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Consolidation enhanced membrane behavior of a geosynthetic clay liner

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ABSTRACT

Semipermeable membrane behavior in clays refers to the ability of clays to restrict the migration of solutes. Thus, membrane behavior represents a potential benefit to the containment function of clay barriers used for hydraulic containment applications. In this regard, the potential influence of consolidation effective stress, σ', on the membrane behavior of a geosynthetic clay liner (GCL) containing sodium bentonite was evaluated in the laboratory by establishing differences in salt (KCl) concentrations ranging from 3.9 to 47 mM across specimens of the GCL in a flexible-wall cell under closed-system boundary conditions. The membrane behavior exhibited by the GCL was enhanced via consolidation such that an increase in σ' from 34.5 kPa (5 psi) to 241 kPa (35 psi) correlated with an increase in membrane efficiency from 0.015 (1.5%) to 0.784 (78.4%), respectively. The membrane efficiencies measured in this study at σ' of 172 kPa (25 psi) and 241 kPa (35 psi) were similar to those previously reported for the same GCL using a rigid-wall cell but at unknown states of stress. The practical significance of the results is illustrated in the form of an analysis showing a reduction in liquid flux across the GCL with increasing membrane efficiency.

1. Introduction

Geosynthetic clay liners (GCLs) are manufactured hydraulic barriers typically consisting of a thin layer (~5–15 mm) of natural or treated bentonite (sodium or calcium) sandwiched between two geotextiles and/or glued to a geomembrane (Daniel et al., 1993; Koerner and Daniel, 1995; Bouazza, 2002; Koerner, 2005). The primary differences among GCLs are the mineralogy (e.g., content of montmorillonite) and form (e.g., powdery versus granular) of bentonite used in the GCL, the type of geotextile (e.g., woven versus non-woven), the hydration condition (e.g., non-prehydrated versus prehydrated), and the method of bonding the component materials together (e.g., Daniel et al., 1993; Koerner and Daniel, 1995; Shackelford et al., 2000; Lee and Shackelford, 2005).

Prefabricated GCLs are used extensively as barriers or components of barriers designed and constructed for a wide variety of hydraulic containment applications, including landfill liners and covers, surface impoundments (e.g., ponds and lakes, aeration lagoons, fly ash lagoons, and other surface impoundments), canals, storage tanks, and secondary containment of above-grade fuel storage tanks (e.g., Koerner, 2005; Benson et al., 2007, 2010; Bouazza and Vangpaisal, 2007a,b; Lake et al., 2007; Abduel-Naga and Bouazza, 2009, 2010; Guyonnet et al., 2009; Dickinson and Brachman, 2010; Dickinson et al., 2010; Hornsey et al., 2010; Kang and Shackelford, 2010; Lange et al., 2007, 2009, 2010; Mendes et al., 2010a,b; Rossin-Poumier et al., 2010, 2011; Scalia and Benson 2010, 2011; Shackelford et al., 2010). The use of GCLs for hydraulic containment applications has increased over the past decade due to several advantages, including relatively easy installation, resistance to freezing/thawing and wetting/drying cycles (i.e., in the absence of multivalent for monovalent cation exchange), low cost, and low hydraulic conductivity to water (i.e., $<10^{-10}$ m/s) (Estornell and Daniel, 1992; Daniel et al., 1993; Koerner and Daniel, 1995; Boardman and Daniel, 1996; Hewitt and Daniel, 1997; Lee and Shackelford, 2005; Meer and Benson, 2007; Benson and Meer, 2009). In addition, GCLs also have been found to behave as semipermeable membranes, thereby restricting the migration of solutes (Malusis and Shackelford, 2002a,b). Since one purpose of clay barriers used in hydraulic containment applications is to restrict the migration of aqueous miscible contaminants (i.e., solutes), the existence of membrane behavior in GCLs represents a potentially significant beneficial aspect in the use of GCLs for such applications.

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