DAMES & MOORE

Sheet No. 1/3
Calc. No.
Rev. No.

Job No 21752-007-152 Job Bert Ave. Closure By BCP Date 4/1/98

Client Chemetron Subject Slope Stability - GCL @ 1% Chk'd. [illegible] Date 4/10/98

Objective

Evaluate the stability of the 1% slope at the bottom of the engineered cell within the geosynthetic clay liner (GCL) at Chemetron Corp., Inc Bert Ave. Site in Newburgh Heights, OH.

References

1. Huang, Yang H. Stability Analysis of Earth Slopes, Van Nostrand Reinhold Company, New York, New York, 1983
2. R.A. Jelic Co, Fluid Systems Bentofix Thermal Lock GCL, "NS" Certified Properties, Pittsburgh, PA. FIX-501 NS.

Assumptions

1. Internal friction angle, ϕ, equals 0 for GCL. Assumed conservative value.
2. Internal shear strength of GCL = 500 lb/ft^2. From manufacturer's certified properties, Ref 2. enclosed. (Hydrated 24 hrs @ 200 psf normal stress).

Summary

By calculating the estimated DRIVING FORCE and RESISTING FORCE, the Factor of Safety (FS) against slope failure is:

$$FS = \frac{\text{RESISTING FORCE}}{\text{DRIVING FORCE}} = \frac{500\ lb/ft}{38.8\ lb/ft} = \underline{\underline{12.9}}$$

946.9 (7/91)

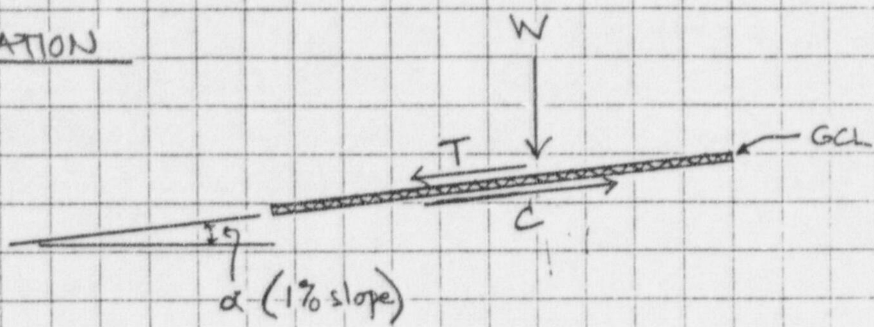
DAMES & MOORE

Sheet No. 2/3
Calc. No.
Rev. No.

Job No. 21752-007-152 Job Bert Ave. Closure By BEP Date 4/1/98

Client Chemetron Subject Slope Stability - GCL Chk'd. [illegible] Date 4/1/98

CALCULATION



$\alpha = \tan^{-1}(1/100) = 0.57°$

W = Weight of overburden, approx. 30' at avg. unit weight of 130 lb/ft³ = 3900 lb/ft.

T = Driving Force = $W \sin\alpha$

C = Resisting Force : Internal shear strength of GCL per unit foot

$\text{Factor of Safety} = F.S. = \frac{C}{T} = \frac{500}{3900 \sin(0.57)} = \frac{500}{39} = 12.9$

$\boxed{\text{F.S.} = 12.9 \text{ Against sliding along GCL @ 1\% slope}}$

Note: Frictional sliding is not an issue due to the fact that the friction angle between GCL and sand/clay is much larger than 0.57°. The friction angle for GCL is similar to that of a geotextile since the GCL is comprised of geotextile.

Sheet 3/3

FIX - 501NS

BENTOFIX®

Thermal Lock "NS" Geosynthetic Clay Liner

• Technical Bulletin •

Bentofix Thermal Lock "NS" is a needlepunch reinforced GCL comprised of a uniform layer of granular sodium bentonite encapsulated between a slit-film woven and a virgin staple fiber nonwoven geotextile. The needlepunched fibers are thermally fused to the woven geotextile to enhance the reinforcing bond.

