Permit No.	Scan Date	DIN
1910-STRUCT-2015	**July 23, 2015**	**24772**

RECEIVED
July 22, 2015
Solid Waste Section
Asheville Regional Office

July 22, 2015

Mr. Larry Frost, Environmental Engineer (via electronic mail only)
Permitting Branch, Solid Waste Section
Division of Waste Management, NCDENR
1646 Mail Service Center
Raleigh NC 27699

Re: Technical Specification Updates

Dear Mr. Frost,

On behalf of Green Meadow, LLC and Charah, Inc., HDR provides the following supplemental and revised information for Permit No. 1910 for the Brickhaven No. 2 Mine Site Tract "A" Structural Fill. This information relates to geotechnical and laboratory testing results obtained since initiation of the project and associated modifications to the technical specifications recommended by HDR.

MODIFICATION TO THE TECHNICAL SPECIFICATIONS SECTION 01060 SPECIAL CONDITIONS
Section 2.1 INTERFACE FRICTION TESTS, Subsection B.1, currently reads as the following:

"Testing will include the interfaces between the following adjacent materials with a minimum peak friction angle of 26 degrees is required for each interface"

We propose modifying the text of this requirement to the following:

"Testing will include the interfaces between the following adjacent materials with a minimum peak friction angle of 13 degrees and minimum peak adhesion of 100 psf is required for each interface"

The purpose for this modification is to allow for use of on-site clay soils that have shear strengths less than that previously specified for minimum required interface shear strength friction angle. In the previously submitted permit application, global slope stability analyses and geosynthetic allowable stress analyses were performed to determine the minimum required interface shear strength between each of the liner elements. The requirement previously specified was a minimum interface friction angle of 26 degrees and 0 psf of adhesion between each layer, and this was based partly on typical published design values from the Geosynthetics Research Institute (GRI) used in the original analyses.

Site specific interface shear strength testing (according to ASTM D6243) has been performed for the interface between the geosynthetic clay liner (GCL) and two different samples of soil clay liner, and the test results indicated interface shear strengths of 17.9 degrees / 159 psf adhesion and 21.2 degrees / 187 psf adhesion, respectively for each soil sample. A triaxial compression test was also performed (according to ASTM D4767) on a remolded clay sample that corresponds to the clay soil liner sample used in the 17.9 degrees / 159 psf adhesion interface friction testing result, and similar shear strengths were obtained on the clay soil liner sample tested by itself in the triaxial

compression test (17.8 degrees friction angle, 153 psf cohesion). The triaxial test performed on this clay soil liner sample indicates that the clay soil liner material is the limiting factor that is causing the interface shear friction angle to be less than the Technical Specifications currently require as a minimum (26 degrees and 0 psf of adhesion).

The global slope stability analyses and geosynthetic allowable stress analyses were reviewed to determine the minimum required shear strength parameters for the GCL to soil clay liner interface. The original analyses assumed no adhesion was available at this interface that could contribute to shear strength, but now that lab test results have been obtained, it is apparent that adhesion is available between the GCL and soil clay liner, even in an inundated condition. The analyses were revised to use a friction angle of 13 degrees and an adhesion of 100 psf, each of which is less than both interface shear strength tests indicated, which justifies the modification to the Technical Specifications. The revised calculations and aforementioned interface shear strength and triaxial compression lab test results that support our revised requirements are attached to this letter.

MODIFICATION TO THE TECHNICAL SPECIFICATIONS SECTION 02276 SOIL LINER SYSTEM

Section 2.1 MATERIALS, Subsection B.4.b., currently reads as the following:

“The plasticity index shall be at least 10 and less than 30 as measured by ASTM D4318.”

We propose modifying the text of this requirement to the following:

“The plasticity index shall be at least 10 as measured by ASTM D4318.”

The purpose for this modification is to allow for use of on-site clay soils that have plasticity indices higher than limit currently in the specifications. Atterberg limits tests performed according to ASTM D4318 with on-site materials have indicated plasticity indices as high as 50 and as low as 10 throughout samples collected to-date. Typically, the upper bound limit on plasticity index is specified to limit the difficulty of soil placement during construction because ‘fatter’ clays with higher plasticity indices tend to stick to the equipment and can be difficult to place and compact. Our experience working with on-site soils to-date has indicated that placement of these ‘fatter’ clays has not been an issue during construction, and there has been minimal difficulty in reaching the required compaction percentage indicated in the Technical Specifications. An additional concern is that higher plasticity indices are indicative of soils with lower remolded shear strengths and tend to be more expansive than a ‘leaner clay’ with a lower plasticity index. The potential for lower shear strength seen through interface shear strength testing is not a concern based on revised calculations regarding the minimum required interface shear strength of the clay that is discussed below. Additionally, the increased potential of desiccation cracks occurring in the clay liner prior to placement of geosynthetics is already dealt with in the Technical Specifications in Section 3.2 MATERIALS, Subsection J., where ‘the exposed finished lifts of the soil liner material is required to be sprinkled with water to minimize desiccation…’ and ‘…all defective areas shall be repaired by the Contractor to the satisfaction of the CQA/CQC Consultants.’ The added benefit of using these soils with higher plasticity indices is that they tend to have lower permeabilities, which is evidenced

by the permeability testing performed to-date, all of which has been less permeable than the 10^{-5} cm/sec permeability requirement prescribed.

MODIFICATION TO THE TECHNICAL SPECIFICATIONS SECTION 02777 DRAINAGE COMPOSITE

Section 2.2 MATERIALS AND MANUFACTURE, Subsection C.2., currently reads as the following:

"The bond between the geotextile and the geonet shall exhibit a MARV ply adhesion of 1 LBS/IN when tested in accordance with ASTM D7005."

We propose modifying the text of this requirement to the following:

"The bond between the geotextile and the geonet shall exhibit a minimum ply adhesion of 0.5 LBS/IN when tested in accordance with ASTM D7005."

The purpose of this modification is to minimize production time and the impact to transmissivity. In order to obtain the higher ply adhesion strength more of the net must be melted to bond with the geotextile creating a reduction in transmissivity of the geocomposite.

The purpose of specifying ply adhesion is to prevent a sliding failure (delamination) between the geotextile and the geonet. The Geosynthetic Research Institute recommends a ply adhesion range of 0.5 to 1 lbs/in as highlighted in the standard guide for GRI-GN2 and GRI-GC13 which is included for reference. In addition, the manufacturer GSE Environmental states in the attached letter "Based on past experience, CoalDrain Geocomposite with a 0.5 lb Ply Adhesion (ASTM D7005) value will exceed the specified 26 degree peak interface friction angle." GRI industry standards and the manufacturer's concurrence supports HDR's recommendation to reduce the ply adhesion value to 0.5 lbs/in.

If you have any questions, comments, or require additional information, please contact me at 704. 338.6843.

Sincerely,
HDR Engineering, Inc. of the Carolinas

Michael D. Plummer, PE
Project Manager

cc: Ed Mussler, NCDENR (via electronic mail with one hard copy via UPS)
Joe Readling, HDR (via electronic mail only)
Norman Divers, Charah (via electronic mail only)
Glen Amey, Charah (via electronic mail only)

Attachments

- Technical Specifications
  - 01060 – Special Conditions, page 4 (revised)
  - 02276 – Soil Liner System, page 3 (revised)
  - 02777 – Drainage Composite, page 3 (revised)
- Interface Shear Strength Testing between GCL and Soil Clay Liner Laboratory Data
- Triaxial Compression Testing on Soil Clay Liner
- Global Slope Stability Analyses, revised
- Geosynthetic Stress Analyses, revised
- GRI Standard Guide for Joining and Attaching Geonets and Drainage Composites
- GSE CoalDrain Geocomposite Specifications

Technical Specifications

01060 – Special Conditions, page 4 (revised)

any interface doesn't meet the requirements, or if the CONTRACTOR changes geosynthetic materials, then the additional cost to qualify those materials shall be borne by the CONTRACTOR.

B. Base Liner

1. Testing will include the interfaces between the following adjacent materials with a minimum peak friction angle of ~~26~~ 13 degrees and minimum peak adhesion of 100 psf is required for each interface.

MATERIAL	SPECIFICATION SECTION
Ash	----
Drainage Composite	02777
60 Mil HDPE (textured)	02775
Geosynthetic Clay Liner (GCL)	02800
Soil liner	02276

C. Cap System

1. The CONTRACTOR may select one of the following cap systems. Testing will include the interfaces between the following adjacent materials with a minimum peak friction angle of 26 degrees is required for each interface.

a. Option 1

MATERIAL	SPECIFICATION SECTION
Drainage Soil	N/A
40 Mil (textured HDPE or textured LLDPE)	02775 or 02774
Ash	---

b. Option 2

MATERIAL	SPECIFICATION SECTION
Unclassified Soil	N/A
Drainage Composite	02777
40 Mil (textured HDPE or textured LLDPE)	02775 or 02774
Ash	----

D. Testing shall be performed in accordance with ASTM D6243. The liner system materials shall be tested at normal stressed of 2,000, 4,000, and 6,250 psf. The cap system materials shall be tested at normal stressed of 500, 1,000, and 1,500 psf. Displacement rates shall be in accordance with ASTM D6243 Procedure A for geosynthetic to geosynthetic interfaces and Procedure B for soil to geosynthetic interfaces. Soil components shall be compacted to the same moisture-density requirements specified for full-scale field placement and saturated prior to shear for 24 hours. All geosynthetic interfaces shall be tested in a wet condition. Geosynthetics shall be oriented such that the shear force is parallel to the downslope orientation of these components in the field. The testing laboratory shall confirm these criteria with the CQA firm prior to performing the tests.

E. Report results in accordance with ASTM D6243 provide complete test data, including plots of shear force versus horizontal displacement and a plot of peak shear stress versus normal stress for the tests conducted. Test results must be satisfactory for material shop drawings to be approved.

PART 3 - EXECUTION (NOT USED)

END OF SECTION

Technical Specifications

02276 – Soil Liner System, page 3 (revised)

3. Some soils not meeting the requirements of B.1. and B.4. below, may be acceptable for use in the Work at the sole discretion of the Engineer. The contractor may submit data on soils for the Engineer's review. For the Engineer to approve the materials, the submittal should contain: a statement signed by a qualified professional Engineer that the proposed soils will meet the hydraulic conductivity requirement and are otherwise suitable for use in the Work; and, supporting geotechnical test results and data.
4. All soils must be approved for use by the Engineer prior to use in the Work.

B. Natural Fine-Grained Soil
1. Classification: Natural fine-grained soil shall have a classification of SC, SM, CH, CL, MH, or ML as determined by ASTM D2488.
2. Grain sizes shall be within the following gradation:

Sieve Size	Percent Passing by Weight
3/4 IN	100
No. 4	> 90
No. 200	> 30

3. Hydraulic Conductivity: The saturated hydraulic conductivity of the natural fine-grained soil shall meet the stated tolerances, when compacted in accordance with requirements established by the CQC Consultant and Contractor on the basis of the soil liner test strip as specified herein.
4. Other Soil Liner Properties:
   a. The liquid limit shall be at least 25 as measured by ASTM D4318.
   b. The plasticity index shall be at least 10 ~~and less than 30~~ as measured by ASTM D4318.

C. Bentonite Amended Soil (where applicable):
1. Hydraulic conductivity of constructed bentonite amended soil shall meet the tolerances when compacted in accordance with requirements established by the CQC Consultant on the basis of test results from the soil liner test strip and the borrow soil characterization study.
2. Soil used in the bentonite amended soil shall be free from roots, organic matter, debris, particles larger than 3/4 IN, and other deleterious material. All soil used in the bentonite amended soil shall be taken from a borrow area approved by the CQA Consultant and Engineer.
3. Unless approved otherwise by the CQA Consultant, the soil used in the bentonite amended soil shall meet the following washed sieve gradation:

Sieve Size	Percent Passing by Weight
¾ IN	100
No. 4	55-100
No. 20	45-75
No. 200	10-40

4. Bentonite:
   a. Bentonite shall be free-flowing, powdered, high-swelling, sodium montmorillonite clay (bentonite) free of additives.
   b. Acceptable bentonite manufacturers are:
      1) American Colloid Co., (800) 276-2737.
      2) Bentonite Performance Minerals, LLC (281) 871-7900.
      3) WYO-BEN, Inc. (800) 548-7055.
      4) Approved equal.
   c. The Contractor may propose a bentonite supplier other than those listed above if it is demonstrated that its use in the amended soil satisfies the requirements of these Specifications.

Technical Specifications

02777– Drainage Composite, page 4 (revised)

B. Geotextile:
   1. Cover geonet core on both sides with a geotextile complying with requirements specified in Section 02778: Geotextiles.

C. Drainage Composite:
   1. Create a composite by heat bonding geotextiles to the geonet. The bond between the geotextile and the geonet shall exhibit a ~~MARV~~minimum ply adhesion of ~~1~~0.5 LBS/IN when tested in accordance with ASTM D7005
   2. Effective Transmissivity MARV of 3.3×10^{-3} square meters per second @ 100 hrs.

2.3 SOURCE QUALITY CONTROL

A. Transmissivity Testing:
   1. Measure in place flow rate using water at 68 DegF with a normal compressive load of 6,250 psf, a hydraulic gradient of 0.02, and 100-hour loading.
   2. Attach geotextiles to the geonet in the same configuration as will be used in the field.
   3. Boundary conditions shall match the upper and lower interfaces to be used in the field.
   4. Testing frequency: 1 test for every 200,000 SF of installed product.
   5. Report shall include:
      a. Graph of flow rate vs. hydraulic gradient.
      b. Calculate transmissivity under laminer flow conditions.
      c. Calculated effective transmissivity at hydraulic gradient of 0.3.

B. Interface Friction Tests.
   1. Test materials using ASTM D 6243. Section 01060-Special Conditions, outlines the conditions under which this material shall be tested.
   2. This material is part of a system. The system shall meet the requirements before the component material can be deemed acceptable.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Prior to placement of the drainage composite, clean the substrate of all soil, rock, and other materials which could damage the composite.

B. The geocomponent drainage media shall be placed only on geomembrane that has been approved by the Geomembrane Installer and accepted by the Geotech Engineer.

3.2 INSTALLATION

A. Install geocomposite drain in accordance with manufacturer’s written recommendations.

B. Deploy the drainage composite ensuring that the drainage composite and underlying materials are not damaged. Replace or repair faulty or damaged drainage composite as directed by Engineer.

C. Unroll drainage composite downslope keeping in slight tension to minimize wrinkles and folds.

D. Maintain free of dirt, mud, or any other foreign materials at all times during construction. Clean or replace rolls which are contaminated.

E. Place adequate ballast to prevent uplift by wind.

F. Overlap adjacent rolls a minimum of 6 IN. Overlap new drainage composite over existing as shown on the drawings.

G. Use manufacturer's fasteners to join adjacent rolls. Metallic fasteners will not be allowed. Space fasteners a maximum of 5 FT along downslope roll overlaps and a maximum of 1 FT along cross slope roll overlaps. Use fasteners of contrasting color from the drainage composite to facilitate visual inspection. Do not weld drainage composite to geomembranes.

Interface Shear Strength Testing between GCL and Soil Clay Liner

Laboratory Data

CHESAPEAKE
CONTAINMENT SYSTEMS, INC.
352 Earls Road Middle River, MD 21220
410-335-5886 phone 443-303-1682 fax

SUBMITTAL

Date: June 23, 2015

COVER SHEET

Project: Brickhaven No. 2 Mine Tract 'A' Mine

General Contractor: **Charah Inc.**
12601 Plantside Drive
Louisville, KY

Spec Section: **01060**
Submittal Ref: **Interface Friction Testing- Clay vs. GCL**

NOTES:

Inclusions:

1. **Geotechnics Testing Data CLAY 01**
2. **Geotechnics Testing Data CLAY 02**

Note: A triaxial clay strength test is being provided under separate cover.

