QUARTERLY PROGRESS REPORT 1

Title: Effects of Florida Leachates on Geosynthetic Clay Liners (GCLs)

Project Duration: September 1st, 2016 – August 31st, 2017
Budget: $37,054
Investigators: Prof: Tarek Abichou, Ph.D. P.E. and Youneng Tang, Ph.D.
FAMU – FSU Dept. of Civil and Env. Eng.

PROJECT WEB SITE:
https://www.eng.famu.fsu.edu/~abichou/MSWI%20GCL%20FL%20Project.html

Present Goals:
The main objective of this study is to test the resistance of conventional GCLs from different vendors to synthetic permeant solutions and aggressive leachates from MSW, MSW+ASH, MSW-I landfills and CCPP landfills from Florida and possibly other states in the USA. Further, the intent is to identify conditions where these GCLs might not be adequate (such as negative gradient landfills and fluctuating groundwater table). On the GCLs, conventional tests were utilized (Swell Index, Atterberg limits, 1D Swell Test, hydraulic conductivity). The synthetic permeant solutions and aggressive leachates underwent chemical characterization such as ratio of monovalent and divalent cations (RMD), ionic strength (IC), electrical conductivity (EC), and pH.

Work accomplished during this reporting period:

Presents Achievements
On February 2th, 2018, we received comments and feedback from TAG members on the present achievements and goals of the project that influenced our progressive advancement of the current GCL study. Feedback was also received regarding the determination of the physical properties, characteristics, and grain size distribution of vendor conventional and polymer modified GCLs. More lab testing was performed such as Atterberg limits, swell index, one-dimensional swell, and permeability (hydraulic conductivity) testing. Also, the synthetic permeant solutions and aggressive leachates underwent chemical characterization such as ratio of monovalent and divalent cations (RMD), ionic strength (IC), electrical conductivity (EC), and pH. All testing procedures are conducted in accordance with the American Standardized Testing Manuals (ASTM). Before the next TAG meeting, we would like to have few direct shear tests and cation exchange tests completed on the GCLs. Our future work is to analyze the results obtained from lab testing and form conclusions, so we can formulate a paper and showcase the work we have completed on GCLs.

Next, we will showcase some of the work accomplished during this reporting period:

1. GCL Properties and Characterization of Conventional and Polymer Modified

Six types of GCLs (exactly five conventional and one polymer modified) have been received so far from three different vendors and we expect to receive more in the future. The manufacturer specified properties for these GCLS were found to be similar. The physical properties of the bentonite and geotextile in used in the finished GCLs are summarized in Table 1, and their hydraulic properties in Table 2.

Table 1. Manufacturer GCL Physical Properties

GCL	Bentonite		Top Geotextile	Bottom Geotextile	Reinforcement
	Type	Texture			
A-1	Sodium	Granular	nonwoven	woven	needle-punched
A-2	Sodium	Granular	nonwoven	nonwoven	needle-punched
C-1	Sodium	Granular	nonwoven	woven	needle-punched
G-1	Sodium	Granular	nonwoven	woven	needle-punched
G-2	Sodium	Granular	nonwoven	scrim-nonwoven	needle-punched
GP-1*	Sodium-Polymer	Granular	nonwoven	scrim-nonwoven	needle-punched

*Polymer Modified

Table 2. Manufacturer GCL Hydraulic and Strength Properties

GCL	Swell Index	Hydraulic Conductivity	Internal Shear Strength	Tensile Strength	
	SI (2 mL/2g)	k (cm/sec)	(kPa)	(lb/in)	(N/cm)
A-1	24	5×10^{-9}	500	30	53
A-2	24	5×10^{-9}	500	50	87
C-1	24	5×10^{-9}	500	30	53
G-1	24	5×10^{-9}	500	30	-
G-2	24	5×10^{-9}	500	45	-
GP-1*	24	5×10^{-9}	500	45	-

*Polymer Modified

Present Results

Because the aggregate-size distribution of the bentonite used in the GCL may have an influence on the hydraulic conductivity of the GCL, the various GCLs were further characterize by performed aggregate-size distribution on only the dry bentonite aggregates used in the GCLs following the specifications of ASTM E 112. Figure 1 shows the aggregates-size distribution curves for the various GCLs. In addition, the dry bentonite aggregates from each GCL were classified in accordance with the Unified Soil Classification System (ASTMD 2487) to be clayey sand (SC).

