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A Numerical Study of Chemical Compatibility of GCLs

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Abstract: A series of COMSOL numerical models were established to study the chemical compatibility of GCLs (geosynthetic clay liner). The effect of chemistry on the mesoscopic structure and the hydraulic conductivity of GCLs was investigated. The factors, including the initial mobile porosity, the swelling ratio, the pore size, and the ionic strength, were discussed as well. The mesoscopic mechanism of the physical and chemical processes of GCLs was explored by the COMSOL models. The hypothesis that the final mobile porosity and the final pore size are the key factors of the hydraulic conductivity of GCLs was proven by the simulation. Meanwhile, when the ionic strength increased from low to medium, the changes in pore size, mobile porosity, and hydraulic conductivity were obvious. However, when the ionic strength increased from medium to high, the changes of these parameters tended to be gentle, and the changes in hydraulic conductivity were not obvious. Moreover, a theoretical model considering the effect of the initial particle size, the initial mobile porosity, and the ionic strength was developed to predict the hydraulic conductivity of GCLs in a chemical solution. This theoretical model was verified by experimental data. A good agreement was obtained.

Keywords: chemistry compatibility; COMSOL; mesoscopic mechanism; GCLs; hydraulic performance

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1. Introduction

Geosynthetic clay liners (GCLs) are factory-manufactured hydraulic barriers consisting of a thin layer of sodium bentonite (Na-B) clay (approximately 3–5 kg/m^2) sandwiched between two geotextiles, which are bonded by needle punching or stitching [1]. GCLs are common elements in waste containment facilities because of their low hydraulic conductivity to deionize water (DIW, typically <10^{-10} m/s) [1–5].

Chemical compatibility is generally defined as the degree of change in the engineering properties of the barrier due to its exposure to contaminants [6]. Jo [7] and Kolstad [3] demonstrated that ionic strength is the main variable affecting the hydraulic conductivity of bentonite in GCLs. However, the mesoscopic structure effect of a chemical solution on the permeability of GCLs is difficult to be observed in the experiments. Many kinds of research have shown that the hydraulic conductivity of GCLs depends on the mobile porosity (or the mobile water) [8–12], which is sensitive to the chemical solution [13–15]. However, a direct translation of X-ray data to GCLs is difficult because GCLs are multi-component systems [16–18]. Meanwhile, the porosity estimates for GCLs depend on subtle interactions within the pore spaces governed by the leachate flux process [19–21]. At present, few studies have focused on the mesoscopic mechanism of hydration and swelling under the effect of inorganic chemical solutions. Therefore, the influence of chemistry on the mesoscopic structure and the permeability of GCLs needs to be assessed [22,23].

The finite-element COMSOL Multiphysics software is very convenient to simulate and analyze the infiltration process of GCLs [24–26]. In this work, we will establish a