REVIEWER NOTES

INTERFACE FRICTION TEST RESULTS
ASTM D 6243

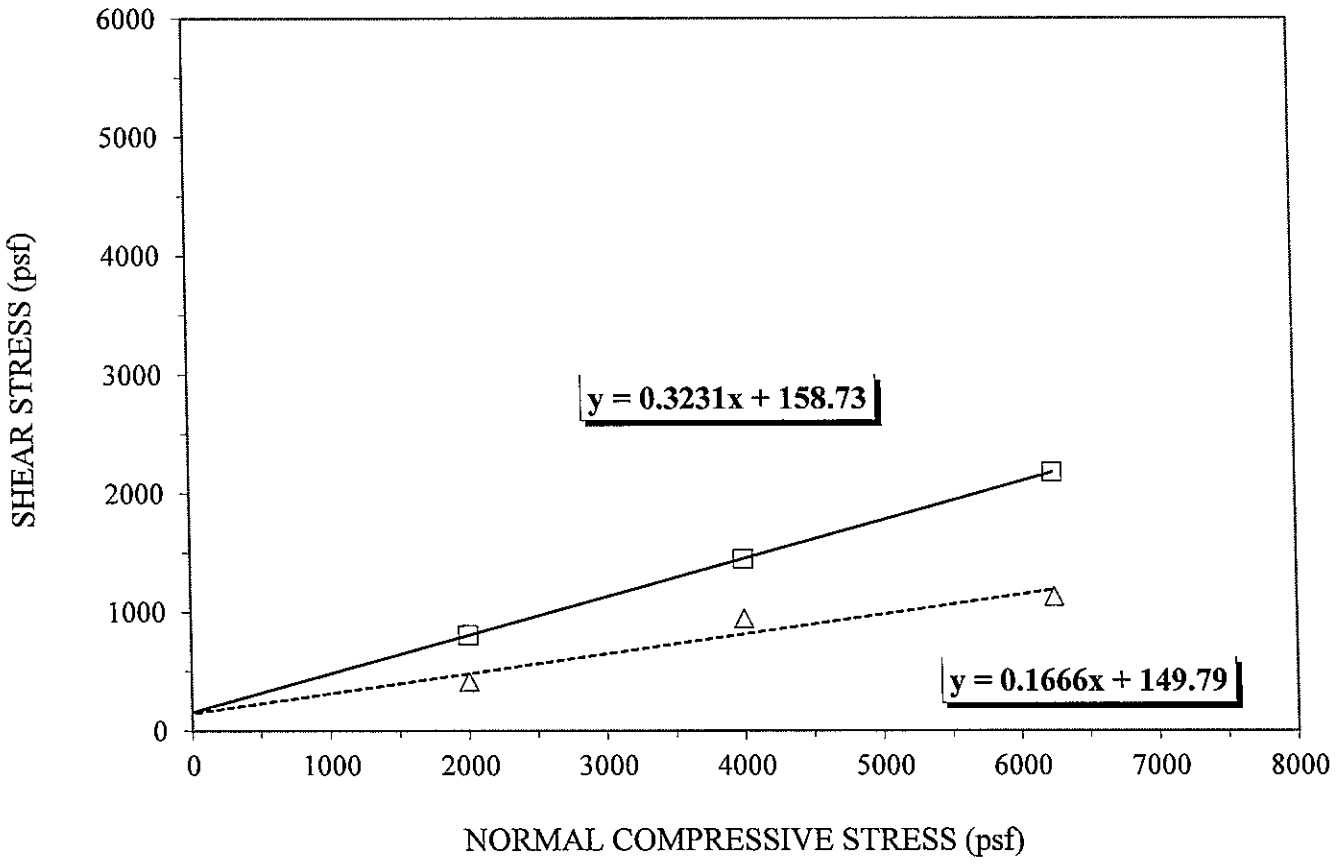
geotechnics
INTEGRITY IN TESTING

CLIENT : Chesapeake Containment Systems, Inc.
CLIENT PROJECT : Brickhaven No. 2 Mine Tract "A"
PROJECT NO. : L15058-02
LAB I. D. NO.: CSL-01 (2015-664-04-01)
GSE BentoLiner CAR CNSL, Roll # 135032036 (L15058-01-02)

INTERFACE : **Soil @ 100.7 pcf & 20.9 % M.C.**
vs. GCL (Coated Side)

	PEAK SHEAR		RESIDUAL SHEAR	
FRICTION ANGLE (deg) :	Φ =	**17.9**	Φ =	**9.5**
COEFFICIENT OF FRICTION :	=	**0.323**	=	**0.167**
ADHESION [Calculated] (psf):	a =	**159**	a =	**150**

NOTES:
1.) Soil placement was based on 95% maximum dry density and a moisture content +2% of optimum.
2.) The interface was loaded, inundated with water and consolidated for 24 hours prior to shearing.
3.) The peak friction angle was calculated using linear regression on the three data points.
4.) The residual friction angle was calculated using linear regression on the end of test values.



□PEAK SHEAR DATA △RESIDUAL SHEAR DATA

APPROVED BY : JDK DATE : 6-23-15

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INTERFACE FRICTION TEST RESULTS
ASTM D 6243

geotechnics
INTEGRITY IN TESTING

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INTERFACE : **Soil @ 100.7 pcf & 20.9 % M.C.**
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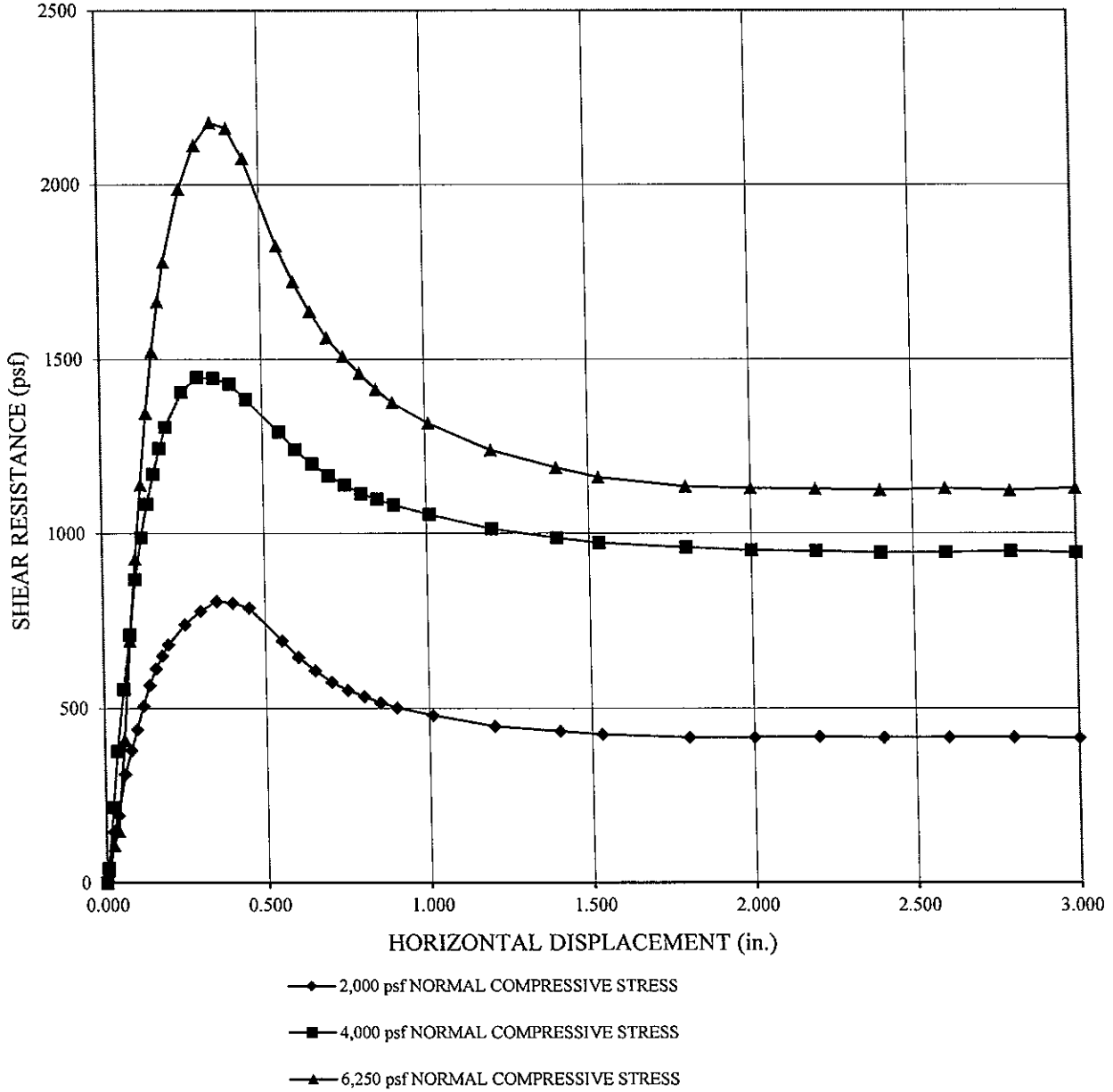
SHEAR RESISTANCE VS HORIZONTAL DISPLACEMENT



APPROVED BY : JDK DATE : 6-23-15

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LAB I. D. NO.S: CSL-01 (2015-664-04-01)
GSE BentoLiner CAR CNSL, Roll # 135032036 (L15058-01-02)

INTERFACE : **Soil @ 100.7 pcf & 20.9 % M.C.**
vs. GCL (Coated Side)

STRAIN RATE (in / min) : 0.04 DIRECT SHEAR UNIT: Durham Geo
PLACEMENT CONDITION: Inundated NORMAL LOAD: Bladder System

NORMAL LOAD (psf)	2000	NORMAL LOAD (psf)	4000	NORMAL LOAD (psf)	6250
PEAK SHEAR STRESS (psf)	806	PEAK SHEAR STRESS (psf)	1449	PEAK SHEAR STRESS (psf)	2179
PEAK SECANT ANGLE (deg)	21.9	PEAK SECANT ANGLE (deg)	19.9	PEAK SECANT ANGLE (deg)	19.2
RESIDUAL SHEAR (psf)	415	RESIDUAL SHEAR (psf)	945	RESIDUAL SHEAR (psf)	1131
RESID. SECANT ANGLE (deg)	11.7	RESID. SECANT ANGLE (deg)	13.3	RESID. SECANT ANGLE (deg)	10.3

HORIZONTAL			HORIZONTAL			HORIZONTAL		
DISPLACE. (in.)	SHEAR FORCE (lbs)	STRESS (psf)	DISPLACE. (in.)	SHEAR FORCE (lbs)	STRESS (psf)	DISPLACE. (in.)	SHEAR FORCE (lbs)	STRESS (psf)
0.000	0	0	0.000	0	0	0.000	0	0
0.005	21	21	0.005	41	41	0.005	18	18
0.023	146	146	0.023	216	216	0.023	108	108
0.038	193	193	0.038	377	377	0.038	149	149
0.060	311	311	0.060	555	555	0.060	410	410
0.080	380	380	0.080	710	710	0.080	694	694
0.100	440	440	0.100	868	868	0.100	928	928
0.120	507	507	0.120	989	989	0.120	1140	1140
0.140	567	567	0.140	1085	1085	0.140	1346	1346
0.160	614	614	0.160	1171	1171	0.160	1522	1522
0.180	651	651	0.180	1245	1245	0.180	1666	1666
0.200	683	683	0.200	1305	1305	0.200	1778	1778
0.250	739	739	0.250	1406	1406	0.250	1988	1988
0.300	778	778	0.300	1449	1449	0.300	2114	2114
0.350	806	806	0.350	1446	1446	0.350	2179	2179
0.400	801	801	0.400	1430	1430	0.400	2163	2163
0.450	787	787	0.450	1385	1385	0.450	2076	2076
0.550	693	693	0.550	1292	1292	0.550	1825	1825
0.600	647	647	0.600	1241	1241	0.600	1723	1723
0.650	608	608	0.650	1200	1200	0.650	1637	1637
0.700	575	575	0.700	1166	1166	0.700	1562	1562
0.750	552	552	0.750	1140	1140	0.750	1509	1509
0.800	534	534	0.800	1114	1114	0.800	1461	1461
0.850	516	516	0.850	1099	1099	0.850	1415	1415
0.900	502	502	0.900	1082	1082	0.900	1376	1376
1.010	480	480	1.010	1054	1054	1.010	1317	1317
1.200	448	448	1.200	1013	1013	1.200	1240	1240
1.400	434	434	1.400	987	987	1.400	1190	1190
1.530	425	425	1.530	973	973	1.530	1162	1162
1.800	416	416	1.800	960	960	1.800	1136	1136
2.000	417	417	2.000	952	952	2.000	1131	1131
2.200	419	419	2.200	949	949	2.200	1128	1128
2.400	416	416	2.400	945	945	2.400	1125	1125
2.600	417	417	2.600	946	946	2.600	1130	1130
2.800	417	417	2.800	949	949	2.800	1124	1124
3.000	415	415	3.000	945	945	3.000	1131	1131

APPROVED BY : JPK DATE : 6-23-15
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INTERFACE FRICTION TEST RESULTS
ASTM D 6243

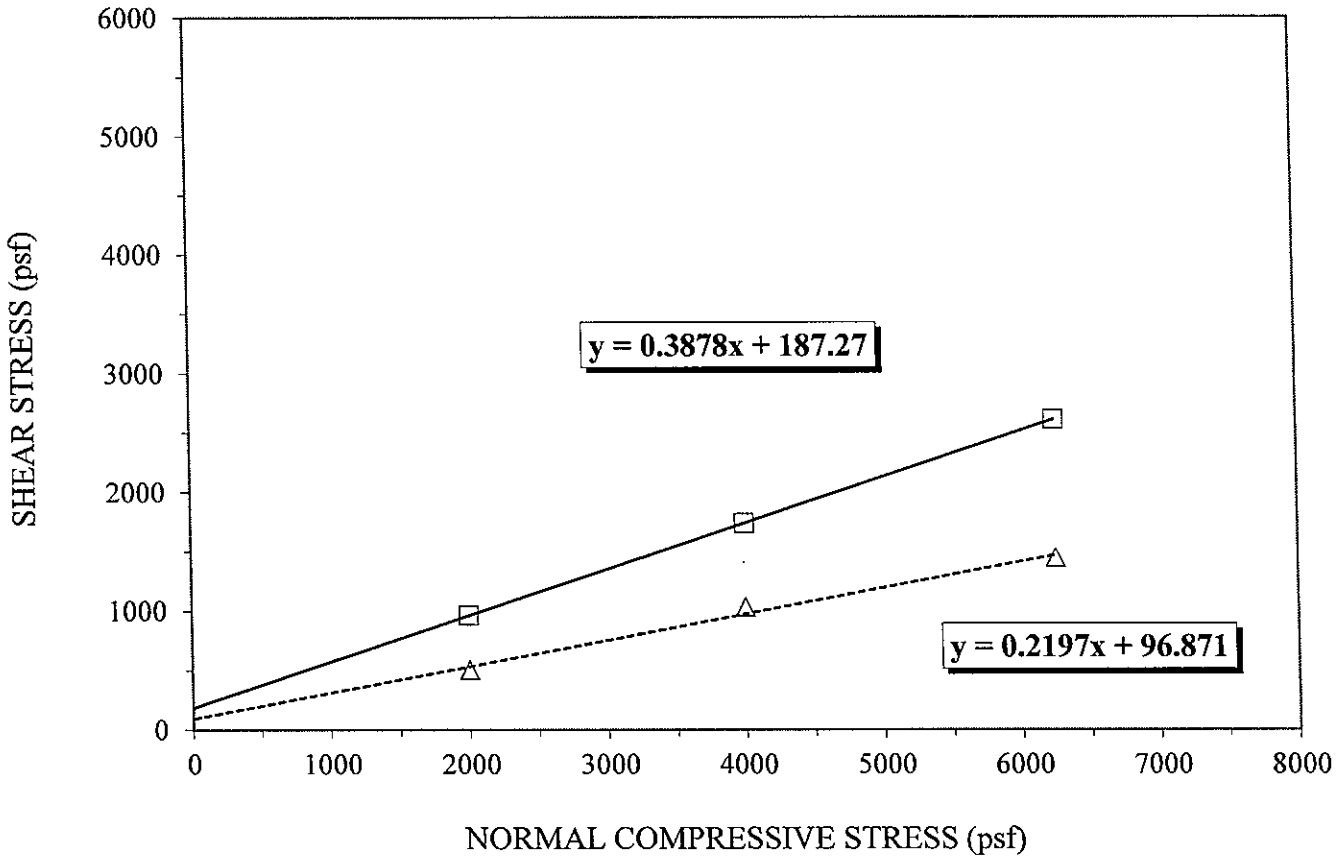
geotechnics
INTEGRITY IN TESTING

CLIENT : Chesapeake Containment Systems, Inc.
CLIENT PROJECT : Brickhaven No. 2 Mine Tract "A"
PROJECT NO. : L15058-02
LAB I. D. NO.: CSL-02 (2015-664-04-02)
GSE BentoLiner CAR CNSL, Roll # 135032036 (L15058-01-02)

INTERFACE : **Soil @ 111.1 pcf & 14.9 % M.C.**
vs. GCL (Coated Side)

	PEAK SHEAR		RESIDUAL SHEAR	
FRICTION ANGLE (deg) :	Φ =	**21.2**	Φ =	**12.4**
COEFFICIENT OF FRICTION :	=	**0.388**	=	**0.220**
ADHESION [Calculated] (psf):	a =	**187**	a =	**97**

NOTES:
1.) Soil placement was based on 95% maximum dry density and a moisture content +2% of optimum.
2.) The interface was loaded, inundated with water and consolidated for 24 hours prior to shearing.
3.) The peak friction angle was calculated using linear regression on the three data points.
4.) The residual friction angle was calculated using linear regression on the end of test values.