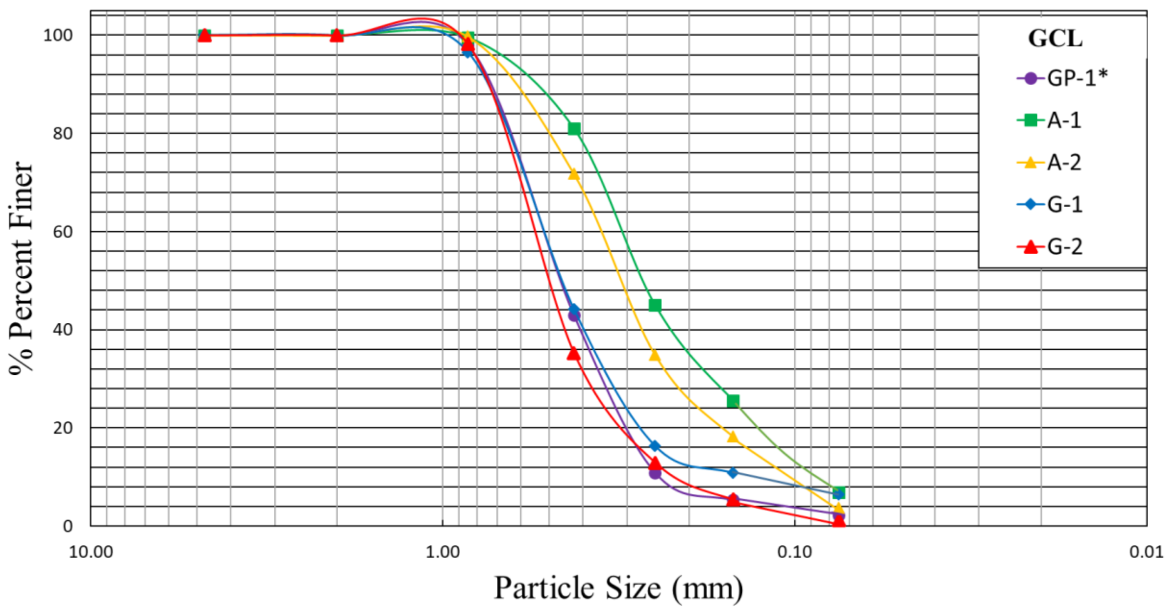

Figure 1: Grain Size Distribution for bentonite in GCL from Different Vendors

2. Chemical Characterization of Synthetic Permeant Solutions

In line with the goals of the current study, synthetic leachates were created using calcium (Ca) salts and humic acid (HA). The chemical composition and characteristics using appropriate analytical instruments along with standard pH and EC Probes. Table 3 and 4 provides the summary of the chemical composition and characteristics of these permeant solutions.

Table 3. Chemical Characteristics of Calcium Salt Solutions

Permeant solutions	Chemical Characteristics							
	Ca (mM)	Mg (mM)	Na (mM)	K (mM)	pH	EC (µS/cm)	IC (mM)	RMD (mM1/2)
5 mM CaCl2	-	-	-	-	6.1	1160	19	-
10 mM CaCl2	8	0.010	0.358	0.012	6.1	1935	31	0.131
20 mM CaCl2	-	-	-	-	6.1	4037	65	-
50 mM CaCl2	53	0.013	0.139	0.017	6.4	10773	172	0.021
100 mM CaCl2	85	0.019	0.209	0.024	6.0	24960	399	0.025
200 mM CaCl2	173	0.041	12.174	0.048	6.0	44370	710	0.929

Table 4. Chemical Characteristics of Calcium Salt and Humic Acid Solutions

Permeant solutions	Chemical Characteristics							
	Ca (mM)	Mg (mM)	Na (mM)	K (mM)	pH	EC (µS/cm)	IC (mM)	RMD ($mM^{1/2}$)
5 mM CaCl2 + 100 mg/L HA	2	0.009	0.148	0.016	6.8	1310	20	0.107
10 mM CaCl2 + 100 mg/L	5	0.013	0.162	0.019	6.7	2587	41	0.084
20 mM CaCl2+ 100 mg/L HA	10	0.016	0.191	0.051	6.9	4170	67	0.077
50 mM CaCl2+ 100 mg/L HA	24	0.025	0.287	0.042	6.3	10070	161	0.067
100 mM CaCl2+ 100 mg/L HA	45	0.025	0.384	0.490	6.4	18747	300	0.130

3. Atterberg limits testing

In accordance with ASTM D 4318, Atterberg limit tests were performed on bentonite extracted from the various GCLs to determine their liquid limits (LL) and plastic limits (PL). Figure 1 and 2 shows some of our undergraduate students conducting these tests.

