



Long Term Properties of Geosynthetics and Clayey Soils from 10-years-old Landfill Covers



TAG Meeting 2

Sponsored by:

HINKLEY CENTER FOR SOLID AND HAZARDOUS WASTE
MANAGEMENT



Meeting Agenda

GCL Related Updates

Geomembranes Related Updates

Future Work

Discussions

Manual Digging to the Liner System

machine excavation stopped once the gravel layer was encountered.



Manual Digging to the Liner System

Once the gravel layer was encountered, manual shoveling was conducted to meet the liner system without hindering the integrity of the textured, 60 mil-thick, low-density linear polyethylene geomembrane and the geocomposite drainage layer.



Sampling of Liner Systems

Large rectangular samples were obtained of low-density linear polyethylene geomembrane and the geocomposite drainage layer for further study.



Sampling of Liner Systems

Large rectangular samples were obtained of low-density linear polyethylene geomembrane and the geocomposite drainage layer for further study.



Sampling of Liner Systems

Also, large rectangular samples were obtained of Geosynthetic clay liner from the conventional cover test section for advance testing.



Step 4: Sampling of Subgrade Soil

Once samples of liner systems were obtained, additional sampling of subgrade soils beneath the liner systems were extracted.



Geosynthetic Clay Liner (GCL): Test Preparations

Extracted Bentonite from GCL



Geosynthetic Clay Liner (GCL): Test Preparations



Geosynthetic Clay Liner (GCL): Atterberg Limit Tests

Plastic Limit Test



Geosynthetic Clay Liner (GCL): Atterberg Limit Tests

Liquid Limit Test

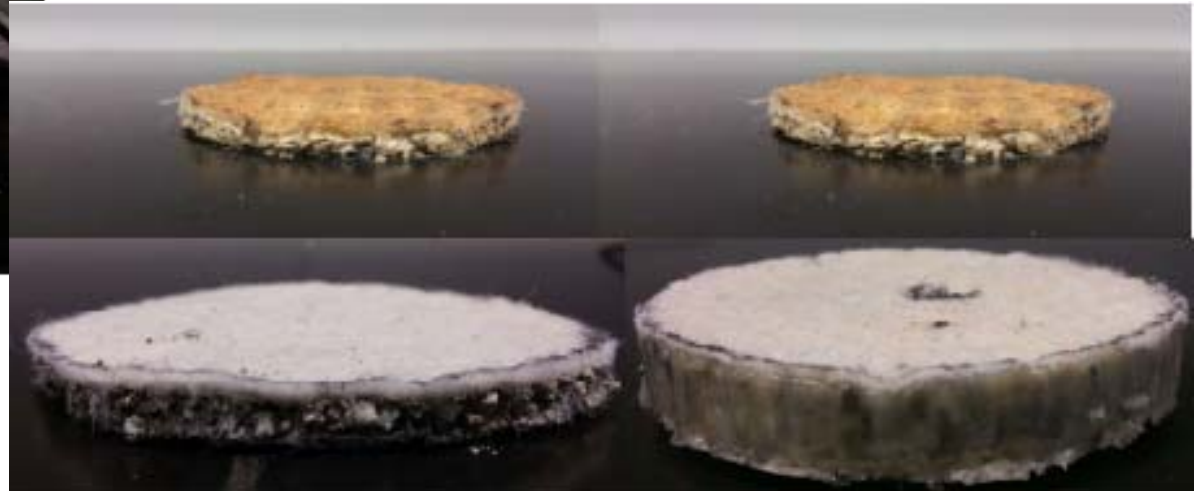
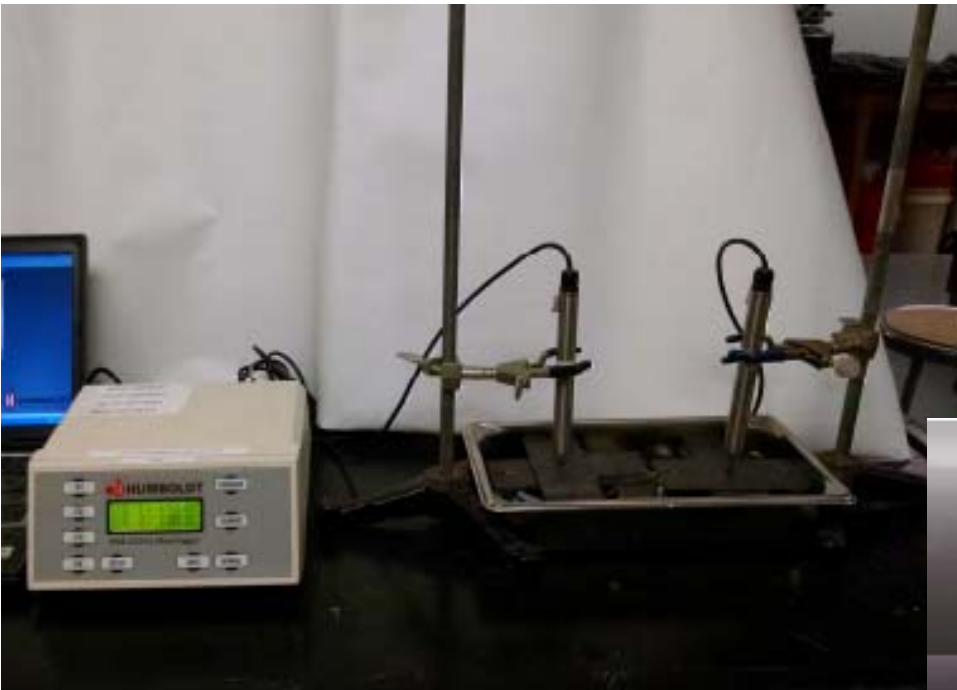


Geosynthetic Clay Liner (GCL): Swell Index Test Preparations

Weighed Bentonite of 2 grams



1D Swell Test (ASTM D 4318)



Hydraulic Conductivity Test ASTM D 5084-03



ASTM D7503 - 10

Standard Test Method for Measuring the Exchange Complex and Cation Exchange Capacity of Inorganic Fine-Grained Soils

Active Standard ASTM D7503 | Developed by Subcommittee: D18.04

Cation Exchange Capacity (CEC)

