GCL Chemical Compatibility Testing with CCR Landfill Leachate

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ABSTRACT

In recent years, the industry has come to recognize that standard bentonite Geosynthetic Clay Liners (GCL's) are not chemically compatible with select coal combustion residual (CCR) landfill leachates. Laboratory testing has demonstrated that the hydraulic conductivity of GCL's can substantially increase when exposed to some types of CCR leachates, particularly those generated by flue-gas desulfurization (FGD) wastes and wastes generated at power plants using trona.

A laboratory testing program was completed to identify a chemically compatible GCL with site-specific leachate for use in construction of a new CCR landfill liner. Leachate was collected from an existing leachate collection system and tested to characterize the ionic strength and cation concentration. Four (4) GCL's were permeated with the leachate in the laboratory to evaluate hydraulic properties using the *Standard Test Method for Evaluation of Hydraulic Properties of Geosynthetic Clay Liners with Potentially Incompatible Aqueous Solutions* (ASTM D6766). The GCL's tested were constructed of both standard bentonite and polymer modified bentonite specifically developed for use at CCR landfills. The measured hydraulic conductivity of the GCL's varied widely between products with increases in hydraulic conductivity occurring in as little as 1 week to as much as 3 months after initiation of testing. The testing program did identify a chemically compatible GCL that maintained the required hydraulic conductivity when subjected to the leachate for a period of 6 months.

Following hydraulic conductivity testing, interface shear strength testing was completed to confirm design values of the polymer modified GCL. Based on the results of the study, the landfill quality control plan was modified to require continued demonstration of chemical compatibility for future products.

INTRODUCTION

Geosynthetic clay liners (GCL's) are a common alternative to compacted clay liners for use as a hydraulic barrier in a landfill liner system. A GCL typically consists of a layer of sodium bentonite sandwiched between two geotextiles that are needle-punched together. The GCL is popular in areas where importing clay is cost prohibitive.

Although approximately 10 mm thick at the time of installation, the bentonite layer of a GCL is able to provide equivalent protection to a compacted clay liner (CCL) due to its significantly lower hydraulic conductivity. The bentonite is primarily composed of the clay mineral montmorillonite. The low hydraulic conductivity of the montmorillonite can be attributed to the small particle size (increased surface area), interlayer swelling and the amount of bound water (Mesri and Olson 1971).

Landfill liner systems are required to be chemically compatible to the leachate generated from the waste. In recent years, chemical incompatibility has been identified between standard bentonite geosynthetic clay liners (GCL's) and select coal combustion residual (CCR) leachates (Chen et al. 2014). The hydraulic conductivity of the bentonite within the GCL has been shown to be affected by the concentration, cation valence and pH of the permeant solution (Kolstad et al. 2004).

This paper discusses a laboratory testing program that was completed using a site-specific CCR leachate and four different GCL products. The study was performed to confirm GCL product compatibility with the leachate generated at the landfill.

BACKGROUND

On April 17, 2015 the United States Environmental Protection Agency (USEPA) published new rules (CCR Rules) for landfills and surface impoundments that contain CCR materials produced from electric utilities. The rules specified that CCR landfills must have a composite bottom liner. The default liner consists of a 600 mm (24 inch) compacted clay liner (CCL) exhibiting a maximum hydraulic conductivity of 1E-07cm/s in combination with a geomembrane meeting minimum thickness requirements. GCL's were allowed as an acceptable alternative to the CCL provided that their equivalency could be demonstrated using Darcy's Law equation for flow. The parameters in the equation include the thickness of the porous medium (CCL or GCL), hydraulic conductivity of the liner, and the hydraulic head above the liner.

$$q = k\left(\frac{h}{t} + 1\right)$$

q = flow rate per unit area ($cm^3/s/cm^2$)
k = hydraulic conductivity of the liner (cm/s)
h = hydraulic head above the liner (cm)
t = thickness of the liner (cm)

Equivalency demonstration using Darcy's Law is the only option available in the CCR rules. Since a regulatory review process is not part of the current CCR Rules, a demonstration of equivalency referencing other considerations such as the benefit of a manufactured product could not be utilized.

