Compatibility of Geosynthetic Clay Liners with Organic and Inorganic Permeants

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ABSTRACT: Geosynthetic clay liners (GCLs) are increasingly used as hydraulic barriers in the construction of landfills and holding ponds. The low hydraulic conductivity of GCLs, the ease of placement, their resistance to freeze-thaw and desiccation deterioration, as well as their ability to heal minor manufacturing or placement defects make them well suited for these applications. However, the incompatibility between a GCL and a given permeant may adversely affect the permeability of the GCL, and thus, may reduce the GCL's ability to act as a hydraulic barrier against the migration of the permeant.

The paper briefly presents several specific procedures which should be followed when performing permeability/compatibility testing on GCLs. Results of several compatibility studies are also presented where organic compounds as well as an aqueous solution containing mainly inorganic compounds were used as permeating fluids.

1. INTRODUCTION

A geosynthetic clay liner (GCL) is a composite material consisting of bentonite clay sandwiched between two backing geotextiles, or bentonite clay affixed to a geomembrane backing. Eith et al. (1991) provide a brief review of the presently available GCL products (i.e., Bentofix, Bentomat, Claymax and Gundseal). The low permeability of GCLs, typically less than 1E-9 cm/sec, combined with their ease of placement and resistance to freeze-thaw and desiccation deterioration make them ideal for use as hydraulic barriers. Compatibility of a GCL with permeants that it may come in contact with during a project design life is an important consideration for the design engineer.

There is currently very limited information available in the literature regarding compatibility of GCLs with different permeants. Based on the available information (e.g., Shan and Daniel, 1991 and Eith et al. 1991), it appears that water saturated GCLs are generally resistant to attack by many organic and inorganic permeants. However, considering the wide range of permeants that GCLs may come in contact with and the limited information currently available in the literature, the compatibility of GCLs with a specific permeant should be studied on a project specific basis.

The authors have been involved in several projects requiring permeability testing of GCLs with water and other permeants. Based on these experiences, there are several procedures which should be followed when testing GCLs; these are summarized in this paper. Additionally, the results of several compatibility testing programs performed on one GCL product (i.e., Claymax) are presented. Organic permeants as well as an aqueous solution containing mainly inorganic compounds were used in these studies. Finally, a discussion of the observations and conclusions from these testing programs is presented.

2. TESTING PROCEDURAL CONSIDERATIONS

The general guidelines outlined in the United States Environmental Protection Agency (USEPA) Standard Method 9100, or the American Society for Testing and

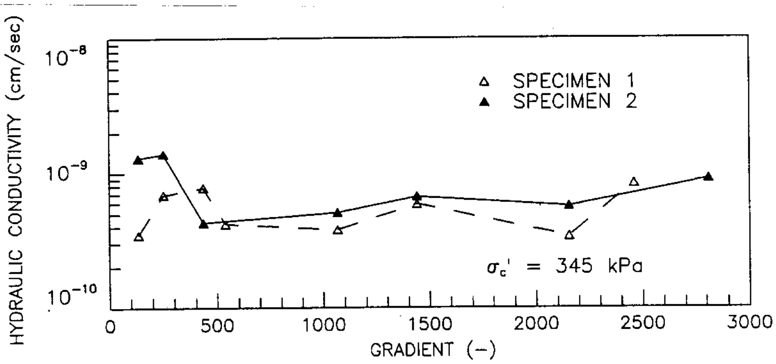
Materials (ASTM) D 5084 may be used when studying the compatibility of a GCL product and a given permeant. However, the following guidelines should be considered, as the authors have noticed their influence on test results:

