CONSTRUCTION QUALITY ASSURANCE
FINAL REPORT
ON-SITE DISPOSAL FACILITY, PHASE I AND LEACHATE CONVEYANCE SYSTEM

REVISION 0
JANUARY 1998
VOLUME VII

United States Department of Energy
Fernald Environmental Management Project
Fernald, Ohio

prepared by
GEOSYNTEC CONSULTANTS
1100 Lake Hearn Drive, NE, Suite 200
Atlanta, Georgia 30342

under
Fluor Daniel Fernald
Subcontract 95PS005028

GCL 04

COMPUTATION COVER SHEET

1269

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) QA04 and QC02 - Compliance Package

Computations By:
(Cognizant Engineer)

Signature MCOROZCO — Date Nov 7 1997

Printed Name and Title: M. CATALINA OROZCO, STAFF ENGINEER

Assumptions and Procedures Checked By:
(Checker)

Signature Robert A. Morgan III — Date 7 NOV 1997

Printed Name and Title: ROBERT A. MORGAN III, SR. STAFF ENGINEER

Computations Checked by:

Signature Robert A. Morgan III — Date 7 NOV 1997

Printed Name and Title: ROBERT A. MORGAN III, SR. STAFF ENGINEER

Computations Backchecked by:
(Cognizant Engineer)

Signature MCOROZCO — Date Nov 7 1997

Printed Name and Title: M. CATALINA OROZCO, STAFF ENGINEER

Approved by:
(PDP)

Signature [illegible] — Date 19 Dec 97

Printed Name and Title: Gary R. Schmertmann, Sr. Project Engineer

Approved by:
(DTL and TETL)

Signature [illegible] — Date 22 Dec 97

Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

Written By: YMO Date: 11 / 7 / 97 Reviewed by: RAM Date: 11 / 7 / 97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL lot number 97082002 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3). The evaluation is based on the shear test results from GCL QA sample no. 04 and GCL QC sample no. 02.

METHOD

The method for evaluating the GCL samples is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL samples to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 04 and the results of the GCL internal shear tests performed on QC sample no. 02 are shown in the following table. The results of the GCL internal shear tests for QA sample no. 04 were averaged with the results of the GCL internal shear tests for QC sample no. 02. The averaged values for the GCL internal shear tests were used in the stability analyses. The laboratory test results for GCL QA sample no. 04 are presented in Appendix A. The laboratory test results for GCL QC sample no. 02 are presented in Appendix B.

Test Type	Case	Sample No.	Measured Shear Strengths (psi)		
			5 psi	20 psi	45 psi
GCL Internal	Peak	QA 04	5.9	11.1	18.9
		QC 02	3.81[1]	9.28	18.06
		Average QA04-QC02	**5.90**	**10.19**	**18.48**
	Large-displacement	QA 04	2.7	3.4	4.1
		QC 02	3.25[1]	2.70	3.98
		Average QA04-QC02	**2.70**	**3.05**	**4.04**
GCL/GMB Interface	Peak	QA 04	**2.3**	**7.7**	**15.0**
	Large-displacement	QA 04	**1.7**	**5.1**	**10.0**

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[1] Shear strength values for QC sample 02 at 5 psi normal stress were measured using a shear displacement rate of 0.04 in/min which is faster than the rate used for all other tests. The measured values were therefore not used to compute the average shear strength for the slope stability analysis.

Written By : MCO Date: 11 / 7 /97 Reviewed by: RAM Date: 11 / 7 /97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix C.

Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
Average QA04-QC02	GCL Internal	NPPK04AS ✓	2.6 ✓	YES ✓
QA 04	GCL/GMB Interface	NPK04BS ✓	2.1 ✓	YES ✓
Baseline	Large-displacement	NA	1.6	NA
Average QA04-QC02	GCL Internal	NPL04ADS ✓	1.6 ✓	YES ✓
QA 04	GCL/GMB Interface	NLD04BS ✓	2.5 ✓	YES ✓

✓

YMCO NOV 7 1997

RAM 7 NOV 1997

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 4I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-04). GCL's initial moisture content was 9.3%. GCL's final moisture content ranged from 75% to 87% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 4G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

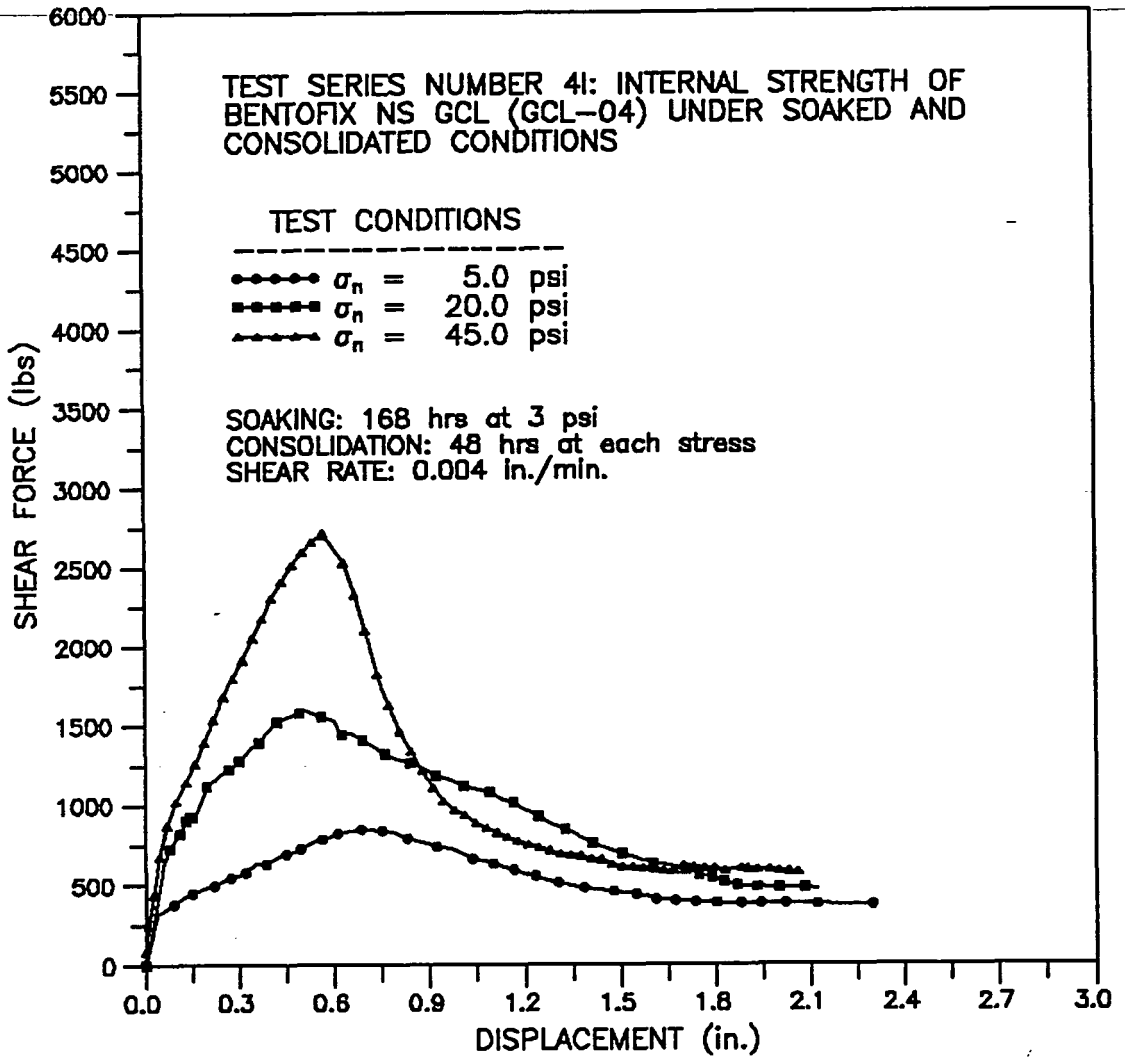
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-04) with woven geotextile against geomembrane. GCL's initial moisture content was 9.0%. GCL's final moisture content ranged from 70 to 112% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-8); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.

