APPENDIX D

DIRECT SHEAR INTERFACE TEST RESULTS

ONONDAGA LAKE
PRE DESIGN INVESTIGATION
SEDIMENT CONSOLIDATION AREA (SCA)
INTERFACE DIRECT SHEAR TESTING
SUMMARY REPORT

Prepared For:

Honeywell

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Prepared By:

PARSONS

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JANUARY 2010

1.0 INTRODUCTION

This summary report describes the results of direct shear interface testing for the geotextile tubes and liner materials to be used in construction of the Sediment Consolidation Area (SCA). Interface direct shear testing was performed on the geotextile tube material to evaluate both the peak and residual strength of the interface between two tubes. Interface testing was also performed on the composite liner system to establish a reasonable interface strength value (both peak and residual) to be used in the slope stability analyses. The details regarding the methods of sample collection and analysis and results are described below.

2.0 SAMPLE COLLECTION AND ANALYSIS

Interface direct shear testing was performed in accordance with ASTM D5321. The geotextile-tube to geotextile-tube interface was modeled during testing by placing two samples of geotextile tubes against each other. The composite liner was modeled during testing using the following components (layered from top to bottom):

- concrete sand;
- non-woven geotextile (i.e., geotextile cushion);
- geomembrane; and
- compacted low-permeability soil.

Several types of geomembranes were tested. The geosynthetic material types and manufacturers are provided in Table 1. Samples of low-permeability soil were obtained from the Hansen Quarry in Jamesville, NY. The low-permeability soil was compacted to 95% of the maximum modified Proctor dry density at 3% of optimum water content.

Interface testing was performed at normal stresses of 700, 2,100, and 3,500 pounds per square foot (psf) to represent the potential range of pressures expected during SCA operation.

Table 1. Geosynthetic Materials

Geosynthetic Material	Manufacturer	Description
Geotextile Tube	Tencate	GT500, woven, polypropylene, woven, 17.3 oz/yd^2
Geotextile Cushion	Tencate	S1600, non-woven, polypropylene, 16 oz/yd^2
High Density Polyethylene (HDPE)	GSE	40 mil, smooth
High Density Polyethylene (HDPE)	GSE	40 mil, textured
Polypropylene (PP)	Firestone	45 mil, smooth
Ethylene Propylene Diene Monomer (EPDM)	Firestone	45 mil, smooth

3.0 RESULTS

The peak and residual (i.e., large displacement) effective stress friction angles of the geotextile-tube to geotextile-tube interface were measured to be 15 degrees and 12 degrees, respectively. The peak effective stress friction angle of the composite liner system varied depending on the type of geomembrane tested. Based on these results, smooth HDPE geomembrane is not being considered for use on this project. Among the remaining geomembrane options tested, the peak effective stress friction angle varied from 19 degrees to 27 degrees, and the residual effective stress friction angle varied from 17 degrees to 18 degrees. The laboratory test report is provided in Attachment 1, and additional discussion of the results is provided in Appendix G, “Slope Stability Analyses for SCA Design” of the SCA Final Design.

ATTACHMENT 1

LABORATORY TEST REPORT

SGI TESTING SERVICES
A Georgia Limited Liability Company

5 April 2009

Mr. David Steele
Parsons
290 Elwood Davis Road, Suite 312
Liverpool, NY 13088

Subject: Laboratory Test Results Transmittal
Interface Direct Shear Testing

Dear Mr. Barker,

SGI Testing Services, LLC (SGI) is pleased to present the attached results for the above-mentioned testing program. The note section below addresses sample preparation, sample disposal and a disclosure statement.

SGI appreciates the opportunity to provide laboratory testing services to Parsons. Should you have any questions regarding the attached document(s), or if you require additional information, please do not hesitate to contact the undersigned.

