0018

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DIVISION OF OIL, GAS AND MINING
FACSIMILE COVER SHEET

DATE: April 14, 2003

FAX #: (303) 832-8106

ATTN: Harry Ranney

COMPANY: Colorado Division of Minerals and Geology

DEPARTMENT: Coal Program

NUMBER OF PAGES: (INCLUDING THIS ONE) 19

FROM: Priscilla Burton

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Table 2. Summary of Shear Strength Parameters Used in the Slope Stability Model

Engineering Lithology	Unit Weight (pcf)		Shear Strength	
	Moist	Saturated	Cohesion (psf)	Internal Friction Angle (deg)
Basal sandstone	155.0	155.0	111,168	45
Topsoil	130.0	130.0	1,700	39
Coal and interbedded sandstone and siltstone	78.6	78.6	14,112	35
Backfill material	138.0	138.0	1877	54
Interbedded sandstone and limestone	155.0	155.0	111,168	45
Residual soil	134	134	1,515	42
Rockfill	120.0	120.0	100	40
Geotextile composite drain	100.0	100.0	0	18

testing was essential for the Backfill and Topsoil materials because the performance of the reclaimed slope will depend primarily on the shear strength of these materials. Laboratory testing was conducted on the Residual soil to assure that the properties, all materials involved in the stability of the reclaimed slope, were rigorously determined. The sources and analyses used to develop shear strength parameters for the geotechnical model are presented in the remainder of this section.

The moist (unsaturated) and saturated weights were set at the same value in the slope stability model for the bedrock units because the slope lies above the phreatic surface. Therefore, the slope stability model only considers moist unit weight, and the existing highwall is currently stable. The saturated unit weights of the soil materials were used because the moist unit weights were not directly determined by laboratory analysis. The saturated unit weights were calculated from the maximum dry densities determined by the Standard Proctor Compaction Tests (Appendix A). Using saturated unit weights is more conservative than using moist unit weights.

3.3.1 Bedrock Units

The shear strength parameters for the bedrock units, including the engineering lithologies termed coal, interbedded sandstone and siltstone, and basal sandstone, were derived from testing conducted by the U.S. Bureau of Mines (USBM) on lithologies from the nearby Sunnyside Mine (Schriebner 1979). Schriebner (1979) tested sandstones, siltstones, and coal in triaxial compression. The values for coal were taken directly from the one set of values presented by Schriebner (1979).

Schriebner (1979) also presented three sets of data for siltstones and two sets of data for sandstones. These five sets of data were averaged to produce mean values for the relevant parameters. The mean laboratory test values from Schriebner (1979) for Unconfined Compressive Strength (UCS), Internal Friction Angle (φ), Cohesion (c), along with estimated values for RQD and joint spacing, were used to derive estimated rock mass strengths, based on the Hoek and Brown (1980) failure criterion method to convert laboratory rock test values to practical *in situ* rock mass strengths, expressed in terms of the Mohr-Coloumb Failure Criterion. This conversion is prudent because test results on laboratory specimens are typically high because they do not reflect the reduced strength of the rock mass that is due to the presence of discontinuities and other effects of scale. The resultant values are friction angle of 45 degrees and cohesion of 111,168 psf.

3.3.2 Soils

The engineering lithologies included in the soils category are Residual soil, Topsoil, and Backfill. The shear strength values for these units are based on the mean of values generated by laboratory testing conducted for Revision No 4. These values were determined by direct shear tests on samples remolded to 90% of optimum dry density and +2% above optimum moisture content, as determined by Standard Proctor Compaction specifications (Appendix A).

3.3.3 Geosynthetics

The geosynthetic products used in this slope design include a composite drain, a filter fabric, and geogrid. The composite drain will be used to drain any seeps. The composite drain is comprised of an open-weave HDPE grid to transmit water, backed with a filter fabric to permit water to enter but prevent the intrusion of fine soil particles. A filter fabric is also recommended between the rockfill and the overlying Backfill. The filter fabric modeled for this evaluation is a non-woven geotextile. Geogrid will be used to reinforce the surficial rooting zone.

The shear strengths of the geosynthetic products were determined by consultation with Tensar, which is the manufacturer of the specified geosynthetic products. The minimum shear strength parameters for composite drain and filter fabric, as reported by Tensar, are a friction angle of 18 degrees and zero cohesion. The shear strength of the geogrid/soil interaction was determined by Tensar.

3.3.4 Backfill Material

Laboratory testing was conducted on samples of the Backfill material. The tests were designed to rigorously characterize the material and generate shear strength values. The raw direct

shear test data have been corrected by AAI for changing area during the direct shear test. Shear stress, normal stress, and displacement are measured during direct shear testing. Normal stress is a function of normal load and the area of the sample in shear at any given point in time. The effectve area of a direct shear test decreases as shearing progresses. Stress is defined as force divided by area. Therefore, the normal stress changes as the effective area changes, and accurate direct shear test values are only obtained when area-correction is applied. Table 3 is a summary of laboratory test results for the Backfill material. The raw laboratory data and the area correction worksheets are presented in Appendix A.

