Postprint: Study on the Variation of Bound Water Content with Temperature in Saturated Clay

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Abstract

Bound water in saturated clay, due to its unique electrical double-layer structure, plays a critical role in controlling the macroscopic thermo-mechanical behavior of clay. This paper discusses the mechanism of bound water variation with temperature in saturated clay. Comparative analysis of research findings from various scholars reveals that slight variations in bound water density can lead to substantial differences in the calculated bound water content, thus influencing the analysis of thermal response patterns. Additionally, this study examines the applicability and limitations of the isothermal adsorption method, pointing out that this method essentially simulates unsaturated conditions, its measured bound water content is often lower than the true level under saturated conditions, and it is difficult to distinguish bound water from free water at high humidity. To investigate the trend of bound water content variation with temperature, this study employs an improved specific gravity test to measure changes in specific gravity as temperature increases from 20 °C to 50 °C, combines theoretical calculations to derive the evolution law of bound water content, and proposes that bound water displays a typical "slow-fast-slow" attenuation characteristic with increasing temperature. Research demonstrates that this thermal response of bound water essentially stems from variations in electrical double-layer thickness and reconstruction of the particle-water interface energy structure. In engineering applications, accurate characterization of the temperature dependence of bound water is essential for predicting volume and strength changes in clay, and can substantially improve the safety and reliability of underground energy structures and geothermal systems under thermo-mechanical coupling conditions.

Full Text

Study on the Temperature-Dependent Variation of Bound Water Content in Saturated Clays

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Abstract

Bound water in saturated clays, characterized by its unique electric double-layer structure, plays a critical role in controlling the macroscopic thermo-mechanical behavior of clayey soils. This paper investigates the mechanisms governing temperature-dependent variations of bound water content in saturated clays. A comparative analysis of previous studies reveals that minor discrepancies in assumed bound water density can lead to significant differences in calculated bound water content, thereby substantially influencing the interpretation of thermal response patterns. Furthermore, this study examines the applicability and limitations of the isothermal adsorption method, noting that this technique essentially simulates unsaturated conditions. Consequently, measured bound water contents often underestimate true values under saturated conditions, and the method struggles to distinguish bound water from free water at high humidity levels.

To address these challenges, this research employs improved specific gravity tests to measure variations in specific gravity as temperature increases from 20°C to 50°C. Combined with theoretical calculations, this approach enables characterization of the evolution of bound water content. The results demonstrate that bound water exhibits a characteristic "slow-fast-slow" attenuation pattern with increasing temperature. This thermal response fundamentally arises from changes in electric double-layer thickness and reconstruction of the particle-water interfacial energy structure.

In engineering practice, accurate characterization of the temperature dependence of bound water is essential for predicting clay volume and strength changes, significantly enhancing the safety and reliability of underground energy structures and geothermal systems operating under thermo-mechanical coupling conditions.

Keywords: saturated clays; bound water content; bound water density; temperature; thermo-mechanical coupling

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