

**Wednesday, 3/15/2017**

**9:45–11:15 a.m.**

**Bentonite Barrier Materials**

Chairs: Joseph Scalia, Colorado State University; Kristin Sample-Lord, Villanova University

**Effect of Anion Ratio on Hydraulic Conductivity of a Bentonite-Polymer Geosynthetic Clay Liner**

*Kuo Tian and Craig H. Benson, University of Virginia; William J Likos, University of Wisconsin–Madison*

Hydraulic conductivity and swell index tests were conducted on a commercially available geosynthetic clay liner (GCL) containing a dry-blended bentonite-polymer (B-P) mixture using solutions with a single monovalent cation ( $\text{Na}^+$ ) and varying anion ratio,  $R$ , defined as the molar concentration ratio of  $\text{Cl}^-$  to  $\text{SO}_4^{2-}$ .  $\text{Na}^+$  solutions with pure  $\text{Cl}^-$  or  $\text{SO}_4^{2-}$  and with anion ratios of 5 and 20 were used as permeant liquids. Swell index of the B-P in 300 mM  $\text{Na}^+$  solutions was independent of anion ratio ( $\text{SI} \approx 22.5 \text{ mL/2 g}$  for all solutions). However, hydraulic conductivity of the B-P GCL permeated with  $\text{NaCl}$  was approximately three orders of magnitude greater than the hydraulic conductivity to  $\text{Na}_2\text{SO}_4$ . Comparative tests were conducted on a conventional GCL with sodium-bentonite (Na-B) with 100 and 300 mM  $\text{Na}^+$  solutions with pure  $\text{SO}_4^{2-}$  and pure  $\text{Cl}^-$  as anions. Hydraulic conductivity of the Na-B GCL was unaffected by anion species ( $1.5 \times 10^{-11} \text{ m/s}$  for 100 mM  $\text{NaCl}$ ,  $2.1 \times 10^{-11} \text{ m/s}$  for 50 mM  $\text{Na}_2\text{SO}_4$ ). Sensitivity of the B-P GCL to anion species is attributed to collapse of the polymer as the  $\text{Cl}^-$  concentration increases, which opens intergranular pores and results in higher hydraulic conductivity.

**Compatibility of Phosphate-amended Ca-bentonite Soil Backfill with Groundwater Impacted by Coal Ash Leachate**

*Yuling Yang, Yanjun Du, and Ridong Fan, Southeast University; Krishna Reddy, University of Illinois at Chicago*

The compatibility of phosphate-amended bentonite soil backfill with coal combustion residual impacted groundwater is investigated in this study. A series of laboratory experiments including free swell, liquid limit, flexible wall permeability, and consolidation tests using deionized/tap water or coal combustion residual impacted groundwater are conducted to explore chemical compatibility of the amended soil-bentonite backfill. The results indicate that the contaminated groundwater has different impacts on various engineering properties of the backfill materials. For example, free swell index of the amended bentonite and liquid limit of the backfill materials tested with contaminated groundwater are 29% and 3% lower than those tested with deionized water. The CCR groundwater has little effects on hydraulic conductivity, and the hydraulic conductivities obtained from both tap water and CCR groundwater are lower than  $10^{-9} \text{ m/s}$ . The compression and swell indices for backfill in contaminated groundwater are 17% and 47% lower than those in the tap water scenario.

**Diffusion of Calcium Chloride through Polymerized Bentonite**

*Kristin M. Sample-Lord and Shan Tong, Villanova University; Gretchen L. Bohnhoff, University of Wisconsin–Platteville*

Sodium bentonite (Na-bentonite) commonly is used in chemical containment barriers to limit transport of contaminants into the environment. The potential for decreased performance of Na-bentonite barriers due to cation exchange with multivalent species (chemical incompatibility) has led to the development of chemically modified bentonites (CMBs), such as polymer-modified bentonites, for

improved chemical resistance. Results of experimental research to date generally indicate that CMBs may maintain values of hydraulic conductivity,  $k$ , less than  $10^{-9}$  m/s, even when permeated with solutions with high ionic strength and concentrations of multivalent species (e.g., 500 mM calcium chloride ( $\text{CaCl}_2$ )). However, there is limited data available regarding diffusion through CMBs, even though diffusion has been shown to be a significant to dominant contaminant transport mechanism in clays when  $k$  is less than  $10^{-9}$  m/s. In this paper, results are presented for diffusion of chloride ( $\text{Cl}^-$ ) through a bentonite-polymer composite (BPC) for source concentrations of  $\text{CaCl}_2$  ranging from 0.005 M to 0.1 M. Effective diffusion coefficients ( $D^*$ ) for  $\text{Cl}^-$  through BPC were measured using a multistage through-diffusion method as well as a single-stage, dialysis-leaching test (DLT) method. The values of  $D^*$  for  $\text{Cl}^-$  increased from  $3.3 \times 10^{-11}$  m<sup>2</sup>/s to  $3.5 \times 10^{-10}$  m<sup>2</sup>/s as the average  $\text{Cl}^-$  concentration in the BPC increased from 0.005 M to 0.173 M. In addition, there generally was good agreement between the results of the two test methods over the range of  $D^*$  evaluated, despite significant differences in the procedures and test durations (e.g., > 2 months for through-diffusion test, 7–10 days for DLT). The results of the study are compared with available literature for diffusion in Na-bentonite and other CMBs, and recommendations for future research are provided.