GEOTEXTILE PROPERTIES	TEST METHOD	MINIMUM TEST FREQUENCY	VALUE - ENGLISH -	VALUE - SI -
Cap Nonwoven Mass/Unit Area	ASTM D 5261	1/200,000 sq. ft (1/20,000 sq. m)	6.0 oz./yd^2 MARV	200 g / m^2 MARV
Woven Scrim Mass/Unit Area	ASTM D 5261	1/200,000 sq. ft (1/20,000 sq. m)	3.1 oz./yd^2 MARV	105 g / m^2 MARV

BENTONITE PROPERTIES				
Swell Index	ASTM D 5890	1/100,000 lbs. (50,000 kg)	24 ml / 2g min.	24 ml / 2g min.
Moisture Content	ASTM D 4643	1/100,000 lbs. (50,000 kg)	12 % max.	12 % max.
Fluid Loss	ASTM D 5891	1/100,000 lbs. (50,000 kg)	18 ml max.	18 ml max.

FINISHED GCL PROPERTIES				
Bentonite Mass Per Unit Area[1]	ASTM D 5993	1/40,000 sq. ft (1/4,000 sq. m)	0.893 lb. / sq. ft MARV	4.34 kg / m^2 MARV
Grab Strength[2]	ASTM D 4632	1/40,000 sq. ft (1/4,000 sq. m)	95 lbs MARV	422 N MARV
Grab Elongation[2]	ASTM D 4632	1/40,000 sq. ft (1/4,000 sq. m)	150 % Typical	150 % Typical
Peel Strength[3]	ASTM D 4632	1/40,000 sq. ft (1/4,000 sq. m)	15 lbs. min.	66 N
Permeability[4]	ASTM D 5084	1/100,000 sq. ft (1/10,000 sq. m)	5 x 10^{-9} cm/sec max	5 x 10^{-9} cm/sec max
Index Flux[4]	ASTM D 5887	1/Week	1 x 10^{-8} m^3/m^2/sec max	1 x 10^{-8} m^3/m^2/sec max
Internal Shear Strength[5]	ASTM D 5321	Periodic	500 psf Typical	24 kPa Typical

DIMENSIONS				
Width x Length	nominal	Every Roll	15.5 x 150 ft	4.7 x 45.72 m
Area per Roll	nominal	Every Roll	2325 ft^2	216 m^2
Packaged Weight	typical	Every Roll	2600 lbs	1179 kg

1. Oven-dried measurement. Equates to 1.0 lb when indexed to a 12% moisture content.
2. Measured at maximum peak, in the weakest principal direction.
3. Modified to use a 4-inch wide grip. The maximum peak of five specimens averaged.
4. De-Aired Tap Water @ 5 psi maximum effective confining stress and 2 psi head.
5. Typical peak value for specimen hydrated for 24 hr. and sheared under a 200 psf normal stress.

DAMES & MOORE

Sheet No. 1/9
Calc. No.
Rev. No.

Job No. 21752-037-152 Job Bert Ave. Closure
Client Chemetron Subject Slope Stability - Geosynthetics
By BEP Date 3/23/98
Chk'd. Date 4/10/98

OBJECTIVE

Evaluate the stability of the 3H:1V eastern slope with respect to sliding for geosynthetics in the final cover at Chemetron Corp, Inc. Bert Ave. Facility in Newburgh Heights, OH.

REFERENCES

1. Dames & Moore. Final Closure / Post-Closure Plan, Bert Avenue Site, Chemetron Corporation, Inc. Newburgh Heights, Ohio, December 1994.
2. Koerner, Robert M. Designing With Geosynthetics, 2nd Edition, Prentice Hall, Englewood Cliffs, N.J., 1990.
3. Algermissen, D.M., et al., Probabilistic Earthquake Acceleration and Velocity Maps for the United States and Puerto Rico, U.S. Geological Survey Map MF-2120, 1990.