Sincerely,

Zehong Yuan, Ph.D., P.E.
Laboratory Manager

Attachments

Notes:
(1) Unless otherwise noted in the test results the sample(s)/specimen(s) were prepared in accordance with the applicable test standards or generally accepted sampling procedures.
(2) Contaminated/chemical samples and all related laboratory generated waste (i.e., test liquids, PPE, absorbents, etc.) will be returned to the client or designated representative(s), at the client's cost, within 60 days following the completion of the testing program, unless special arrangements for proper disposal are made with SGI.
(3) Materials that are not contaminated will be discarded after test specimens and archived specimens are obtained. Archived specimens will be discarded 30 days after the completion of the testing program, unless long-term storage arrangements are specifically made with SGI.
(4) The reported results apply only to the materials and test conditions used in the laboratory testing program. The results do not necessarily apply to other materials or test conditions. The test results should not be used in engineering analysis unless the test conditions model the anticipated field conditions. The testing was performed in accordance with general engineering testing standards and requirements. The reported results are submitted for the exclusive use of the client to whom they are addressed.

SGI9002.REPORT.09.01

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P.O. Box 2427
Lilburn, Georgia 30048-2427

Web Site: www.interactionspecialists.com

Facility Location
4405 International Boulevard
Suite B-117
Norcross, Georgia 30093

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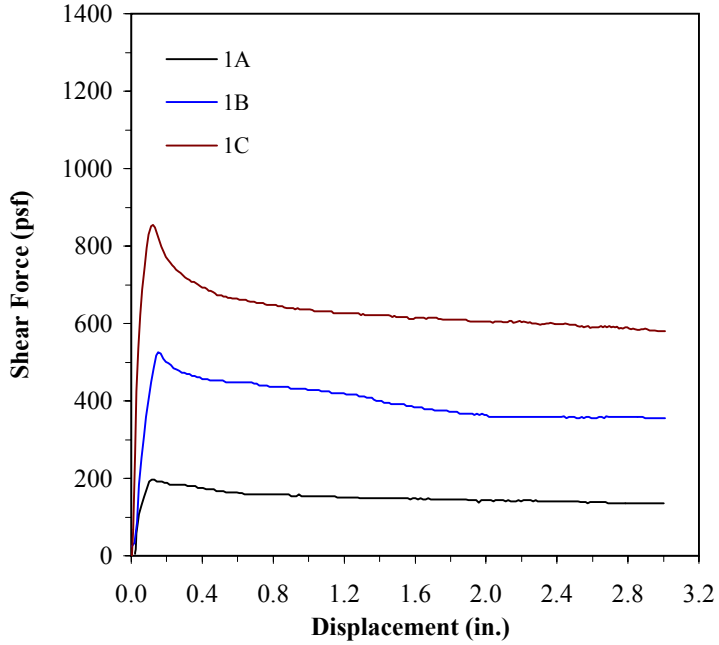
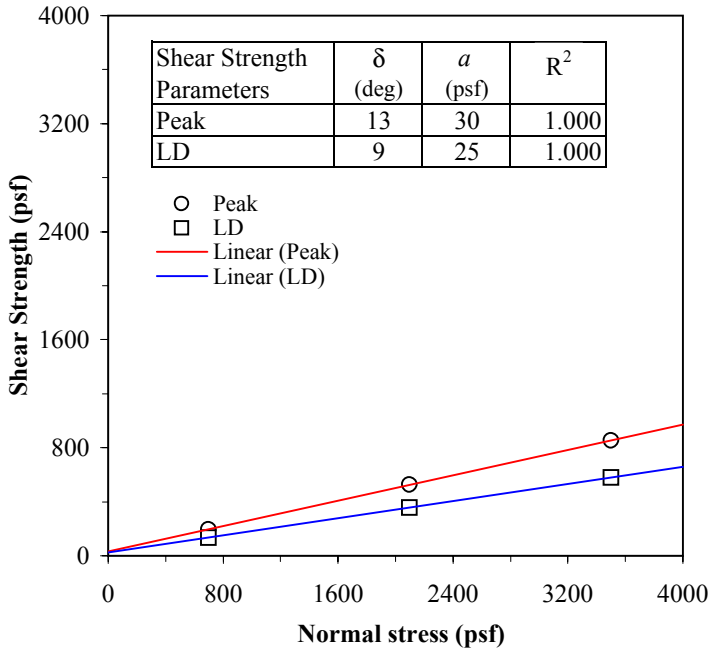
ATTACHMENT A