□PEAK SHEAR DATA △RESIDUAL SHEAR DATA

APPROVED BY : JDK DATE : 6-23-15

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INTERFACE FRICTION TEST RESULTS
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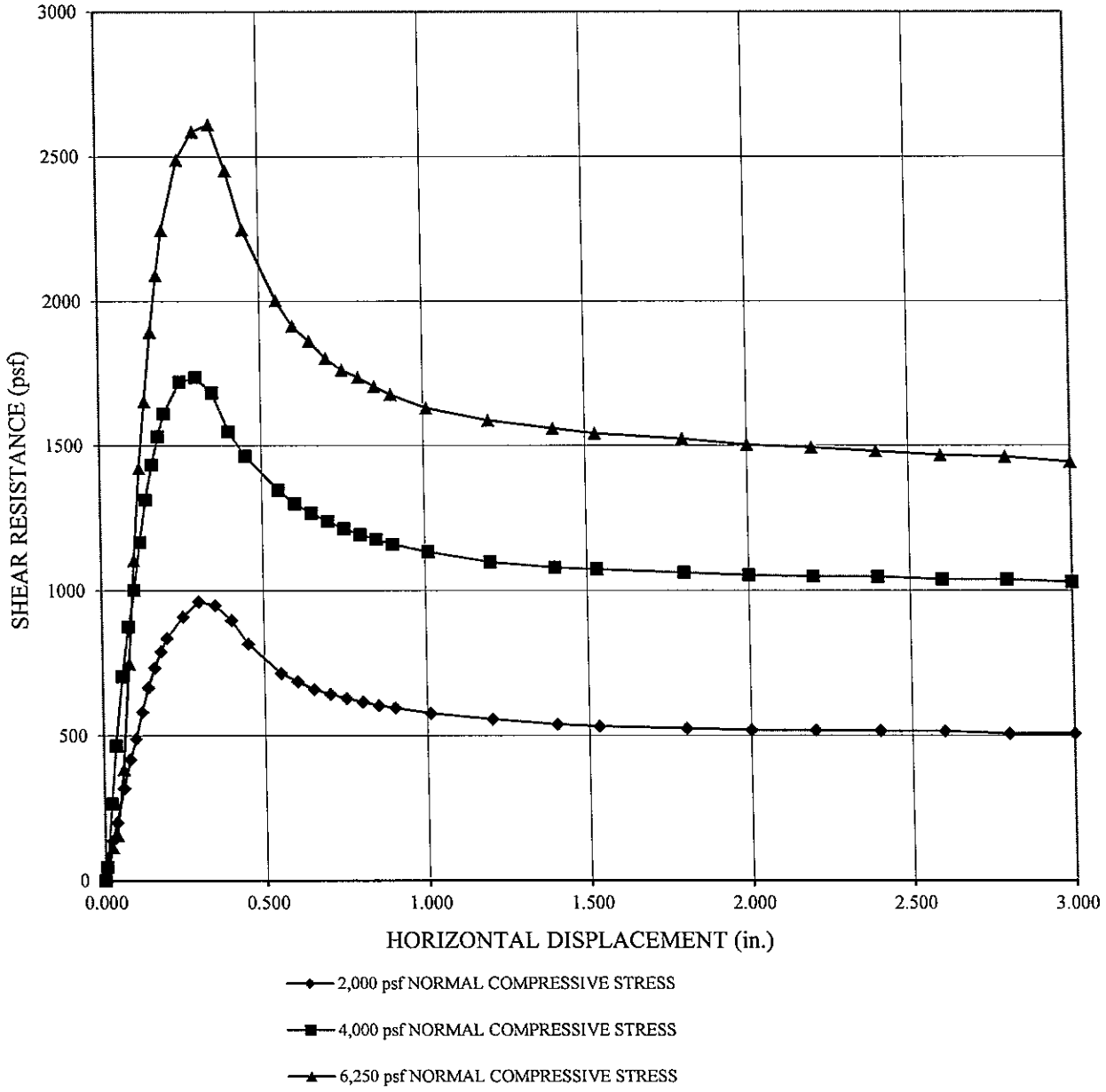

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PLACEMENT CONDITION: Inundated NORMAL LOAD: Bladder System

NORMAL LOAD (psf)	2000	NORMAL LOAD (psf)	4000	NORMAL LOAD (psf)	6250
PEAK SHEAR STRESS (psf)	963	PEAK SHEAR STRESS (psf)	1738	PEAK SHEAR STRESS (psf)	2611
PEAK SECANT ANGLE (deg)	25.7	PEAK SECANT ANGLE (deg)	23.5	PEAK SECANT ANGLE (deg)	22.7
RESIDUAL SHEAR (psf)	507	RESIDUAL SHEAR (psf)	1031	RESIDUAL SHEAR (psf)	1444
RESID. SECANT ANGLE (deg)	14.2	RESID. SECANT ANGLE (deg)	14.5	RESID. SECANT ANGLE (deg)	13.0

HORIZONTAL			HORIZONTAL			HORIZONTAL		
DISPLACE. (in.)	SHEAR FORCE (lbs)	STRESS (psf)	DISPLACE. (in.)	SHEAR FORCE (lbs)	STRESS (psf)	DISPLACE. (in.)	SHEAR FORCE (lbs)	STRESS (psf)
0.000	0	0	0.000	0	0	0.000	0	0
0.005	35	35	0.005	47	47	0.005	16	16
0.023	138	138	0.023	265	265	0.023	114	114
0.038	200	200	0.038	466	466	0.038	156	156
0.060	318	318	0.060	705	705	0.060	384	384
0.080	419	419	0.080	876	876	0.080	749	749
0.100	490	490	0.100	1002	1002	0.100	1105	1105
0.120	582	582	0.120	1167	1167	0.120	1423	1423
0.140	667	667	0.140	1313	1313	0.140	1653	1653
0.160	735	735	0.160	1434	1434	0.160	1894	1894
0.180	791	791	0.180	1532	1532	0.180	2091	2091
0.200	837	837	0.200	1611	1611	0.200	2246	2246
0.250	911	911	0.250	1722	1722	0.250	2489	2489
0.300	963	963	0.300	1738	1738	0.300	2586	2586
0.350	950	950	0.350	1684	1684	0.350	2611	2611
0.400	899	899	0.400	1549	1549	0.400	2451	2451
0.450	817	817	0.450	1464	1464	0.450	2248	2248
0.550	716	716	0.550	1347	1347	0.550	2003	2003
0.600	687	687	0.600	1301	1301	0.600	1915	1915
0.650	661	661	0.650	1268	1268	0.650	1863	1863
0.700	644	644	0.700	1240	1240	0.700	1804	1804
0.750	629	629	0.750	1214	1214	0.750	1763	1763
0.800	617	617	0.800	1193	1193	0.800	1738	1738
0.850	605	605	0.850	1178	1178	0.850	1706	1706
0.900	597	597	0.900	1160	1160	0.900	1678	1678
1.010	578	578	1.010	1134	1134	1.010	1631	1631
1.200	557	557	1.200	1099	1099	1.200	1588	1588
1.400	540	540	1.400	1080	1080	1.400	1560	1560
1.530	533	533	1.530	1074	1074	1.530	1543	1543
1.800	526	526	1.800	1062	1062	1.800	1524	1524
2.000	520	520	2.000	1054	1054	2.000	1503	1503
2.200	519	519	2.200	1050	1050	2.200	1494	1494
2.400	517	517	2.400	1049	1049	2.400	1481	1481
2.600	516	516	2.600	1040	1040	2.600	1468	1468
2.800	507	507	2.800	1039	1039	2.800	1462	1462
3.000	507	507	3.000	1031	1031	3.000	1444	1444

 APPROVED BY : DK DATE : 6-23-15

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Triaxial Compression Testing on Soil Clay Liner

June 23, 2015

Project No. 2015-339-001

Jimmy Youngblood
GSE Environmental
19103 Gundle Road
Houston, TX 77073

Transmittal
Laboratory Test Results
Brickhaven No. 2 Mine

Please find attached the laboratory test results for the above referenced project. The tests were outlined on the Project Verification Form that was transmitted to your firm prior to the testing. The testing was performed in general accordance with the methods listed on the enclosed data sheets. The test results are believed to be representative of the samples that were submitted for testing and are indicative only of the specimens that were evaluated. We have no direct knowledge of the origin of the samples and imply no position with regard to the nature of the test results, i.e. pass/fail and no claims as to the suitability of the material for its intended use.

The test data and all associated project information provided shall be held in strict confidence and disclosed to other parties only with authorization by our Client. The test data submitted herein is considered integral with this report and is not to be reproduced except in whole and only with the authorization of the Client and Geotechnics. The remaining sample materials for this project will be retained for a minimum of 90 days as directed by the Geotechnics' Quality Program.

We are pleased to provide these testing services. Should you have any questions or if we may be of further assistance, please contact our office.

Respectively submitted,
Geotechnics, Inc.

David R. Backstrom
Laboratory Director

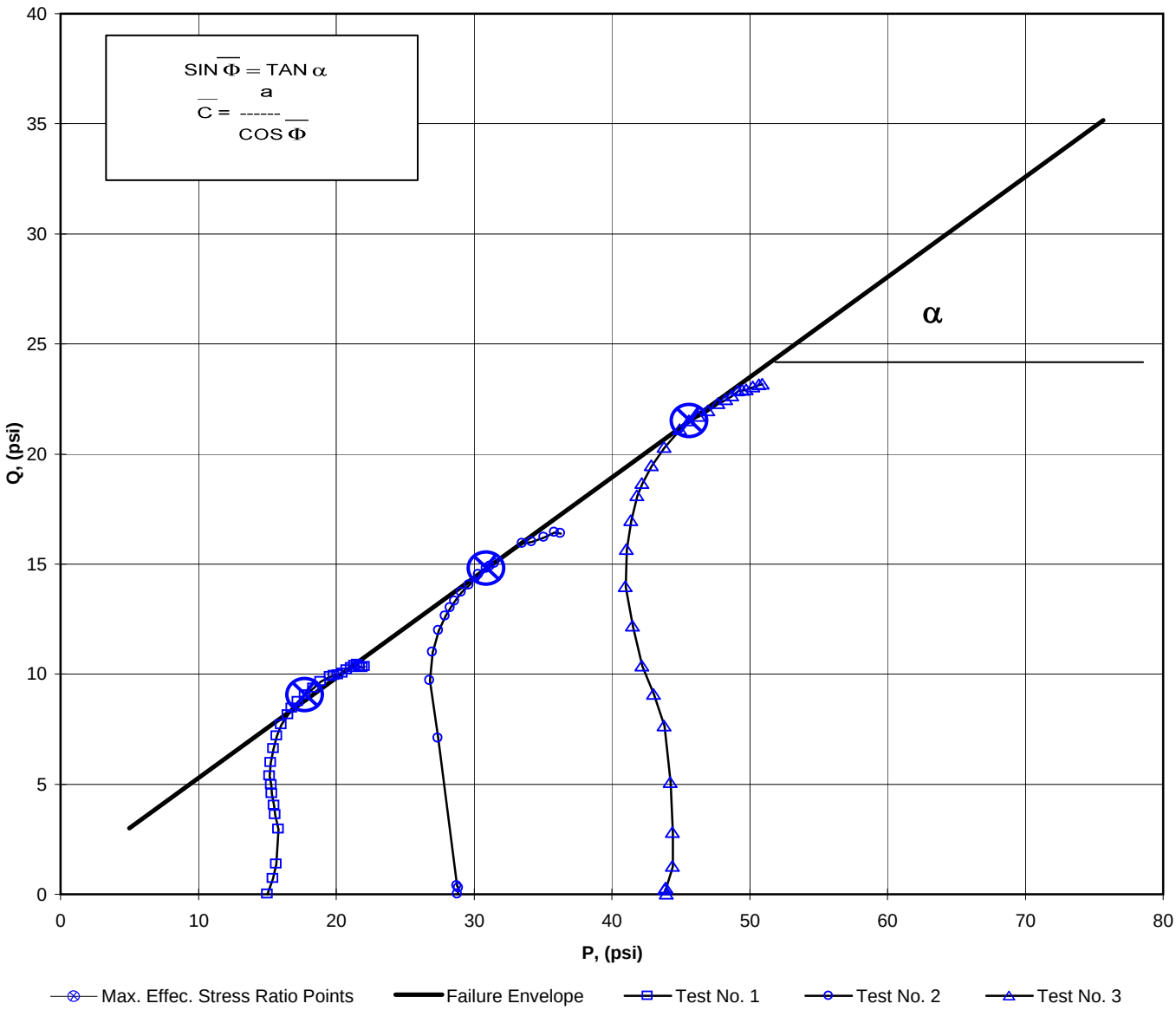
We understand that you have a choice in your laboratory services and we thank you for choosing Geotechnics.

DCN: Data Transmittal Letter Date: 1/28/05 Rev.: 1

CONSOLIDATED UNDRAINED TRIAXIAL TEST
WITH PORE PRESSURE READINGS
ASTM D4767-11

Client:	GSE Environmental	Boring No.:	NA
Client Reference:	Brickhaven No. 2 Mine	Depth (ft):	1-6
Project No.:	2015-339-001	Sample No.:	CSL-01
Lab ID:	2015-339-001-001		

Consolidated Undrained Triaxial Test with Pore Pressure



a	=	**0.00**	**C̄**	=	**0.00**
α	=	**24.5**	**Φ̄**	=	**27.08**

Tested By: JAB Date: 6/19/15 Approved By: DB Date: 6/23/15

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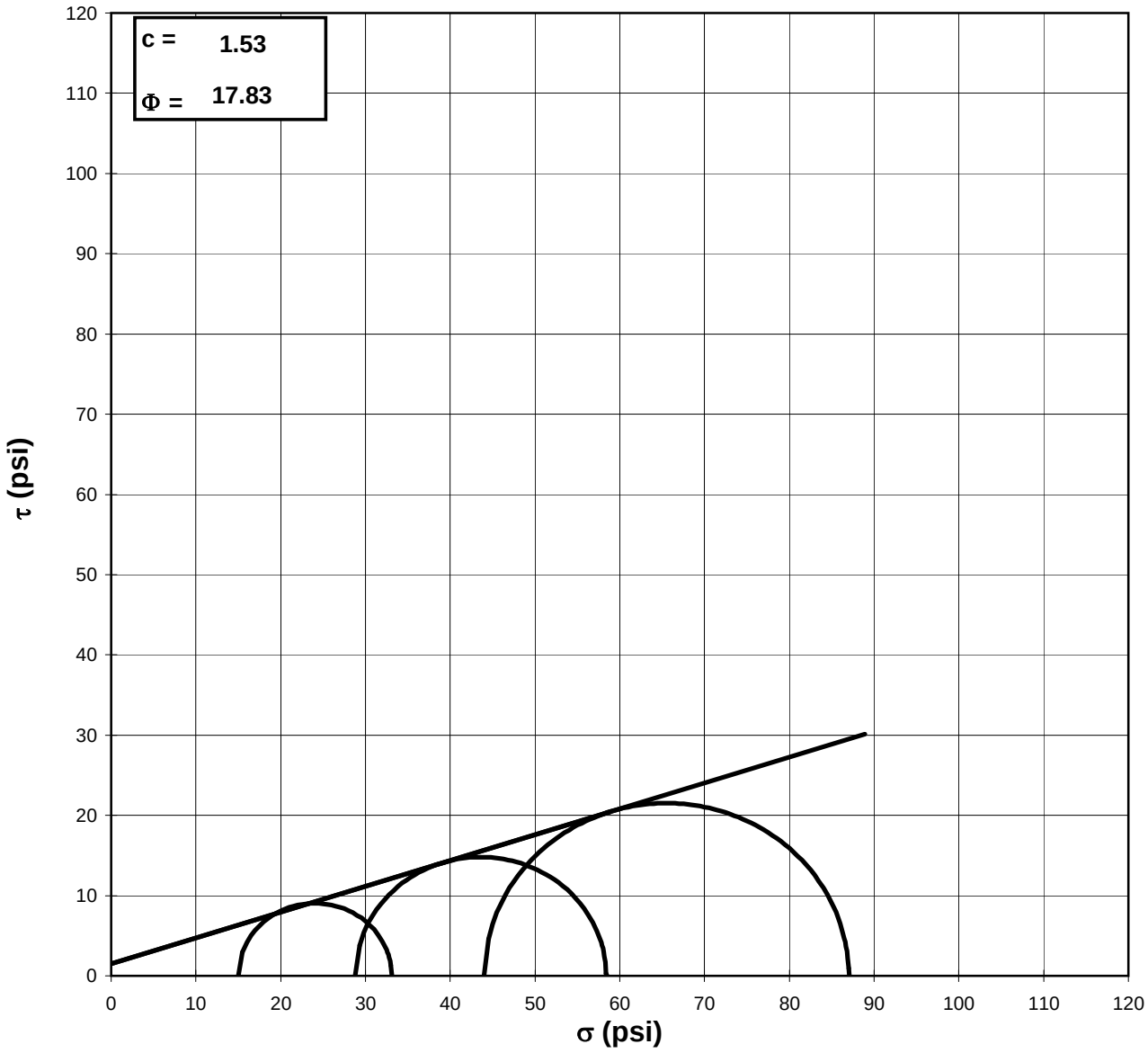
MOHR TOTAL STRENGTH ENVELOPE

ASTM D4767-11

Client:	GSE Environmental	Boring No.:	NA
Client Reference:	Brickhaven No. 2 Mine	Depth (ft):	1-6
Project No.:	2015-339-001	Sample No.:	CSL-01
Lab ID:	2015-339-001-001		
Visual Description:	Brown Clay (remolded)		