Based on the manufacturer's reported GCL thickness for typical GCL products and the maximum allowable hydraulic head above the liner, a hydraulic conductivity of 3E-09cm/s or less is necessary to achieve equivalency between the GCL and CCL. This hydraulic conductivity value was below the manufacturer's reported Maximum Average Roll Value (MARV) for the standard bentonite GCL. Therefore, project specific testing was necessary to demonstrate equivalency.

Section 257.70 of the CCR rules also specify that the CCL or GCL layer must be chemically compatible with the CCR leachate. Chemical compatibility can be demonstrated through the performance of a hydraulic conductivity laboratory test *Standard Test Method for Evaluation of Hydraulic Properties of Geosynthetic Clay Liners with Potentially Incompatible Liquids* (ASTM D6766). The test was specifically developed to test for the hydraulic conductivity and index flux of a GCL specimen permeated with chemical solutions and/or leachates.

OVERVIEW OF LANDFILL

The composite liner system at the landfill consists of a 60-mil double-sided textured HDPE geomembrane over a GCL. The landfill waste consists of a mixture of FGD and fly ash. The power plant producing the waste placed in the landfill uses trona, at least on a periodic basis. It has been demonstrated that the hydraulic conductivity of GCL's can be substantially reduced when exposed to some types of CCR leachates, particularly those generated by FGD wastes and wastes where trona is used in the pollution control process (Chen et al. 2014).

There is an existing leachate collection system in operation at the site from which representative leachate was obtained for the study.

LEACHATE CHARACTERISTICS

Prior to performing hydraulic conductivity testing with GCL's, the leachate was tested to determine the ionic concentration and to determine the presence of monovalent and divalent cations. The ionic concentration and abundance of monovalent and divalent cations has been shown to be directly proportional to the hydraulic conductivity of the GCL (Kolstad et. al 2004).

Two leachate samples were collected at different times from the same leachate collection point. The leachate collection point is located upstream of any mixing with stormwater runoff that would cause dilution of the sample. The samples were tested to estimate the hydraulic conductivity of the GCL when subjected to the leachate using the

Kolstad (2004) regression analysis. The tested parameters were calcium, magnesium, sodium, potassium, specific conductance, pH, sulfate and chloride concentration.

The results of the leachate analytical testing are summarized in Table 1 for each sample as well as the predicted GCL hydraulic conductivity value based on the Kolstad (2004) regression analysis.

Table 1: Leachate Testing Results

Parameter	**Test Method**	**Leachate Sample 1**	**Leachate Sample 2**
Calcium (mg/L)	EPA 6010	844	825
Magnesium (mg/L)	EPA 6010	31.1	27.3
Sodium (mg/L)	EPA 6010	1,460	1,430
Potassium (mg/L)	EPA 6010	735	720
Specific Conductance (umhos/cm)	SM 2510B	11,800	12,300
pH	SM 4500-H+B	7.3	7.4
Sulfate	EPA 9038	2,450	2,170
Chloride Concentration	SM 4500-Cl-E	2,770	3,120
Estimated hydraulic conductivity based on Kolstad (2004) regression analysis:		3.1E-08 cm/s	3.7E-08 cm/s

With the above parameters, the Kolstad (2004) regression analysis predicts a GCL hydraulic conductivity above the targeted value of 3E-09 cm/s for the site-specific leachate with standard bentonite GCL's. To this end, the decision was made to move forward with a laboratory testing program to better understand the impact of the leachate on the permeability of the GCLs considered for use at the landfill.

GEOSYNTHETIC CLAY LINERS

Laboratory hydraulic conductivity testing was performed using four (4) different GCL's. One GCL did not contain polymer-modified (PM) bentonite and the other three GCL's did contain PM bentonite mixes selected by the manufacturer based on a review of the Table 1 leachate parameters. The tested GCL's are summarized in Table 2.