INTERFACE DIRECT SHEAR TEST RESULTS

PARSONS
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
TenCate S1600 (16 oz) nonwoven geotextile #000167745 with non heat-treated side down/
GSE 40-mil double smooth HDPE geomembrane # 101130132/
Lower Shear Box: Clay soil compacted to approximately 95% of max modified Proctor density at 3% wet of optimum moisture content





Shear Strength Parameters	δ (deg)	*a* (psf)	R^2
Peak	13	30	1.000
LD	9	25	1.000

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	GCL Soaking Stress (psf)	GCL Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Clay Soil γ_d (pcf)	Clay Soil ω_i (%)	Clay Soil ω_f (%)	Upper Soil γ_d (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_P (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
1A	12 x 12	700	0.04	-	-	-	-	118.6	13.9	13.1	-	-	-	-	-	196	135	(1)
1B	12 x 12	2100	0.04	-	-	-	-	118.9	13.6	12.5	-	-	-	-	-	526	355	(1)
1C	12 x 12	3500	0.04	-	-	-	-	119.3	13.2	12.7	-	-	-	-	-	855	580	(1)

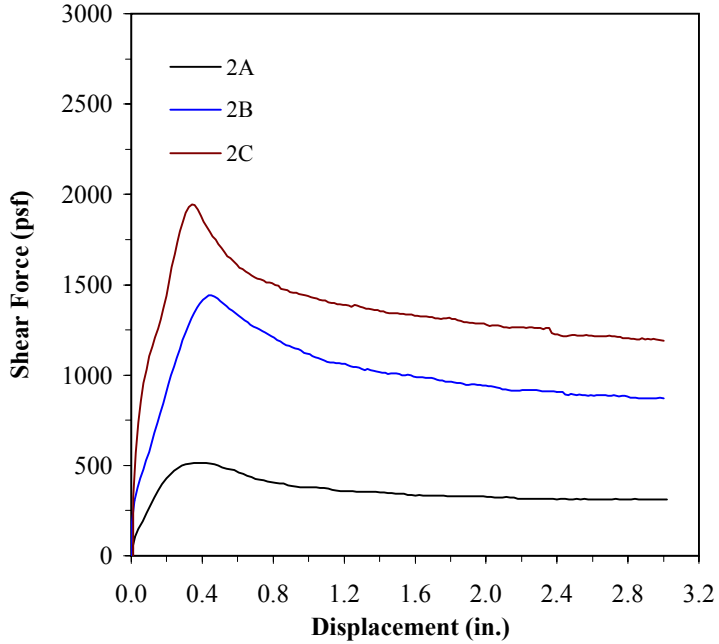
NOTES:
(1) Sliding (i.e., shear failure) occurred at the interface between the non heat-treated side of 16 oz nonwoven geotextile and geomembrane.
(2) Each geosynthetic specimen was tested in the machine direction (i.e., direction of shearing parallel to MD)