Table 3. Summary of Laboratory Testing Results on Backfill Material

Test	ASTM Designation	Results
Direct Shear (large scale, normal loads = 25, 50, and 75 psi)	ASTM D3080 (12 by 12-inch shear box)	Post-peak friction angle (φ) = 54 degrees Cohesion (c) = 1877 psf
Moisture Content	ASTM D2216	0.9%
USCS classification	ASTM D2487	GM (silty gravel with sand)
Mechanical Analysis - Sieve Test Data	ASTM D422	See grain size curve, Appendix A
Atterberg Limits	ASTM D431s8	Liquid limit = non-plastic Plastic limit = non-plastic Plasticity index = non-plastic
Standard Proctor Compaction Test	ASTM D698 C	Optimum Density = 138 pcf Optimum Moisture Content = 8.9%

The results of the laboratory analyses indicate that the Backfill material has a Unified Soil Classification System (USCS) classification of GM (silty gravel with sand). The material is non-plastic, as determined by Atterberg Limits testing. The non-plastic determination is consistent with the USCS classification. A Standard Proctor Compaction test was conducted on the Backfill material to determine optimum moisture content and density for placement during backfilling.

Large-scale (12 by 12-inch) direct shear tests were conducted to determine Mohr-Coulomb strength criteria for the material. Three tests were conducted at normal loads of 20, 30, and 40 psi. The sample material was compacted in the shear box at 2% greater than the optimum moisture content (11%) and 90% of optimum density (120 pcf). The results of the three-point direct shear test program indicates that the post-peak friction angle is 54 degrees and the cohesion is 1877 psf.

Residual friction angle values are not typical for direct shear tests on coarse-grained material because the coarse particles tend to rotate, causing dilation and strain hardening, such that post-peak values are the most representative of actual field conditions. During a direct shear test, the upper and lower shear boxes are translated relative to one another at several predetermined normal loads. The shear forces are necessary to cause initial and post-peak displacement measured during the test. A plot of shear displacement versus shear force is recorded during the test. For most materials, a peak shear force is observed, which represents the force required to initiate shearing. The post-peak behavior of the shear-force-versus-displacement curve reflects the behavior of the material after shearing has been initiated. Fine-grained materials, such as clays, typically undergo a reduction in shear strength following peak shear strength. A post-peak shear strength measured for such a test would be termed the "residual shear strength", and is represented by the nearly linear portion of the displacement-versus-shear-strength curve (Appendix A). In the case of the Backfill material for this evaluation, there was adequate coarse-grained material present so that at the low normal loads used for these tests, the material continued to gain strength after shearing had begun. This was probably because the larger particles in the material were rotating, causing the larger particles to act as keys and increase shearing resistance. Low normal loads were chosen to simulate the relatively small amount of overburden that will be present above a hypothetical shear plane. Post-peak shear strengths are typically used in slope evaluation because the conservative assumption is made that the material has already undergone peak shearing.

4.0 DESIGN RECOMMENDATIONS

The design criteria for the proposed reclaimed portal cut slope that were considered for this evaluation include:

- Slope angle reduction
- Minimum reclaimed slope performance safety factors of 1.3_{static} and $1.1_{pseudostatic}$
- Maintaining the toe of the reclaimed slope at the current toe of the lower bench
- Preventing excess pore water pressure development
- Revegetation rate of at least 70%
- Aesthetically blended appearance

PHYSICAL PROPERTIES TESTS

BACKFILL

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT	Agapito Associates	JOB NO.	2452-08
BORING NO.	Composite	SAMPLED	
DEPTH		DATE TESTED	
SAMPLE NO.	Backfill 1,2,3,4,5	WASH SIEVE	Yes
SOIL DESCR.	Project #460-03	DRY SIEVE	No
LOCATION	Westridge Mine		

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No

Wt. Wet Soil & Pan (g)	53.42
Wt. Dry Soil & Pan (g)	52.99
Wt. Lost Moisture (g)	0.43
Wt. of Pan Only (g)	3.65
Wt. of Dry Soil (g)	49.34
Moisture Content %	0.9

Wt. Hydrom. Sample Wet (g)	213.72
Wt. Hydrom. Sample Dry (g)	211.89

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	3819.92
Weight of + #10 Before Washing (g)	1930.80
Weight of + #10 After Washing (g)	1733.91
Weight of - #10 Wet (g)	1889.12
Weight of - #10 Dry (g)	2068.15
Wt. Total Sample Dry (g)	3802.06

Calc. Wt. "W" (g)	389.54
Calc. Mass + #10	177.65

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	426.30	426.30	426.30	11.2	88.8
3/4"	0.00	225.67	225.67	651.97	17.1	82.9
3/8"	0.00	441.55	441.55	1093.52	28.8	71.2
#4	0.00	345.67	345.67	1439.19	37.9	62.1
#10	0.00	294.72	294.72	1733.91	45.6	54.4
#20	3.73	28.01	24.28	24.28	51.8	48.2
#40	3.59	17.67	14.08	38.36	55.5	44.5
#60	3.62	19.54	15.92	54.28	59.5	40.5
#100	3.69	39.38	35.69	89.97	68.7	31.3
#200	3.58	29.43	25.85	115.82	75.3	24.7