(2) For each test, sliding (i.e., internal shear failure) was observed to occur within the GCL.

000009

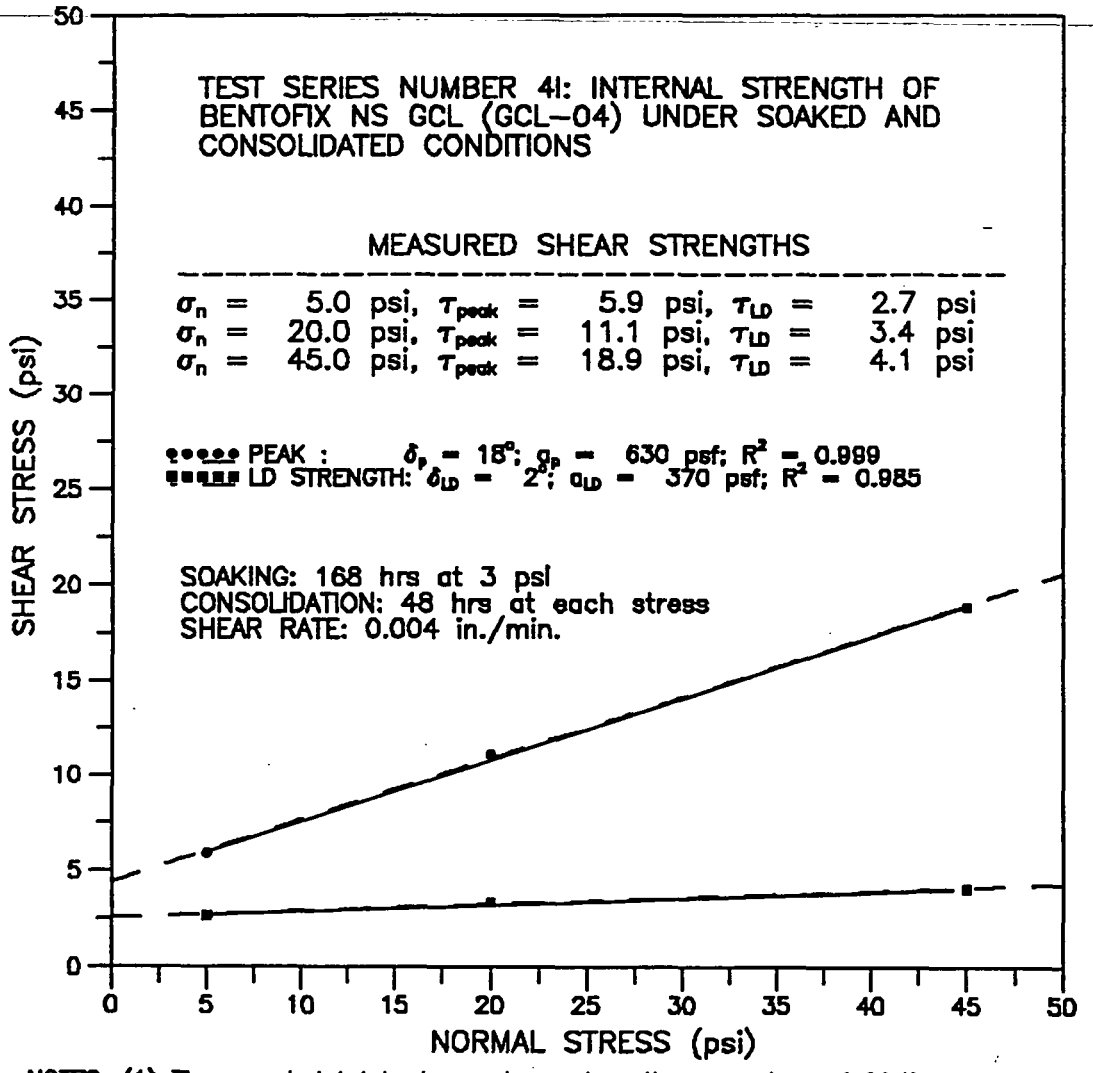
DATE TESTED: 3 TO 12 SEPTEMBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730107
FILE NO.	