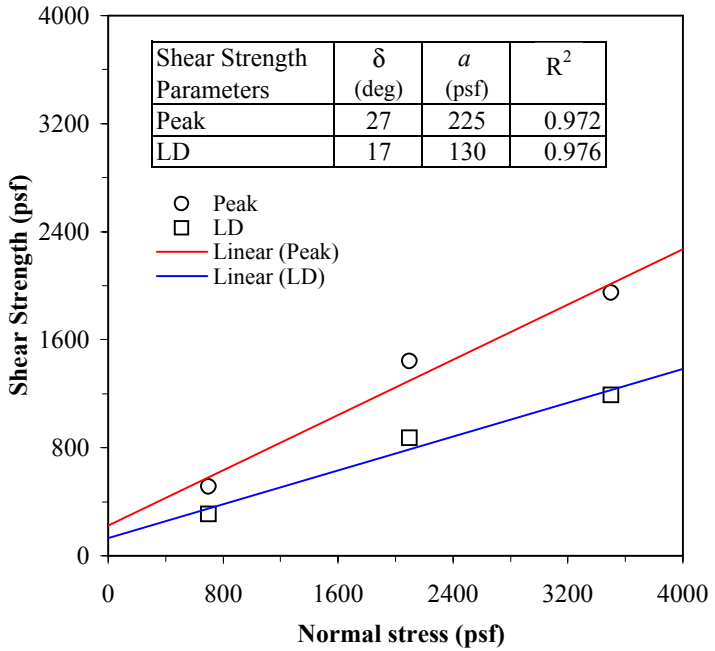
SGI TESTING SERVICES, LLC

DATE OF REPORT:	2/2/2009
FIGURE NO.	C-1
PROJECT NO.	SGI9002
DOCUMENT NO.	
FILE NO.	

PARSONS
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
TenCate S1600 (16 oz) nonwoven geotextile #000167745 with non heat-treated side down/
GSE 40-mil double textured HDPE geomembrane # 105140273/
Lower Shear Box: Clay soil compacted to approximately 95% of max modified Proctor density at 3% wet of optimum moisture content





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	GCL Soaking		Consolidation		Clay Soil			Upper Soil			GCL		Shear Stress		Failure Mode
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	γ_d (pcf)	ω_i (%)	ω_f (%)	ω_i (%)	ω_f (%)	τ_P (psf)	τ_{LD} (psf)	
2A	12 x 12	700	0.04	-	-	-	-	119.6	12.9	12.2	-	-	-	-	-	514	310	(1)
2B	12 x 12	2100	0.04	-	-	-	-	119.9	12.6	12.0	-	-	-	-	-	1441	870	(1)
2C	12 x 12	3500	0.04	-	-	-	-	118.9	13.6	12.9	-	-	-	-	-	1946	1189	(1)

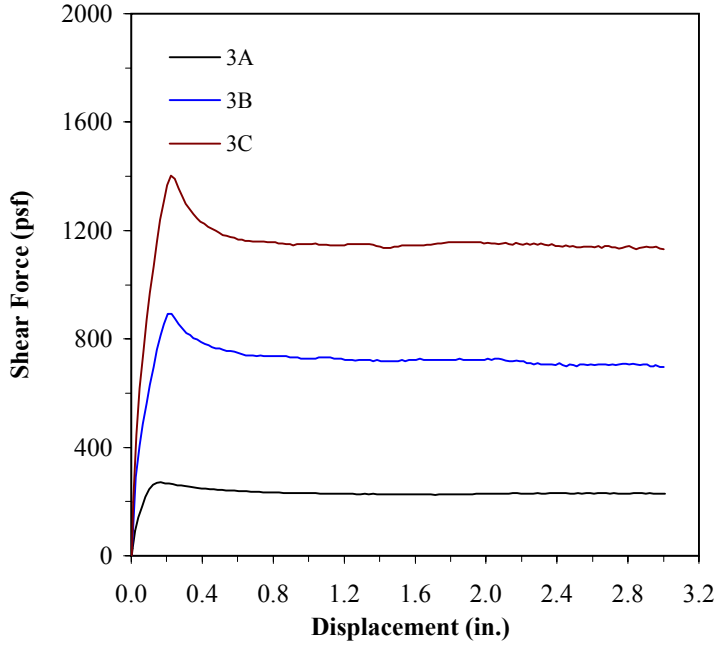
NOTES:
(1) Sliding (i.e., shear failure) occurred at the interface between the non heat-treated side of 16 oz nonwoven geotextile and geomembrane.
(2) Each geosynthetic specimen was tested in the machine direction (i.e., direction of shearing parallel to MD)