Figure 2: Liquid Limits Testing conducted by Nora & Tristan

Figure 3: Plastic Limits Testing conducted by Alyssa

Present Results

The Atterberg limit tests were conducted using deionized water (DIW) and different leachates. The results of the LL test (given in Table 5) indicates that for the conventional GCLs, there was a significant decrease in the LL when the test was performed with MSW and MSW+ASH leachates. For the polymer modified GCL, the LL was slight higher when wetted with the MSW+ASH leachate than with DIW, however, when wetted with the MSW leachate the LL slightly decreased as shown Figure 4. More LL and PL tests are currently being done on the various GCL with various aggressive landfill leachates as well as synthetic leachates.

Table 5. Liquid Limit Test Performed on Vendor Conventional GCLs with various Permeant Solutions

GCL	DIW	Leachates					
		L1 (MSW)	L2 (MSW+ASH)	L3 (MSW-I)	L4	L5	L6
A-1	561	180	194	-	-	-	-
A-2	449	163	183	-	-	-	-
C-1	539	328	348	-	-	-	-
G-1	557	255	205	-	-	-	-
G-2	-	-	-	-	-	-	-
GP-1*	364	307	408	-	-	-	-

*Polymer Modified

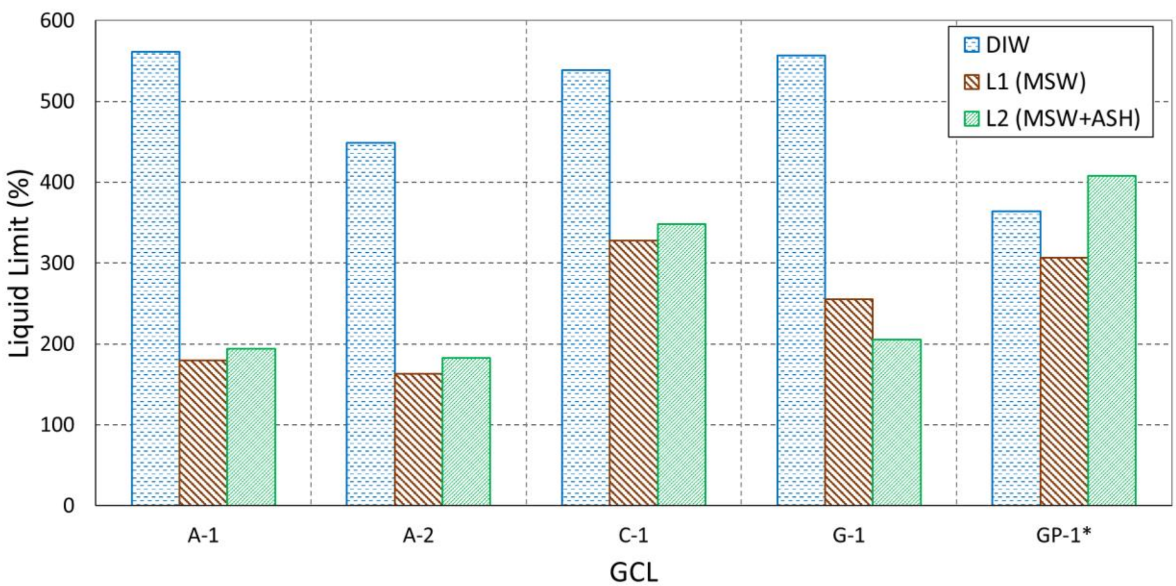

Figure 4. Liquid Limit Test Performed on Vendor Conventional GCLs with various Permeant Solutions

4. Swell index test

A quick assessment of the hydraulic conductivity of GCL can be made using the swelling capacity of its constituent bentonite. In accordance with ASTM D 5980, the swell index test was used to determine the free swelling capacity (under zero normal stress) of the bentonite extracted from the various types of GCLs (both conventional and polymer modified). Figure 5 shows the undergraduate students performing the swell index tests. Researchers and manufacturers have recommended a minimum swell index of 24 mL per 2.0 g of bentonite.

Figure 5: Swell Index Test conducted by Alyssa & Avery

Present Results

The results of the tests are tabulated in Table 6. It was observed that for the conventional bentonite as well as the polymer modified bentonite, swell volume reduced substantially when introduced to the MSW, MSW+ ASH and the MSW-I leachates (see Figure 6).