Table 2: GCL Summary

Geosynthetic Clay Liner	Polymer Modified (Y/N)	Permeant Leachate Sample
GCL 1	No	1
GCL 2	Yes	1
GCL 3	Yes	1
GCL 4	Yes	2

HYDRAULIC CONDUCTIVITY TESTING

The hydraulic conductivity tests were performed using the *Standard Test Method for Evaluation of Hydraulic Properties of Geosynthetic Clay Liners Permeated with Potentially Incompatible Aqueous Solutions* (ASTM D6766, Scenario I, Method C). All samples were saturated with de-ionized water prior to beginning the testing (Scenario I), as it is theorized that the GCL will become hydrated through capillary action of the subgrade soil. Other published studies have developed recommendations using the leachate for the hydration stage (Scenario II) (Jo. et al. 2001). Still others have concluded that the pre-hydration permeant selection does not have a noticeable effect on the final hydraulic conductivity of the GCL when permeated with a salt (leachate) solution (Vasko et al. 2001).

All tests were performed with an effective confining pressure of 5 psi. This low level of confinement was conservatively selected to yield the highest hydraulic conductivity and is only representative of the field confinement near the edges of the landfill as well as certain lined ditches. The vast majority of the liner will be subject to significantly higher loading.

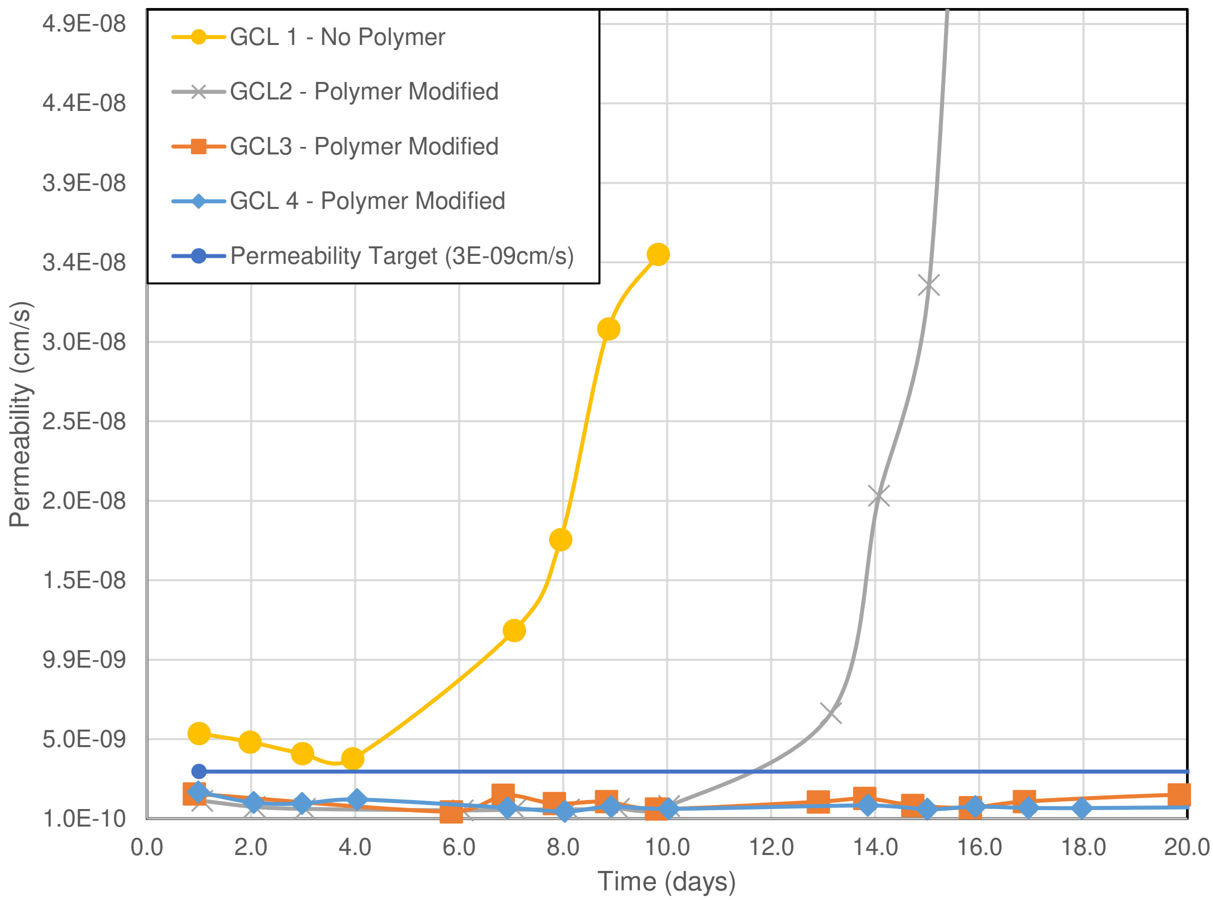
The tests were continued until the measured hydraulic conductivity of the GCL was observed to be above the targeted hydraulic conductivity value 3E-09 cm/s for several days; or for a period of 6 months, whichever occurred first. The pH and electrical conductivity of the effluent were monitored before and after flow through the GCL as an indication that the specimen had come to chemical equilibrium as recommended by Shackleford et al. (2000). Chemical equilibrium was also verified prior to terminating a test.