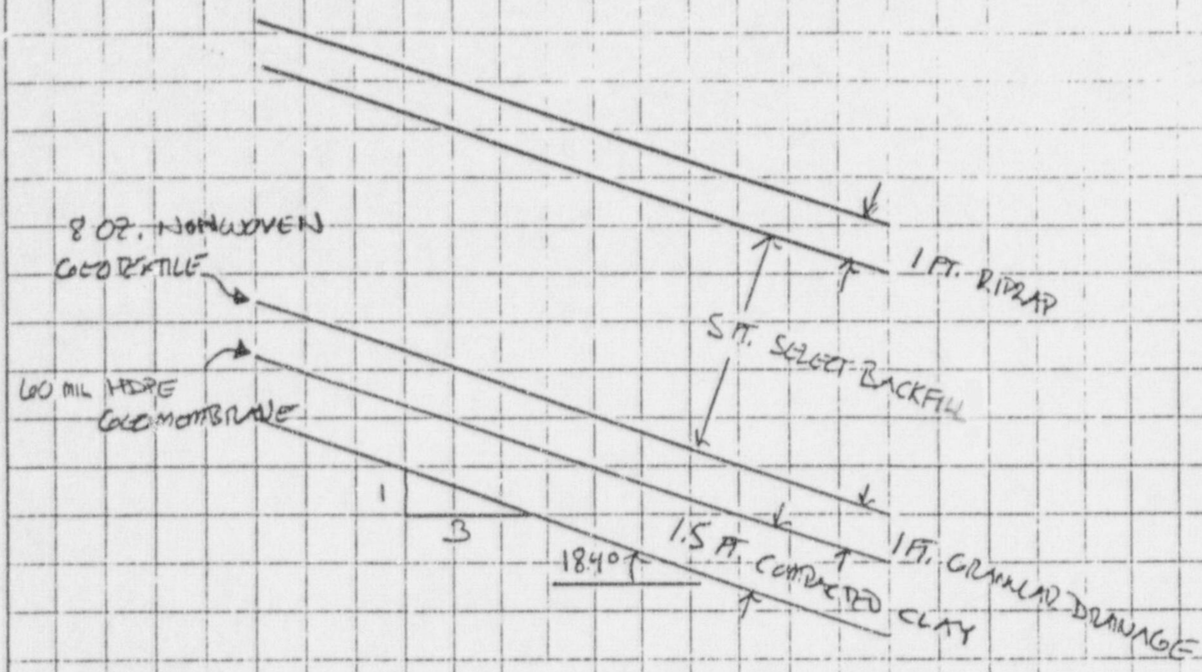
SUMMARY

Material	F.S. Against Sliding	Req. F.S.
• Geotextile	1.74	1.5
• Textured HDPE Geomembrane	1.53	1.5
• Textured HDPE Under Dynamic Loading	1.34	1.3

DAMES & MOORE

Sheet No. 2/9
Calc. No.
Rev. No.

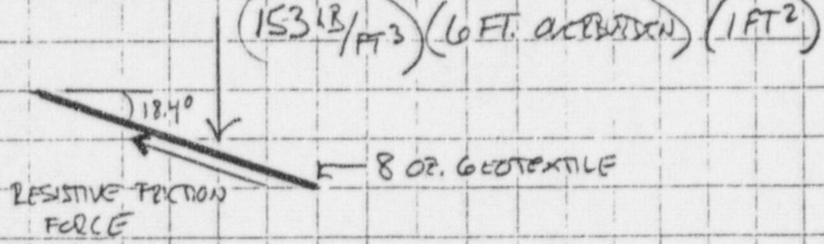
Job No. 21752-007-152   Job Bert Ave Closure   By BEP   Date 3/23/98
Client Chevron   Subject Slope Stability Geosynthetics   Chk'd. [illegible]   Date 4/1/98



FROM DWGS., REF. 1, CAP HEIGHT IS ~ 30 FT. MAX.
AVG. UNIT WEIGHT OF CAP MTL ~ 153 lb/ft^3

CALCULATE F.S. AGAINST SLIDING

1) GEOTEXTILE



RESOLVE FORCES ONTO GEOTEXTILE PLANE:

DRIVING FORCE = $153(6)\left(\frac{1}{\sin 18.4}\right)(\sin 18.4) = 918$ LB

FRICTION ANGLES: FROM REF. 2, attached

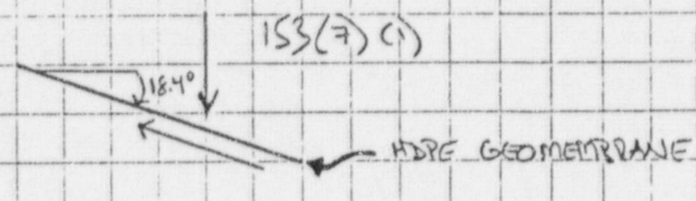
$\delta = 30°$ FOR SILTY SAND ($\phi = 30°$)

RESISTING FORCE:

