DISCUSSION OF TWO RESEARCH PAPERS ON GCL PERFORMANCE IN CONTAMINATED LIQUIDS

Introduction

Two important technical papers have been published (references below) regarding the chemical compatibility and hydraulic performance of GCLs upon exposure to various contaminated liquids. The papers present the results of recent laboratory studies, which suggest that GCLs used in cover applications can be damaged by the effects of wet-dry cycling in the presence of pore waters rich in calcium and magnesium ions. The purpose of this discussion is to summarize and interpret these results with respect to their relevance and applicability in real-world GCL applications.

Research Descriptions

In the first paper, *"Effect of Wet-Dry Cycling on Swelling and Hydraulic Conductivity of GCLs,"* by L. Lin and C.H. Benson (2000), tests were performed to determine whether the performance of a GCL could be degraded by the combined effects of wet-dry cycling and permeation with a calcium chloride solution. GCL samples were exposed to these two conditions both independently and in combination. Atterberg Limits and bentonite swell values were measured, along with hydraulic conductivity values after each cycle of exposure. It should be noted that drying of the GCL specimens was achieved by air-drying them at zero confining stress until they achieved constant mass. Swell testing was performed in accordance with GRI GCL-1, which differs from the commonly practiced method in ASTM D5890. Permeability testing was performed using GRI GCL-2 with a confining stress of 2.5 psi (17.5 kPa) and a hydraulic gradient of 80.

In the second paper, *"Hydraulic Conductivity and Swelling of Nonprehydrated GCLs Permeated with Single-Species Salt Solutions,"* by H.Y. Jo et al (2001), GCL samples were exposed to a variety of salt solutions such as sodium chloride (NaCl), potassium chloride (KCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), and others. Testing was performed at various concentrations of these solutions, with bentonite swell and hydraulic conductivity evaluated as a function of ion valence, ion size (hydrated radius), and pH. As stated in the paper title, fresh water prehydration was not performed prior to chemical exposure.

Results and Conclusions

Lin and Benson (2000)

The experiments demonstrated that the hydraulic performance of the GCL could be degraded upon exposure to certain salt solutions (such as $CaCl_2$ and $MgCl_2$), in conjunction with wet-dry cycling. It was found that desiccation cracks formed as a result of this cycling which did not heal as the GCL hydrated. This was attributed to a reduction in the swelling capacity of the GCL caused by the exchange of calcium ions for natural sodium ions in the bentonite. In contrast, a specimen continuously permeated with a calcium chloride solution and not subjected to multiple wet-dry cycles, retained its low hydraulic conductivity of ~$1x10^{-9}$ cm/sec, even after being permeated for 10 months. Therefore, neither wet-dry cycling nor calcium exposure alone appears to be sufficient to cause a permeability increase (see TR-215 regarding GCL wet-dry cycling with tap water). Only when both of these factors were combined did the GCLs exhibit increased permeability.

It is also important to note that during wet-dry cycling, the GCL samples were air-dried without confining stress. The GCL will likely be less susceptible to desiccation and subsequent ion exchange under the confining pressure of cover soil, or the protection of an overlying geomembrane. Confining pressure would also be expected to reduce the amount of cracking that occurs if moisture is drawn out of the GCL. More work is needed to determine the field conditions under which desiccation occurs so that proper levels of protective cover, or a protective geomembrane, can be specified.

The practical implication of this study is that GCLs should be used with care in situations where ion exchange and desiccation are expected to occur (e.g., landfill caps). The GCL should be covered with a geomembrane, so that the bentonite would be less likely to become desiccated and to undergo ion exchange reactions. This system will allow a low hydraulic conductivity to be maintained in the long term.

Jo et al (2001)
The experiments showed that solutions with higher cation concentrations and cation valences tended to result in lower swell and higher hydraulic conductivity. These findings suggest that free swell could be a good indicator of compatibility (for more on the topic of surrogate compatibility tests, please see TR-252). The baseline hydraulic testing performed with the nonprehydrated GCL specimens would likely be applicable in situations where the GCL is not properly hydrated before being exposed to contaminated permeants. Because GCLs have been shown to hydrate through precipitation and subgrade moisture absorption (see TR-222), the GCL would become hydrated with contaminated solutions only if it is installed as the upper clay component of a double composite landfill liner, or if it is installed on an especially dry subgrade. Nevertheless, the relationships observed between permeant pH, ion size, and permeant concentration could serve as useful criteria for identifying compatibility concerns for projects where saline permeants are expected.

References

Lin, L. C., and C. H. Benson (2000) "Effect of Wet-Dry Cycling and Hydraulic Conductivity of GCLs," *Journal of Geotechnical and Geoenvironmental Engineering,* January 2000, pp. 40-49.

Jo, H. Y., Katsumi, T., Benson, C. H., and T. B. Edil (2001) "Hydraulic Conductivity and Swelling of Nonprehydrated GCLs Permeated with Single-Species Salt Solutions," *Journal of Geotechnical and Geoenvironmental Engineering,* July 2001, pp. 557-567.