### **Water Vapor Sorption of Bentonite/Polymer Mixtures Contacted with Aggressive Leachates**

*Idil Deniz and William J. Likos, University of Wisconsin–Madison; Jiannan Chen, Southwest Jiaotong University; Craig H. Benson, University of Virginia*

Water vapor sorption was investigated as an alternative screening test for chemical compatibility of geosynthetic clay liners (GCLs) exposed to aggressive leachates. Water vapor sorption isotherms for sodium bentonite (Na-B) and a bentonite-polymer (B-P) mixture sampled from commercially available GCLs were measured before and after exposing the materials to synthetic coal combustion product (CCP) leachates and other solutions. Differences in the isotherms were quantified using the Freundlich isotherm ( $C$ ) parameter. Systematic relationships were observed between the  $C$  parameter and hydraulic conductivity of the GCLs to the leachates, suggesting that water vapor sorption has potential application as rapid screening method for assessing chemical compatibility of GCLs contacted with aggressive solutions. Water vapor sorption testing was also shown to have potential application for quantitatively estimating polymer content of B-P GCLs.

### **Interface Shear Strength of a Bentonite/Polymer Geosynthetic Clay Liner and Textured Geomembrane**

*Jiannan Chen, Southwest Jiaotong University; Craig H. Benson, University of Virginia; William J. Likos and Tuncer B. Edil, University of Wisconsin–Madison*

Interface shear strength was investigated between a bentonite-polymer (B-P) geosynthetic clay liner (GCL) and a 1.5-mm textured high-density polyethylene (HDPE) geomembrane (GM). Comparative tests were conducted with a conventional GCL containing sodium bentonite. All tests were conducted to a maximum displacement of 50 mm under normal stresses of 20, 100, 250, and 400 kPa. Interfaces with the B-P GCL had lower peak shear strength than interfaces with the conventional GCL under the same normal stress. The interface strength envelope for the B-P GCL was highly non-linear with lower shear strengths occurring at 400 kPa relative to those at 250 kPa, suggesting that the mechanism controlling shear strength changes with normal stress. Extrusion of polymer hydrogel into the GCL-GM interface was identified as the likely cause for lower interface shear strength and the non-linear strength envelope for interfaces with the B-P GCL.

### **Effect of Backpressure Saturation on Hydraulic Conductivity of GCLs**

*Joel Conzelmann, Joseph Scalia, and Charles Shackelford, Colorado State University*

The sensitivity of laboratory measured hydraulic conductivity,  $k$ , to backpressure saturation is investigated for a fiber reinforced GCL containing natural sodium bentonite (Na-B GCL) and a non-reinforced GCL containing a polymer modified bentonite. Hydraulic conductivity tests were performed using a synthetic soil pore water (ionic strength,  $I = 4$  mM, ratio of monovalent-to-divalent cations,  $RMD = 0.22$  mM<sup>1/2</sup>), and a synthetic gold pregnant leach solution (PLS;  $I = 42$  mM,  $RMD = 11$  mM<sup>1/2</sup>). Both GCLs were permeated by two methods under matching average effective stresses (27.6 kPa) and hydraulic gradients (160-200) following the ASTM D6766-12 default method (average pore water pressure = 524 kPa) and following ASTM D6766-12 but without backpressure saturation (average pore-water pressure = 6.9 kPa) or permeant interface devices. Both methods resulted in complete saturation of the GCL specimens by the termination of permeation, i.e., backpressure saturation was not necessary to attain saturation. Measured values of  $k$  were similar for both test methods for the GCL containing polymer-modified bentonite, but resulted in 50 to 100 times higher  $k$  for the Na-B GCL permeated without backpressure saturation relative to the ASTM D6766-12 default method. Flow through Na-B GCLs permeated without backpressure saturation (i.e., Na-B GCLs with higher  $k$ ) was visually observed to occur through needle-punching fiber bundles.