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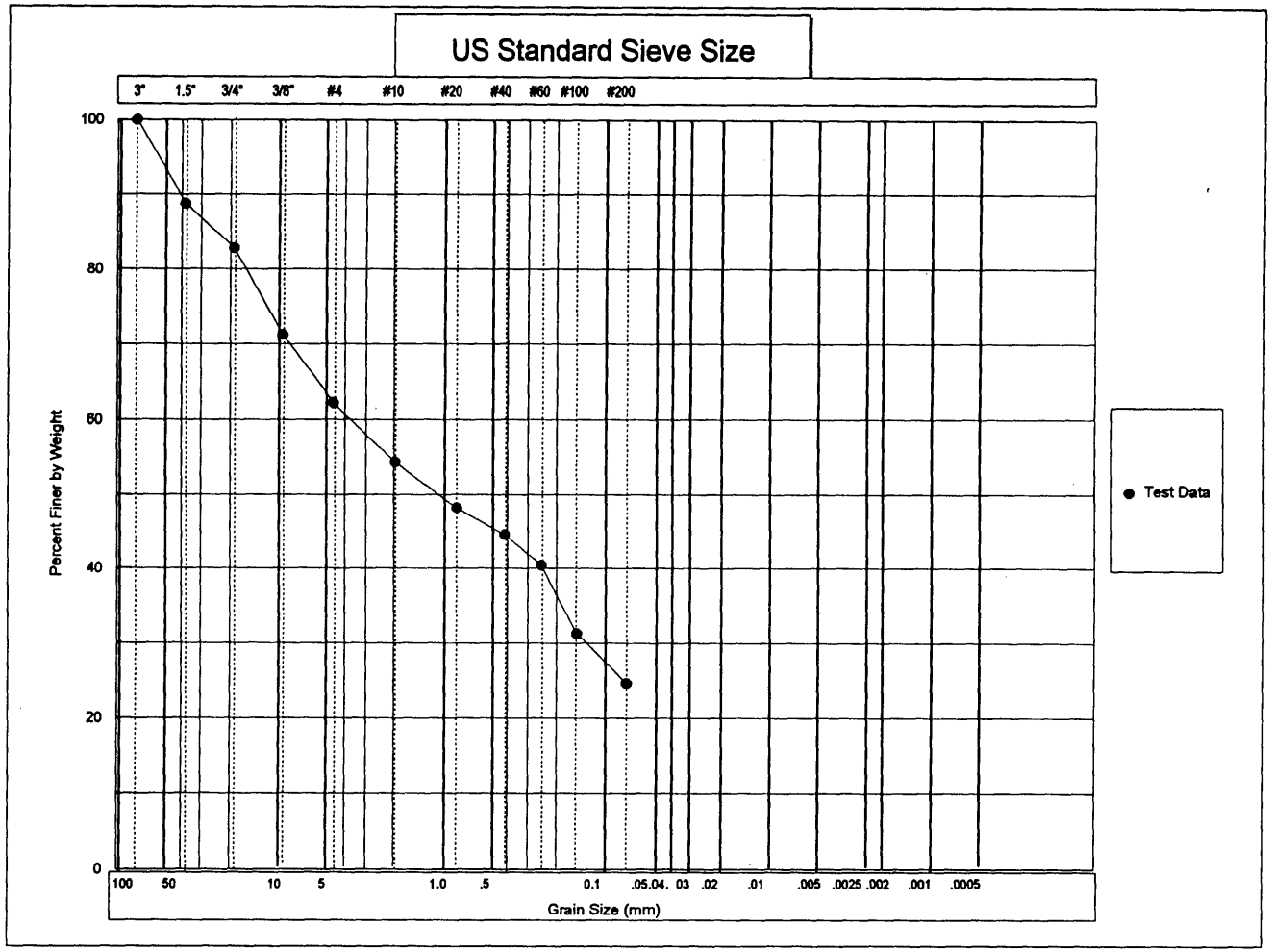
Data checked by: Cue Date: 01/29/03
FileName: AOMU1234

ADVANCED TERRA TESTING, INC.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	CRS	MEDIUM	FINE	

USCS

COBBLES	PEBBLE GRAVEL				SAND			SILT	CLAY
TO BOULDERS	COARSE	MED	FINE	GRAN	COARSE	MED	FINE		

WENTWORTH

Client: Agapito Associates Boring No.: Composite Sample No.: Backfill 1,2,3,4,5

Job Number: 2452-08 Depth:

Classification: GM, Silty gravel with sand

Advanced Terra Testing, Inc.