- The bulk sample sent to the laboratory for testing preferably should be roll-width long and 600 to 700 mm wide. It should be tightly wrapped around a solid tube with an outer diameter of at least 100 to 150 mm. The edges of the bulk sample should be hydrated utilizing tap water or taped with duct tape, to prevent loss of bentonite during transportation.
- The test specimen should be carefully trimmed from the bulk sample. Regardless of the method used to cut the specimen, extreme care must be exercised (a) to avoid loss of bentonite during this stage, and (b) to assure, when testing a GCL product with geotextile backings, fibers from the primary and the secondary geotextile backings do not come in contact.
- To date, the authors have not found any evidence that the specimen size has any effects on the hydraulic conductivity of GCLs (assuming that the specimen is properly prepared with a minimal loss of bentonite). The authors commonly use specimens that are approximately 70 mm in diameter to allow testing in a conventional triaxial cell.
- The specimen must be encapsulated in a membrane compatible with the permeant. Compatibility of a membrane with a given permeant may be investigated by (a) performing simple index testing (Rad and Acar, 1984), or (b) simply soaking the membrane in the permeant for several days and visually examining the membrane for signs of deterioration and incompatibility.
- The GCL specimen may be first saturated and then consolidated to different effective confining pressures. The authors note that several days may be required to achieve full saturation and consolidation.
- Assuming that the specimen is saturated with water, permeation should preferably be initiated with deaired water and continued until the measured hydraulic conductivity values are consistent and the inflow and outflow volumes are approximately equal (this is commonly referred to as the baseline hydraulic conductivity). The water should then be replaced with the permeating fluid and the testing should continue until (a) consistent hydraulic conductivity values are attained, (b) the inflow and outflow volumes are approximately equal, and (c) preferably, a minimum of 1 to 2 pore volumes of the permeating fluid have passed through the specimen.

Given the low permeability of GCLs, the passage of a minimum of 1 to 2 pore volumes of the permeant under recommended hydraulic gradients (e.g., ASTM D 5084) often requires several months of testing. To expedite the testing program, the following two options may be exercised:

- Hydraulic gradients higher than the recommended values can be used. As presented in Fig. 1, in many cases and depending upon the magnitude of the consolidation pressure, hydraulic gradients as high as 1000 to 2000 may be used without any apparent detrimental effects on the permeability of the specimen.

FIG. 1 EFFECT OF GRADIENT MAGNITUDE ON HYDRAULIC CONDUCTIVITY OF CLAYMAX



- As an attempt to study the worst case scenario, the specimen can be directly saturated with the permeating fluid. However, Shan and Daniel (1991) showed that, in some cases, this approach may results in hydraulic conductivity values which are several orders of magnitude higher than those obtained for water saturated specimens.

3. EXEMPLARY TEST RESULTS

The authors have had the opportunity to test Claymax with several permeants. Selected test results are presented in this paper. Similar behavior is expected for other GCL products.

It should be noted that all the test specimens were saturated with deaired tap water at an effective stress of 5 to 21

TABLE 1 COMPATIBILITY TEST RESULTS FOR CLAYMAX WITH DIFFERENT PERMEANTS

Effective Stress During Saturation (kPa)	Consolidation Pressure (kPa)	Average Hydraulic Gradient (-)	Hydraulic Conductivity/Compatibility						
			Baseline (water permeation)			Compatibility			
			Elapsed Time (days)	Pore Volumes (-)	Hydraulic Conductivity (cm/s)	Test Fluid	Elapsed Time (days)	Pore Volumes (-)	Hydraulic Conductivity (cm/s)
14	14	30	10	0.04	2.4E-9	Benzene	19	0.13	3.9E-9
14	14	30	3	0.02	2.6E-9	Styrene	14	0.12	1.5E-9
5	14	30	7	0.04	3.5E-9	Ethanol	42	0.17	1.5E-9
21	210	500	2	0.3	3.4E-10	Unleaded Gasoline	18	1.5	1.8E-10
21	210	500	16	2.3	8.5E-10	Gasohol[1]	23	0.9	1.5E-10
21	210	500	4	0.7	9.0E-10	Diesel Fuel	17	1.5	9.0E-10
21	210	500	4	0.4	8.5E-10	Jet Fuel	17	3.3	8.8E-10
5	35	150	21	0.6	2.2E-9	MSW[2] Leachate	30	1.0	2.8E-9