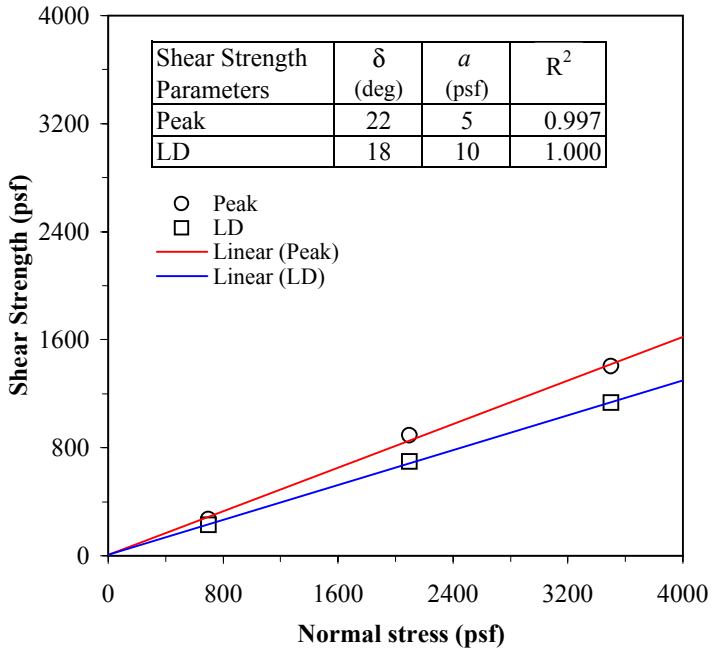
SGI TESTING SERVICES, LLC

DATE OF REPORT:	2/2/2009
FIGURE NO.	C-2
PROJECT NO.	SGI9002
DOCUMENT NO.	
FILE NO.	

PARSONS
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
TenCate S1600 (16 oz) nonwoven geotextile #000167745 with non heat-treated side down/
40-mil EPDM geomembrane # AZ 12343/
Lower Shear Box: Clay soil compacted to approximately 95% of max modified Proctor density at 3% wet of optimum moisture content





Shear Strength Parameters	δ (deg)	*a* (psf)	R^2
Peak	22	5	0.997
LD	18	10	1.000

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	GCL Soaking Stress (psf)	GCL Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Clay Soil γ_d (pcf)	Clay Soil ω_i (%)	Clay Soil ω_f (%)	Upper Soil γ_d (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_P (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
3A	12 x 12	700	0.04	-	-	-	-	119.8	12.7	12.3	-	-	-	-	-	271	228	(1)
3B	12 x 12	2100	0.04	-	-	-	-	119.4	13.1	12.5	-	-	-	-	-	892	697	(1)
3C	12 x 12	3500	0.04	-	-	-	-	119.1	13.4	12.8	-	-	-	-	-	1402	1132	(1)

NOTES:
(1) Sliding (i.e., shear failure) occurred at the interface between the non heat-treated side of 16 oz nonwoven geotextile and geomembrane.
(2) Each geosynthetic specimen was tested in the machine direction (i.e., direction of shearing parallel to MD)