$153(6)\left(\frac{1}{\sin 18.4}\right)\cos 18.4 \tan 30 = 1593$ LB

$$\boxed{F.S. = \frac{\text{RESISTING FORCE}}{\text{DRIVING FORCE}} = \frac{1593}{918} = 1.74 \text{ OK}}$$

2) HDPE GEOMEMBRANE



DRIVING FORCE:

$153(7)\left(\frac{1}{\sin 18.4}\right)\sin 18.4 = 1071$ LB

FRICTION ANGLES: From Ref. 2, attached

USE $\delta = 18°$ FOR SANDS TO HDPE OR CLAY TO HDPE

RESISTING FORCE :

$$153(7)\left(\frac{1}{\sin 18.4}\right)\cos 18.4 \ \tan 18 = 1046 \text{ LB}$$

$$F.S. = \frac{1046}{1071} = 0.98 < 1.0 \text{ NO GOOD!}$$

USE TEXTURED HDPE , $\delta = 25° - 27°$ (From conversation w/ Serrot Corporation & Ref 7.)

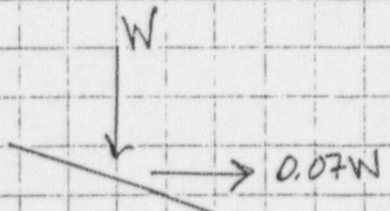
RESISTING FORCE : use $\delta = 27°$ for concrete sand, and clay (CL)

$$153(7)\left(\frac{1}{\sin 18.4}\right)\cos 18.4 \ \tan 27 = 1640$$

$$\boxed{F.S. \ \frac{1640}{1071} = 1.53 \text{ OK } \checkmark}$$

∴ textured HDPE is sufficient for sand and clay.

APPLY A LATERAL SEISMIC ACCEL. OF 0.15 g TO GEOMEMBRANE SCENARIO (Ref. 3)



DRIVING FORCE CHANGES TO $1071 + 1071(.15)\cos 18.4 =$
$1071 + 152 = 1223$ LB

$$\boxed{F.S. = \frac{1640}{1223} = 1.34 > 1.3 \text{ OK}}$$

pg. 5/

Designing with Geosynthetics

Second Edition

Robert M. Koerner, Ph. D., P. E.

Bowman Professor of Civil Engineering
Director, Geosynthetic Research Institute
Drexel University

PRENTICE HALL, Englewood Cliffs, N.J. 07632

Pj 6/9

c = the cohesion of soil,

δ = the friction angle of soil to fabric, and

ϕ = the friction angle of soil.

Results from such a test setup by Martin, et al. [13], are presented in Table 2.6 for four geotextile types against three different cohesionless soils. Soil-to-fabric friction angles are given, as well as the fabric efficiency versus the soil friction angle by itself as per Equation 2.8. Here it is seen that most geotextiles can mobilize a high percentage of the soil's friction and can be used to advantage in situations requiring this feature. A review and compilation of a number of direct shear tests on various fabrics against different granular soils is given by Richards and Scott [14]. Another review by Williams and Houlihan [15] covers a wider range of soils, including some sands, silts, and mixed soils.

2.2.3.11 Pullout (Anchorage) Tests

Geotextiles are often called upon to provide anchorage for many applications within the reinforcement function. Such anchorage usually has the fabric sandwiched between soil on each side of it. The resistance can be modeled in the laboratory using a pullout test, shown schematically in Figure 2.8b. The pullout resistance is obviously dependent on the normal force applied to the soil surrounding it, which mobilizes shear forces on both sides of the fabric.

Test results by Collios et al. [16] show a relationship of pullout test results to shear test results with some notable exceptions. If the soil particles are smaller than the fabric openings, efficiencies are higher; if not, they can be lower. In all cases, however, pullout test resistances are less than shear test resistances. This is due to the fact that the fabric is taut and exhibits large deformations. This in turn causes the soil particles to reorient themselves into a reduced-shear-strength situation at the soil-fabric interfaces, resulting in lower pullout resistance. The stress state mobilized in this test is a very complex one requiring additional research.