ATTERBERG LIMITS TEST
ASTM D 4318

CLIENT	Agapito Associates	JOB NO.	2452-08
BORING NO.	Composite	DATE SAMPLED	
DEPTH		DATE TESTED	01-24-03 RS
SAMPLE NO.	Backfill 1,2,3,4,5		
SOIL DESCR.	Project #460-03		
LOCATION	Westridge Mine		

Plastic Limit
Determination

Wt Dish & Wet Soil	
Wt Dish & Dry Soil	
Wt of Moisture	
Wt of Dish	NON-PLASTIC
Wt of Dry Soil	
Moisture Content	

Liquid Limit Device Number 0966
Determination

Number of Blows

Wt Dish & Wet Soil	
Wt Dish & Dry Soil	
Wt of Moisture	
Wt of Dish	NON-PLASTIC
Wt of Dry Soil	
Moisture Content	

Liquid Limit	NP
Plastic Limit	NP
Plasticity Index	NP

Atterberg Classification NP

Data entry by: SR Date: 01/24/2003
Checked by: Cae Date: 1/29/03
FileName: AOG0CPBC

ADVANCED TERRA TESTING, INC.

Moisture Content Determinations
ASTM D 2216

CLIENT: Agapito Associates JOB NO.: 2452-08
LOCATION: Westridge Mine, Project #460-03

BORING	Composite	Composite	Composite	Composite
SAMPLE DEPTH				
SAMPLE NO.	Backfill 1,2,3,4,5	Top Soil 1,2,3,4,5	RS2-1,2	RS1-1,2,3
DATE SAMPLED				
DATE TESTED	01-16-03 RS	01-16-03 RS	01-16-03 RS	01-16-03 RS
SOIL DESCRIPTION				
MOISTURE DETERMINATIONS				
Wt. of Wet Soil & Dish (gms)	1330.20	732.46	1198.30	1009.01
Wt. of Dry Soil & Dish (gms)	1240.53	646.47	1049.54	864.87
Net Loss of Moisture (gms)	89.67	85.99	148.76	144.14
Wt. of Dish (gms)	15.09	14.95	15.24	15.19
Wt. of Dry Soil (gms)	1225.44	631.52	1034.30	849.68
Moisture Content (%)	7.3	13.6	14.4	17.0

Data entered by: SR Date: 01/17/2003
Data checked by: CAL Date: 1/17/03
FileName: AON01234

ADVANCED TERRA TESTING, INC.

STANDARD PROCTOR TEST

BACKFILL

COMPACTION TEST
ASTM D 698 C

CLIENT:	Agapito Associates		JOB NO. 2452-08
BORING NO.	Composite	DATE SAMPLED	
DEPTH		DATE TESTED	01/24/03 RS
SAMPLE NO.	Backfill - 1,2,3,4,5	LOCATION	Westridge Mine
SOIL DESCR.	Proj #460-03		

Moisture Determination

	1	2	3	4
Wt of Moisture added (ml)	300.00	200.00	100.00	0.00
Wt. of soil & dish (g)	1193.27	1136.41	1094.83	1013.59
Dry wt. soil & dish (g)	1063.27	1036.88	1016.97	963.62
Net loss of moisture (g)	130.00	99.53	77.86	49.97
Wt. of dish (g)	15.99	15.11	15.32	15.28
Net wt. of dry soil (g)	1047.28	1021.77	1001.65	948.34
Moisture Content (%)	12.41	9.74	7.77	5.27
Corrected Moisture Content	10.63	8.35	6.66	4.52