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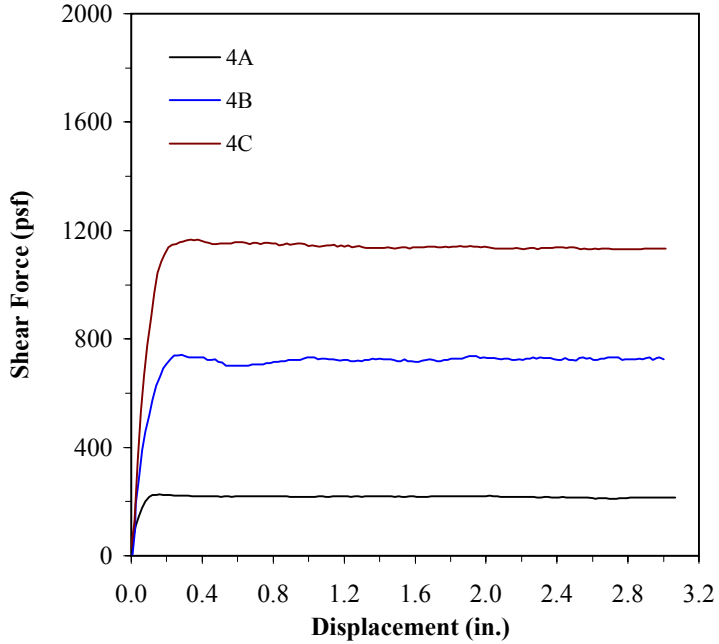
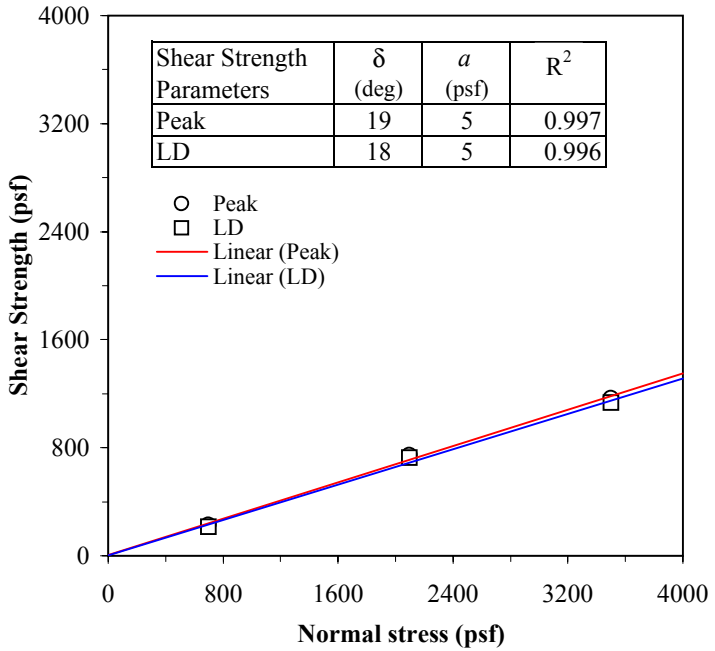
DATE OF REPORT:	2/4/2009
FIGURE NO.	C-3
PROJECT NO.	SGI9002
DOCUMENT NO.	
FILE NO.	

PARSONS
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
TenCate S1600 (16 oz) nonwoven geotextile #000167745 with non heat-treated side down/
40-mil PP geomembrane with rough side up to geotextile and smooth side down to clay soil/
Lower Shear Box: Clay soil compacted to approximately 95% of max modified Proctor density at 3% wet of optimum moisture content





Shear Strength Parameters	δ (deg)	*a* (psf)	R^2
Peak	19	5	0.997
LD	18	5	0.996

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	GCL Soaking		Consolidation		Clay Soil			Upper Soil			GCL		Shear Stress		Failure Mode
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	γ_d (pcf)	ω_i (%)	ω_f (%)	ω_i (%)	ω_f (%)	τ_P (psf)	τ_{LD} (psf)	
4A	12 x 12	700	0.04	-	-	-	-	118.6	13.9	13.3	-	-	-	-	-	226	215	(1)
4B	12 x 12	2100	0.04	-	-	-	-	119.0	13.5	12.9	-	-	-	-	-	742	726	(1)
4C	12 x 12	3500	0.04	-	-	-	-	118.8	13.7	12.5	-	-	-	-	-	1166	1133	(1)

NOTES:
(1) Sliding (i.e., shear failure) occurred at the interface between the non heat-treated side of 16 oz nonwoven geotextile and rough side of geomembrane.
(2) Each geosynthetic specimen was tested in the machine direction (i.e., direction of shearing parallel to MD)