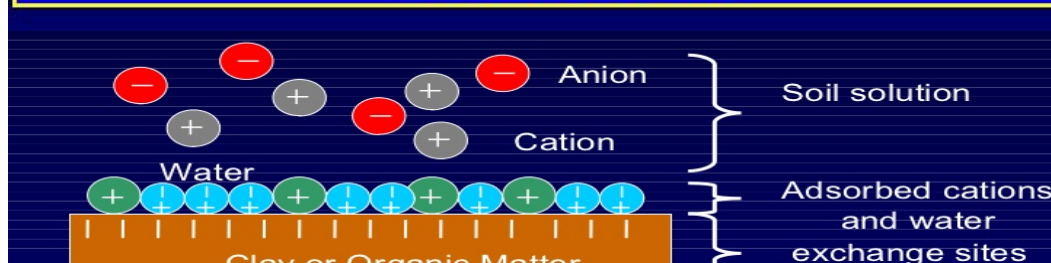
- The sum total of all **exchangeable cation charges** that a soil can potentially adsorb
- Determined experimentally in the lab
- Expressed in terms of **positive charge adsorbed** per unit mass [$\text{cmols}_{\text{charge}}/\text{kg}_{\text{soil}}$]

1 mol = 6.022×10^{23} atoms

(1 cmol = 1/100 mol)

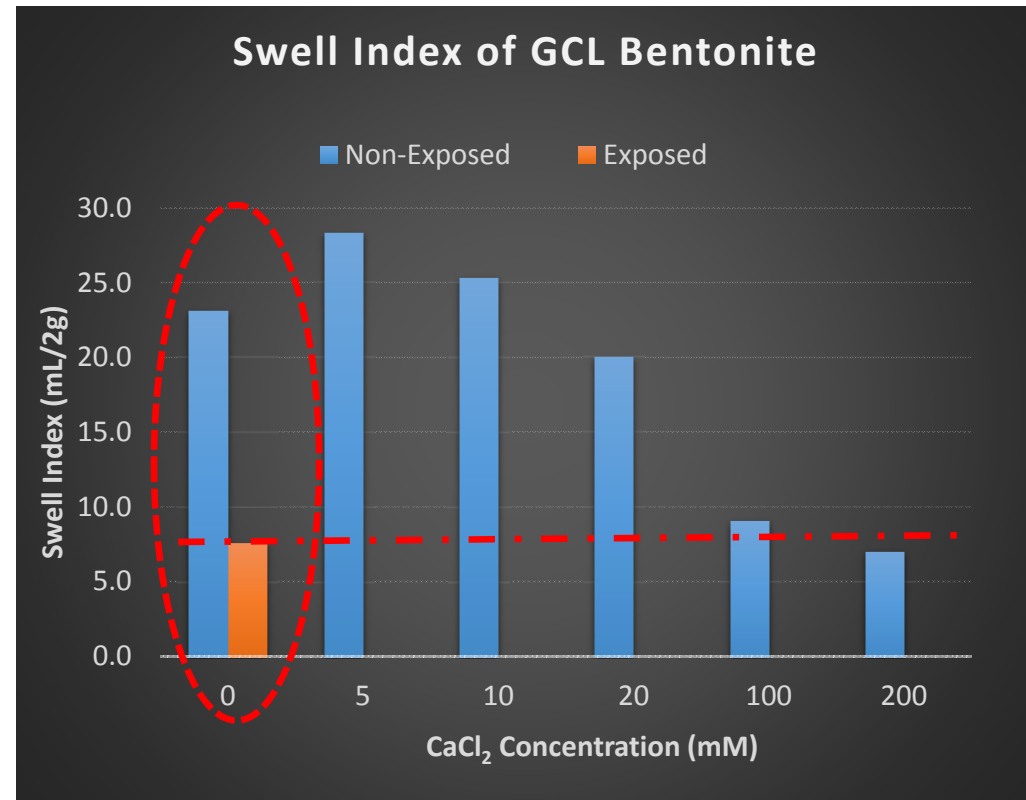
- **If:** CEC = 10 cmol_c/kg
- **Then:** soil adsorbs 10 cmol of H^+ which can be exchanged with 10 cmol K^+ , or 5 cmol Ca^{2+}

Number of charges, not the number of ions, is what matters



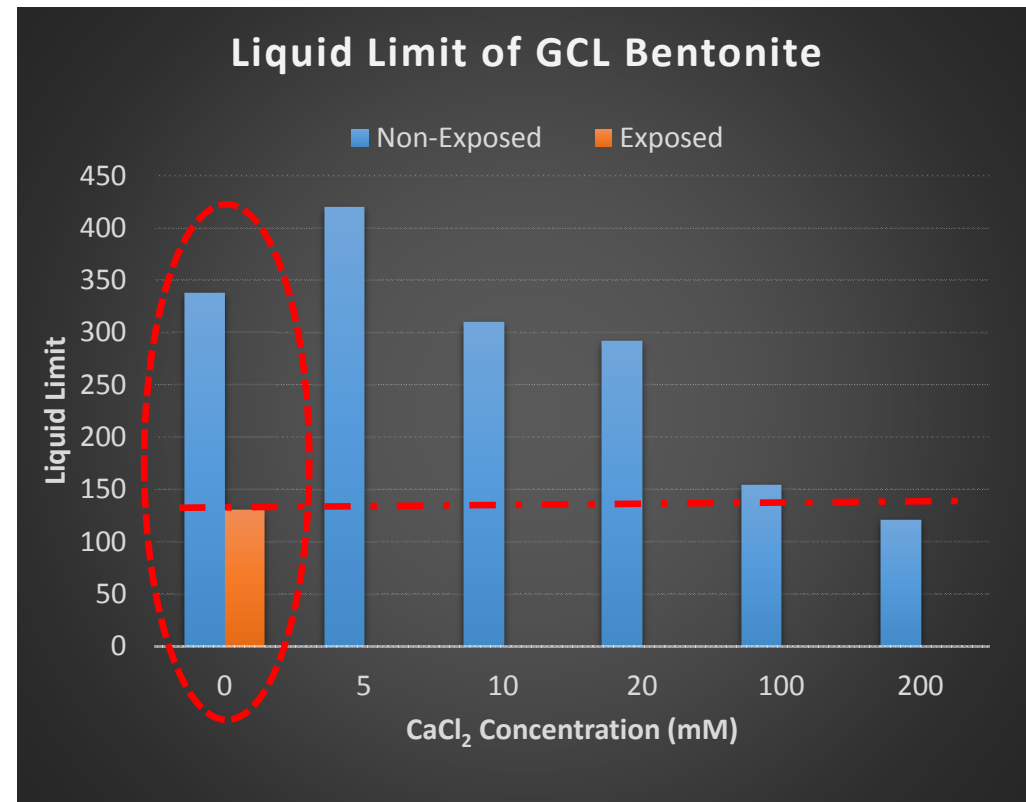
Geosynthetic Clay Liner (GCL): Swell Index Test Results