Density determination

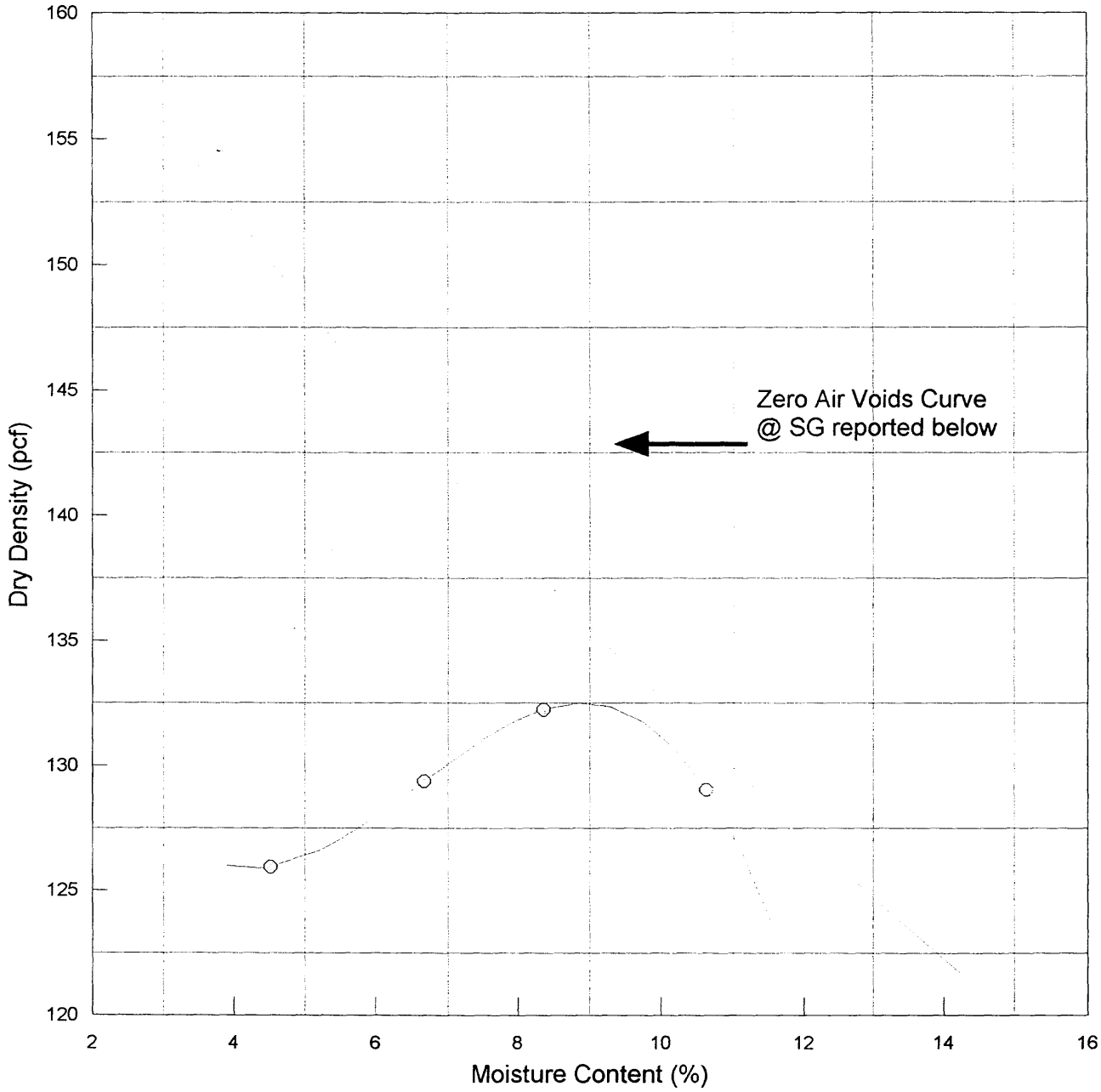
Wt of soil & mold (lb)	24.79	24.86	24.45	23.96
Wt. of mold (lb)	14.49	14.49	14.49	14.49
t wt. of wet soil (lb)	10.30	10.37	9.96	9.47
Net wt of dry soil (lb)	9.31	9.57	9.34	9.06
Dry Density, (pcf)	124.13	127.61	124.50	120.80
Corrected Dry Density (pcf)	129.04	132.25	129.38	125.95
Volume Factor	13.33333	13.3333333	13.33333	13.33333

Data entered by: RS Date: 01/29/2003
Data checked by: Cae Date: 01/29/03
FileName: AOPRCOMB

ADVANCED TERRA TESTING, INC

Proctor Compaction Test

Composite, , Backfill - 1,2,3,4,5



– Best Fit Curve ○ Actual Data

– Zero Air VoidsCurve @ SG = 2.70

OPTIMUM MOISTURE CONTENT = 8.9 MAXIMUM DRY DENSITY = 132.5
ASTM D 698 C, Rock correction applied? Y

ADVANCED TERRA TESTING, INC.

DIRECT SHEAR TEST DATA & DATA ANALYSIS

BACKFILL

conducted at 90% of Standard Proctor
and +2% above optimum moisture.

LARGE SCALE INTERNAL DIRECT SHEAR TEST DATA

ASTM D 3080 MODIFIED - 12" x 12" Box

CLIENT:	Agapito Associates	Date:	03-10-03
Project No:	2452-08	Test date:	03-07&10-03
Project:	West Ridge, JN: #460-03	Technician:	SR
Interface:	Backfill	Shear Rate:	0.04"/min
Special conditions:		Test Series:	DS-3

Displacement (inches)	Normal Force 2880 psf Shear Stress (psf)	Normal Force 4320 psf Shear Stress (psf)	Normal Force 5760 psf Shear Stress (psf)
0	0	0	0
0.029	1129	1222	1295
0.088	2017	2921	3000
0.153	2442	3814	4047
0.217	2766	4303	4653
0.284	3023	4680	5105
0.349	3226	4981	5467
0.414	3397	5238	5814
0.48	3549	5464	6088
0.548	3674	5670	6350
0.612	3783	5778	6576
0.675	3883	5911	6803
0.741	3958	6038	7003
0.808	4029	6145	7194
0.872	4096	6251	7330
0.937	4162	6374	7472
1.002	4227	6478	7585
1.069	4295	6603	7705
1.132	4360	6729	7788
1.195	4431	6862	7894
1.259	4506	6988	8015
1.325	4570	7122	8105
1.389	4648	7237	8235
1.451	4712	7330	8337
1.515	4785	7350	8442
1.58	4853	7446	8528
1.644	4922	7526	8630
1.707	4989	7607	8766
1.769	5039	7679	8882
1.835	5068	7752	8897
1.896	5123	7825	9000
1.959	5171	7916	9134
2.023	5231	8011	9211
2.088	5276	8079	9272

NOTE: The values are not corrected.