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) For each test, sliding (i.e, internal shear failure) was observed to occur within the GCL.

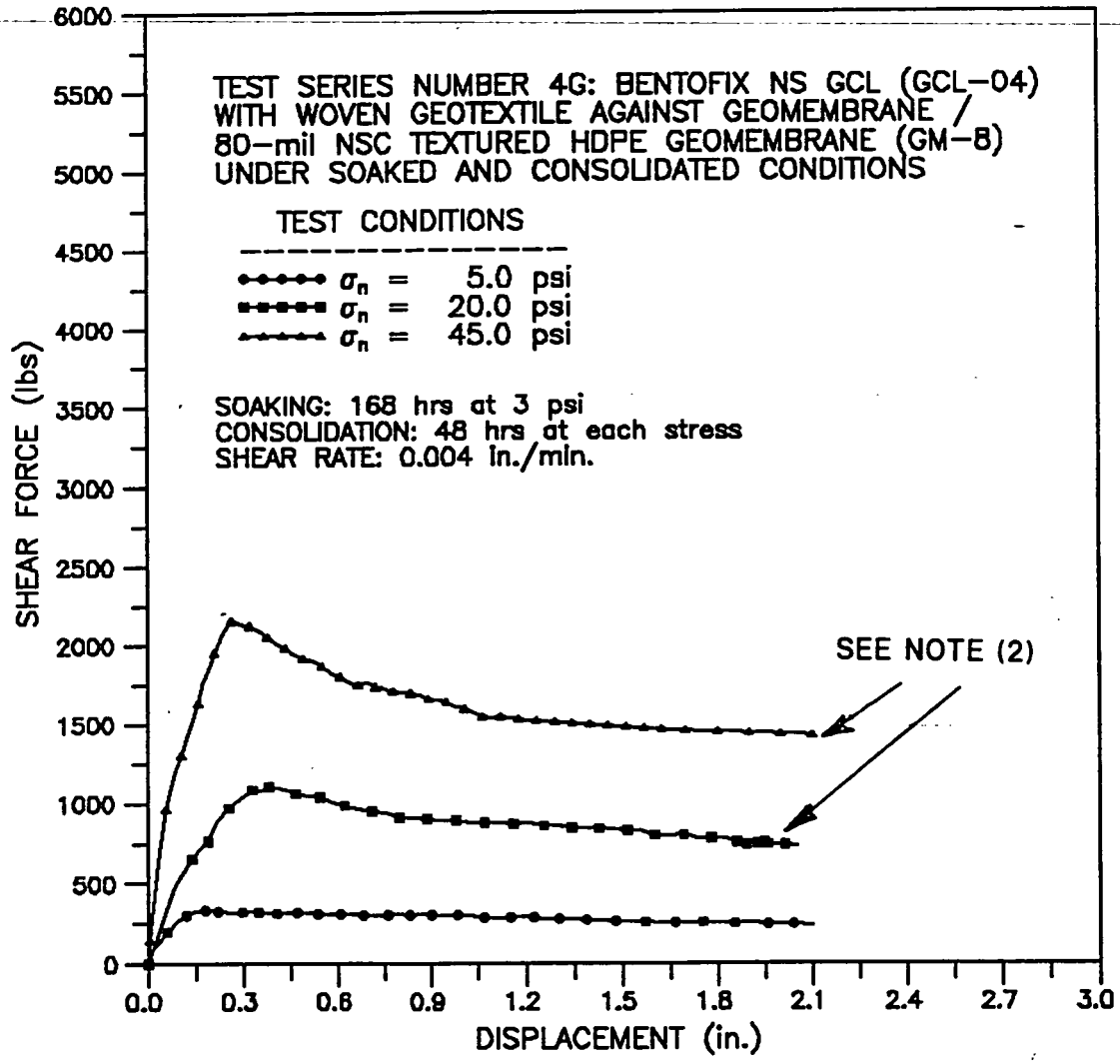
000010

DATE TESTED: 3 TO 12 SEPTEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730107