Bentonite	CaCl ₂ Concentration (mM)	Swell Index (mL/2g)
Non-Exposed	DIW	23.1
	5	28.3
	10	25.3
	20	20.0
	100	9.0
	200	7.0
Manufacturer's Data	DIW	24
Exposed	DIW	7.6

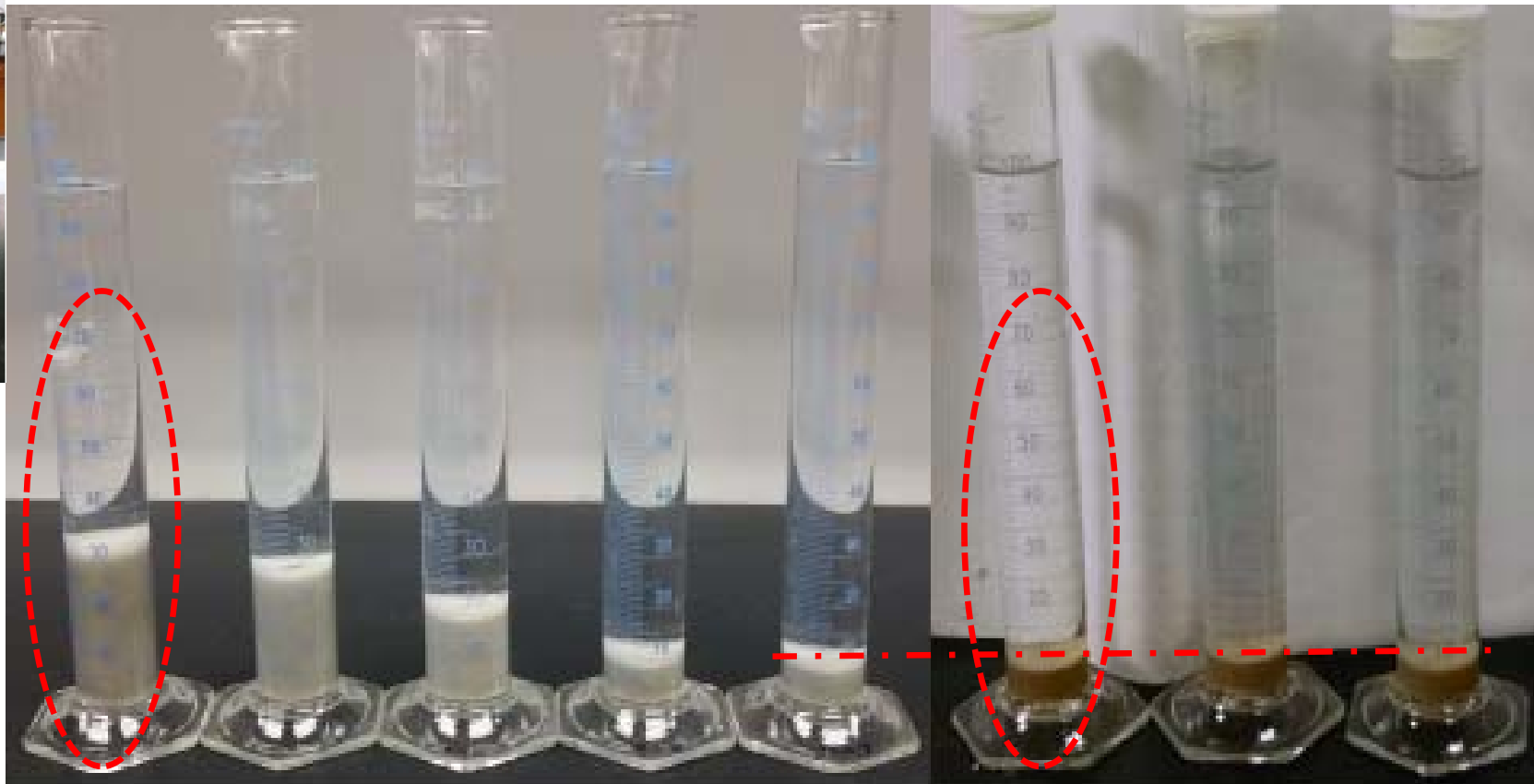


Geosynthetic Clay Liner (GCL): Atterberg Limits Tests Results

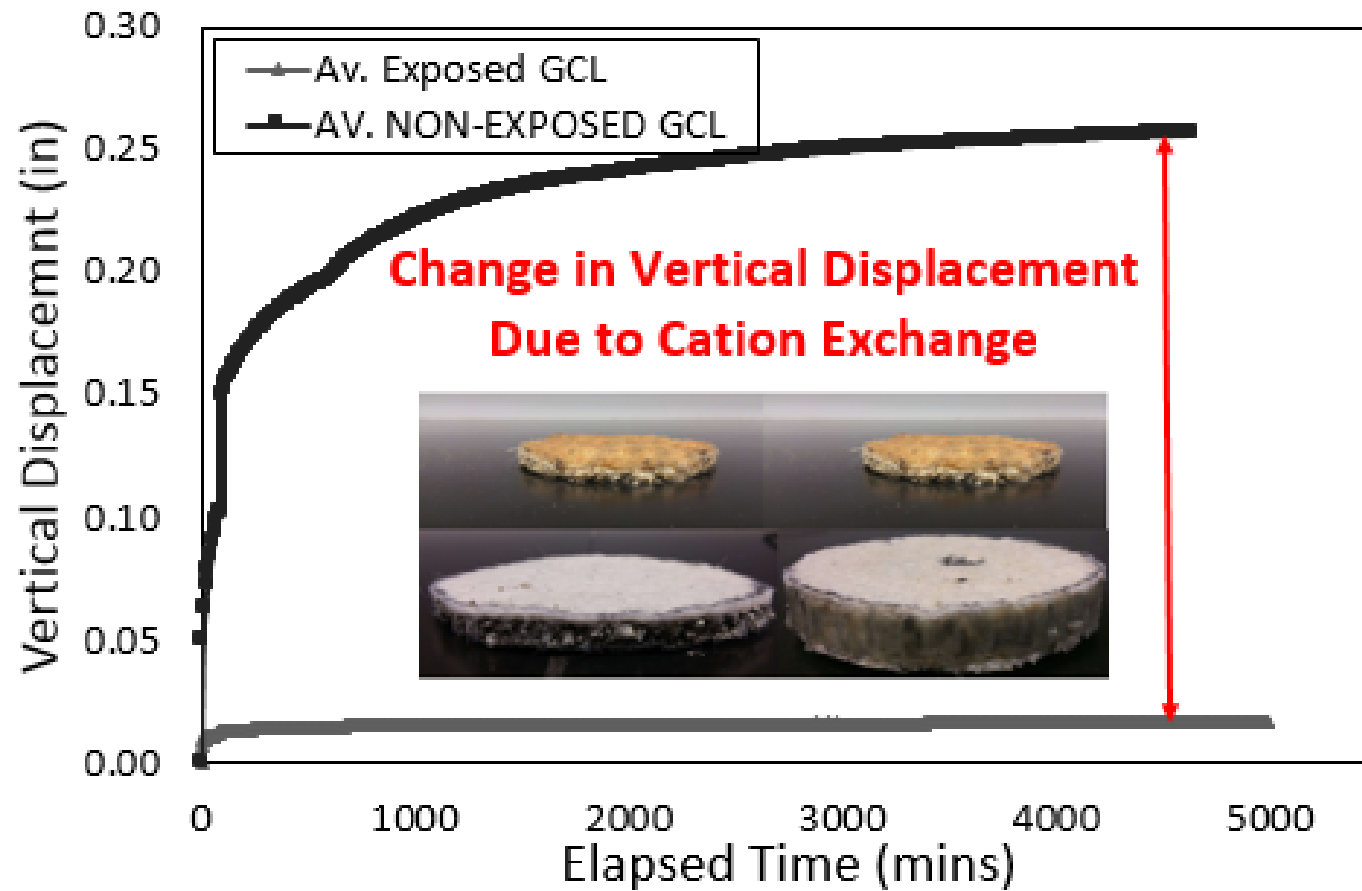
Bentonite	CaCl ₂ Concentration (mM)	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI=LL-PL)
Non-Exposed	DIW	337.9	40.6	297.3
	5	420.1	52.9	367.2
	10	310.1		310.1
	20	291.9		291.9
	100	154.5		154.5
	200	120.9		120.9
	Exposed	DIW	131.0	46.1



Free Swell Index (ASTM D 5890)



1D Swell Test Tap Water (ASTM D 4318)



Permeant Exhumed GCL Sample	DIW		
	1	2	3
Start (days)	1/28/2016	1/28/2016	2/1/2016
Stop (days)	2/1/2016	2/1/2016	2/7/2016
Duration (days)	4	4	6
Porous stone weight (g)	55.1	55.1	55.1
Porous Stone Pressure (N/m ²)	66.7	66.7	66.7
tare (g)	149.70	148.56	148.30
t _{in} (in)	0.25	0.25	0.23
t _{fin} (in)	0.31	0.31	0.31
Δt (in)	0.0625	0.0625	0.0833
Δt (m)	0.0016	0.0016	0.0021
Percent 1D Swell	25%	25%	36%