TABLE 2.6 SOIL-TO-FABRIC FRICTION ANGLES AND EFFICIENCIES (IN PARENTHESES) IN COHESIONLESS SOIL

Geotextile type	Manufacturer's designation	Concrete sand ϕ = 30 deg.	Rounded sand ϕ = 28 deg.	Silty sand ϕ = 26 deg.
Woven, monofilament	Polyfilter X	26 deg. (84%)	—	—
Woven, silt film	500X	24 deg. (77%)	24 deg. (84%)	23 deg. (87%)
Nonwoven, melt-bonded	3401	26 deg. (84%)	—	—
Nonwoven, needle-punched	CZ600	30 deg. (100%)	26 deg. (92%)	25 deg. (96%)

Source: After Martin et al. [13]

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TABLE 5.5 FRICTION VALUES AND EFFICIENCIES (IN PARENTHESES) FOR (a) SOIL-TO-GEOMEMBRANE, (b) GEOMEMBRANE TO-GEOTEXTILE, AND (c) SOIL-TO-GEOTEXTILE COMBINATIONS*

(a) Soil-to-geomembrane friction angles

	Soil types		
Geomembrane	Concrete sand ($\phi = 30°$)	Ottawa sand ($\phi = 28°$)	Mica schist sand ($\phi = 26°$)
EPDM	24° (0.77)	20° (0.68)	24° (0.91)
PVC			
rough	27° (0.88)	—	25° (0.96)
smooth	25° (0.81)	—	21° (0.79)
CSPE	25° (0.81)	21° (0.72)	23° (0.87)
HDPE	18° (0.56)	18° (0.61)	17° (0.63)

(b) Geomembrane-to-geotextile friction angle

	Geomembrane				
		PVC			
Geotextile	EPDM	Rough	Smooth	CSPE	HDPE
nonwoven, needle-punched	23°	23°	21°	15°	8°
nonwoven, melt-bonded	18°	20°	18°	21°	11°
woven, monofilament	17°	11°	10°	9°	6°
woven, slit film	21°	28°	24°	13°	10°

(c) Soil-to-geotextile friction angle

	Soil types		
Geotextile	Concrete sand ($\phi = 30°$)	Ottawa sand ($\phi = 28°$)	Mica schist sand ($\phi = 26°$)
nonwoven, needle-punched	30° (1.00)	26° (0.92)	25° (0.96)
nonwoven, melt-bonded	26° (0.84)	—	—
woven, monofilament	26° (0.84)	—	—
woven, slit film	24° (0.77)	24° (0.84)	23° (0.87)

Source: After Martin, et al. [8]

*Efficiency values in parentheses are based on the relationship $E = (\tan \delta)/(\tan \phi)$

on smooth geotextiles giving the lowest friction values. For reference purposes, Part c of Table 5.5 gives the soil-to-geotextile friction values that are necessary for slope design of lined slopes with geotextiles under or over the liner.

The frictional behavior of geomembranes placed on clay soils is of considerable importance in the composite liners of waste landfills. Current requirements are for the pg. 8/9

TABLE 5.6 FRICTION VALUES AND EFFICIENCIES (IN PARENTHESES) FOR VARIOUS CLAY SOILS TO VARIOUS GEOMEMBRANES [9]

	Soil no. 1 ML-CL				Soil no. 2 CL-ML			
Description	c	E_c (%)	ϕ	E_ϕ (%)	c	E_c (%)	ϕ	E_ϕ (%)
Soil-to-soil	9.0	100	38	100	12.0	100	34	100
	c_a	E_c (%)	δ	E_ϕ (%)	c_a	E_c (%)	δ	E_ϕ (%)
Geomembrane-to-soil								
PVC	8.5	94	39	100	3.7	31	23	69
CPE	8.0	89	40	100	3.2	27	24	71
EPDM	5.0	55	33	87	5.0	42	23	67
HDPE	5.0	88	26	68	2.0	17	23	67
Embossed HDPE	9.0	100	35	92	11.0	92	29	58

	Soil no. 3 CL				Soil no. 4 SP-CH			
Description	c	E_c (%)	ϕ	E_ϕ (%)	c	E_c (%)	ϕ	E_ϕ (%)
Soil-to-soil	20	100	30	100	25	100	24	100
	c_a	E_c (%)	δ	E_ϕ (%)	c_a	E_c (%)	δ	E_ϕ (%)
Geomembrane-to-soil								
PVC	14.0	70	16	53	7.0	28	24	100
CPE	13.0	65	17	57	8.0	32	23	96
EPDM	8.0	40	23	77	7.5	30	20	83
HDPE	14.0	70	15	50	3.0	12	21	88
Embossed HDPE	18.0	90	27	90	15.0	60	26	100