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

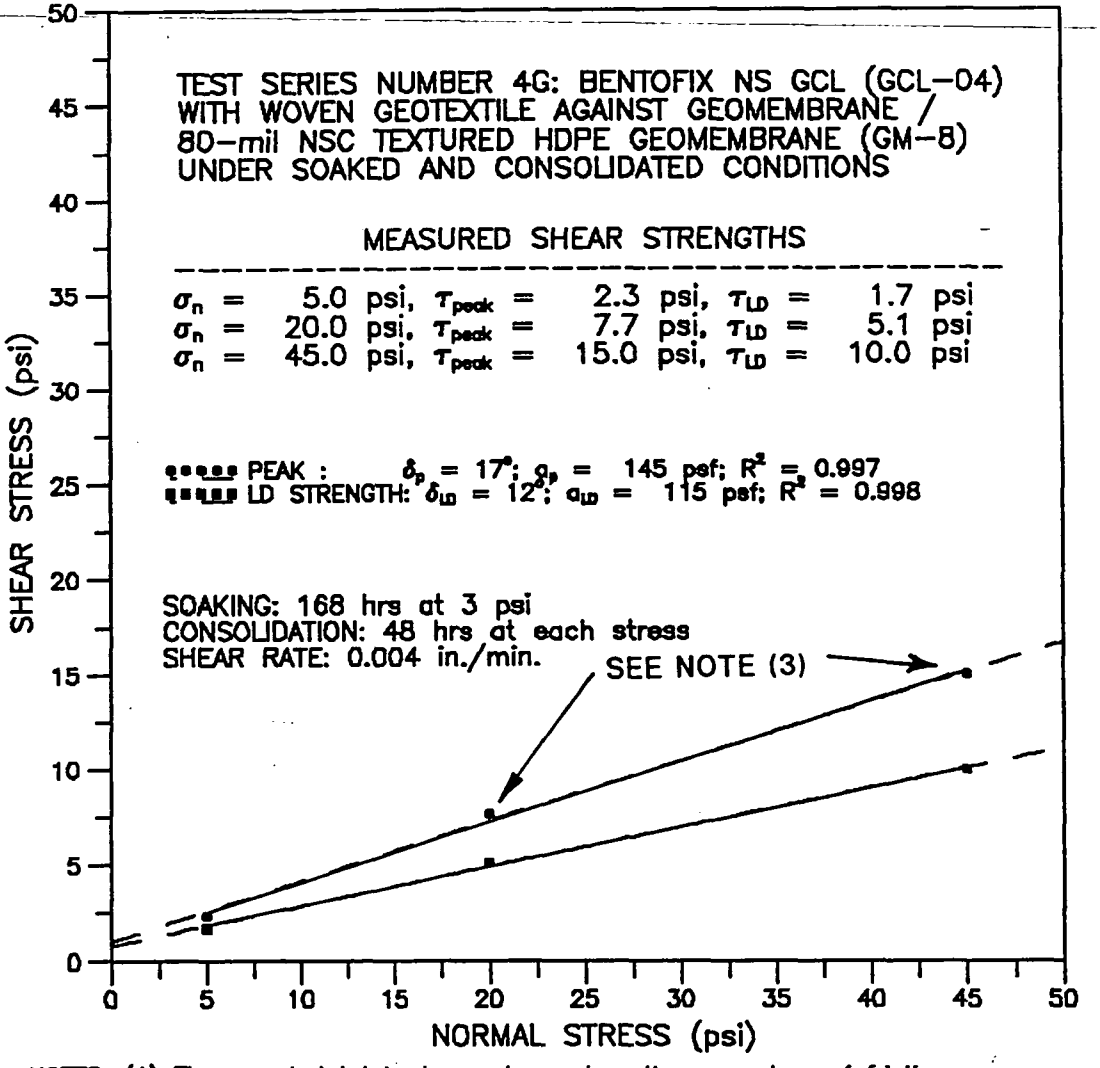
DATE TESTED: 6 TO 15 SEPTEMBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730107
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