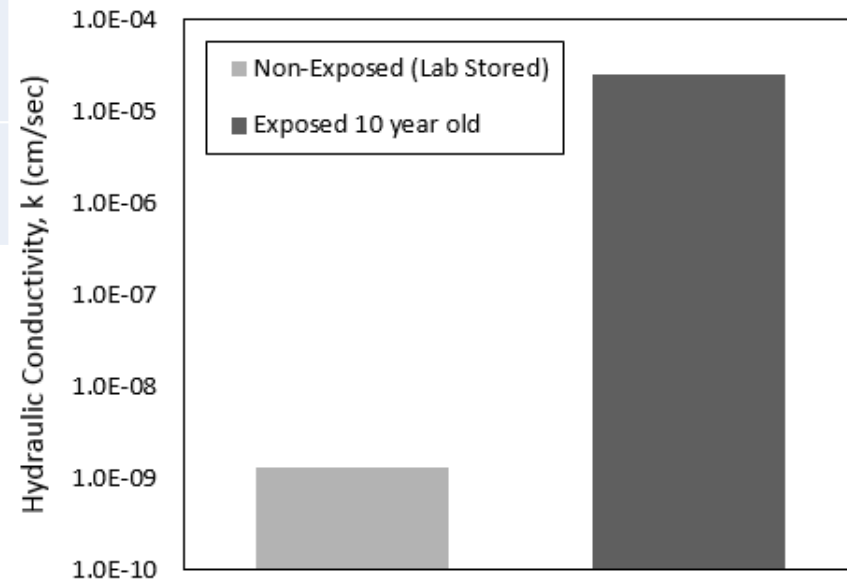
Permeant	DIW			10mM of CaCl ₂			200mM of CaCl ₂		
Lab Stored GCL Sample	1	2	3	1	2	3	1	2	3
Start (days)	2/1/2016	2/7/2016	2/7/2016	2/18/2016	2/18/2016	2/24/2016			
Start (days)	2/7/2016	2/16/2016	2/16/2016	2/24/2016	2/24/2016	3/1/2016			
Duration (days, 2016)	6	9	9	6	6	6			
t _{in} (in)	0.25	0.25	0.25	0.25	0.25	0.25			
t _{fin} (in)	0.59	0.67	0.58	0.5	0.48	0.47			
Δt (in)	0.34	0.42	0.33	0.25	0.23	0.22			
Δt (m)	0.008731	0.010583	0.008467	0.006350	0.005821	0.005556			
Percent 1D Swell	138%	167%	133%	100%	92%	88%			

1D Swell Test (ASTM D 4318)



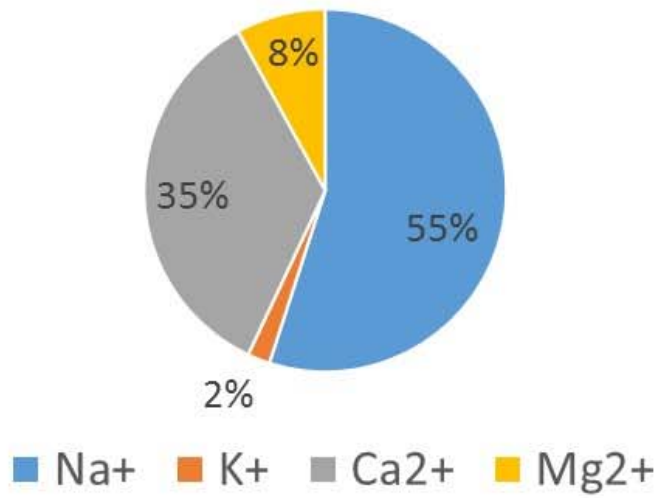
H.C. Test ASTM D 5084-03

GCL Type	Samples	Permeant	k (cm/s)	
			Measured	Av. Measured
BENTOMAT ST (Manufacturer)	-	-	5.0E-09	5.0E-09
Exposed	GCL_1-1	Tap water	2.5E-05	2.5E-05
	GCL_1-2		2.9E-05	
	GCL_1-3		2.3E-05	
	GCL_2-1		2.7E-05	
	GCL_2-2		3.0E-05	
	GCL_2-3		2.4E-05	
	GCL_3-1		1.9E-05	
	GCL_3-2		3.0E-05	
	GCL_4-1		1.7E-05	
Lab Stored	GCL_1	Tap water	1.4E-09	1.3E-09
	GCL_2		7.8E-10	
	GCL_3		1.7E-09	