Data Entered By: SR Date: 03-10-03

Data Checked By: KP Date: 3/10/03

File Name: AODSBF30

Advanced Terra Testing, Inc.

Direct Shear Test
West Ridge
slope reclamation
Backfill
Initial area = 144 in^2
(12" x 12" box)
Normal Load = 2880 lb-f

Displacement (inches)	Corrected Area (in^2)	Corrected Normal Stress (psf) @ Normal Force (lb-f) = 2880	Shear Load (lb-f)	Shear Stress (psf)	Internal Friction Angle (deg)
0	144.000	2880.000	0	0	0.0
0.029	143.652	2886.977	1129	1132	21.4
0.088	142.944	2901.276	2017	2032	34.8
0.153	142.164	2917.194	2442	2474	39.9
0.217	141.396	2933.039	2766	2817	43.3
0.284	140.592	2949.812	3023	3096	45.7
0.349	139.812	2966.269	3226	3323	47.4
0.414	139.032	2982.910	3397	3518	48.7
0.48	138.240	3000.000	3549	3697	49.8
0.548	137.424	3017.813	3674	3850	50.6
0.612	136.656	3034.773	3783	3986	51.3
0.675	135.900	3051.656	3883	4114	51.8
0.741	135.108	3069.544	3958	4218	52.2
0.808	134.304	3087.920	4029	4320	52.5
0.872	133.536	3105.679	4098	4419	52.8
0.937	132.756	3123.927	4162	4515	53.1
1.002	131.976	3142.390	4227	4612	53.4
1.069	131.172	3161.650	4295	4715	53.6
1.132	130.416	3179.978	4360	4814	53.9
1.195	129.660	3198.519	4431	4921	54.2
1.259	128.892	3217.578	4506	5034	54.5
1.325	128.100	3237.471	4570	5137	54.7
1.389	127.332	3256.997	4648	5256	55.0
1.451	126.588	3276.140	4712	5360	55.2
1.515	125.820	3296.137	4785	5476	55.4
1.58	125.040	3316.699	4853	5589	55.7
1.644	124.272	3337.196	4922	5703	55.9
1.707	123.516	3357.622	4989	5816	56.1
1.769	122.772	3377.969	5039	5910	56.2
1.835	121.980	3399.902	5068	5983	56.1
1.896	121.248	3420.428	5123	6084	56.3
1.959	120.492	3441.888	5171	6180	56.4
2.023	119.724	3463.967	5231	6292	56.5
2.088	118.944	3486.683	5276	6387	56.5

Note: Direct shear test data analysis worksheet prepared by AAI.

Direct Shear Test
West Ridge
slope reclamation
Backfill
Initial area = 144 in^2
(12" x 12" box)
Normal Load = 4320 lb-f

Displacement (inches)	Corrected Area (in^2)	Normal Stress (psf) @ Normal Force (lb-f) = 4320	Shear Load (lb-f)	Shear Stress (psf)	Internal Friction Angle (deg)
0.001	143.988	4320.360	0	0	0.0
0.023	143.724	4328.296	1222	1224	15.8
0.083	143.004	4350.088	2921	2941	33.9
0.145	142.260	4372.838	3814	3861	41.1
0.207	141.516	4395.828	4303	4379	44.4
0.271	140.748	4419.814	4680	4788	46.6
0.335	139.980	4444.063	4981	5124	48.3
0.398	139.224	4468.195	5238	5418	49.5
0.462	138.456	4492.980	5464	5683	50.6
0.527	137.676	4518.435	5670	5930	51.4
0.59	136.920	4543.383	5778	6077	51.8
0.654	136.152	4569.011	5911	6252	52.3
0.717	135.396	4594.523	6038	6422	52.7
0.782	134.616	4621.145	6145	6573	53.1
0.846	133.848	4647.660	6251	6725	53.4
0.911	133.068	4674.903	6374	6898	53.7
0.974	132.312	4701.614	6478	7050	54.0
1.038	131.544	4729.064	6603	7228	54.4
1.102	130.776	4756.836	6729	7409	54.7
1.166	130.008	4784.936	6862	7601	55.1
1.231	129.228	4813.817	6988	7787	55.4
1.296	128.448	4843.049	7122	7984	55.8
1.359	127.692	4871.723	7237	8161	56.1
1.424	126.912	4901.664	7330	8317	56.2
1.489	126.132	4931.976	7350	8391	56.1
1.554	125.352	4962.665	7446	8554	56.3
1.617	124.596	4992.777	7526	8698	56.4
1.682	123.816	5024.230	7607	8847	56.6
1.749	123.012	5057.068	7679	8989	56.6
1.814	122.232	5089.338	7752	9133	56.7
1.877	121.476	5121.012	7825	9276	56.8
1.941	120.708	5153.594	7916	9443	56.9
2.006	119.928	5187.112	8011	9619	57.1
2.072	119.136	5221.595	8079	9765	57.1