The 6-month duration for the test was selected recognizing that past studies have had specimens fail after several months of testing. Additionally, the state regulatory agency for this landfill had previously provided guidance that 6 months was an acceptable duration to display chemical compatibility.

RESULTS

The laboratory hydraulic conductivity test results are provided in Figure 1 for the first 20 days of testing. During this time period, both GCL 1 and GCL 2 failed to maintain the maximum hydraulic conductivity value required for the landfill. The standard bentonite product (GCL 1) never achieved the lower hydraulic conductivity value required for the project (3E-09cm/s) and exceeded the manufacturer's MARV value after 4 days. GCL 2 failed after 10 days, even with the manufacturer's chosen polymer modified mixture. The results of the study from the beginning through day 20 is summarized in Figure 1.

Figure 1: GCL Hydraulic Conductivity Test Results through Day 20.



GCL 3 failed to maintain the targeted hydraulic conductivity value after a period of 96 days. GCL 4 maintained a hydraulic conductivity below the maximum allowable value for the project for 183 day test duration. These laboratory results are provided in Figure 2 and the test results are summarized in Table 3.

Figure 2: GCL Hydraulic Conductivity Test Results

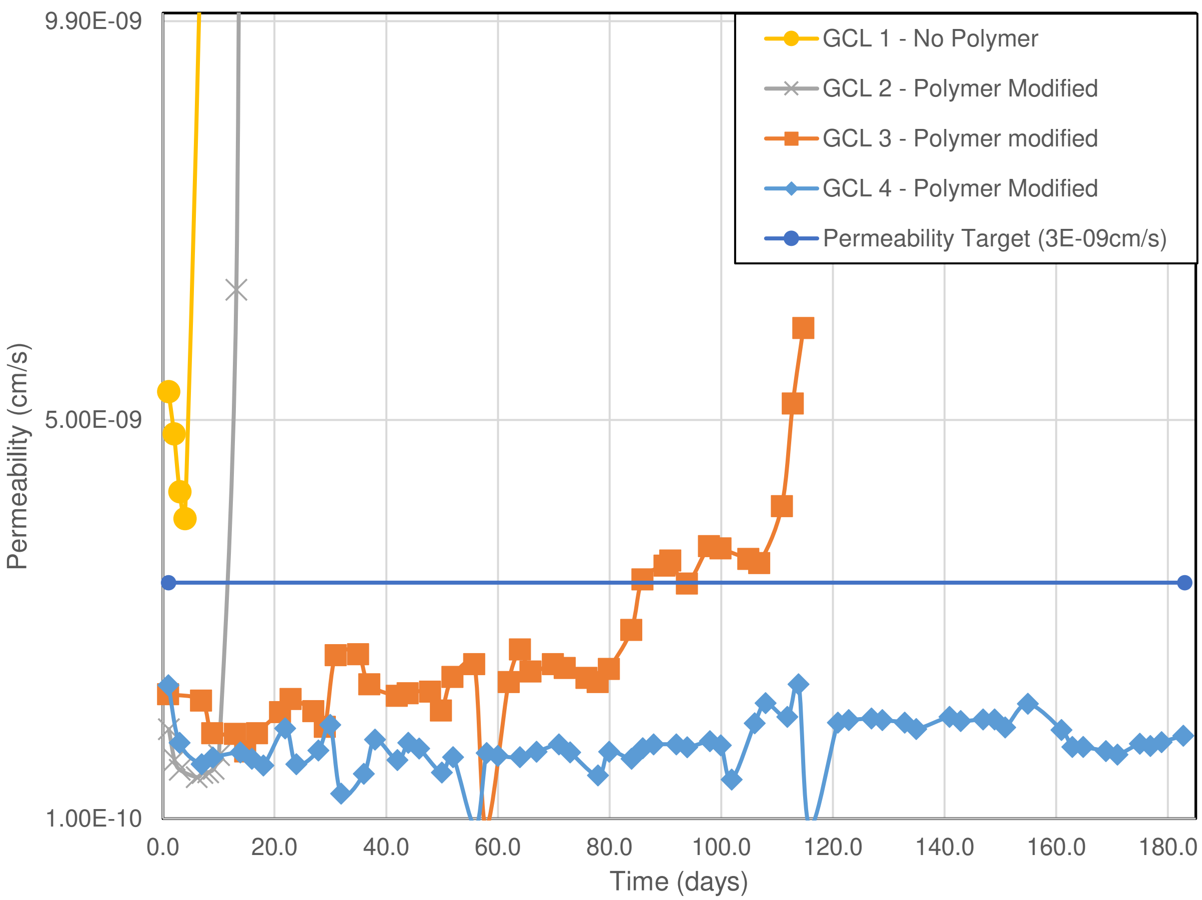


Table 3: GCL Results Summary

Geosynthetic Clay Liner	Polymer Modified (Y/N)	Days Before Maximum Hydraulic Conductivity Exceeded
GCL 1	No	4
GCL 2	Yes	10
GCL 3	Yes	96
GCL 4	Yes	>183

After passing hydraulic conductivity test results were achieved for a period of 6 months, GCL 4 was tested in interface shear with the underlying subgrade soils and overlying HDPE geomembrane to confirm that the design values could still be achieved with the presence of polymer. The landfill Construction Quality Control Plan was also updated to reflect the changes in GCL requirements. The plan was altered to require chemical compatibility testing to allow for the use of additional polymer modified products developed for future parts of landfill construction.

CONCLUSIONS

A laboratory hydraulic conductivity testing study was performed to determine the chemical resistance properties of the GCL's and the site-specific landfill leachate. A GCL was selected for the next phase of landfill construction based on the results of the testing. The following conclusions are provided:

- Chemical analysis of the site specific leachate for cation concentration and ionic strength can provide an indication as to the severity of the site-specific leachate following the recommendations of Kolstad (2004);
- Chemical compatibility testing of GCL's proposed for use in CCR landfills is recommended using ASTM D6766, regardless of the type of CCR materials proposed for the landfill;
- A sudden increase in the measured hydraulic conductivity of a polymer-modified GCL was observed after as much as 3 months of consistent test results suggesting that testing should be continued for an extended period of time;
- The 6 month testing duration required by the state does not appear to be unreasonable considering the observed results;
- Periodic verification of GCL compatibility may be warranted as power plants modify pollution control methods and procedures or manufacturers modify products, and;
- Owing to the life span of a landfill, the permit documents should be written such that new products can be proven effective and implemented as they become available.
- Recognizing the length of time required to carry out a testing program, early planning is necessary to ensure that multiple GCLs are pre-qualified when obtaining construction bids.

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