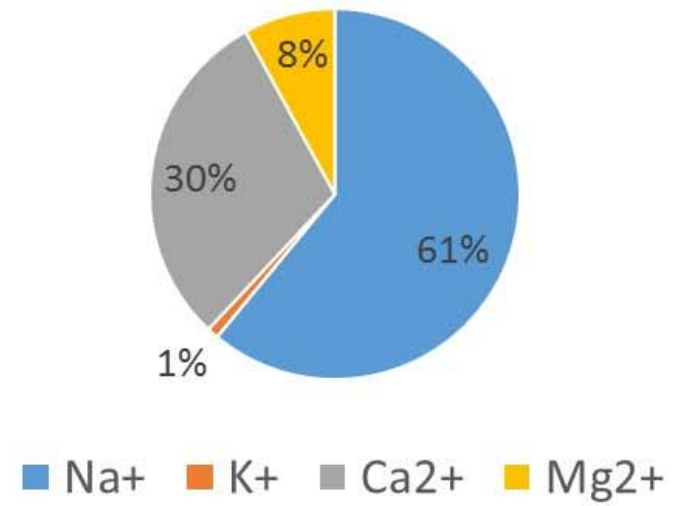


Cation Exchange Capacity

Lab Stored

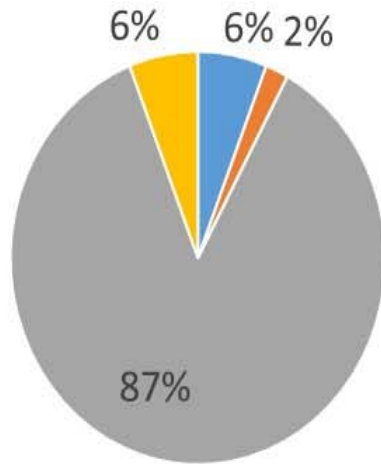


Lab Stored



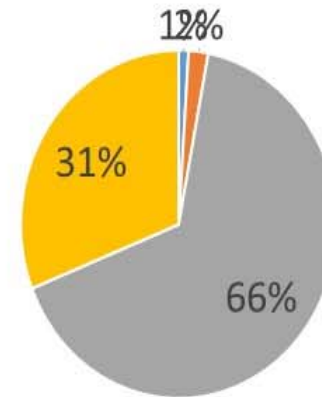
Cation Exchange Capacity

Hydrated with 0.1M CaCl₂



■ Na⁺ ■ K⁺ ■ Ca²⁺ ■ Mg²⁺

Exhumed from field (Hydrated with soil water)

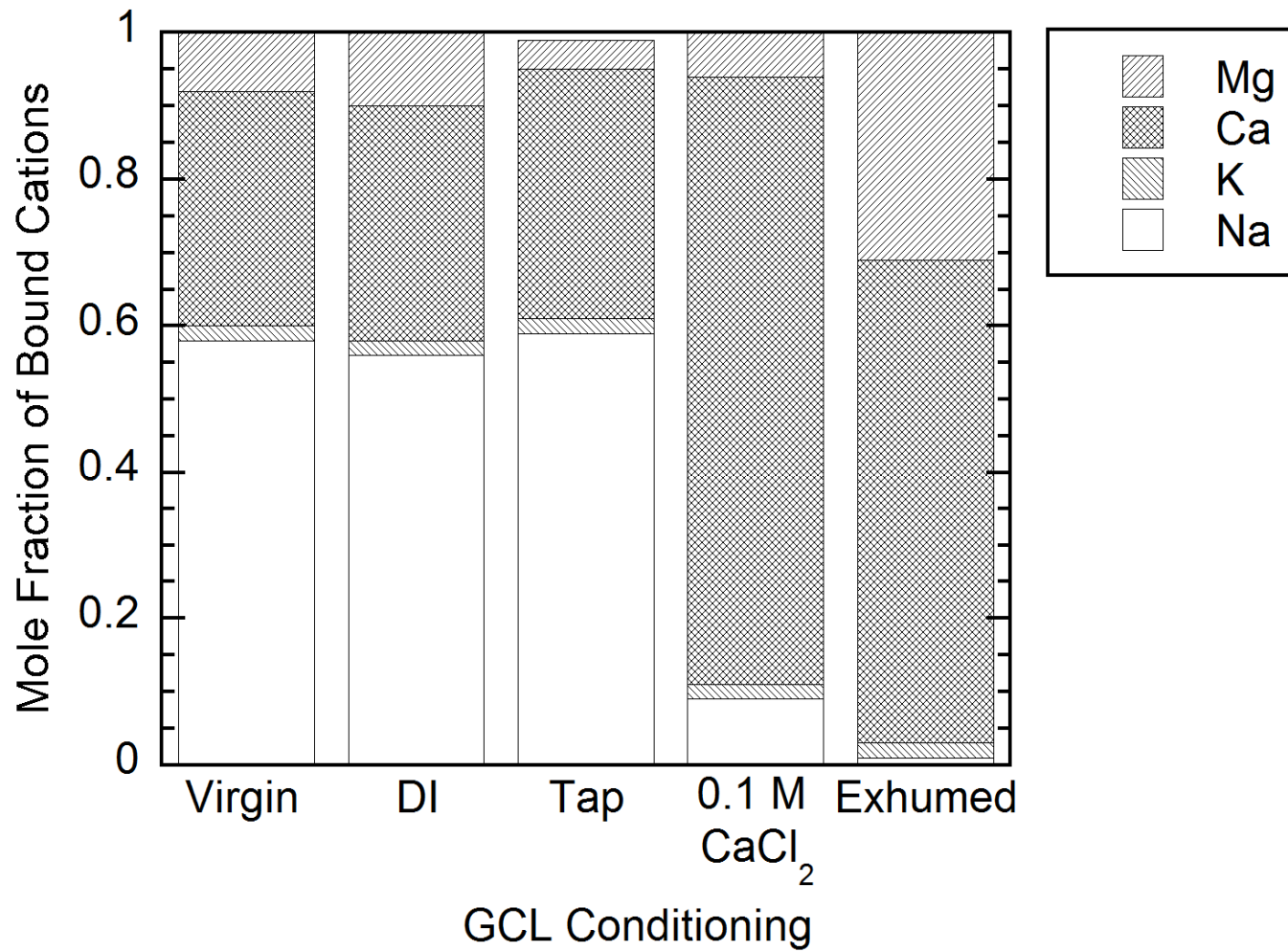


■ Na⁺ ■ K⁺ ■ Ca²⁺ ■ Mg²⁺

Cation Exchange Capacity (Early Results, Not to share yet)