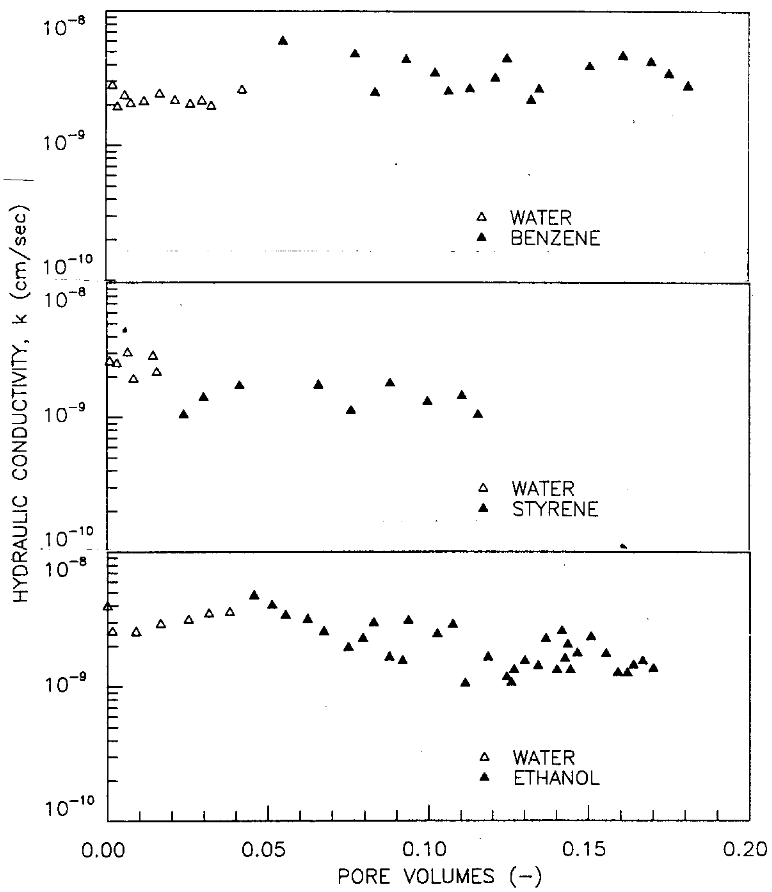
Notes:
1. Gasohol contains approximately 90 percent unleaded gasoline and 10 percent ethanol.
2. MSW = Municipal Solid Waste

kPa. After full saturation was achieved, the specimens were consolidated. At the end of the consolidation stage, the specimens were permeated with deaired tap water until consistent baseline hydraulic conductivity values were obtained. Afterwards, permeation with the test permeant commenced.

Test results obtained utilizing three volatile organic fluids (two non-polar, i.e., benzene and styrene, and one polar, i.e., ethanol) are presented in Table 1 and Fig. 2. The test specimens were consolidated using a consolidation pressure of 14 kPa, and permeated using an average hydraulic gradient of approximately 30. The results indicated no significant change in the baseline hydraulic conductivity values. However, it should be noted that due to time constraints, the testing was terminated after approximately 0.1 pore volumes of each permeant was passed through the specimen. Thus, even though the test duration varied from approximately 2 to 6 weeks, specific conclusions regarding long term compatibility may not be justified. The results, however, can be applied to short-term contact situations such as containment dikes at tank farms where the GCL is pre-hydrated with water.