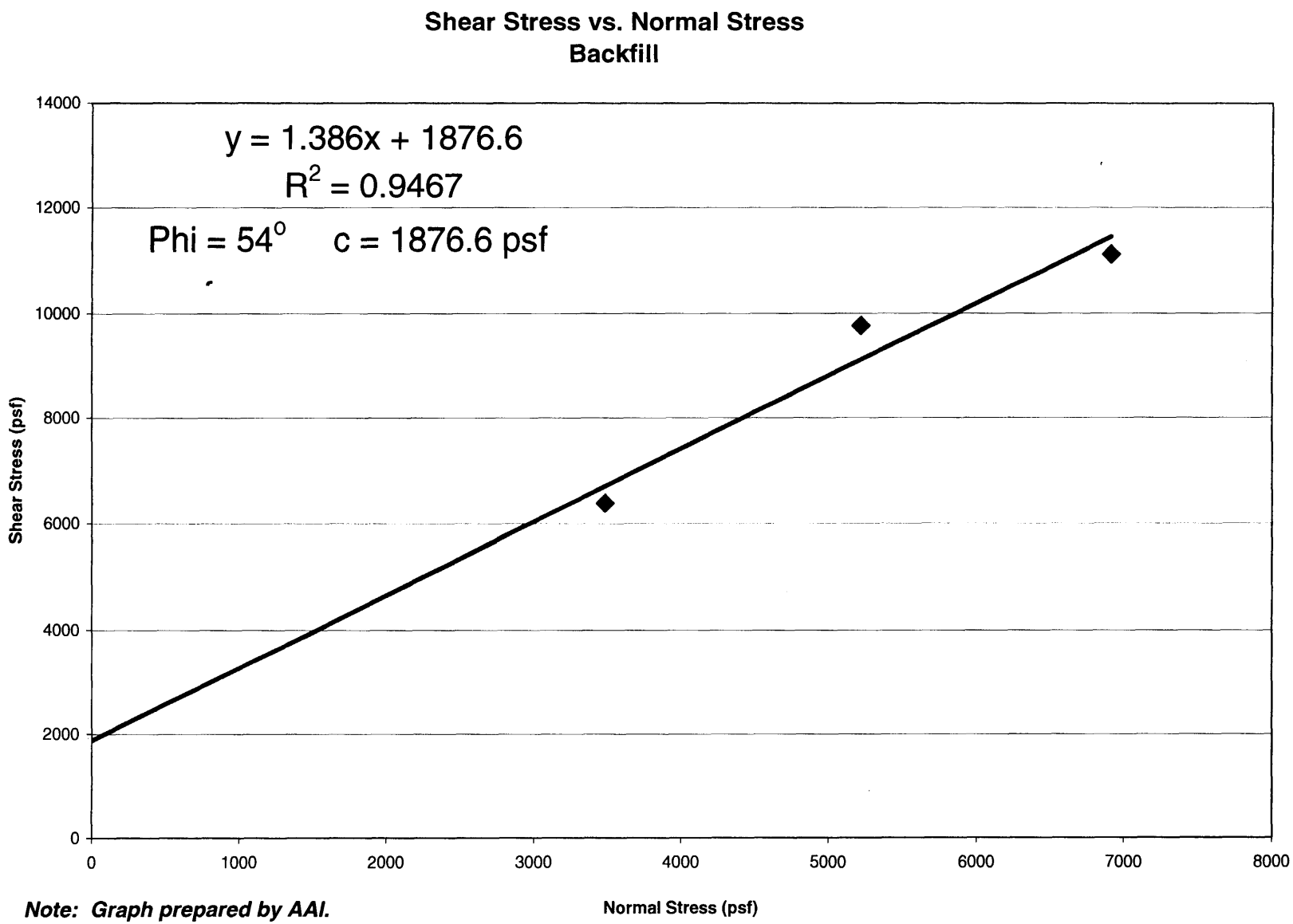
Note: Direct shear test data analysis worksheet prepared by AAI.

Direct Shear Test
West Ridge
slope reclamation
Backfill

Initial area = 144 in^2
(12" x 12" box)
Normal Load (lb-f) = 5760

Displacement (inches)	Corrected Area (in^2)	Normal Stress (psf) @ Normal Force (lb-f) = 5760	Shear Load (lb-f)	Shear Stress (psf)	Internal Friction Angle (deg)
0.001	143.988	5760.480	0	0	0.0
0.023	143.988	5760.480	1295	1295	12.7
0.083	143.724	5771.061	3000	3006	27.5
0.145	143.004	5800.117	4047	4075	34.9
0.207	142.260	5830.451	4653	4710	38.6
0.271	141.516	5861.104	5105	5195	41.1
0.335	140.748	5893.086	5467	5593	42.9
0.398	139.980	5925.418	5814	5981	44.5
0.462	139.224	5957.594	6088	6297	45.6
0.527	138.456	5990.640	6350	6604	46.7
0.59	137.676	6024.579	6576	6878	47.5
0.654	136.920	6057.844	6803	7155	48.3
0.717	136.152	6092.015	7003	7407	49.0
0.782	135.396	6126.030	7194	7651	49.6
0.846	134.616	6161.526	7330	7841	49.9
0.911	133.848	6196.880	7472	8039	50.3
0.974	133.068	6233.204	7585	8208	50.6
1.038	132.312	6268.819	7705	8386	50.9
1.102	131.544	6305.419	7788	8525	51.0
1.166	130.776	6342.448	7894	8692	51.2
1.231	130.008	6379.915	8015	8878	51.5
1.296	129.228	6418.423	8105	9031	51.6
1.359	128.448	6457.399	8235	9232	51.9
1.424	127.692	6495.630	8337	9402	52.1
1.489	126.912	6535.552	8442	9579	52.3
1.554	126.132	6575.968	8528	9736	52.4
1.617	125.352	6616.887	8630	9914	52.5
1.682	124.596	6657.036	8766	10131	52.8
1.749	123.816	6698.973	8882	10330	53.0
1.814	123.012	6742.757	8897	10415	52.8
1.877	122.232	6785.784	9000	10603	53.0
1.941	121.476	6828.015	9134	10828	53.2
2.006	120.708	6871.458	9211	10988	53.3
2.072	119.928	6916.150	9272	11133	53.3