Failure Based on Maximum Effective Principal Stress Ratio

NOTE: GRAPH NOT TO SCALE

Tested By: JAB *Date:* 6/19/15 *Approved By:* DB *Date:* 6/23/15

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CONSOLIDATED UNDRAINED TRIAXIAL TEST
WITH PORE PRESSURE READINGS
ASTM D4767-11

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Client:	GSE Environmental	Boring No.:	NA
Client Reference:	Brickhaven No. 2 Mine	Depth (ft):	1-6
Project No.:	2015-339-001	Sample No.:	CSL-01
Lab ID:	2015-339-001-001		

Visual Description: Brown Clay (remolded)

Stage No.	1
Test No.	1

PRESSURES (psi)

Cell Pressure (psi)	46.9
Back Pressure (psi)	31.9
Eff. Conf. Pressure (psi)	15.0
Pore Pressure Response (%)	96

MAXIMUM OBLIQUITY POINTS

$\overline{P}$	=	17.74
Q	=	9.04

INITIAL SAMPLE DIMENSIONS (in)

Length 1:	6.011	Diameter 1:	2.867
Length 2:	6.011	Diameter 2:	2.867
Length 3:	6.011	Diameter 3:	2.867
Avg. Length:	6.011	*Avg. Diam.:*	2.867

VOLUME CHANGE

Initial Burette Reading (ml)	48.0
Final Burette Reading (ml)	15.3
Final Change (ml)	32.7

Initial Dial Reading (mil)	13
Dial Reading After Saturation (mil)	20
Dial Reading After Consolidation (mil)	85

LOAD (LB)	DEFORMATION (IN)	PORE PRESSURE (PSI)
11.2	0.000	31.9
19.8	0.001	32.2
27.9	0.002	32.6
47.8	0.006	34.0
55.7	0.012	34.9
61.2	0.018	35.4
67.7	0.027	36.1
72.9	0.036	36.6
78.0	0.048	37.1
85.9	0.069	37.6
94.1	0.098	38.1
101.9	0.134	38.4
108.8	0.169	38.6
115.6	0.211	38.6
119.9	0.242	38.6
124.6	0.284	38.4
129.7	0.341	38.2
134.9	0.400	37.9
139.9	0.445	37.7
144.7	0.506	37.2
146.3	0.551	37.0
147.9	0.596	36.7
150.1	0.641	36.5
153.0	0.671	36.3
155.1	0.701	36.1
157.6	0.731	36.0
159.1	0.761	35.8
158.8	0.807	35.6
159.6	0.852	35.3
161.0	0.882	35.2
162.4	0.912	35.1

Tested By: JAB Date: 6/19/15 Input Checked By: KC Date: 6/23/15

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CONSOLIDATED UNDRAINED TRIAXIAL TEST
WITH PORE PRESSURE READINGS
ASTM D4767-11

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Client:	GSE Environmental	Boring No.:	NA
Client Reference:	Brickhaven No. 2 Mine	Depth (ft):	1-6
Project No.:	2015-339-001	Sample No.:	CSL-01
Lab ID:	2015-339-001-001		

Visual Description: Brown Clay (remolded)

Effective Confining Pressure (psi)	15.0	*Stage No.*	1
		Test No	1

INITIAL DIMENSIONS

Initial Sample Length (in)	6.01
Initial Sample Diameter (in)	2.87
Initial Sample Area (in^2)	6.46
Initial Sample Volume (in^3)	38.81

VOLUME CHANGE

Volume After Consolidation (in^3)	36.67
Length After Consolidation (in)	5.94
Area After Consolidation (in^2)	6.175

Strain (%)	Deviation Stress	ΔU	$\overline{\sigma}_1$	$\overline{\sigma}_3$	Effective Principle Stress Ratio	$\overline{A}$	$\overline{P}$	Q
0.02	1.39	0.30	16.09	14.7	1.095	0.22	15.40	0.70
0.03	2.70	0.72	16.99	14.3	1.189	0.28	15.64	1.35
0.11	5.92	2.15	18.77	12.9	1.460	0.38	15.81	2.96
0.21	7.18	3.00	19.19	12.0	1.599	0.43	15.59	3.59
0.31	8.08	3.54	19.53	11.5	1.705	0.46	15.50	4.04
0.46	9.11	4.22	19.89	10.8	1.845	0.48	15.33	4.56
0.61	9.94	4.68	20.25	10.3	1.963	0.49	15.29	4.97
0.81	10.73	5.19	20.54	9.8	2.094	0.50	15.18	5.37
1.16	11.95	5.72	21.23	9.3	2.288	0.50	15.25	5.97
1.65	13.20	6.15	22.05	8.8	2.493	0.49	15.45	6.60
2.25	14.36	6.49	22.87	8.5	2.688	0.47	15.69	7.18
2.85	15.35	6.67	23.68	8.3	2.844	0.45	16.01	7.68
3.56	16.30	6.65	24.65	8.3	2.953	0.43	16.50	8.15
4.07	16.89	6.68	25.22	8.3	3.030	0.41	16.77	8.45
4.79	17.48	6.53	25.95	8.5	3.064	0.39	17.21	8.74
5.74	18.09	6.31	26.78	8.7	3.081	0.36	17.74	9.04
6.73	18.69	6.00	27.69	9.0	3.076	0.33	18.35	9.35
7.49	19.28	5.76	28.52	9.2	3.087	0.31	18.88	9.64
8.51	19.78	5.33	29.45	9.7	3.045	0.28	19.56	9.89
9.28	19.84	5.08	29.76	9.9	3.000	0.27	19.84	9.92
10.04	19.92	4.83	30.08	10.2	2.959	0.25	20.12	9.96
10.79	20.06	4.57	30.49	10.4	2.924	0.24	20.46	10.03
11.29	20.38	4.43	30.95	10.6	2.928	0.23	20.76	10.19
11.80	20.55	4.18	31.38	10.8	2.898	0.21	21.10	10.28
12.30	20.79	4.08	31.72	10.9	2.904	0.20	21.32	10.40
12.82	20.88	3.90	31.98	11.1	2.882	0.19	21.54	10.44
13.58	20.66	3.65	32.01	11.3	2.820	0.18	21.68	10.33
14.35	20.58	3.39	32.19	11.6	2.773	0.17	21.90	10.29
14.85	20.66	3.26	32.40	11.7	2.759	0.16	22.07	10.33
15.35	20.72	3.18	32.54	11.8	2.753	0.16	22.18	10.36

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CONSOLIDATED UNDRAINED TRIAXIAL TEST
WITH PORE PRESSURE READINGS
ASTM D4767-11

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Client:	GSE Environmental	Boring No.:	NA
Client Reference:	Brickhaven No. 2 Mine	Depth (ft):	1-6
Project No.:	2015-339-001	Sample No.:	CSL-01
Lab ID:	2015-339-001-001		

Visual Description: Brown Clay (remolded)

Stage No.	1
Test No.	2

PRESSURES (psi)

Cell Pressure (psi)	60.4
Back Pressure (psi)	31.6
Eff. Conf. Pressure (psi)	28.8
Pore Pressure Response (%)	98

MAXIMUM OBLIQUITY POINTS

$\overline{P}$	=	30.90
Q	=	14.80

INITIAL SAMPLE DIMENSIONS (in)

Length 1:	6.011	Diameter 1:	2.867
Length 2:	6.011	Diameter 2:	2.867
Length 3:	6.011	Diameter 3:	2.867
Avg. Length	6.011	*Avg. Diam.:*	2.867

VOLUME CHANGE

Initial Burette Reading (ml)	96.0
Final Burette Reading (ml)	42.1
Final Change (ml)	53.9

Initial Dial Reading (mil)	8
Dial Reading After Saturation (mil	13
Dial Reading After Consolidation(mil)	159

LOAD (LB)	DEFORMATION (IN)	PORE PRESSURE (PSI)
10.8	0.000	31.6
14.2	0.002	31.8
15.3	0.003	32.0
97.0	0.038	40.1
130.0	0.098	43.3
146.9	0.142	44.4
160.2	0.187	44.9
169.9	0.232	45.1
175.4	0.263	45.1
180.1	0.293	45.1
186.1	0.324	45.0
191.5	0.354	44.8
199.2	0.399	44.6
204.4	0.444	44.3
206.6	0.474	44.1
209.5	0.504	43.9
226.4	0.625	42.8
231.2	0.715	42.2
237.8	0.806	41.5
244.7	0.881	41.0
248.3	0.971	40.5

Tested By: JAB Date: 6/19/15 Input Checked By: KC Date: 6/23/15

DCN: CT-S28 DATE: 4/12/13 REVISION: 3

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CONSOLIDATED UNDRAINED TRIAXIAL TEST
WITH PORE PRESSURE READINGS
ASTM D4767-11

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Client:	GSE Environmental	Boring No.:	NA
Client Reference:	Brickhaven No. 2 Mine	Depth (ft):	1-6
Project No.:	2015-339-001	Sample No.:	CSL-01
Lab ID:	2015-339-001-001		

Visual Description: Brown Clay (remolded)

Effective Confining Pressure (psi)	28.8	*Stage No.*	1
		Test No	2

INITIAL DIMENSIONS

Initial Sample Length (in)	6.01
Initial Sample Diameter (in)	2.87
Initial Sample Area (in^2)	6.46
Initial Sample Volume (in^3)	38.81

VOLUME CHANGE

Volume After Consolidation (in^3)	35.42
Length After Consolidation (in)	5.86
Area After Consolidation (in^2)	6.044

Strain (%)	Deviation Stress	ΔU	$\overline{\sigma}_1$	$\overline{\sigma}_3$	Effective Principle Stress Ratio	$\overline{A}$	$\overline{P}$	Q
0.03	0.56	0.20	29.16	28.6	1.020	0.36	28.88	0.28
0.05	0.74	0.40	29.14	28.4	1.026	0.55	28.77	0.37
0.65	14.17	8.50	34.47	20.3	1.698	0.61	27.38	7.08
1.67	19.39	11.70	36.49	17.1	2.134	0.62	26.80	9.70
2.42	21.97	12.80	37.97	16.0	2.373	0.59	26.99	10.99
3.19	23.93	13.30	39.43	15.5	2.544	0.57	27.46	11.96
3.96	25.28	13.50	40.58	15.3	2.652	0.54	27.94	12.64
4.49	26.01	13.50	41.31	15.3	2.700	0.53	28.31	13.01
5.00	26.61	13.50	41.91	15.3	2.739	0.52	28.60	13.30
5.53	27.40	13.40	42.80	15.4	2.779	0.50	29.10	13.70
6.04	28.09	13.20	43.69	15.6	2.801	0.48	29.65	14.05
6.81	29.05	13.00	44.85	15.8	2.838	0.46	30.32	14.52
7.58	29.60	12.70	45.70	16.1	2.839	0.44	30.90	14.80
8.09	29.77	12.50	46.07	16.3	2.827	0.43	31.19	14.89
8.60	30.05	12.30	46.55	16.5	2.821	0.42	31.52	15.02
10.67	31.87	11.20	49.47	17.6	2.811	0.36	33.53	15.93
12.20	32.02	10.60	50.22	18.2	2.759	0.34	34.21	16.01
13.75	32.39	9.90	51.29	18.9	2.714	0.31	35.10	16.20
15.03	32.88	9.40	52.28	19.4	2.695	0.29	35.84	16.44
16.57	32.78	8.90	52.68	19.9	2.647	0.28	36.29	16.39

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CONSOLIDATED UNDRAINED TRIAXIAL TEST WITH PORE PRESSURE READINGS

ASTM D4767-11

Client:	GSE Environmental	Boring No.:	NA
Client Reference:	Brickhaven No. 2 Mine	Depth (ft):	1-6
Project No.:	2015-339-001	Sample No.:	CSL-01
Lab ID:	2015-339-001-001		

Visual Description: Brown Clay (remolded)

Stage No.	1
Test No.	3

PRESSURES (psi)

Cell Pressure (psi)	76.3
Back Pressure (psi)	32.3
Eff. Conf. Pressure (psi)	44.0
Pore Pressure Response (%)	100

MAXIMUM OBLIQUITY POINTS

$\overline{P}$	=	45.63
Q	=	21.51

INITIAL SAMPLE DIMENSIONS (in)

Length 1:	6.011	Diameter 1:	2.867
Length 2:	6.011	Diameter 2:	2.867
Length 3:	6.011	Diameter 3:	2.867
Avg. Length:	6.011	*Avg. Diam.:*	2.867

VOLUME CHANGE

Initial Burette Reading (ml)	72.0
Final Burette Reading (ml)	13.4
Final Change (ml)	58.6

Initial Dial Reading (mil)	19
Dial Reading After Saturation (mil	25
Dial Reading After Consolidation(mil)	162

LOAD (LB)	DEFORMATION (IN)	PORE PRESSURE (PSI)
10.1	0.000	32.3
12.6	0.002	32.7
13.5	0.004	32.6
25.1	0.010	33.1
43.7	0.015	34.7
71.0	0.023	37.1
102.0	0.033	40.1
119.6	0.042	42.3
135.1	0.054	44.5
157.6	0.074	46.9
180.1	0.103	49.3
201.9	0.138	50.9
219.3	0.176	51.8
235.1	0.219	52.5
243.2	0.250	52.7
255.3	0.292	52.9
268.3	0.349	52.8
281.6	0.410	52.5
289.2	0.456	52.2
294.9	0.516	51.7
300.4	0.559	51.3
307.2	0.604	50.8
312.4	0.651	50.5
316.7	0.682	50.2
321.4	0.712	50.0
323.7	0.743	49.7
325.9	0.773	49.4
330.4	0.818	49.1
334.8	0.864	48.7
337.0	0.895	48.5
339.6	0.925	48.3

Tested By: JAB Date: 6/19/15 Input Checked By: KC Date: 6/23/15

DCN: CT-S28 DATE: 4/12/13 REVISION: 3

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CONSOLIDATED UNDRAINED TRIAXIAL TEST
WITH PORE PRESSURE READINGS
ASTM D4767-11

Client:	GSE Environmental	Boring No.:	NA
Client Reference:	Brickhaven No. 2 Mine	Depth (ft):	1-6
Project No.:	2015-339-001	Sample No.:	CSL-01
Lab ID:	2015-339-001-001		

Visual Description: Brown Clay (remolded)

Effective Confining Pressure (psi)	44.0	*Stage No.*	1
		Test No	3

INITIAL DIMENSIONS

Initial Sample Length (in)	6.01
Initial Sample Diameter (in)	2.87
Initial Sample Area (in^2)	6.46
Initial Sample Volume (in^3)	38.81

VOLUME CHANGE

Volume After Consolidation (in^3)	35.11
Length After Consolidation (in)	5.87
Area After Consolidation (in^2)	5.984

Strain (%)	Deviation Stress	ΔU	$\overline{\sigma_1}$	$\overline{\sigma_3}$	Effective Principle Stress Ratio	$\overline{A}$	$\overline{P}$	Q
0.04	0.42	0.35	44.07	43.6	1.010	0.83	43.86	0.21
0.06	0.57	0.33	44.24	43.7	1.013	0.58	43.96	0.29
0.16	2.50	0.82	45.68	43.2	1.058	0.33	44.43	1.25
0.25	5.60	2.36	47.24	41.6	1.134	0.42	44.44	2.80
0.38	10.14	4.80	49.34	39.2	1.259	0.47	44.27	5.07
0.56	15.27	7.79	51.48	36.2	1.422	0.51	43.84	7.63
0.72	18.17	10.04	52.13	34.0	1.535	0.55	43.05	9.09
0.91	20.71	12.16	52.55	31.8	1.650	0.59	42.20	10.35
1.26	24.34	14.64	53.70	29.4	1.829	0.60	41.53	12.17
1.76	27.92	16.97	54.95	27.0	2.033	0.61	40.99	13.96
2.35	31.30	18.55	56.75	25.4	2.230	0.59	41.10	15.65
2.99	33.91	19.53	58.38	24.5	2.386	0.58	41.42	16.96
3.73	36.19	20.23	59.96	23.8	2.523	0.56	41.86	18.10
4.26	37.29	20.42	60.87	23.6	2.581	0.55	42.23	18.64
4.98	38.93	20.56	62.38	23.4	2.661	0.53	42.91	19.47
5.95	40.59	20.47	64.12	23.5	2.725	0.50	43.82	20.29
6.98	42.20	20.17	66.04	23.8	2.771	0.48	44.93	21.10
7.77	43.02	19.87	67.14	24.1	2.783	0.46	45.63	21.51
8.79	43.41	19.38	68.03	24.6	2.763	0.45	46.32	21.71
9.53	43.89	18.95	68.94	25.0	2.752	0.43	47.00	21.95
10.29	44.55	18.55	70.00	25.5	2.750	0.42	47.73	22.27
11.09	44.91	18.16	70.75	25.8	2.738	0.40	48.29	22.46
11.62	45.28	17.89	71.39	26.1	2.734	0.40	48.75	22.64
12.14	45.71	17.68	72.03	26.3	2.737	0.39	49.18	22.86
12.66	45.77	17.40	72.37	26.6	2.721	0.38	49.48	22.89
13.17	45.83	17.12	72.71	26.9	2.705	0.37	49.79	22.91
13.94	46.07	16.77	73.30	27.2	2.692	0.36	50.27	23.04
14.72	46.27	16.45	73.82	27.6	2.679	0.36	50.69	23.13
15.24	46.30	16.20	74.10	27.8	2.666	0.35	50.95	23.15
15.77	46.38	16.04	74.33	28.0	2.659	0.35	51.15	23.19