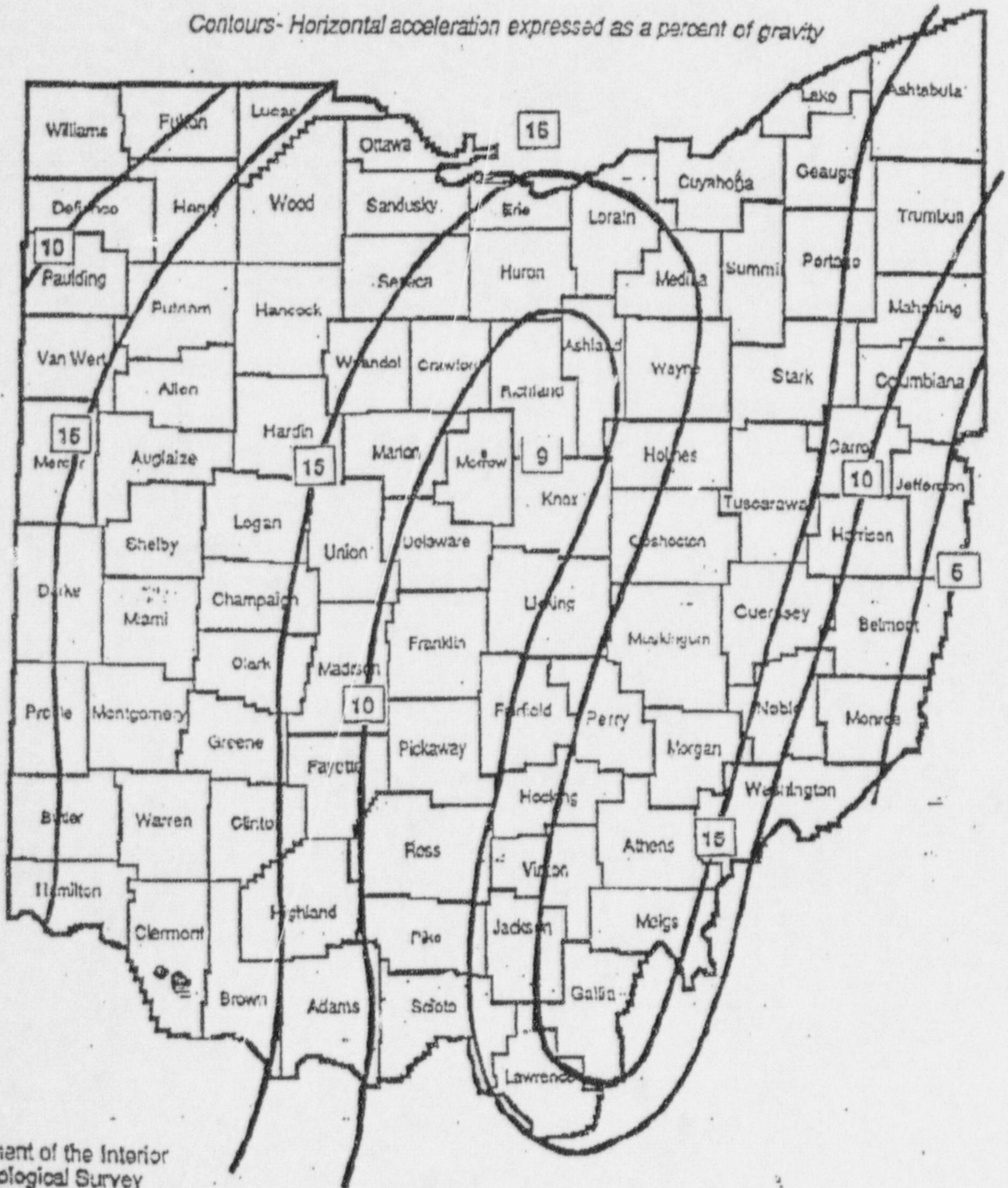
	Soil no. 5 CL-SP			
Description	c	E_c (%)	ϕ	E_ϕ (%)
Soil-to-soil	28	100	22	100
	c_a	E_c (%)	δ	E_ϕ (%)
Geomembrane-to-soil				
PVC	12.0	43	17	77
CPE	10.0	36	19	86
EPDM	9.0	32	18	82
HDPE	14.0	50	15	68
Embossed HDPE	16.0	57	25	100

Note: c and c_a are in units of kN/m^2, ϕ and δ are in degrees.