	Bound Cations (Adsorbed on clay surface)			
	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺
Lab Stored	55%	2%	35%	8%
Lab Stored	61%	1%	30%	8%
Hydrated with DI	61%	2%	29%	8%
Hydrated with Tap	56%	2%	30%	11%
Hydrated with 0.1M CaCl ₂	6%	2%	87%	6%
Exhumed from field (Hydrated with soil water)	1%	2%	66%	31%

Cation Exchange Capacity



Coal Ash Resistant GCL Results

(Provided by Nate Mayer)

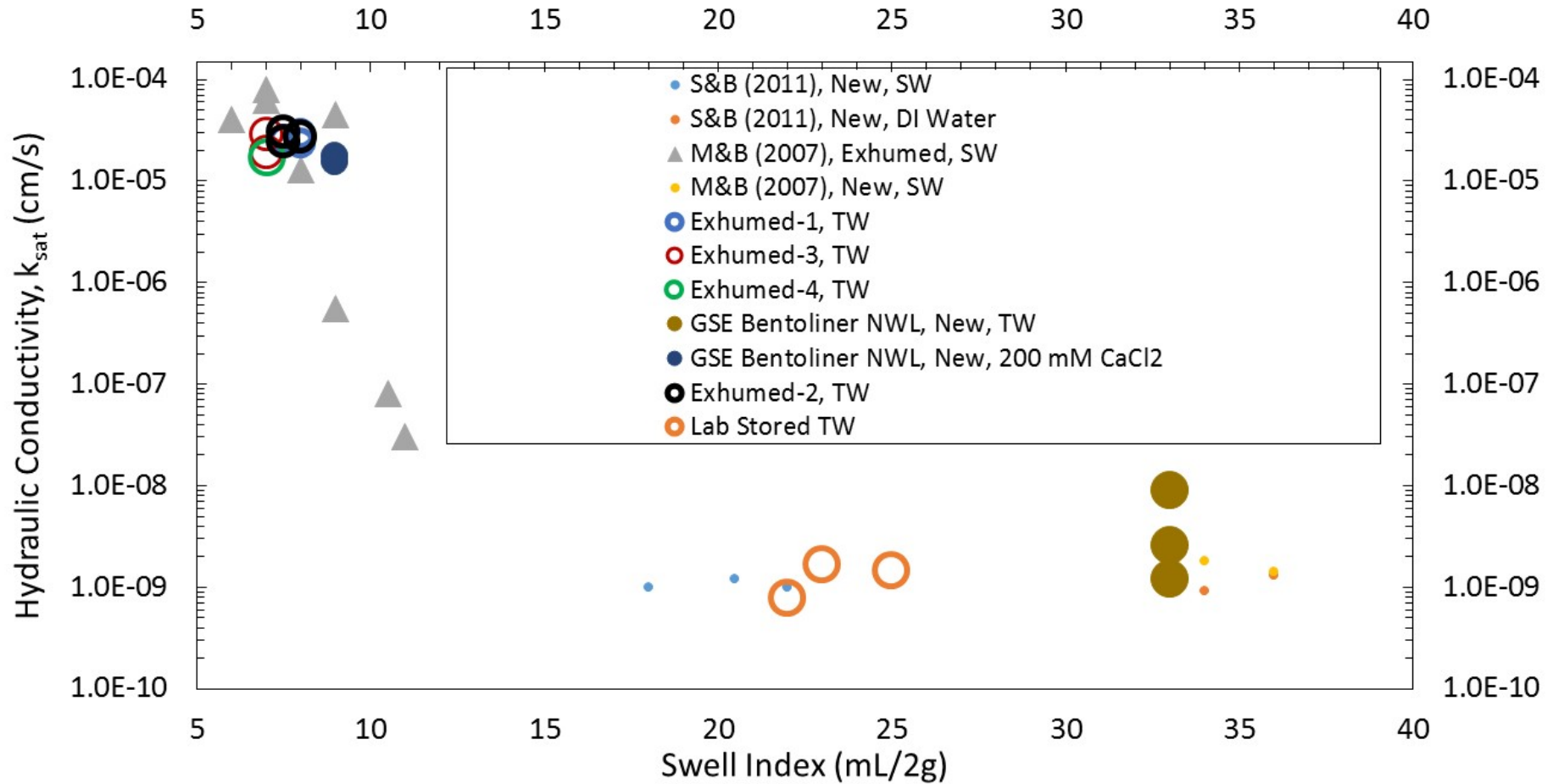
GCL Type	Samples	Permeant	k (cm/s)	
			Measured	Av. Measured
GSE Bentoliner NWL (Manufacturer)	-	-	5.0E-09	5.0E-09
GSE Bentoliner NWL	GCL_1	Tap water	9.0E-09	4.3E-09
	GCL_2		1.2E-09	
	GCL_3		2.6E-09	
GSE Bentoliner NWL	GCL_1	200 mM CaCl ₂	1.7E-05	1.6E-05
	GCL_2		1.5E-05	

Coal Ash Resistant GCL Results

(Provided by Nate Mayer)

Permeant	DIW			10mM of CaCl ₂			200mM of CaCl ₂		
New GCL Sample	1	2	3	1	2	3	1	2	3
Start (days)	3/1/2016	3/1/2016	3/14/2016	2/24/2016	3/1/2016		3/14/2016	3/14/2016	
Start (days)	3/14/2016	3/14/2016	3/30/2016	3/1/2016	3/14/2016		3/30/2016	3/30/2016	
Duration (days, 2016)	13	13	16	6	13		16	16	
Mass _{dry} (g)	32.60	38.4	32.2	42.80	45.7		40.85	35.66	
t _{in} (in)	0.25	0.27	0.25	0.33	0.31		0.25	0.27	
t _{fin} (in)	0.38	0.40	0.40	0.42	0.33		0.25	0.27	
Δt (in)	0.13	0.13	0.15	0.08	0.02		0.00	0.00	
Δt (m)	0.003175	0.003175	0.003704	0.002117	0.000529		0.000000	0.000021	
Percent 1D Swell	50%	46%	58%	25%	7%		0%	0%	