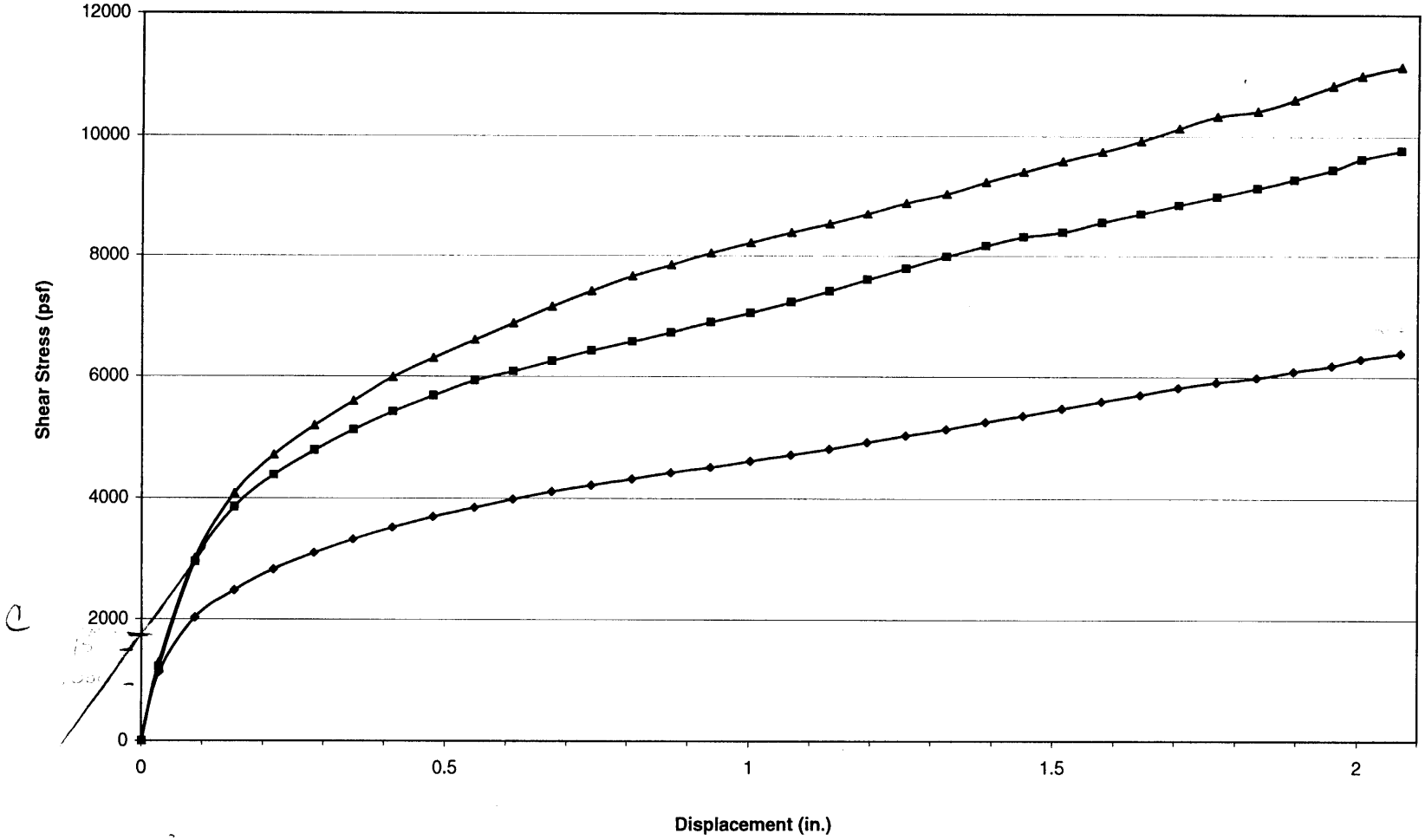
Note: Direct shear test data analysis worksheet prepared by AAI.



Note: Graph prepared by AAI.

Displacement vs. Shear Stress

~~Topsoil~~



Note: Graph prepared by AAI.

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