Table 6. Swell Index Tests Performed on bentonite from Vendor Conventional and Polymer Modified GCLs with various Landfill Leachates in comparison with DIW

GCL	DIW	Leachates					
		L1 (MSW)	L2 (MSW+ASH)	L3 (MSW-I)	L4	L5	L6
A-1	34	8	11	10	-	-	-
A-2	34	11	9	10	-	-	-
C-1	25	12	16	11	-	-	-
G-1	29	10	10	8	-	-	-
G-2	-	-	-	-	-	-	-
GP-1*	33	11	12	12	-	-	-

*Polymer Modified

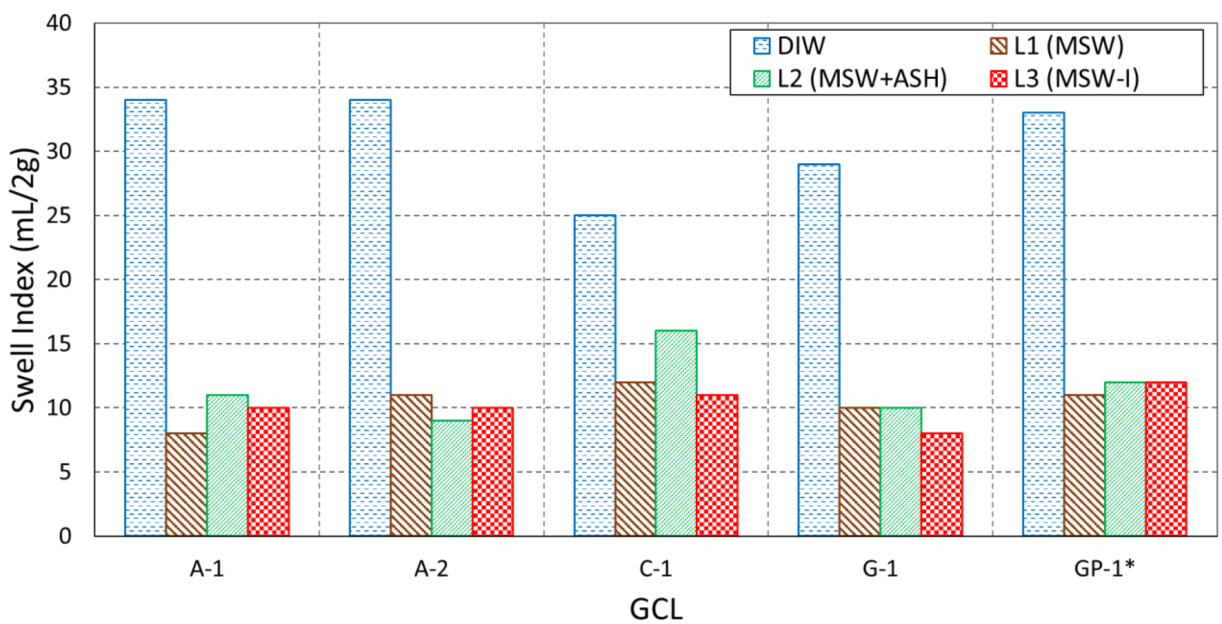

Figure 6. Swell Index Tests Performed on bentonite from Vendor Conventional and Polymer Modified GCLs with various Landfill Leachates in comparison with DIW

Present Results

Swell index tests were also conducted using Ca salt solutions and Ca+ HA solutions with varying ionic strength as shown in Figure 7-9. The results indicate that the swell capacity of the both conventional bentonite (indicated in Figure 7-9 as Ben. ST) and polymer modified bentonite (indicated in Figure 7-9 as CAR) reduced significantly with both synthetic solutions. It was also observed that with the Ca+ HA solution the conventional bentonite swelled slightly less than than with only Ca solution. However, the reverse was observed for the polymer modified bentonite (see Figure 9). Swell index test using different landfill leachates and synthetic leachates are still being performed.