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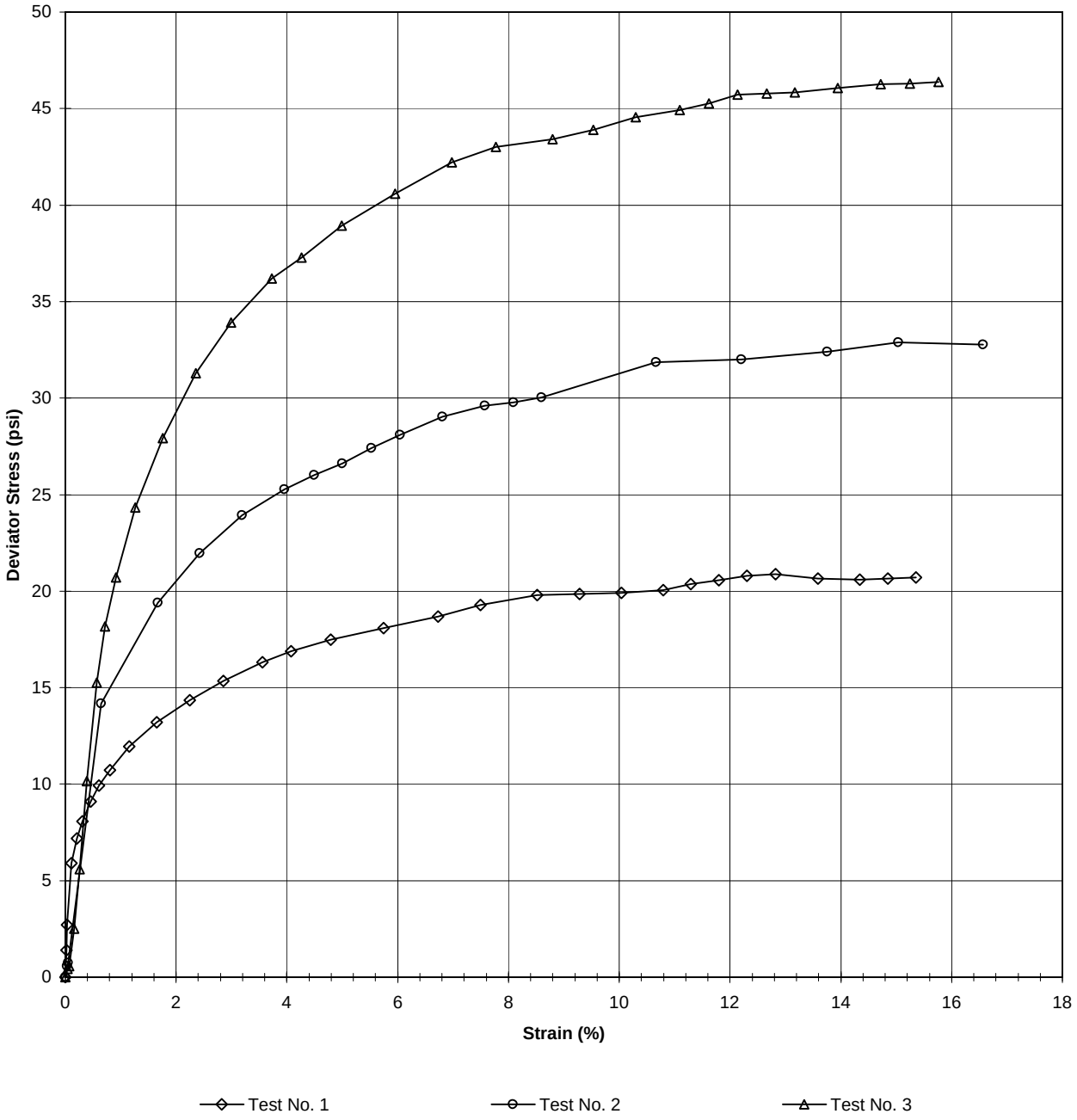
CONSOLIDATED UNDRAINED TRIAXIAL TEST
WITH PORE PRESSURE READINGS
ASTM D4767-11

Client:	GSE Environmental	Boring No.:	NA
Client Reference:	Brickhaven No. 2 Mine	Depth (ft):	1-6
Project No.:	2015-339-001	Sample No.:	CSL-01
Lab ID:	2015-339-001-001		
Visual Description:	Brown Clay (remolded)		



Tested By: JAB Date: 6/19/15 Approved By: DB Date: 6/23/15

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CONSOLIDATED UNDRAINED TRIAXIAL TEST
WITH PORE PRESSURE READINGS
ASTM D4767-11

Client:	GSE Environmental		
Client Reference:	Brickhaven No. 2 Mine		
Project No.:	2015-339-001		
Lab ID:	2015-339-001-001	Specific Gravity (assumed)	2.7
Visual Description:	Brown Clay (remolded)		

SAMPLE CONDITION SUMMARY

Boring No.:	NA	NA	NA
Depth (ft):	1-6	1-6	1-6
Sample No.:	CSL-01	CSL-01	CSL-01
Test No.	T1	T2	T3
Deformation Rate (in/min)	0.002	0.001	0.001
Back Pressure (psi)	31.9	31.6	32.3
Consolidation Time (days)	1	1	1
Moisture Content (%) (INITIAL)	20.7	20.7	20.7
Total Unit Weight (pcf)	121.7	121.4	121.3
Dry Unit Weight (pcf)	100.8	100.6	100.5
Moisture Content (%) (FINAL)	24.6	23.0	22.2
Initial State Void Ratio,e	0.671	0.675	0.677
Void Ratio at Shear, e	0.580	0.529	0.518

Tested By: JAB Date: 6/19/15 Input Checked By: KC Date: 6/23/15

DCN: CT-S28 DATE: 4/12/13 REVISION: 3

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Global Slope Stability Analyses - revised

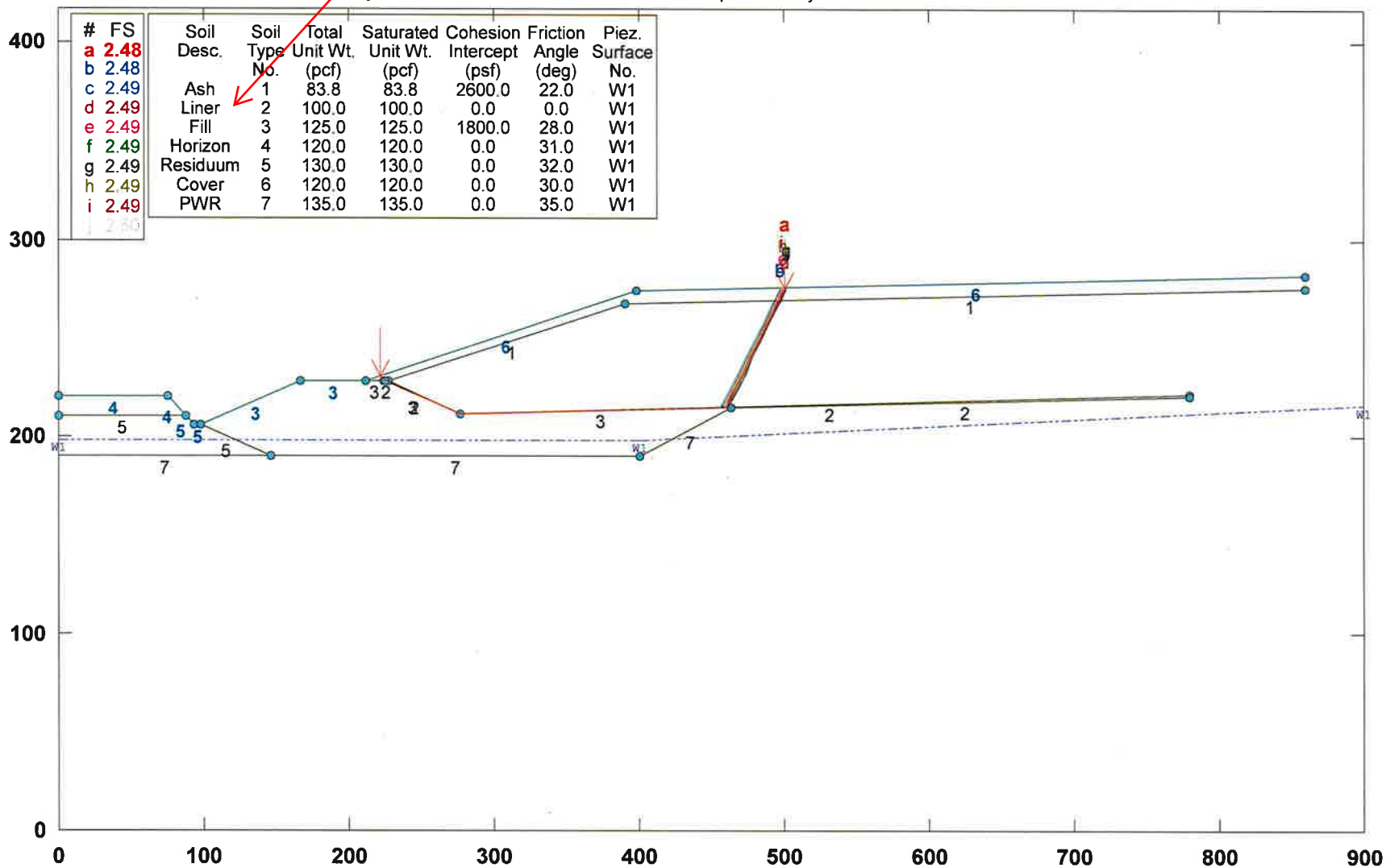
Modification to Liner Strength Properties

Moncure Mine Structural Fill - Section BBlock - Static (Min Liner Interface Phi)

c:\users\tyanosch\documents\stedwin and stabl\m6a1.pl2 Run By: Tom Yanoschak 11/6/2014 12:45AM

#	FS
a	2.48
b	2.48
c	2.49
d	2.49
e	2.49
f	2.49
g	2.49
h	2.49
i	2.49

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Ash	1	83.8	83.8	2600.0	22.0	W1
Liner	2	100.0	100.0	0.0	0.0	W1
Fill	3	125.0	125.0	1800.0	28.0	W1
Horizon	4	120.0	120.0	0.0	31.0	W1
Residuum	5	130.0	130.0	0.0	32.0	W1
Cover	6	120.0	120.0	0.0	30.0	W1
PWR	7	135.0	135.0	0.0	35.0	W1



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Safety Factors Are Calculated By The Modified Janbu Method for the case of c & phi both > 0

Modification to Liner Strength Properties

Moncure Mine Structural Fill - Section BBlock - Seismi (Min Liner Interface Phi)

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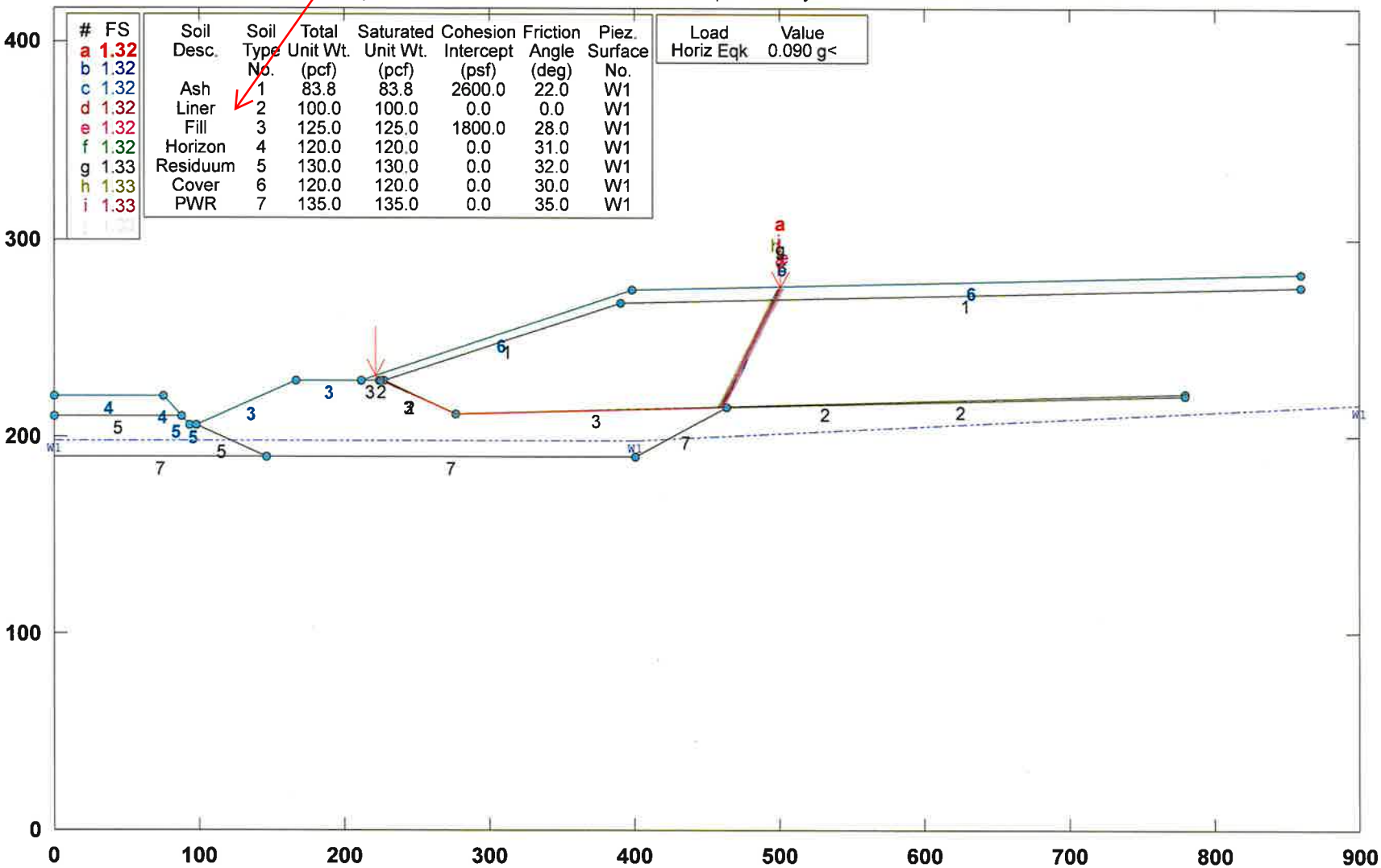
#	FS
a	1.32
b	1.32
c	1.32
d	1.32
e	1.32
f	1.32
g	1.33
h	1.33
i	1.33

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Ash	1	83.8	83.8	2600.0	22.0	W1
Liner	2	100.0	100.0	0.0	0.0	W1
Fill	3	125.0	125.0	1800.0	28.0	W1
Horizon	4	120.0	120.0	0.0	31.0	W1
Residuum	5	130.0	130.0	0.0	32.0	W1
Cover	6	120.0	120.0	0.0	30.0	W1
PWR	7	135.0	135.0	0.0	35.0	W1

Load	Value
Horiz Eqk	0.090 g<



PCSTABL5M/si FSmin=1.32

Safety Factors Are Calculated By The Modified Janbu Method for the case of c & phi both > 0

Geosynthetic Stress Analyses – revised

HDR Computation

Job Number 453925-237673-018		**No.**	
Project Charah Brickhaven No.2 Mine	**Computed** TMY/MGB	**Date**	11/2/2014
Subject Permit Application	**Checked** TMY	**Date**	7/16/2015
Task Geosynthetic Stresses	**Section** 1	**Of**	5

Objective: Determine the stresses in the geosynthetics of the base liner system.

References:

1. Sharma, H. D., & Lewis, S. P. (1994). *Waste Containment Systems, Waste Stabilization, and Landfills: Design and Evaluation* . New York: John Wiley & Sons, Inc.
2. Koerner, G.R., & Narejo, D. (2005). *Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces,* GRI Report #30.
3. HDR (2014). Slope Stability Analyses, Charah Brickhaven No.2 Mine Tract "A" Structural Fill Permit Application.