Horizontal Acceleration

(10 percent probability of being exceeded in 250 years)

Contours- Horizontal acceleration expressed as a percent of gravity



rom
epartment of the Interior
.S. Geological Survey
iscellaneous Field Studies
ap MF-2120

robabilistic Earthquake Acceleration and Velocity Maps for the United States and Puerto Rico" by S.T.
germissen, D.M. Perkins, et al., (1990)

ATTACHMENT 3

UNIT WEIGHT AND UNCONFINED COMPRESSIVE STRENGTH TEST DATA FOR SOLID WASTE

SOLAR TESTING LABORATORIES, INC.
5399 Lancaster Drive, Brooklyn Heights, Ohio 44131
Telephone: (216) 741-7007 • FAX: (216) 741-7011

Post-it® Fax Note 7671	Date	# of pages ▸ 3
To FRED ERDMANN	From LARRY GIWTELLA	
Co./Dept.	Co.	
Phone #	Phone #	
Fax #	Fax #	

Mai

Mr. Ted Adams
B. KOH & ASSOCIATES, INC.
11 West Main Street
Springville, NY 14141

RE: SEVEN DAY UNCONFINED COMPRESSIVE STRENGTH TESTING (ASTM D2166) & UNIT WEIGHTS
WASTE STABILIZATION BENCH SCALE TESTING
CHEMETRON CORPORATION/BERT AVENUE SITE CLOSURE
NEWBURGH HEIGHTS, OHIO
STL PROJECT NO. A98046x24

Dear Mr. Adams:

Solar Testing Laboratories, Inc. has completed unconfined compressive strength tests on prepared samples utilizing the DKD (kiln dust) admixture as requested by Dames & Moore.

Sample Preparation

Samples for unconfined compressive strength testing were prepared by using information obtained from the three one-point proctors conducted previously with the admixture introduced at 5%, 10% & 15% of the sample dry weight at moisture content of approximately 20% similar to that outlined in the *Work Plan*. Those results are as follows.

Percent Admixture	Wet Density	Moisture Content	Dry Density
5%	122.7 pcf	17.4%	104.5
10%	121.3 pcf	16.5%	104.1
15%	119.1 pcf	16.0%	102.7

The three samples were remolded and compacted to the above wet density for each percent admixture. Following preparation each sample was stored in the mold and wrapped in plastic for seven days. Remolded densities and moisture were calculated and those results are as follows:

Percent Admixture	Wet Density	Moisture Content	Dry Density
5%	123.3 pcf	18.1%	104.4
10%	121.3 pcf	17.0%	103.7
15%	119.1 pcf	16.2%	102.5

Mr. Ted Adams
R. KOH & ASSOCIATES, INC.
STL PROJECT NO. A98046x24
Page 2

Testing

Following a seven day curing period each sample was removed from it's mold and placed in the testing apparatus. Proving ring load and axial deformation values were recorded. The data was converted to stress and strain and then plotted. Refer to the attached graph for stress/strain relationships. Stress, strain and shear strength at failure is presented in the following table.

Compressive Strength and Strain at Failure

Percent Admixture	Maximum Compressive Strength	PSF	Strain
5%	59.7 psi	8597	3 %
10%	67.7 psi	9749	2 %
15%	88.9 psi	12802	1 %

Shear Strength

Percent Admixture	Maximum Shear Strength	PSF
5%	29.9 psi	4306
10%	33.9 psi	4882
15%	44.5 psi	6408

Unit Weights

Four samples of waste were collected from the stockpile to be utilized for the test pad. The average loose unit weight is 93.1 pcf. Three samples were used to determine an average unit weight with minimal air voids. The unit weight is 120.5 pcf. The unit weight of the DKD admixture is 53.7 pcf. Average moisture was calculated to be 22%.

If you have any questions, please do not hesitate to contact me.