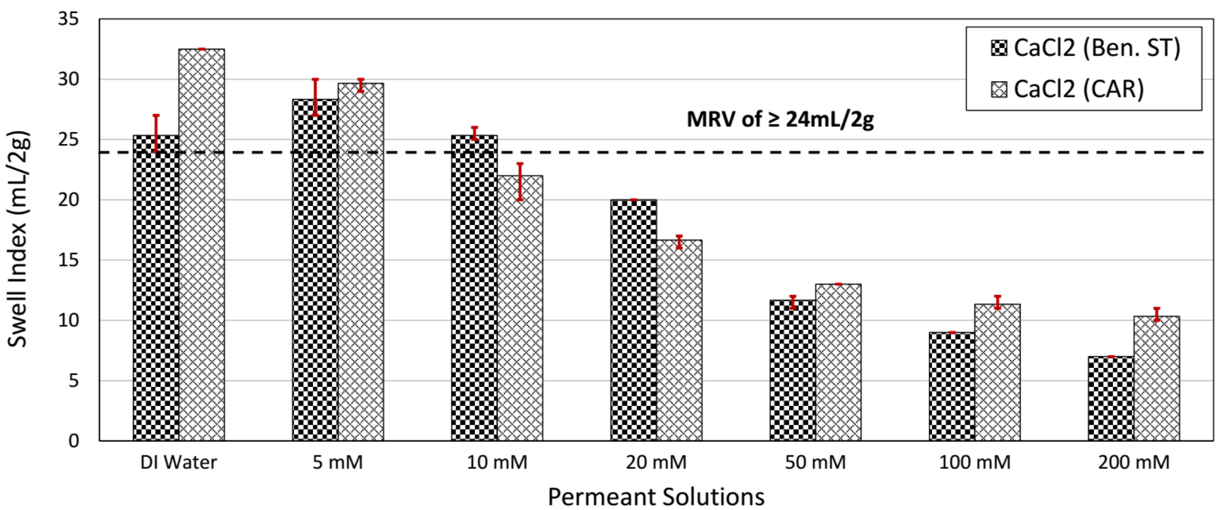

Figure 7. Swell Index Tests Performed on Vendor Conventional (Ben. ST) and Polymer Modified (CAR) bentonite with Ca Solution.

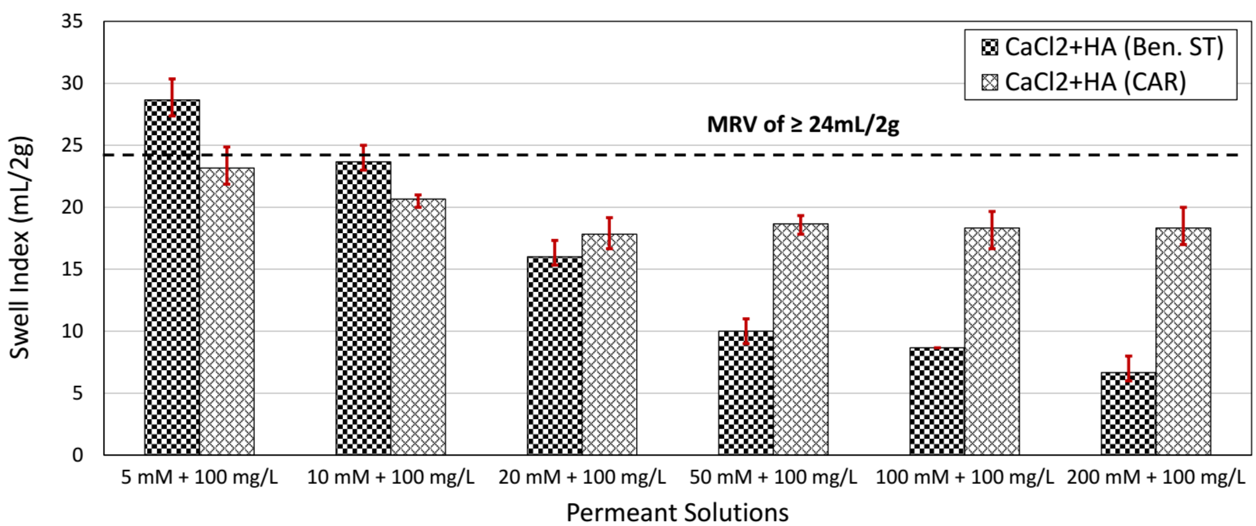

Figure 8. Swell Index Tests Performed on Vendor Conventional (Ben. ST) and Polymer Modified (CAR)bentonite with Ca Solution.