Our Results with Literature



Tensile Strength (ASTM D 4885)

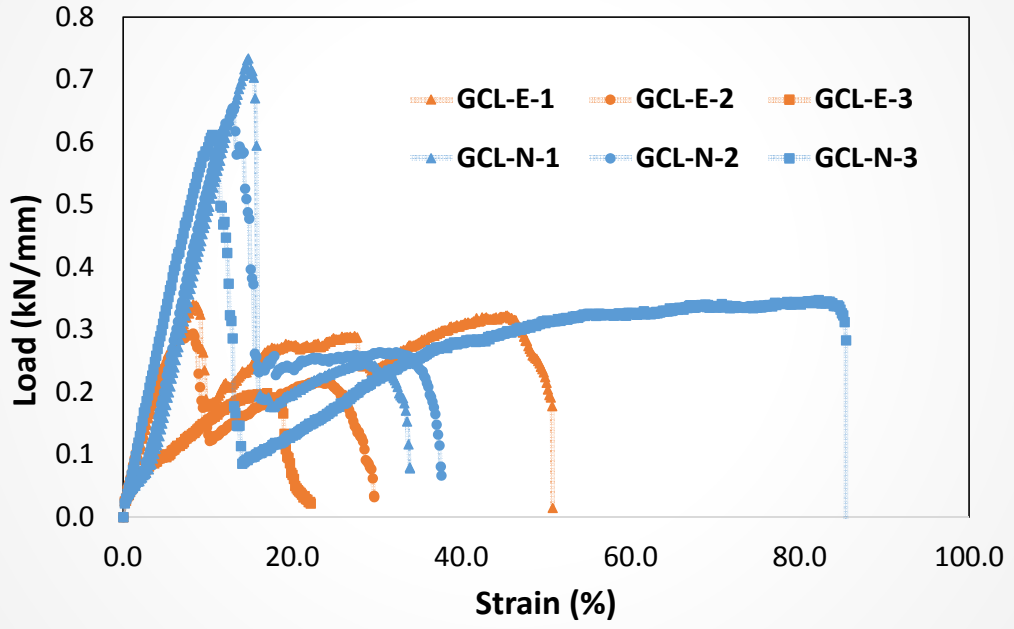


Geosynthetic Clay Liner (GCL): Tensile Test Performed

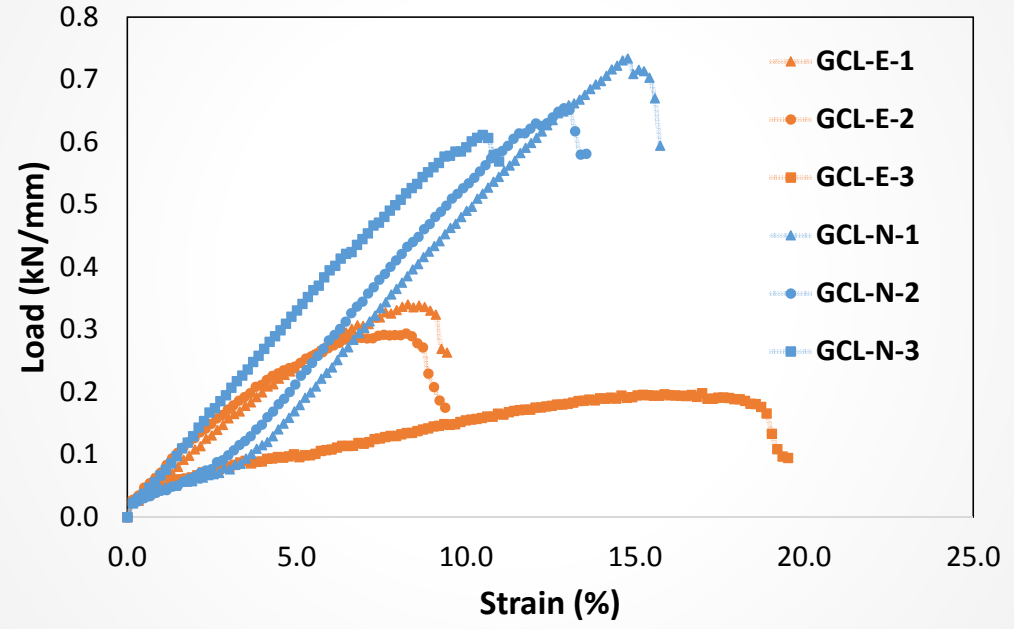


Geosynthetic Clay Liner (GCL): Tensile Test Results

Tensile Behavior of Exposed and Non-Exposed GCLs



Tensile Behavior of Exposed and Non-Exposed GCLs



Tensile Properties of GCLs

Sample ID	Peak Strength (N/mm)	12% Strength (N/mm)
Ex_GCL_1	6.54	4.12
Ex_GCL_2	5.65	2.71
Ex_GCL_3	3.82	3.37
Lab Stored_GCL_1	13.34	11.03
Lab Stored_GCL_2	11.89	11.45
Lab Stored_GCL_3	11.12	8.13