Layer	Material	Thickness (in)	Tensile Strength (lbs/in)*	Allowable Stress (psi)	*Assumed* Allowable stress, σ, psi	Interface Friction		Factor of Safety, Due to:			
						Between surfaces (Ref. 2 - see Attachment A)	°	Self Weight	Operational Cover	Structural Fill	Operational Equipment
Geocomposite	GSE Coaldrain Fabrinet Geocomposite	0.34	100	294	294	Between Nonwoven, needle-punched Geotextile and Textured	27.7	No Stress	No Stress	No Stress	No Stress
Geomembrane	Agru 60 mil Microspike	0.06	126	2,100	2,100	Between Textured HDPE and Nonwoven, needle-	29.0	No Stress	No Stress	No Stress	No Stress
GCL	GSE BentoLiner CNSL Data	0.3	40	133	133	Between Nonwoven Needlepunched	13.00	No Stress	No Stress	No Stress	No Stress

Input Parameters

Sideslopes =	3	H:1V		
Sideslope Angle, β =	18.43	°		
Max Slope Height, H =	24	ft		
Density of water, ρ_w =	62.4	lbs/ft^3		
Geomembrane Thickness, t_{GMB} =	0.06	in	0.005	ft
Geotextile Mass per Unit Area =	8	oz/yd^2 =	0.06	lb/ft^2

Geotextile Thickness, t_{GTEX} =	0.02	in	0.002	ft (assumed)
Geonet Thickness, t_{GNET} =	0.3	in	0.03	ft
GCL Thickness, t_{GCL} =	0.3	in	0.03	ft

12 in/ft

144 oz/yd^2 per lb/ft^2

* Use yield strength for geomembrane.

Results/Conclusions:

The results indicate that for each condition evaluated, there will be no stress developed within the geosynthetics. The frictional resistance between the materials will therefore be sufficient to resist the forces developed during construction and structural fill construction without stressing the components. This is compatible with standard liner system design practices.

Case 1: Stress Due to Self Weight

$$W = \frac{SG\ \gamma_w\ t\ (1 \times H)}{\sin\beta}$$ Ref. 1, Page 394

$$\sigma_{TA} = \frac{W \sin\beta - F}{1 \times t}$$ Ref. 1, Page 394

$$F = W_{total}\cos\beta\tan\delta + a_{clay} * L$$ Ref. 1, Page 395

$$\text{Factor of Safety, FS} = \frac{\sigma_y\ \text{(allowable)}}{\sigma_{TA}}$$

Where:

- W = geomembrane weight
- SG = specific gravity of geomembrane
- γ_w = unit wieght of water 62.4 lb/ft^3
- σ_{TA} = Applied Tensile Stress
- β = slope
- F = interface frictional strength between geomembrane and underlying material
- t = geomembrane thickness
- δ = interface friction angle between geomembrane and underlying material
- a_{Clay} = adhesion between clay soil liner and GCL
- H = slope height

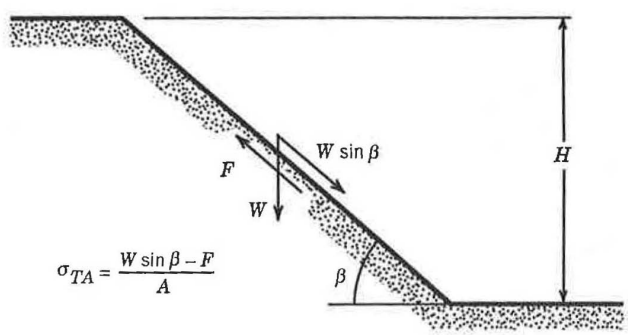


Figure 8.12 Free-body diagram for geomembrane self-weight calculations.

Source of Figure 8.12:
Ref. 1, Page 395

$$\text{Length of Slope, L} = \frac{H}{\sin\beta}$$

H = 34 feet
L = 107.5 feet

ρ_{water} = 1,000 kg/m^3
ρ_{water} = 1.0 g/cm^3

Conversions

0.000001	m^3/cm^3
1000	g/kg
144	in^2/ft^2

$$SG = \frac{\rho_{sample}}{\rho_{water}}$$

Where:

- SG = Specific Gravity
- ρ_{sample} = Density of Sample
- ρ_{water} = Density of Water

$$W = \rho V a$$

Where:

- W = Weight
- ρ = Density
- V = Volume
- a = Acceleration 9.81 m/s^2

V = L(1 x t)

Sideslope Angle, β = 18.43 °

	Geocomposite*	Geomembrane	GCL**	Geotextile	Geonet
Density, ρ (g/cm^3)		0.94			0.94
Specific Gravity, SG (Unitless)		0.94			0.94
Weight, W (lbs)	169.61	31.53	120.23	5.97	157.66
Thickness, t (ft)	0.03	0.005	0.03		0.03
$\sigma_{Allowable}$ (psi)	294	2,100	133		

*Weight of Geocomposite is equal to the weight of the geonet plus the weight of the geotextiles on either side of the geonet.

**The weight of the GCL is determined from the weight of a roll (2,600 lbs) divided by the surface area of the roll (2,325 ft^2) to get a pound per ft^2. The pound per ft^2 is multiplied by a 1 foot wide by length of the slope strip to determine the weight of the geotextile.

Interface	Range (°)	Source & Description	Design Value (°)
$\delta_{Soil - Geocomposite}$	22 - 40	Ref 2 Figure 13a: Nonwoven, needle-punched Geotextile vs Granular Soil	27 **(not applicable for self weight calcs.)**
$\delta_{Geocomposite - Geomembrane}$	15 - 33	Ref 2 Figure 2i: Nonwoven, needle-punched Geotextile vs Textured HDPE	28
$\delta_{Geomembrane - GCL}$	15 - 33	Ref 2 Figure 11a: Nonwoven, needle-punched Geotextile (top of hydrated GCL) vs Textured HDPE	29
$\delta_{GCL - Clay Soil Liner}$	15 - 28	Ref 2 Figure 9e: Woven geotextile (bottom of GCL) vs Clay Soil	13
$a_{GCL - Clay Soil Liner}$	159 - 187	Ref 2 Figure 9e: Woven geotextile (bottom of GCL) vs Clay Soil adhesion	100

Geocomposite - Geomembrane Interface

W =	$W_{geocomposite}$	
W =	169.61	lb
Geocomposite thickness, t_{GT} =	0.03	ft
δ =	28	degrees
a_{Clay}=	100	psf
F =	10,836	lb
σ_{Actual} =	-380,562	lb/ft^2
σ_{Actual} =	-2,643	psi
$\sigma_{Allowable}$ =	294	psi
FS =	**No Stress**	

Geomembrane - GCL Interface

W =	$W_{geomembrane}$ + $W_{geocomposite}$	
W =	201.14	lb
Geomembrane thickness, t_{GM} =	0.01	ft
δ =	29	degrees
a_{Clay}=	100	psf
F =	10,858	lb/ft

σ_{Actual} =	-2,158,782	lb/ft^2
σ_{Actual} =	-14,992	psi
$\sigma_{Allowable}$ =	2,100	psi
FS =	**No Stress**	

GCL - Clay Soil Liner Interface

$W = W_{geomembrane} + W_{geocomposite} + W_{GCL}$

W =	321.38	lb/ft
GCL thickness, t_{GCL} =	0.03	ft
δ =	13	degrees
a_{Clay}=	100	psf
F =	10,822	lb/ft
σ_{Actual} =	-428,820	lb/ft^2
σ_{Actual} =	-2,978	psi
$\sigma_{Allowable}$ =	133	psi
FS =	**No Stress**	

Case 2: Stress due to Operational Cover

Operational Cover Density, ρ_{OC} = 84 lb/ft^3 (fly ash wet density based on 100% standard Proctor compaction, See Ref. 3)

Operational Cover Thickness, t_{OC} = 24 in (assumes 2' protective layer of ash will be placed over liner prior to general filling)

$F_D = W \sin\beta$ Driving Force

$F_R = W \cos\beta \tan\delta_L$ (frictional force)

Tension = $F_D - F_R$ lb/ft 144 in^2/ft^2

Stress = Tension/t/144 psi 12 in/ft

Geocomposite - Geomembrane Interface

W = $W_{Geocomposite}$ from Self Weight + Operational Cover over length of slope

170 lb/ft $W_{Geocomposite}$ from Self Weight

18,020 lb/ft Operational Cover over length of slope

W = 18,190 lb/ft

Geocomposite thickness, t_{GT} = 0.03 ft

δ_L = 28 degrees

a_{Clay}= 100 psf

F_D = 5,752 lb/ft

F_R = 19,811 lb/ft

$T_{Geocomposite}$ = 0 lb/ft

σ_{Actual} = 0 psi

$\sigma_{Allowable}$ = 294 psi

FS = No Stress

Geomembrane - GCL Interface

W = $W_{Geocomposite} + W_{Geomembrane}$ from Self Weight + Operational Cover over length of slope

201 lb/ft $W_{Geocomposite} + W_{geomembrane}$ from Self Weight

18,020 lb/ft Operational Cover over length of slope

W = 18,221 lb/ft

Geomembrane thickness, t_{GM} = 0.01 ft

δ_L = 29 degrees

a_{Clay}= 100 psf

F_D = 5,762 lb/ft

F_R = 20,334 lb/ft

$T_{Geomembrane}$ = 0 lb/ft

σ_{Actual} = 0 psi

$\sigma_{Allowable}$ = 2,100 psi

FS = No Stress

HDR Computation

Job Number	453925-237673-018	**No.**	
Project	Charah Brickhaven No.2 Mine	**Computed** MY/MGB	**Date** 7/10/2015
Subject	Permit Application	**Checked** TMY	**Date** 7/16/2015
Task	Geosynthetic Stresses - Stress Due to Operational Cover	**Section** 3	**Of** 5

GCL - Clay Soil Liner Interface

$W = W_{Geocomposite} + W_{Geomembrane} + W_{GCL}$ from Self Weight + Operational Cover over length of slope

321 lb/ft $W_{Geocomposite} + W_{Geomembrane} + W_{GCL}$ from Self Weight

18,020 lb/ft Operational Cover over length of slope

$W =$ 18,341 lb/ft

GCL thickness, $t_{GCL} =$ 0.03 ft

$\delta_L =$ 13 degrees

$a_{Clay} =$ 100 psf

$F_D =$ 5,800 lb/ft

$F_R =$ 14,769 lb/ft

$T_{GCL} =$ 0 lb/ft

$\sigma_{Actual} =$ 0 psi

$\sigma_{Allowable} =$ 133 psi

FS = No Stress

Case 3: Stress due to Operational Cover and 10' Lift of Structural Fill

Ash Density, ρash = 84 lb/ft^3 (ash wet density based on 100% standard Proctor compaction, See Ref. 3)

Ash Thickness, tash = 10 feet

F_D = W sinβ Driving Force

F_R = W cosβ $\tan\delta_L$ (frictional force)

Tension = F_D - F_R lb/ft 144 in^2/ft^2

Stress = Tension/t/144 psi 12 in/ft

Geocomposite - Geomembrane Interface

W = $W_{Geocomposite}$ from Self Weight + Operational Cover + 10' Ash over length of slope

18,190 lb/ft $W_{Geocomposite}$ and $W_{Operational\ Cover}$

90,315 lb/ft Ash over length of slope

W = 108,504 lb/ft

Geocomposite thickness, t_{GT} = 0.03 ft

δ_L = 28 degrees

a_{Clay}= 100 psf

F_D = 34,312 lb/ft

F_R = 64,794 lb/ft

$T_{Geocomposite}$ = 0 lb/ft

σ_{Actual} = 0 psi

$\sigma_{Allowable}$ = 294 psi

FS = No Stress

Geomembrane - GCL Interface

W = $W_{Geocomposite}$ + $W_{Geomembrane}$ from Self Weight + Operational Cover over length of slope

18,221 lb/ft $W_{Cperatonal\ Cover}$ + $W_{Geocomposite}$ + $W_{geomembrane}$

90,315 lb/ft Ash over length of slope

W = 108,536 lb/ft

Geomembrane thickness, t_{GM} = 0.01 ft

δ_L = 29 degrees

a_{Clay}= 100 psf

F_D = 34,322 lb/ft

F_R = 67,827 lb/ft

$T_{Geomembrane}$ = 0 lb/ft

σ_{Actual} = 0 psi

$\sigma_{Allowable}$ = 2,100 psi

FS = No Stress

GCL - Clay Soil Liner Interface

$W = W_{Geocomposite} + W_{Geomembrane} + W_{GCL}$ from Self Weight + Operational Cover over length of slope

	18,341	lb/ft $W_{Operational\ Cover} + W_{Geocomposite} + W_{Geomembrane} + W_{GCL}$
	90,315	lb/ft Ash over length of slope
$W =$	108,656	lb/ft
GCL thickness, $t_{GCL} =$	0.03	ft
$\delta_L =$	13	degrees
$a_{Clay} =$	100	psf
$F_D =$	34,360	lb/ft
$F_R =$	34,550	lb/ft
$T_{GCL} =$	0	lb/ft
$\sigma_{Actual} =$	0	psi
$\sigma_{Allowable} =$	133	psi

FS = No Stress

Case 4: Stress due to Operational Equipment

CAT D6R WH Waste Handler

Operating Wt. =	45,370	lb	(Assumed to be typical of equipment placing operation cover with contact pressure less than 10 psi)
Ground Contact Area =	4,564	in^2	
Contact pressure =	9.9	psi	

F_D =	W sinβ	Driving Force		
F_R =	W cosβ tanδ_L	(frictional force)	144	in^2/ft^2
Tension =	F_D - F_R	lb/ft	12	in/ft
Stress =	Tension/t/144	psi		

Geocomposite - Geomembrane Interface

$W = W_{geocomposite} + W_{Operational\ Cover} + WAsh + W_{Operational\ Equipment}$

	108,504	lb/ft WAsh + $W_{Geocomposite}$ + $W_{Operational\ Cover}$
	1,431	lb/ft, $W_{Operational\ Equipment}$
W =	109,936	lb/ft
Geocomposite thickness, t_{GT} =	0.03	ft
δ_L =	28	degrees
a_{Clay}=	100	psf
F_u =	34,765	lb
F_L =	65,507	lb
$T_{Geocomposite}$ =	0	lb
σ_{Actual} =	0	psi
$\sigma_{Allowable}$ =	294	psi

FS = No Stress

Geomembrane - GCL Interface

$W = W_{Geomembrane} + W_{Geocomposite} + W_{Operational\ Cover} + WAsh + W_{Operational\ Equipment}$

	108,536	lb/ft WAsh + $W_{Cperatonal\ Cover}$ + $W_{Geocomposite}$ + $W_{geomembrane}$
	1,431	lb/ft, $W_{Operational\ Equipment}$
W =	109,967	lb/ft
Geomembrane thickness, t_{GM} =	0.01	ft
δ_L =	29	degrees
a_{Clay}=	100	psf
F_u =	34,775	lb
F_L =	68,580	lb
$T_{Geomembrane}$ =	0	lb
σ_{Actual} =	0	psi
$\sigma_{Allowable}$ =	2,100	psi

FS = No Stress

GCL - Clay Soil Liner Interface

$W = W_{GCL} + W_{Geomembrane} + W_{Geocomposite} + W_{Operational\ Cover} + WAsh + W_{Operational\ Equipment}$

	108,656	lb/ft WAsh + $W_{Operational\ Cover} + W_{Geocomposite} + W_{Geomembrane} + W_{GCL}$
	1,431	lb/ft, $W_{Operational\ Equipment}$
W =	110,087	lb/ft
GCL thickness, t_{GCL} =	0.03	ft
δ_L =	13	degrees
a_{Clay}=	100	psf
F_u =	34,813	lb
F_L =	34,863	lb
T_{GCL} =	0	lb
σ_{Actual} =	0	psi
$\sigma_{Allowable}$ =	133	psi
FS =	**No Stress**	

GRI Standard Guide for Joining and Attaching Geonets and Drainage Composites

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Folsom, PA 19033-1208 USA
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Original: Sept. 25, 2012

GRI-GN2* and GRI-GC13*

Standard Guide for

"Joining and Attaching Geonets and Drainage Composites"

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1. Scope

1.1 Geocomposite drainage materials consist of at least one geotextile attached to a geonet or other type of drainage core. The geotextile serves as both a filter and separator to the adjacent soil so that it allows for liquid flow yet prevents soil intrusion. Oftentimes, geotextiles are on both sides of the drainage core. The geonet or drainage core is the "drain" component which allows for liquid transmission within its plane to a downgradient exit area; be it a outlet pipe, sump, or swale.

Since manufactured rolls of geocomposite drainage materials must cover large areas, field constructed connections along their sides and ends are necessary. This guide addresses such connections. Even further, the ends of the geocomposites must eventually terminate by attachment to pipes, sumps or swales. These are also made in the field by construction personnel. The following situations are presented in this guide illustrating various connections and attachments which we currently consider to be best-available-practice;

- connection of overlapping geocomposites on their ends and sides
- geocomposite to horizontal pipe connection
- geocomposite to vertical pipe connection
- geocomposite termination in sumps and swales

*This GRI Standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This guide will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

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- geocomposite termination within landfill anchor trenches

1.2 This guide addresses many different types and configurations of geocomposite drainage materials. All of them, however, are characterized by having a geotextile(s) bonded, attached, or laid upon a drainage core. The geotextile can vary, but for reasons of their versatility and economics, needle-punched nonwoven polypropylene fabrics are the most widely used. Much greater variation is in the drainage core. Biplanar and triplanar geonets are commonly used in waste containment applications; see Figure 1a. They are all made from high density polyethylene. Stiff three-dimensional meshes (made from polypropylene or nylon), and built-up polymer columns, cuspatations, and dimples (made from polystyrene or polyolefins) are also available. They are commonly used in transportation and private development applications; see Figure 1b. The manufacturing of geocomposite drainage materials is very active with new products, and variations of existing products, being developed on a regular basis.