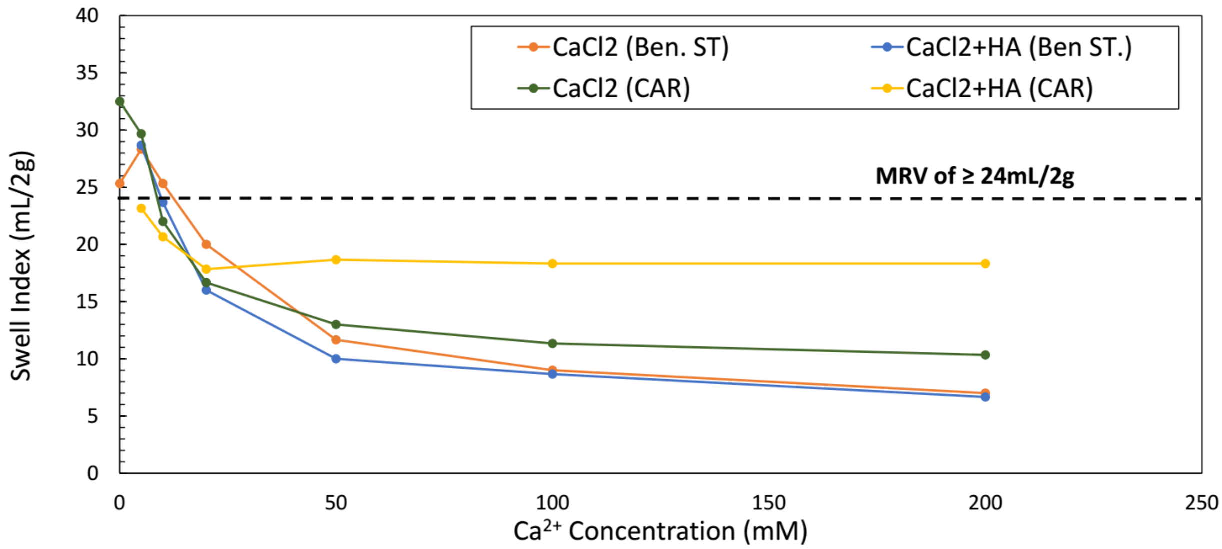

Figure 9: Effects of Synthetic Leachate on Swell Index

5. One-Dimensional Swell Test

The effects of various landfill leachates on the swelling capacity of the various GCLs were also investigated by performing a one-dimensional (1-D) swell test on bulk GCL samples. The setup of the 1-D swell test is show in Figure 10. The test procedure is as follows; a 100 mm diameter sample of GCL was cut and placed in a ring of similar diameter into a pan. To simulate the overburden stress from topsoil of a landfill, a normal stress of 20kPa is applied to the GCL. A dial gauge was then installed on top of the sample to measure the vertical displacement of the GCL during swelling. After that, 500 mL of the permeant solution is poured into the pan to hydrate the GCL sample. The swelling of the sample is monitored throughout the test until there is no more vertical displacement in the sample.

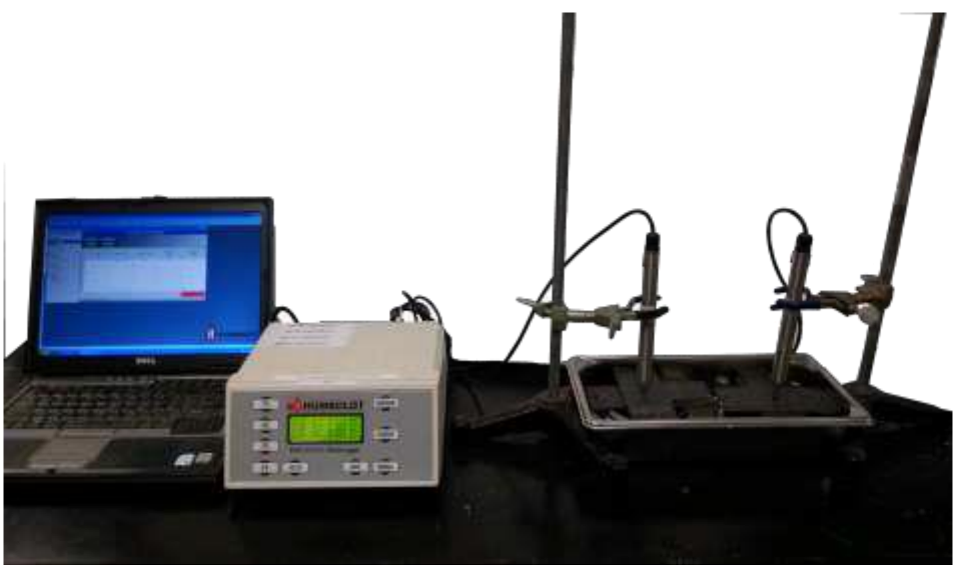

Figure 10: 1-D Swell test setup to measure GCL vertical swelling

Present Results

From Figure 11, it can be shown the rate of swelling was rapid in the first 24 hours for the test with DIW. In the case of DIW for all the GCL samples (conventional GCLs) the maximum displacement was attained after 72 hours. With MSW leachate however, there was an initial rapid rate of swell within the fist few hours, but the swelling ceased abruptly after that. In the general was considerably high swelling in the sample hydrated with DIW than those hydrated with MSW leachate. 1-D swell test with different landfill leachates as well as synthetical leachates will be performed in the future.