Exposed Geomembrane: Tensile Test Preparation

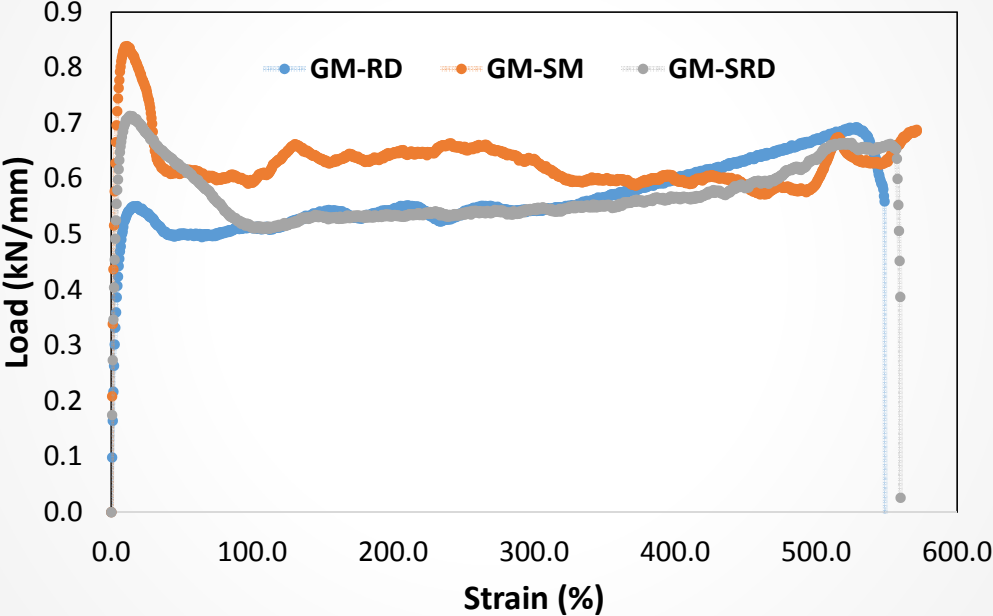


Exposed Geomembrane: Tensile Test Performed

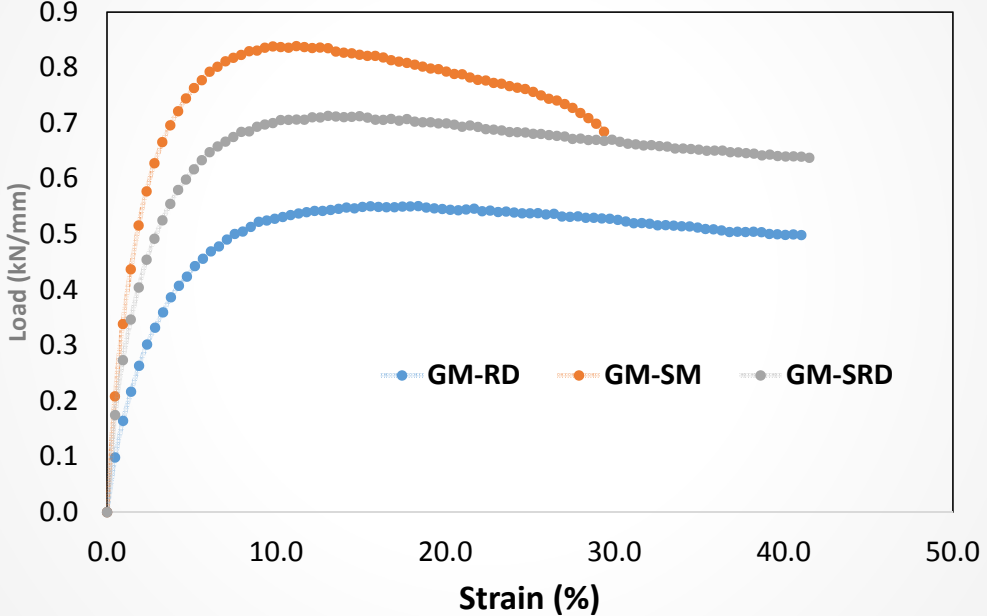


Exposed Geomembrane: Tensile Test Results

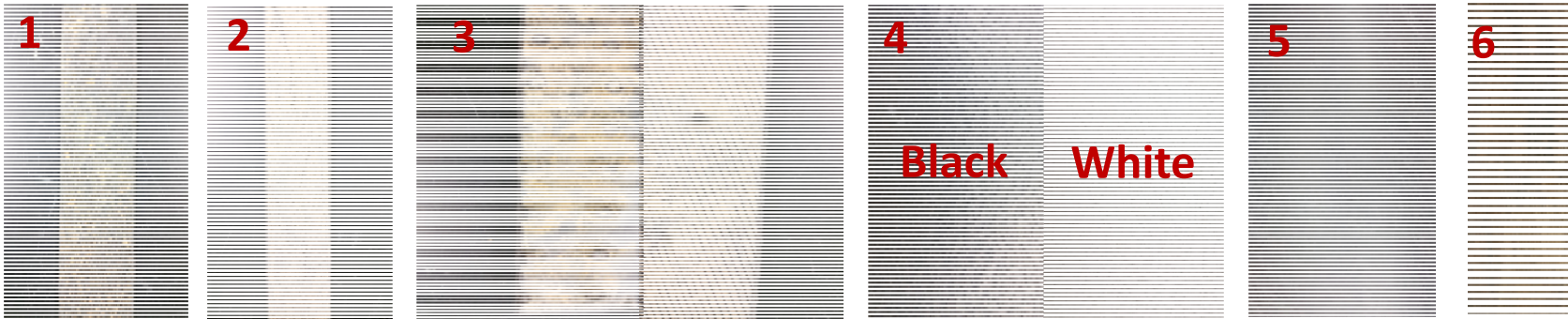
Tensile Behavior of Exposed Geomembrane



Tensile Behavior of Exposed Geomembrane



ID	Type	Location	Contact	Age (years)	Tensile Test	Av. Peak Strength (N/mm)	Minimum (N/mm)
1	60-mil Textured Geomembrane w/ Veins	Leon County Landfill, Tallahassee	DJ	10	3	30	22
2	40-mil HPDE Agru America Microspike	Riverbend Landfill, Oregon	Dr. Abichou	10-12	1	23	15
3	60-HDPE Super Gripnet Geomembrane	Riverbend Landfill, Oregon	Dr. Abichou	8	1	28	22
4	60-mil Black & White Textured Geomembrane w/ Veins	West Palm Beach	Nate Mayers	New	-	-	22
5	60-mil Smooth Geomembrane	West Palm Beach	Nate Mayers	?	-	-	22
6	60-mil HPDE Agru America Microspike	Orange County Landfill	Bo Bruner	12	-	-	22



Future Work

- Geosynthetics Clay Liner
- Geomembrane
 - Polymer Oxidation Test
- Geo-composite
 - Polymer Oxidation Test
- Collect more geosynthetics from different landfills
 - Continue to perform behavior or performance testing
- Compile and create database with results

Property	Test Method	HDPE
Melt Flow Index (g/10 min)	ASTM D 1238 (190/2.16)	≤ 1.0
OIT (minutes)	ASTM D 3895 (1 atm/200°C)	≥ 100

Thank you!!!

TAG Members:

- Ron S. Beladi, P.E.
- Henry Freenberg, P.E.
- Jeremy Clark, P.E.
- Kwasi Badu-Tweneboah, Ph.D., P.E.
- Sam Levin, P.E.
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