000012

DATE TESTED: 6 TO 15 SEPTEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730107
FILE NO.	

10/42

MCO NOV 7 1997
RAM 7 NOV 1997

APPENDIX B

1269 11/A2

PETRO

environmental technologies

TRANSMITTAL FORM

TO: Don Dorty
Ellen Daniel Fernald

DATE October 20, 1997

RE: On-Site Original Facility Project
Project No. FSC 597

☐ **EXPRESS MAIL**

GENTLEMEN:

WE ARE SENDING YOU (✓) Attached ( ) Under separate cover
the following items:

COPIES	DATE	DESCRIPTION
4	10/20/97	Internal Alert Test Results (Roll #3575

THESE ARE TRANSMITTED AS CHECKED BELOW:

( ) For Approval ( ) Approved as Submitted ( ) Resubmit ____ copies for approval
(✓) For Your Use ( ) Approved as Noted ( ) Submit ____ copies for distribution
( ) For Review and Comment ( ) Returned for Corrections ( ) Return ____ corrected prints
( ) For Bids Due _____ 19____ ( ) _____

REMARKS _____

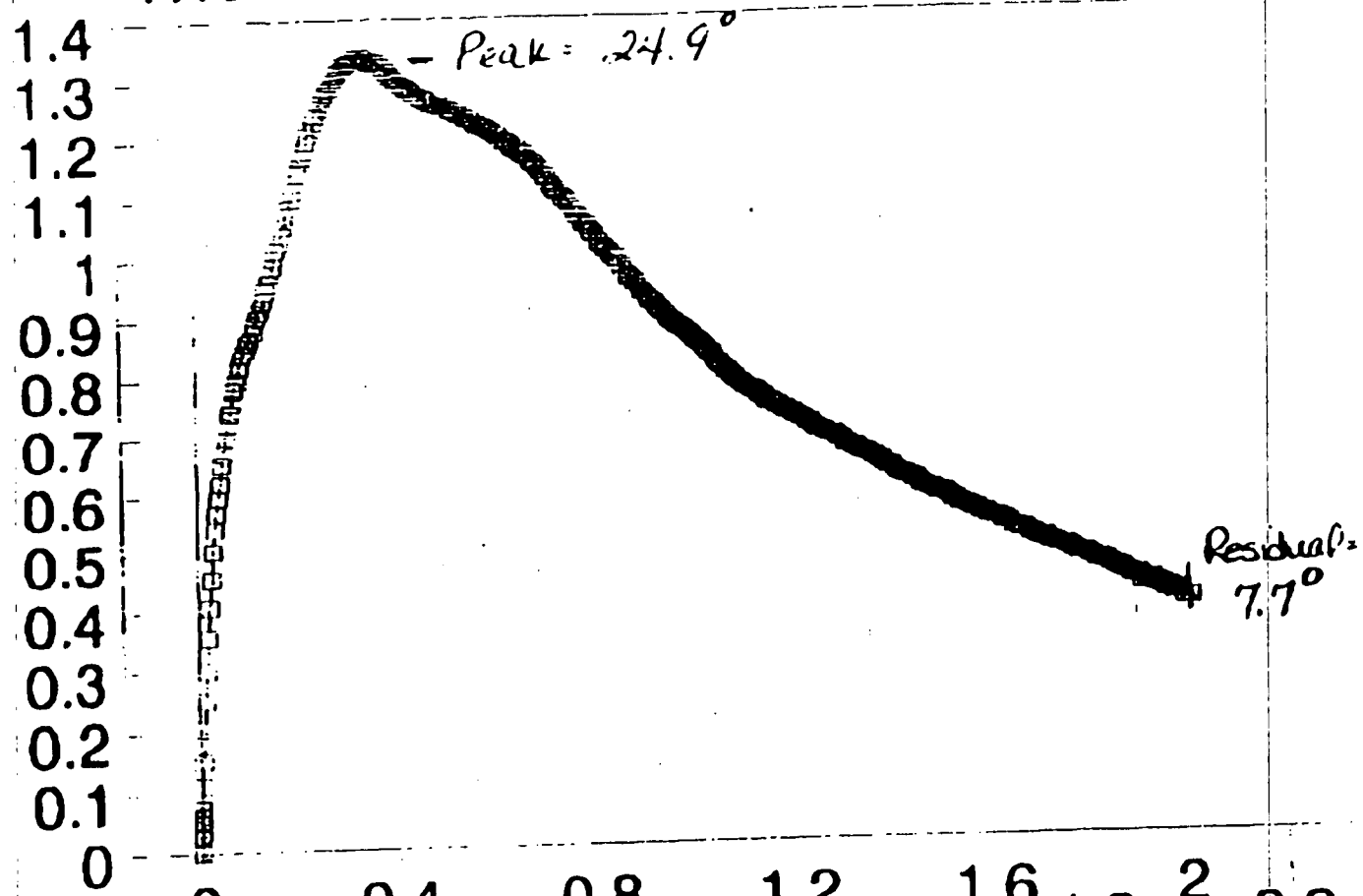
CC:FILE Project File UC7-024
Chester 02772 - Internal Alert Tests
Ted Dynter - Don Bodine