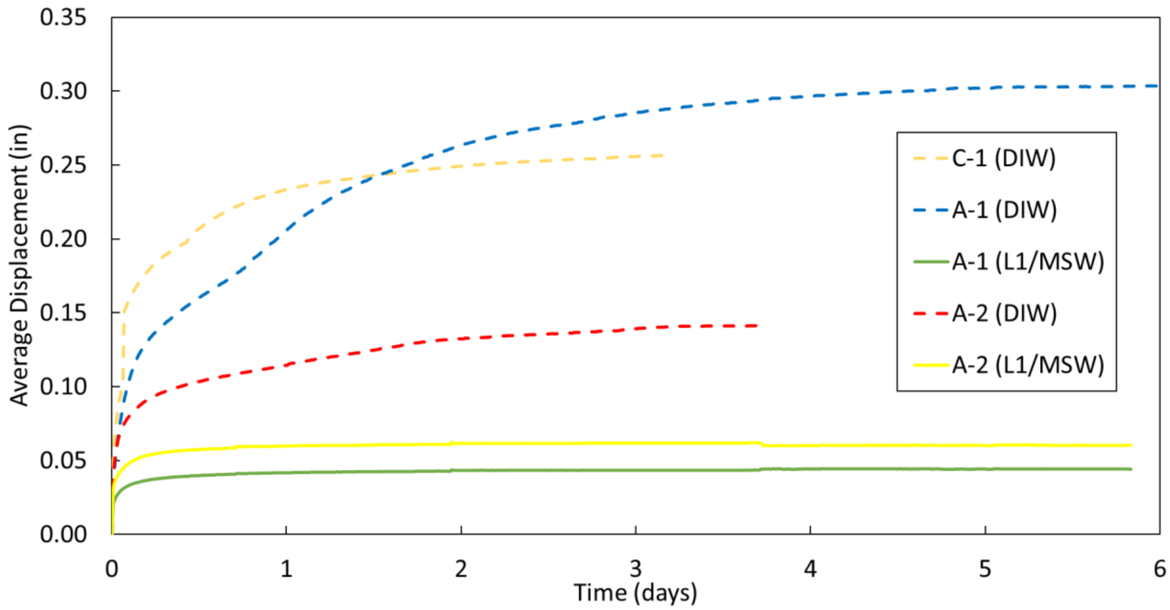

Figure 11: 1-D Swell Tests Performed on Vendor Conventional GCLs with various Permeant Solutions

6. Hydraulic Conductivity Test

The hydraulic conductivity of the various GCLs when permeated with different permeant fluid were determined using the flexible wall permeameter in accordance with ASTM 5887. The setup for the test is shown in Figure 12. The hydraulic conductivity tests were conducted using the falling-head constant tail pressure method. The all sample were both hydrated and permeated with the same solution.

Present Results

The results of the tests which are summarized in Table 7 indicate that the hydraulic conductivity of both the conventional and polymer modified GCL when permeated with MSW leachate were within the vicinity of 10^{-9} to 10^{-10} (also see Figure 12). More hydraulic conductivity tests will be performed using different landfill and synthetic leachates.

Figure 12: Flexible wall perimeter test setup to measure hydraulic conductivity

Table 7. Hydraulic Conductivity Tests Performed on Vendor Conventional GCLs with various Permeant Solutions

GCL	D IW	Leachates					
		L1 (MSW)	L2 (MSW+ASH)	L3 (MSW-I)	L4	L5	L6
A-1	5.1×10^{-9}	7.6×10^{-10}	-	-	-	-	-
A-2	5.8×10^{-9}	4.1×10^{-9}	-	-	-	-	-
C-1	2.2×10^{-9}	1.2×10^{-9}	-	-	-	-	-
G-1	2.3×10^{-9}	-	-	-	-	-	-
G-2	-	-	-	-	-	-	-
GP-1*	2.1×10^{-9}	1.3×10^{-10}	-	-	-	-	-