(a) Geonet composite drains (b) Other geocomposite drains

Figure 1. Various types of sheet drainage geocomposites.

1.3 Regarding the design of drainage composites there is a wealth of knowledge available. GSI's key word data base indicates that forty-three references are available focusing on the required flow rate or transmissivity in myriad applications. An even greater number of references (seventy-eight in our data base) is available for calculation of the required flow rate or permittivity of the covering geotextile.

1.4 Regarding standardized testing of drainage cores for allowable flow rate or transmissivity, one has a choice between ASTM D4716 or ISO 12958. The allowable flow rate or permittivity of geotextiles is addressed in both ASTM D4491 and ISO 11058.

1.5 Of course, the issue of a design value counterpointed against a test value is the customary factor-of-safety (FS) upon which each component (drainage core and geotextile) is selected for a particular project. The tacid assumption, however is that field installation is such that the design and testing is representative of the field

installation. As such, this paper attempts to present proper field installation of connections and attachments of drainage composites to one another, to various outlet systems such as pipes, sumps and swales, and to anchor trenches.

1.6 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

D4491 Water Permeability of Geotextiles by Permittivity

D4716 Determining the (In-Plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head

D7005 Determining the Bond Strength (Ply Adhesion) of Geocomposites

2.2 ISO Standard

12958 Geotextile and Geotextile Related Products – Determination of Water Flow Capacity in Their Plane

2.3 References

Hwu, B.-L. and Koerner, R. M. (1990), "Geocomposite Sheet Drain Joining," Jour. of Geotextiles and Geomembranes, Vol. 9, pp. 501-506.

Koerner, R. M. and Koerner, G. R. (2009), "Geocomposite Drainage Material Connections and Attachments," Proc. GRI-22 Conference, Salt Lake City, Utah, pp. 59-65.

Koerner, R. M. (2012), Designing With Geosynthetics, 6th Edition, Xlibris Publ. Co., 2 Vols., 914 pgs.

3. Summary of Guide

3.1 This guide presents recommended details of five different situations encountered with the connections and attachments of geocomposites to one another or to other materials and systems. The geocomposites addressed are all involved with the drainage of liquids or gases. As such, they are indeed drainage geocomposites. The drainage cores are biplanar or triplanar geonets or a myriad of other core types including three-dimensional meshes and built-up polymer columns, cuspations, and dimples. All of these drainage cores are covered with one or two geotextiles usually bonded to the core at the manufacturing facility. The geotextiles are most often needle-punched nonwovens although any other type could be used depending upon the specific design. They are supplied to the job site in rolls of various lengths and widths.

3.2 The five situations presented in the paper are the following:

- Connection of overlapping geocomposites on their ends and sides (Figure 4).
- Geocomposite to horizontal pipe connection (Figure 5).
- Geocomposite to vertical pipe connection (Figure 6).
- Geocomposite termination in sumps and swales (Figure 7).
- Geocomposite termination within landfill anchor trenches (Figure 8).

3.3 The recommended sketches associated with each situation are not theoretically derived, but are subject to the various caveats given in the guide. They are also based on what GRI feels is best-available-technology as seen over many years of observation.

4. Conditions and Caveats

In the suggested installation details to be presented in this guide there is considerable subjectivity taken on the part of the GRI authors. *In fact, this is an opinion guide, pure and simple.* As such, a few caveats regarding our assumptions are in order.

4.1 Butt joining of upgradient-to-downgradient drainage cores is not appropriate for any of these materials. The reason for this is that even a slight separation of the two ends will allow the covering geotextile(s) to intrude into the open space greatly decreasing the allowable flow rate. Overlapping ends of all drainage geocomposites are required in all applications.

4.2 Liquid flow within an upgradient geocomposite core discharging to an overlapped downgradient geocomposite core or drainage pipe cannot have an imbedded geotextile(s) within the flow area. The upgradient core must empty directly into the dowgradient core or pipe without flow passing through an intervening geotextile.

4.3 The upper and/or lower geotextiles must be capable of being hand stripped off of the geocomposite core. This has direct bearing on the adhesion of the geotextile(s) to the drainage core. In this regard, specifications should be limited to a maximum peel strength; perhaps 175 N/m (1.0 lb/in.). There should obviously be a minimum peel strength as well so as to prevent an interface slide from occurring; perhaps 87 N/m (0.5 lb/in.). See Figure 2 for the peel testing of a geotextile from a biplanar geonet core.

4.4 There can be no exposed drainage core directly against soil, either above or below, at any location. There must be the specified type of geotextile between the drainage core and soil to prevent intrusion of soil into the drainage core. If necessary, the bonding of additional geotextile to the composite's geotextile can be made by heat bonding, adhesive, or sewing.

Figure 2. Peel testing of a drainage composite per ASTM D7005.

Note 3 - It is generally accepted that field patching of areas where destructive samples had been taken using extrusion fillet seaming is less desirable than the original seam which was made by hot wedge welding.

4.5 The mechanical joining of the sides and ends of rolls of geocomposite drainage materials is usually done with electrical ties; see Figure 3. The main purpose is to provide fixed positioning so as to achieve sheet flow throughout the area to be covered. The spacing of these electrical ties is quite arbitrary but a consensus for biplanar and triplanar geonets appears to be about 220 mm (9.0 in.) at the ends and 1.5 m (60 in.) along the sides. These values also seem reasonable for three-dimensional mesh cores, but not for cores with columns, cuspations and dimples. Manufacturers literature should be followed for these latter products.

4.6 The bonding of geotextiles to other geotextiles has been done by many methods. Heat burnishing use a plate or shoe, use of an adhesive, and actually sewing are all acceptable as long as the bonding is continuous. Strength, per se, is not particularly important.

4.7 The various connections and attachments to follow apply to geonets (biplanar and triplanar, the latter requiring flow orientation to be appropriate) and three dimensional meshes. The built-up polymer sheet cores have unique characteristics insofar as their joining is concerned.

Figure 3. Plastic ties joining sides of a biplanar geonet.

5. Suggested Methodology

The sketches presented in this main section of the guide are considered to be best-available-technology by the authors. Each situation conforms to the "caveats" presented in the previous section. At the outset, however, we do realize that it is far easier to sketch various situations than it is to fabricate them (continuously under all weather conditions) in the field.

5.1 Connection of Overlapping Geocomposites on Their Ends and Sides

Figure 4 shows an overlapped geocomposite with the upgradient end overlapping the downgradient end. For the sides of the rolls which is placed, upper or lower, is not important. The recommended lengths of overlap ("L") are 300-450 mm (12-18 in.) for ends and 100-150 mm (4.0-6.0 in.) for sides. One other consideration has to do with the roll ends being factory supplied or cut in the field. The manufacturers of geocomposites usually leave an excess of 300 mm (12 in.) of unbonded geotextile for complete coverage purposes. Field cut geocomposites have no such excess geotextile.

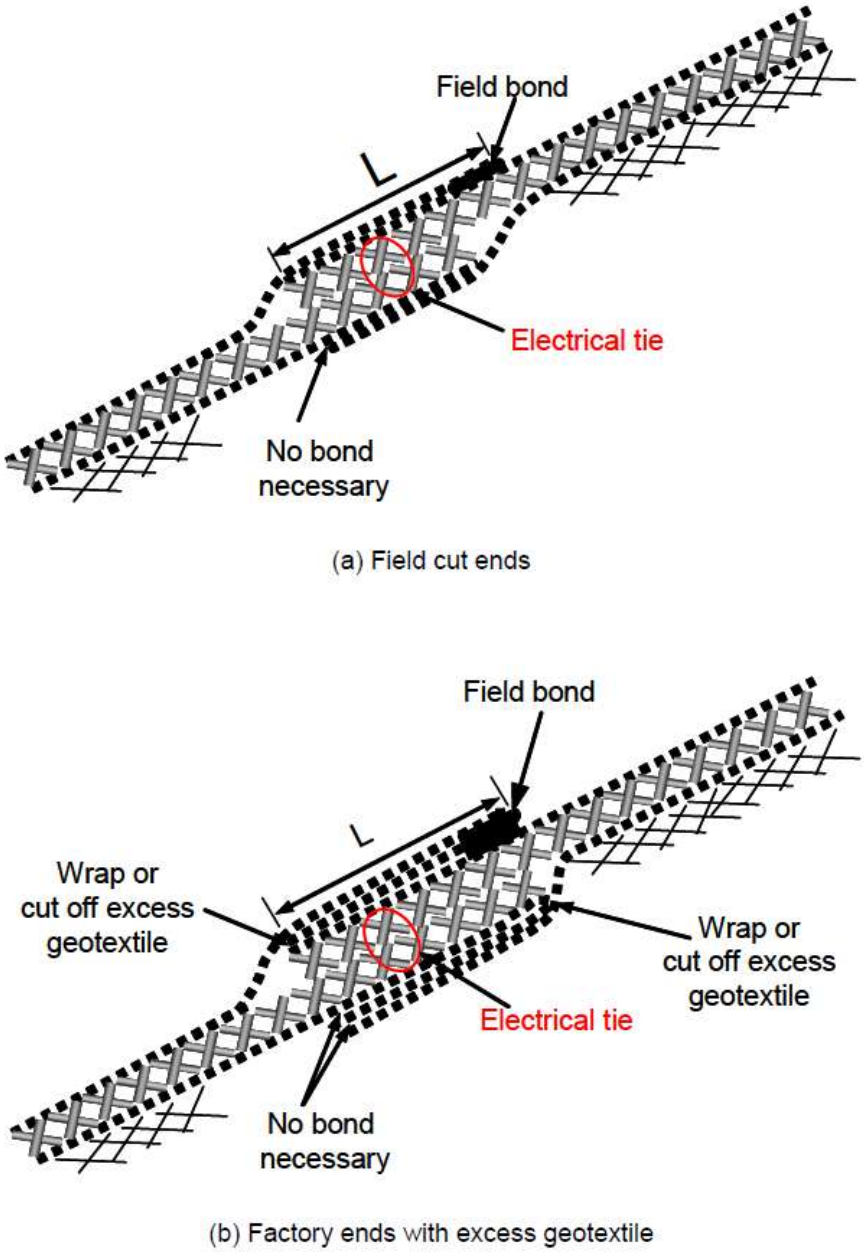
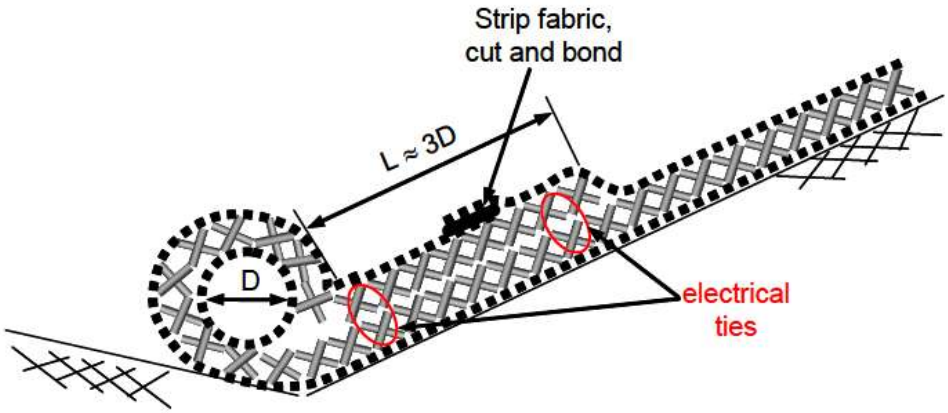


Figure 4. Recommended overlapping of geocomposite drainage materials.

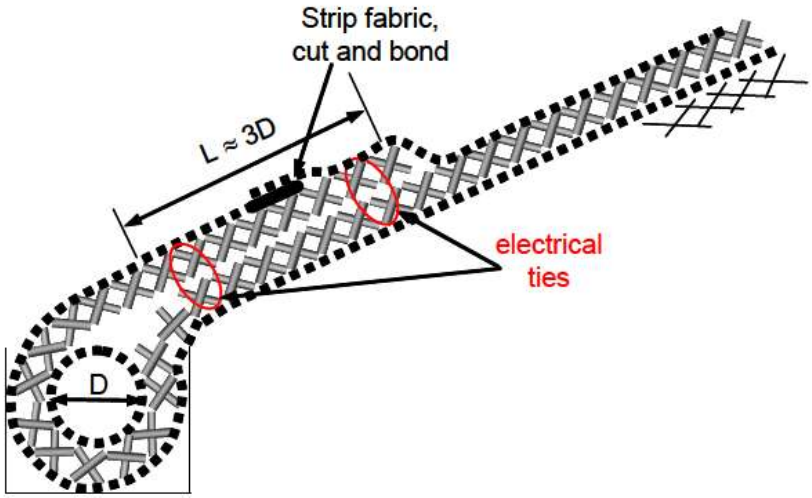
5.2 Geocomposite to Horizontal Pipe Connection

Geocomposites very often empty their flow into a horizontally placed perforated drainage pipe. The drainage pipe is usually corrugated HDPE with slots in the valleys of the corrugations. However, where external stresses are high, the drainage pipe is often solid wall HDPE or PVC pipe with holes drilled in it at uniform spacings. Whatever the pipe type, the geocomposite drainage core should wrap around the entire pipe with no intervening geotextile in the flow transfer area. Figure 5a gives the desired, but admittedly difficult, preferred detail. The geocomposite's upper geotextile must be stripped off the drainage core, greatly trimmed, and then bonded to the reverse

side of the geocomposite with its geotextile intact after wrapping around the pipe. The overlap distance "L" should be approximately three times the encapsulated drainage pipe diameter. Also note that plastic electrical ties are necessary to hold the geonet together particularly for thick biplanar and all triplanar geonet composites. Generally, two ties are necessary to minimize the air space around the encapsulated pipe. This same detail can also be followed if the drainage pipe is located in a trench at a lower elevation than the exiting geocomposite drain; see Figure 5b.



(a) Drainage pipe on a slope



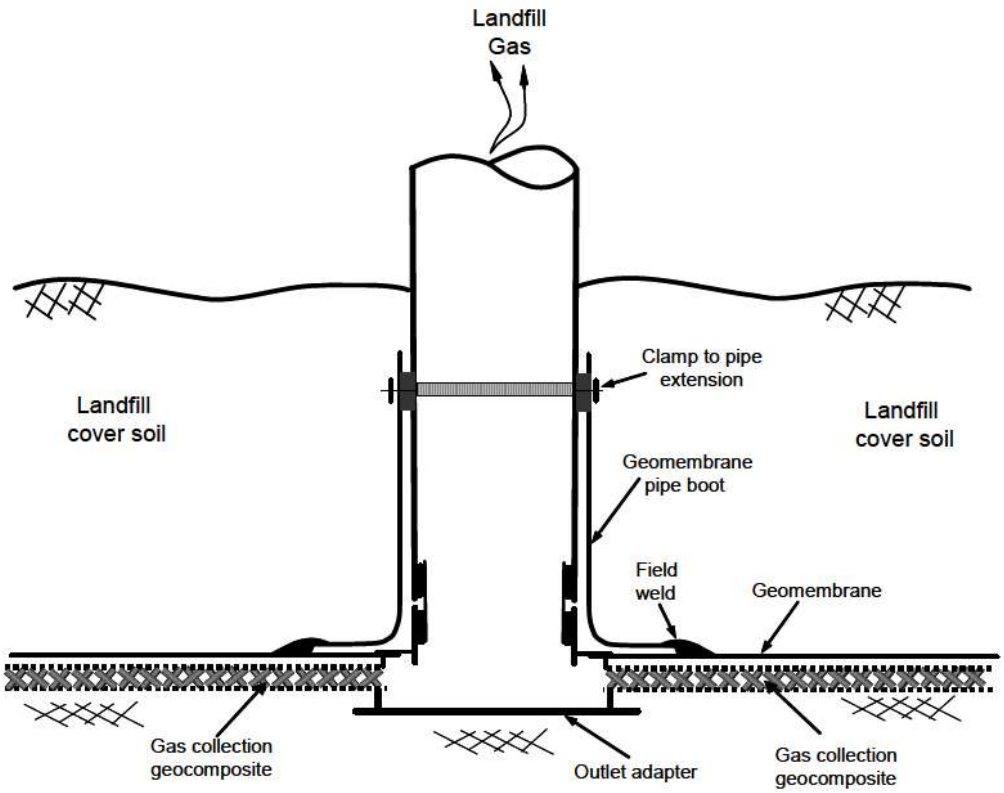
(b) Drainage pipe in a trench

Figure 5. Recommended geocomposite to horizontal drainage pipe condition.