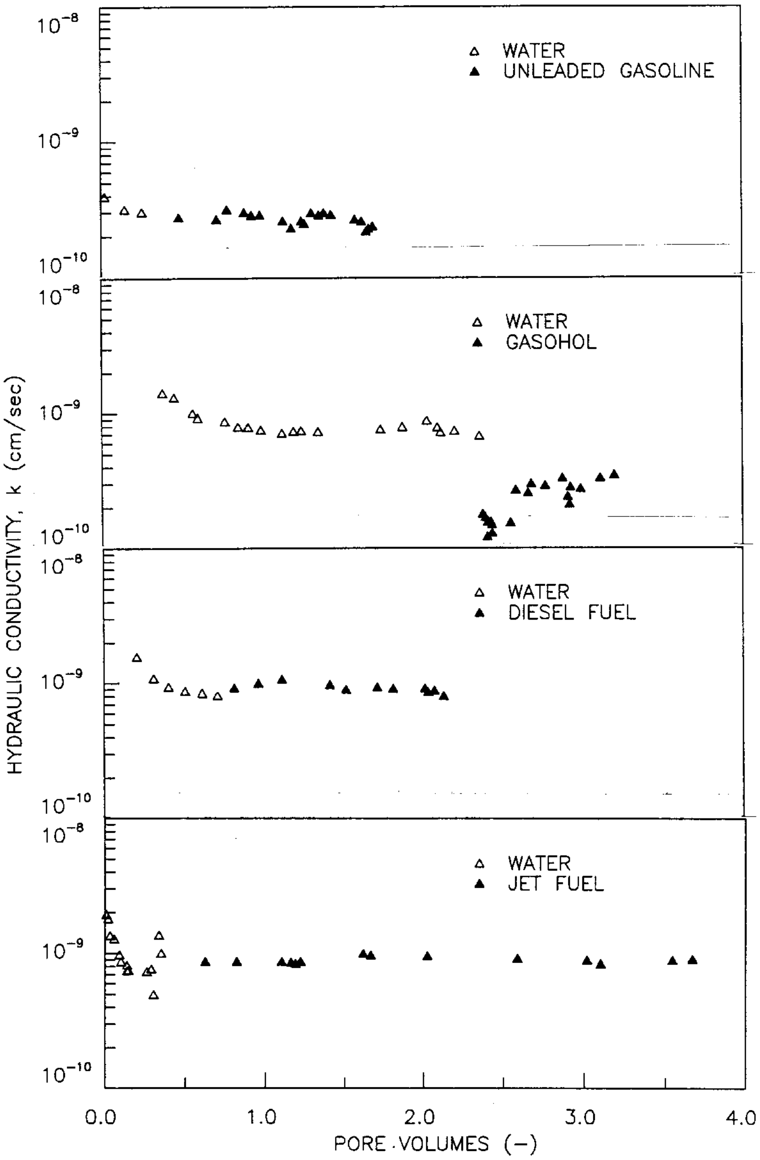
The results of tests performed utilizing several different fuels (i.e., unleaded gasoline, gasohol, diesel fuel and jet fuel) are also summarized in Table 1, and graphically presented in Fig. 3. The test specimens were consolidated using an effective stress of 210 kPa which allowed utilization of an average hydraulic gradient of 500 to expedite the testing. Approximately 1.0 to 3.0 pore volumes of the test permeants were passed through the specimens within 2 to 3 weeks. Based on the test results,

FIG. 2 COMPATIBILITY OF GCL WITH VOLATILE ORGANIC FLUIDS



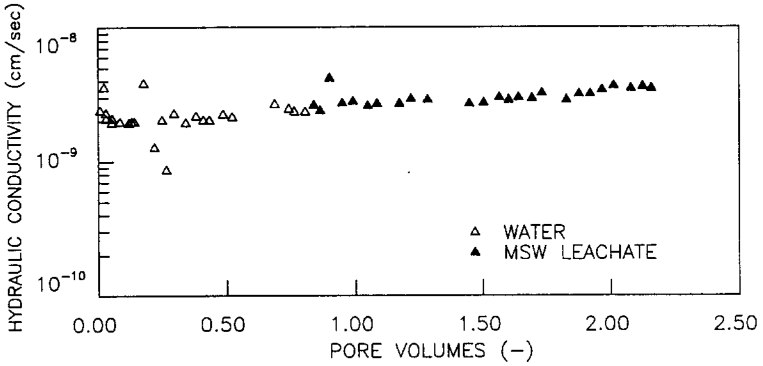
it was concluded that the fuels used in this investigation did not adversely affect the hydraulic conductivity.

FIG. 3 COMPATIBILITY OF GCL WITH COMMON FUELS



To study compatibility of GCLs with aqueous solutions containing mainly inorganic compounds, compatibility testing was performed utilizing a typical leachate from a municipal solid waste landfill. The specimen was consolidated at 35 kPa and permeated utilizing an average hydraulic gradient of 150. Approximately 1.0 pore volume of the leachate was passed through the specimen. The test results are presented in Table 1 and Fig. 4. The test results indicate that the leachate used in this investigation did not adversely affect the hydraulic conductivity.

FIG. 4 COMPATIBILITY OF GCL WITH MUNICIPAL SOLID WASTE LEACHATE



4. CONCLUSIONS

Resistance of GCLs to attack by various chemical compounds is an important consideration for the design engineer. Based on the limited information available in the literature, and the test results presented in this paper, it appears that water saturated GCLs are generally resistant to attack by organic and inorganic compounds. Considering the limited amount of information currently available, it is advisable to perform compatibility tests on a project specific basis. Several months may be required to perform a compatibility test. When applicable, large hydraulic gradients may be used to expedite the testing program.

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