*Polymer Modified

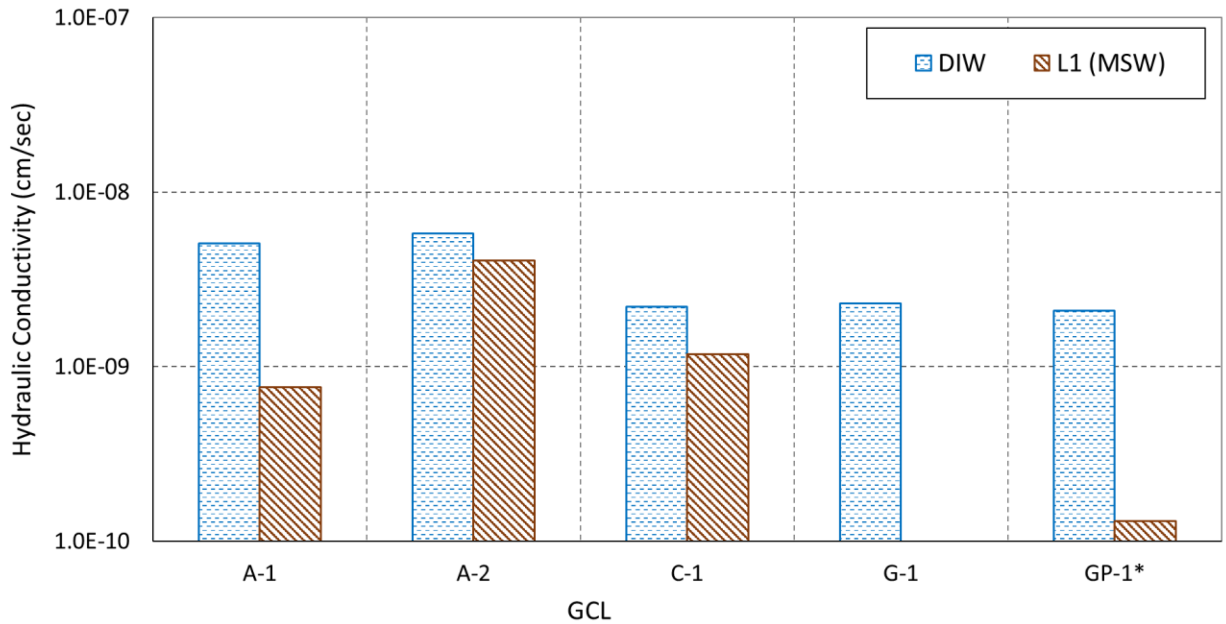

Figure 12. Hydraulic Conductivity Tests Performed on Vendor Conventional GCLs with various Permeant Solutions

Information Dissemination Activities: We are working on a Draft Paper to showcase the testing completed on the Geosynthetic Clay Liners.

Metrics:

1. List of graduate student or postdoctoral researchers **funded** by **THIS** Hinkley Center project

Last name, first name	**Rank**	**Department**	**Professor**	**Institution**
Bently Higgs		Civil & Environmental Engineering	Dr. Tarek Abichou	FAMU-FSU College of Engineering
Christian Wireko		Civil & Environmental Engineering	Dr. Tarek Abichou	FAMU-FSU College of Engineering
Dr. Liang Li		Civil & Environmental Engineering	Dr. Tarek Abichou & Dr. Youneng Tang	FAMU-FSU College of Engineering

2. List undergraduate researchers working on **THIS** Hinkley Center project

Past Undergraduate Researchers

- Name: Alyssa Schubert
  Department: Environmental
  Science
  Professor: Dr. Tarek Abichou, Ph.D, P.E.
  Institution: FAMU-FSU College of
  Engineering

- Name: Nora Sullivan
  Department: Environmental Science
  Professor: Dr. Tarek Abichou, Ph.D,
  P.E.
  Institution: FAMU-FSU College of Engineering

Present Undergraduate Researchers

- Name: David Carbajal
  Department: Civil and Environmental
  Engineering Professor: Dr. Tarek Abichou,
  Ph.D, P.E. Institution: FAMU-FSU College of
  Engineering
- Name: Tristan Wahl
  Department: Mechanical Engineering
  Professor: Dr. Tarek Abichou, Ph.D, P.E.
  Institution: FAMU-FSU College of
  Engineering
- Name: Avery VanRussel
  Department: Civil and Environmental
  Engineering Professor: Dr. Tarek Abichou,
  Ph.D, P.E. Institution: FAMU-FSU College of
  Engineering

3. List research publications resulting from **THIS** Hinkley Center project (use format for publications as outlined in Section 1.13 of this Report Guide).

4. List research presentations (as outlined in 1.13.6 of this Report Guide) resulting from **THIS** Hinkley Center project.
   - Most recently, there was a TAG meeting on February 2th, 2018.

5. List who has referenced or cited your publications from this project?

   .

6. How have the research results from **THIS** Hinkley Center project been leveraged to secure additional research funding?

7. How have the results from **THIS** Hinkley Center funded project been used (**not** will be used) by FDEP or other stakeholders? (1 paragraph maximum).

   With the current results obtained from testing completed on the geosynthetic materials, we hope to provide reliable data to showcase the good and bad qualities of these geosynthetic materials because landfills still generate and contain contaminants long after they are closed. Therefore, we hope that this Hinkley Center funded project would convince FDEP

   and stakeholders that there is a need to create more robust materials that will withstand exposure to harsh conditions of landfills for example leachate and elevated temperatures as a continual effort to protect our environment from harmful contaminants for future generations.

TAG members:

- Ron S. Beladi, P.E.
- Henry Freedenberg, P.E.
- Jeremy Clark, P.E.
- Kwasi Badu-Tweneboah Ph.D., P.E.
- Sam Levin, P.E.
- Lei Yuan, Ph.D, P.E.
- Nathan P. Mayer, P.E.
- Wester Henderson,
- Amy M., P.E.
- Ravi Kadambala, P.E.
- Manuel Hernandez, P.E.
- Ken Rogers, P.E.
- Ron Beladi, P.E.

TAG meetings:

- Tag Meeting #1 –
  Completed Date: Friday,
  February 2th, 2018 Time:
  10am to 12pm
  Venue: FAMU-FSU College of Engineering
  2525 Pottsdamer Street
  Room A127