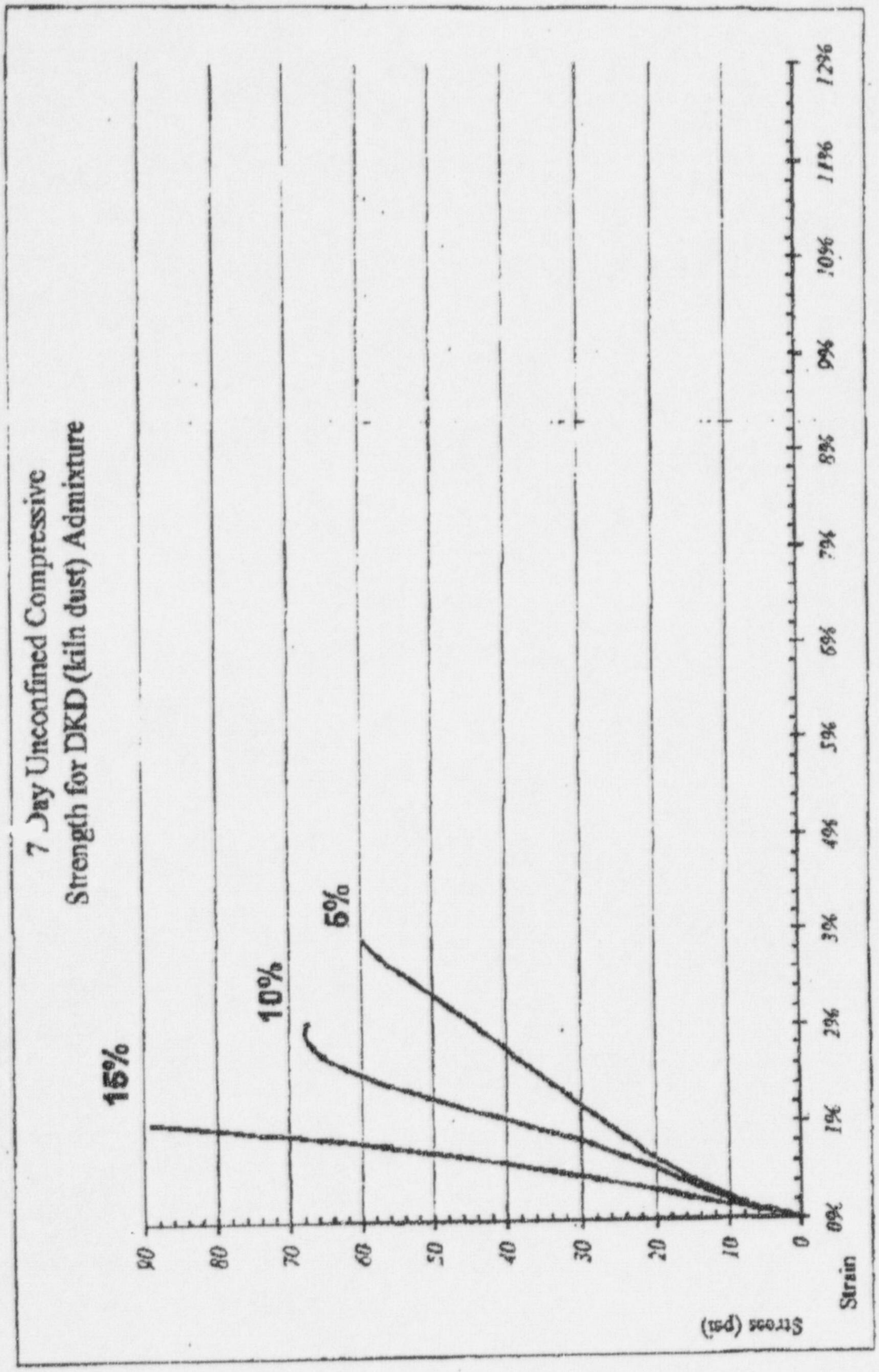
Sincerely yours,

SOLAR TESTING LABORATORIES, INC.

Douglas J. Perisutti, P.E., CPG
Environmental Project Engineer

DJP/mjb
enclosure

cc: Dames & Moore
Mr. Larry Chintella, P.E.


7 Day Unconfined Compressive
Strength for DKD (kiln dust) Admixture
15%
10%
5%
Stress (psi)
Strain
0
10
20
30
40
50
60
70
80
90
0%
1%
2%
3%
4%
5%
6%
7%
8%
9%
10%
11%
12%