic Mechanisms of Thermal Aging on Engineering Barrier Performance of Bentonite Buffer Materials at Elevated Temperatures: Postprint

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Abstract

The thermal aging time-dependency of the engineering barrier performance of bentonite buffer materials under high-temperature conditions is of great significance for evaluating the long-term operational safety of deep geological repositories for nuclear waste. High-temperature pretreatment was conducted on MX-80 bentonite powder at different thermal aging times (t=0, 15, 30, 60, 90, 120d) to investigate the evolution law of engineering barrier performance parameters (thermal conductivity coefficient λ, constant-volume swelling pressure Ps, unconfined compressive strength qu, specific surface area SSA) of the thermally aged bentonite specimens with thermal aging time t; based on tests such as X-ray diffraction, thermogravimetric analysis, and scanning electron microscopy, the changing trends of mineral composition, adsorbed water, and microstructure in MX80 bentonite after high-temperature thermal aging were investigated, revealing from a microscopic perspective the influence mechanism of thermal aging time on the engineering barrier performance of bentonite buffer materials under high-temperature conditions. The test results indicate that: (1) The engineering barrier performance of MX80 bentonite decreases with increasing thermal aging time t, exhibiting a significant time effect, which mainly occurs within 0~15d, with a decay rate of 56.89~68.51%; (2) During the high-temperature thermal aging process, montmorillonite minerals in the bentonite partially transform into paragonite, adsorbed water in the soil is lost, and the soil microstructure evolves, with these microscopic changes showing good consistency with the thermal aging time-dependency of its engineering barrier performance; (3) Under high-temperature conditions, the engineering barrier performance parameters of MX80 bentonite exhibit a linear positive correlation with its montmorillonite content Cm and adsorbed water content w, indicating that mineral composition transformation, changes in adsorbed water, and evolution of soil microstructure are the essential causes of the thermal aging time-dependency of its engineering barrier performance.

Full Text

Influence of Thermal Ageing Time on the Barrier Properties of Bentonite Buffer Materials at High Temperature Conditions and Its Micro-Mechanism

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Abstract

The time-dependent effects of thermal ageing on the engineering barrier properties of bentonite buffer materials under high-temperature conditions are critical for assessing the long-term operational safety of deep geological repositories for nuclear waste. MX-80 bentonite powder was subjected to high-temperature pretreatment for varying thermal ageing durations (t = 0, 15, 30, 60, 90, 120 days) to investigate the evolution of key engineering barrier parameters—including thermal conductivity coefficient (λ), constant volume swelling pressure (Ps), unconfined compressive strength (qu), and specific surface area (SSA)—as a function of ageing time. Microstructural changes in the thermally aged MX-80 bentonite were characterized using X-ray diffraction, thermogravimetric analysis, and scanning electron microscopy to examine variations in mineral composition, adsorbed water content, and microstructural features, thereby revealing the micro-mechanisms through which thermal ageing time influences bentonite buffer performance at elevated temperatures.

The experimental results indicate that: (1) All engineering barrier properties of MX-80 bentonite decrease monotonically with increasing thermal ageing time, exhibiting pronounced time effects that predominantly occur within the initial 0–15 day period with decay rates of 56.89–68.51%; (2) The high-temperature ageing process triggers partial transformation of montmorillonite to paragonite, desorption of pore water, and microstructural evolution, which collectively show good consistency with the temporal degradation of engineering barrier properties; and (3) Under high-temperature conditions, the engineering barrier parameters of MX-80 bentonite exhibit a linear positive correlation with both montmorillonite content (Cm) and adsorbed water content (w), demonstrating that mineralogical transformation, changes in adsorbed water, and microstructural evolution constitute the fundamental mechanisms underlying the time-dependent degradation of bentonite barrier properties during thermal ageing.

Keywords: bentonite buffer material; barrier properties; thermal ageing time;

high temperature state; micro-mechanism

Note: Figure translations are in progress. See original paper for figures.