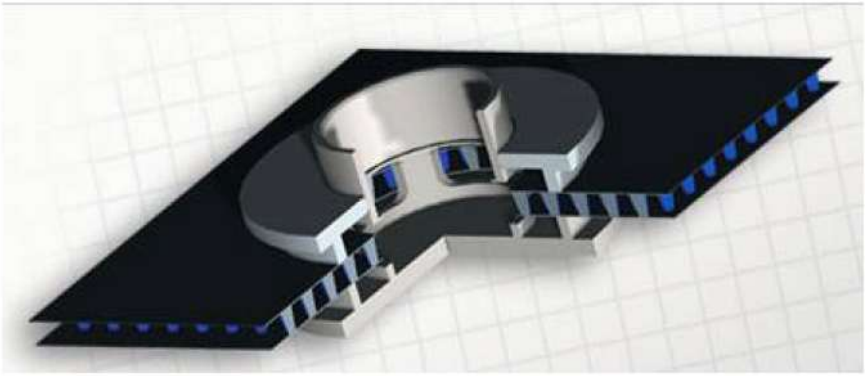
5.3 Geocomposite to Vertical Pipe Connection

A geocomposite drainage system is often used for the collection and transmission of gas under the final covers of solid waste landfills. This drainage composite is located immediately beneath the geomembrane in the cover system. Figure 6a shows the

typical situation. Fortunately, commercially available adapters are ideal for these connections; see Figure 6b. A force fit by opposing flanges of the adapter snugs up the geocomposite and allows for full exit of the gases (or liquids). The final extraction is from solid wall pipe (HDPE or PVC) stantions which penetrate the overlying topsoil, cover soil and geomembrane. A geomembrane pipe boot prefabricated to fit over the connection's shaft is necessary for a proper seal of the geomembrane.



(a) Cross section of adapter and geomembrane pipe boot



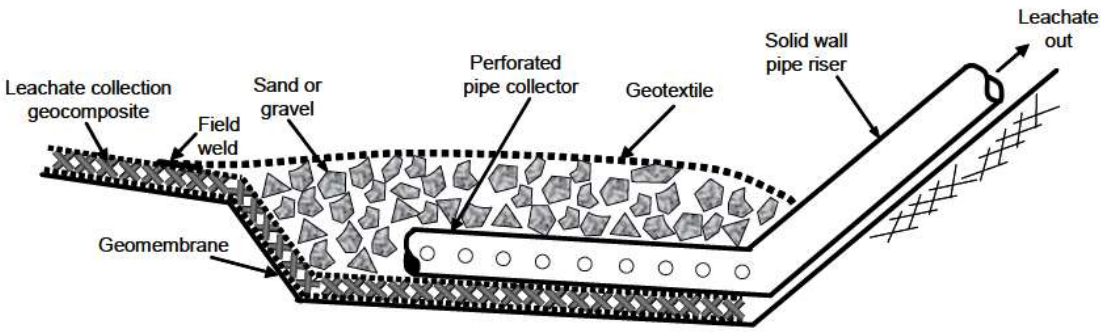
(b) Photograph of a typical adapter without geomembrane boot (compl., Drain Great™)

Figure 6. Recommended geocomposite to vertical pipe connections.

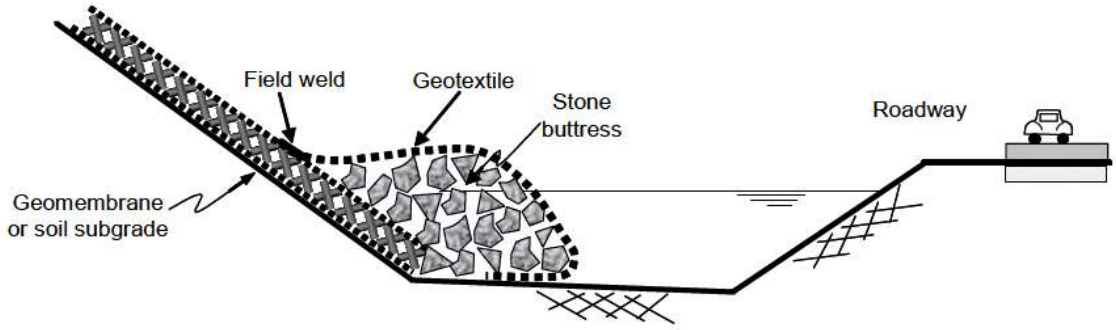
5.4 Geocomposite Termination in Sumps and Swales

Liquid being conveyed by a drainage geocomposite is often emptied in an open area such as a landfill sump or a highway swale. Figure 7a shows the general configuration for leachate removal when exiting into a landfill sump area. Since regulations limit the head on the geomembrane, the leachate must be removed by a submersible pump within a solid wall removal pipe. The drainage geocomposite should cover the entire sump area where it serves a secondary function as a protection for the geomembrane against the coarse gravel generally used as indicated. The geotextile(s) should be left on the drainage core throughout since it will help in filtering out fines leaving the geonet free of sediments.

Figure 7b shows the general configuration for water draining from a slope and emptying into a swale adjacent to a roadway. (Alternatively, it could end by emptying into a drainage pipe as shown in Figure 5). It is important that roadway maintenance operations do not cause a blockage of the exiting core, but otherwise the situation is quite straightforward.



(a) Recommended termination of geocomposite in a landfill sump for subsequent removal



(b) Recommended termination of geocomposite in a swale adjacent to a roadway

Figure 7. Recommended geocomposite terminating into an open collection area.

5.4 Geocomposite Termination Within Landfill Anchor Trenches

Geocomposites are used in three different locations for liquid (water or leachate) drainage purposes in solid waste landfills; (i) surface water drainage above a geomembrane in the final cover, (ii) leachate collection above the primary geomembrane beneath the solid waste, and (iii) leak detection between primary and secondary geomembranes beneath the waste if a double lined system is designed. Note that the gas collection geocomposite shown in Figure 6 is in addition to the three situations described here. In most cases geotextiles will be bonded to both the upper and lower surfaces of the geonet or drainage core. Figure 8 shows one possible strategy for terminating these three liquid drainage geocomposites in their respective anchor trenches.

For the geocomposite drain in the landfill cover the termination can be in a horizontal pipe (recall Figure 5b) or in a drainage swale (recall Figure 7b). One type of alternative to a pipe could be a geocomposite edge drain (Koerner, 2012), but these are seldomly used by landfill designers. For the geocomposite drain terminations beneath the solid waste mass the entire geocomposite generally enters the anchor trench along with its accompanying geomembrane. This is more for physical anchoring (to prevent the geocomposite from sliding downslope) than for drainage purposes. There is no overriding reason to seal off the ends of the geocomposite since capillary rise of moisture is not possible for these products.

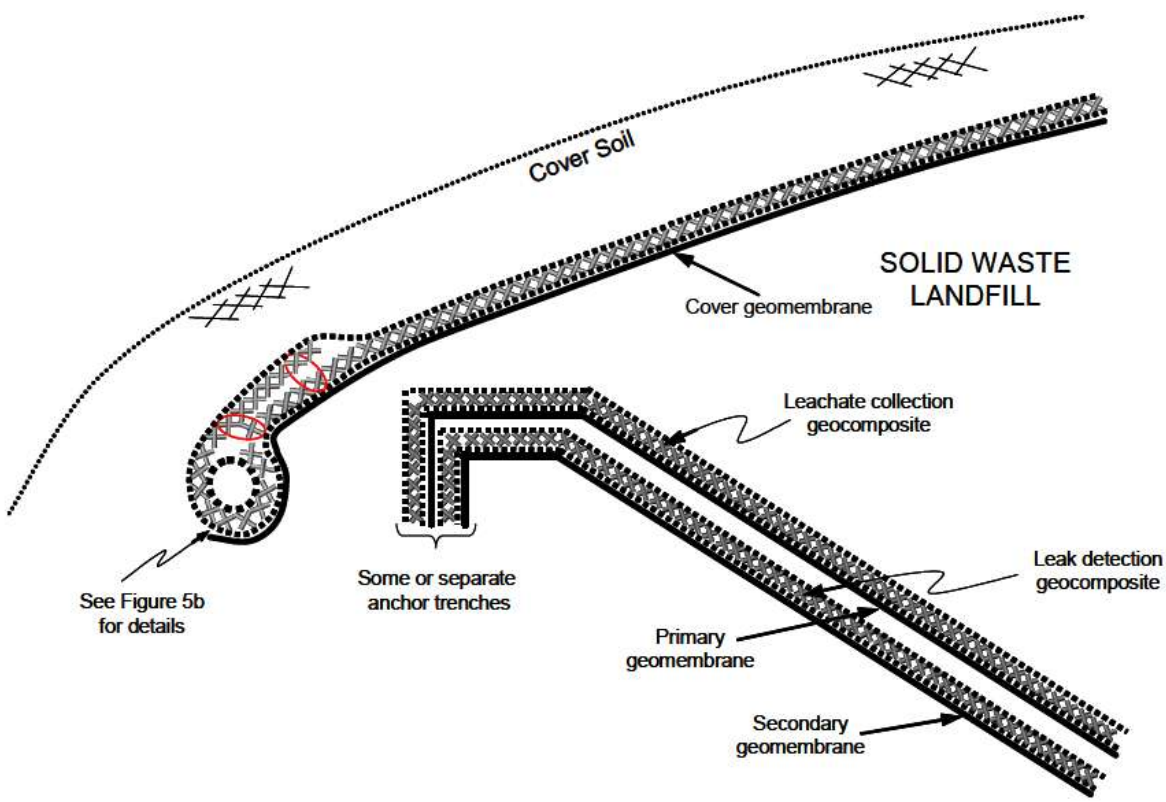


Figure 8. Recommended termination of geocomposites at the boundary and anchor trench of solid waste landfills.

GSE CoalDrain Geocomposite Specifications

19103 Gundle Road
Houston, Texas 77073

281.443.8564
281.875.6010
800.435.2008

GSE ENVIRONMENTAL™

June 16, 2015

Michael Plummer, P.E.
HDR Engineering
440 South Church St.
Suite 1000
Charlotte, NC 28202

RE: GSE Sales Order SO-076037
CCS Brickhaven Mine Project
GSE CoalDrain Geocomposite Specifications

Dear Mr. Plummer,

As discussed in your meeting with Steve Mayes, GSE has submitted the data sheet for the GSE CoalDrain Geocomposite material. The Ply Adhesion value was adjusted as agreed to 0.5 lb/in per ASTM D 7005. As a result of this specification, you can expect to see Ply Adhesion values for individual rolls supplied on the project to range from 0.5 lb/in to 1.5 lb/in or more.

This change represents typical performance for the product. Site specific shear performance at the CoalDrain Geocomposite and fly ash interface will be dependent to some extent on the fly ash's shear strength characteristics. Based on past experience, CoalDrain Geocomposite with a 0.5 lb Ply Adhesion (ASTM D 7005) value will exceed the specified 26 degree peak interface friction strength.

Thank you for your assistance in this matter, and please let me know if any further clarification is required.

Respectfully,

Edward J. Zimmel
Vice President Engineering

19103 Gundle Road
Houston, TX 77073
800 435 2008 • 281 443 8564
281 230 8650 Fax
www.gseworld.com

June 16, 2015

RE: CoalDrain FabriNet TRxH Geocomposite

Certification of Compliance

GSE CoalDrain FabriNet TRxH geocomposite consists of a GSE HyperNet geonet heat laminated with a non-woven geotextile on the bottom side and an innovative composite fabric on the top side. The top geotextile serves as filter against fine materials like coal ash and FGD gypsum while the core serves the drainage function. The innovative geocomposite has been tested extensively in the laboratory and the field and has been proven to meet the performance requirements of an effective filter against coal combustion residuals.

GSE that 8.oz double-side FabriNet 300 Geocomposite will meet or exceed the following properties:

Project: Brickhaven No. 2 Mine Tract "A" Structural Fill

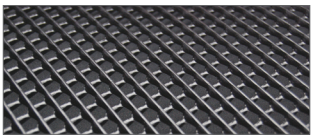
Property	Test Method	MARV(1)
Geocomposite		
Index Transmissivity, m^2/sec	ASTM D 4716	3.3×10^{-3} (2)
Ply Adhesion, lb/in	ASTM D 7005	0.5(5)
Geonet Core		
Melt Index, 10 g/10 minutes	ASTM D 1238	1.1 max
Carbon black content, %	ASTM D 4218	2.0
Density, g/cm^3	ASTM D 1505	0.930
Thickness, mil	ASTM D 5199	300
Compression, psf	ASTM D 6364	25,000
Tensile Strength (MD)(3), lb/in	ASTM D 7179	75
Top Composite Geotextile		
Structure	Hybrid monolithic woven-nonwoven needlepunched	
Mass per unit area, oz/yd^2	ASTM D 5261	14
Grab strength, lb	ASTM D 4632	200
Puncture resistance, lb	ASTM D 6241	775
Trapezoidal Tear Strength, lb	ASTM D 4533	85
AOS, US Sieve (mm)	ASTM D 4751	170 (0.088)
Permittivity, sec-1	ASTM D 4491	0.3
Water Flow Rate, gpm/ft^2	ASTM D 4491	20
UV Resistance, % retained	ASTM D 4355 (after 500 hours)	90
Field Basin Tests		See note 4
Bottom Composite Geotextile		
Mass per unit area, oz/yd^2	ASTM D 5261	8
Grab strength, lb	ASTM D 4632	210
Grab Elongation %	ASTM D 4632	50
Puncture resistance, lb	ASTM D 4833	95
AOS, sieve	ASTM D 4751	70
Permittivity, sec-1	ASTM D 4491	0.5

NOTES:
•(1) Minimum Average roll value, accept where noted.
•(2) Gradient of 0.02, normal load of 6,250 psf, Sand/Geocomposite/Geomembrane, 100 hour seat time.
•(3) MD = Transverse Direction
•(4) Filter compatibility with a minimum of three types of CCP materials (fly ash, stabilized FGD, and FGD gypsum) under simulated field conditions.
•(5) Ply Adhesion value per individual roll in accordance with ASTM D 7005.

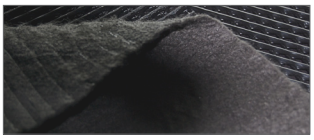
TECHNICAL NOTE

Ply Adhesion vs. Friction Angle

GSE emphasizes the development of geonets and geocomposites drainage products that are manufactured specifically for maximum field performance, with emphasis on their flow capacity. This is the most important property of geonets and geocomposites since their primary function is to transmit fluids (leachate, gases, etc.) in the plane of the geonet or composite to a designated area for collection and/or treatment.



GSE Geonet



GSE Geocomposite

Geotextile is used in conjunction with a geonet to provide filtration and prevent clogging of the drainage layer when placed under a soil layer. In order to facilitate installation of the two geosynthetic materials, the geotextile is laminated (heat bonded) to the geonet creating a composite drainage material that can be installed in one step.

From an engineering perspective, the friction angle of the geonet to geotextile interface will exceed the friction angle of the composite to soil interface with very minimal bonding. Two comprehensive studies were performed by GeoSyntec Consultants ("Final Report Interface Direct Shear Testing, GSE Geocomposite Study," GeoSyntec Consultants, August, 1996 on file at GSE) and Vector Engineering ("Large Scale Direct Shear Report," Vector Engineering, Inc., April, 1998, on file at GSE) that demonstrates this relationship. These reports are available from GSE upon request.

According to the study performed by Vector Engineering, the shear test results "are not influenced by the strength of the composites' fabric to net ply adhesion" (Vector, 1998). The material used in the study was lightly bonded with a ply adhesion strength of <0.5 lb/in (<90 g/cm) and was subjected to three different loads in a direct shear test utilizing ASTM D 5321. The results showed that the failure mechanism was the geotextile and soil interface and not the geonet and geotextile interface demonstrating that the sample with less than a 0.5 lb/in (90 g/cm) ply adhesion had sufficient bond strength to move the failure plane away from the geonet and geotextile interface.

According to the GeoSyntec report (GeoSyntec, 1996), the amount of ply adhesion does not affect the friction angle. A composite consisting of a lightly bonded polypropylene (PP) geotextile, a medium bonded PP geotextile, and a heavily bonded polyester (PET) geotextile all demonstrated comparable friction angles (35°, 36° and 36° respectively). These results clearly demonstrate that minimal ply adhesion is needed to move the failure plane away from the geonet and geotextile interface.

A ply adhesion test (ASTM D 7005, or previously ASTM D 413) is commonly used to measure the bond between the geotextile and the geonet to monitor the manufacturing consistency. Results from a ply adhesion test should not be used for design purposes as summarized by a study presented at the Geosynthetics '99 Conference in Boston, MA (Vol. 2, pp. 799-812). The study, "Use of Increased Frictional Resistance in Landfill Liner System Design and Construction," states that ASTM D 413 "which had previously been used as an index test to determine the strength of the bond, did not produce a shear-type failure which would be the anticipated mode of failure in the field. As such, it is entirely inadequate for design purposes."

GSE is a leading manufacturer and marketer of geosynthetic lining products and services. We've built a reputation of reliability through our dedication to providing consistency of product, price and protection to our global customers.

Our commitment to innovation, our focus on quality and our industry expertise allow us the flexibility to collaborate with our clients to develop a custom, purpose-fit solution.

GSE ENVIRONMENTAL™

[DURABILITY RUNS DEEP] For more information on this product and others, please visit us at GSEworld.com, call 800.435.2008 or contact your local sales office.

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