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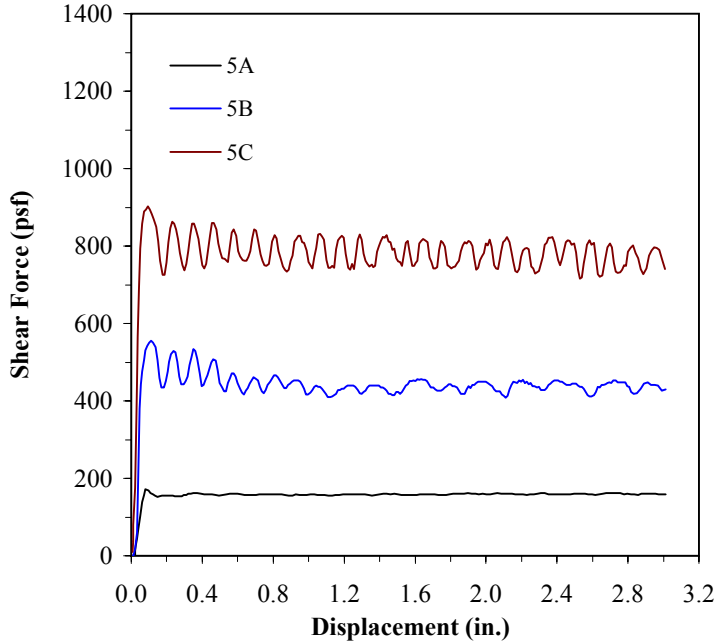
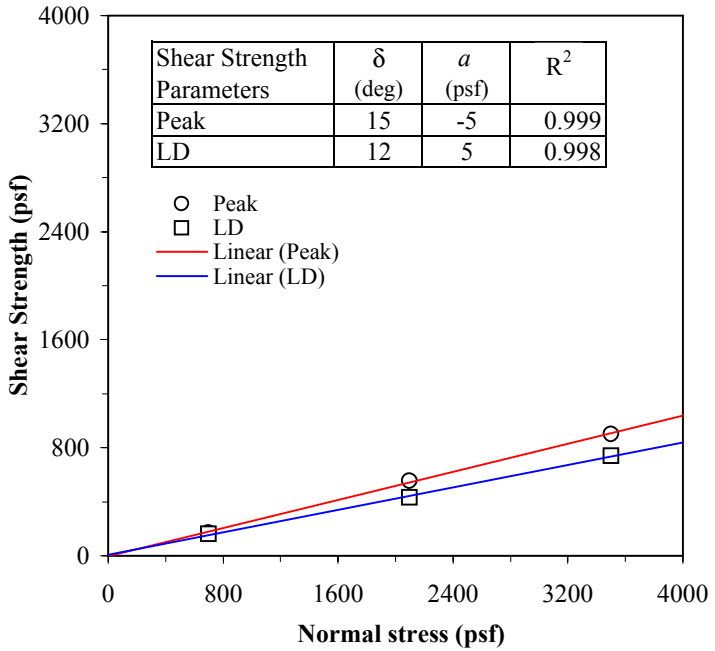
DATE OF REPORT:	2/4/2009
FIGURE NO.	C-4
PROJECT NO.	SGI9002
DOCUMENT NO.	
FILE NO.	

PARSONS
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Rigid substrate
TenCate GT500 geotextile #021812318 in the machine direction/
TenCate GT500 geotextile #021812318 in the machine direction
Lower Shear Box: Concrete sand





Shear Strength Parameters	δ (deg)	*a* (psf)	R^2
Peak	15	-5	0.999
LD	12	5	0.998

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	GCL Soaking Stress (psf)	GCL Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Clay Soil γ_d (pcf)	Clay Soil ω_i (%)	Clay Soil ω_f (%)	Upper Soil γ_d (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_P (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
5A	12 x 12	700	0.04	-	-	-	-	-	-	-	-	-	-	-	-	172	159	(1)
5B	12 x 12	2100	0.04	-	-	-	-	-	-	-	-	-	-	-	-	555	429	(1)
5C	12 x 12	3500	0.04	-	-	-	-	-	-	-	-	-	-	-	-	902	741	(1)

NOTES:
(1) Sliding (i.e., shear failure) occurred at the interface between the GT500 geotextile and GT500 geotextile.
(2) Each geosynthetic specimen was tested in the machine direction (i.e., direction of shearing parallel to MD)

SGI TESTING SERVICES, LLC

DATE OF REPORT:	2/2/2009
FIGURE NO.	C-5
PROJECT NO.	SGI9002
DOCUMENT NO.	
FILE NO.	