By: J. Richard Schlaubitzer

7851 Palace Drive • Cincinnati, Ohio 45249 • 513.489.6769 • Fax 489.7208

PETRO ENVIRONMENTAL 54-7239-00

HYDRATED GCL #035757/DIRECT SHEAR



20 PSI

000015

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2/42

TOTAL P.03

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Grand Rapids, MI • (616) 957-1690

JOB Petro-Fernald Site PROJECT NO 54 7239 SHEET NO. 1
SUBJECT Direct Shear Testing BY KMS DATE 9/29/97
CHK. BY DATE 10/6/97 update

Summary of Test Results

Internal Strength of Hydrated GCL

Peak Strength

Normal Stress (psi)		Measured Shear Strength (psi)	Calculated Secant Angle (°)
Roll #03575 (57)	.5	3.81	37.3
	.45	17.18	20.9
	.45 (*)	18.06	21.9
# 36844	5 (*)	3.55	35.4
Roll # 36344	20 (*)	9.12	24.5
# 37386	45 (*)	18.85	22.7
Roll # 36114	45 (*)	15.76	19.3
Roll # 36344	45 (*)	17.46	21.2
Roll # 036262	45 (*)	14.46	17.8
Roll # 37061	45 (*)	9.20	11.6

Residual Strength @ 2 inches displacement

Normal Stress (psi)		Measured Shear Strength (psi)	Calculated Secant Angle (°)
Roll # 03575 (57)	5	3.25	33.0
	45	3.10	4.0
	45 (*)	3.98	5.1
# 36844	5 (*)	2.53	26.8
# 36344	20 (*)	2.40	6.9
Roll # 37386	45 (*)	4.51	5.7
Roll # 36114	45 (*)	3.35	4.3
Roll # 36344	45 (*)	4.17	5.3
Roll # 036262	45 (*)	3.73	4.7
Roll # 37061	45 (*)	2.92	3.7

(*) Speed for testing = 0.005 inches/minute

Other speed = 0.04 inches/minute

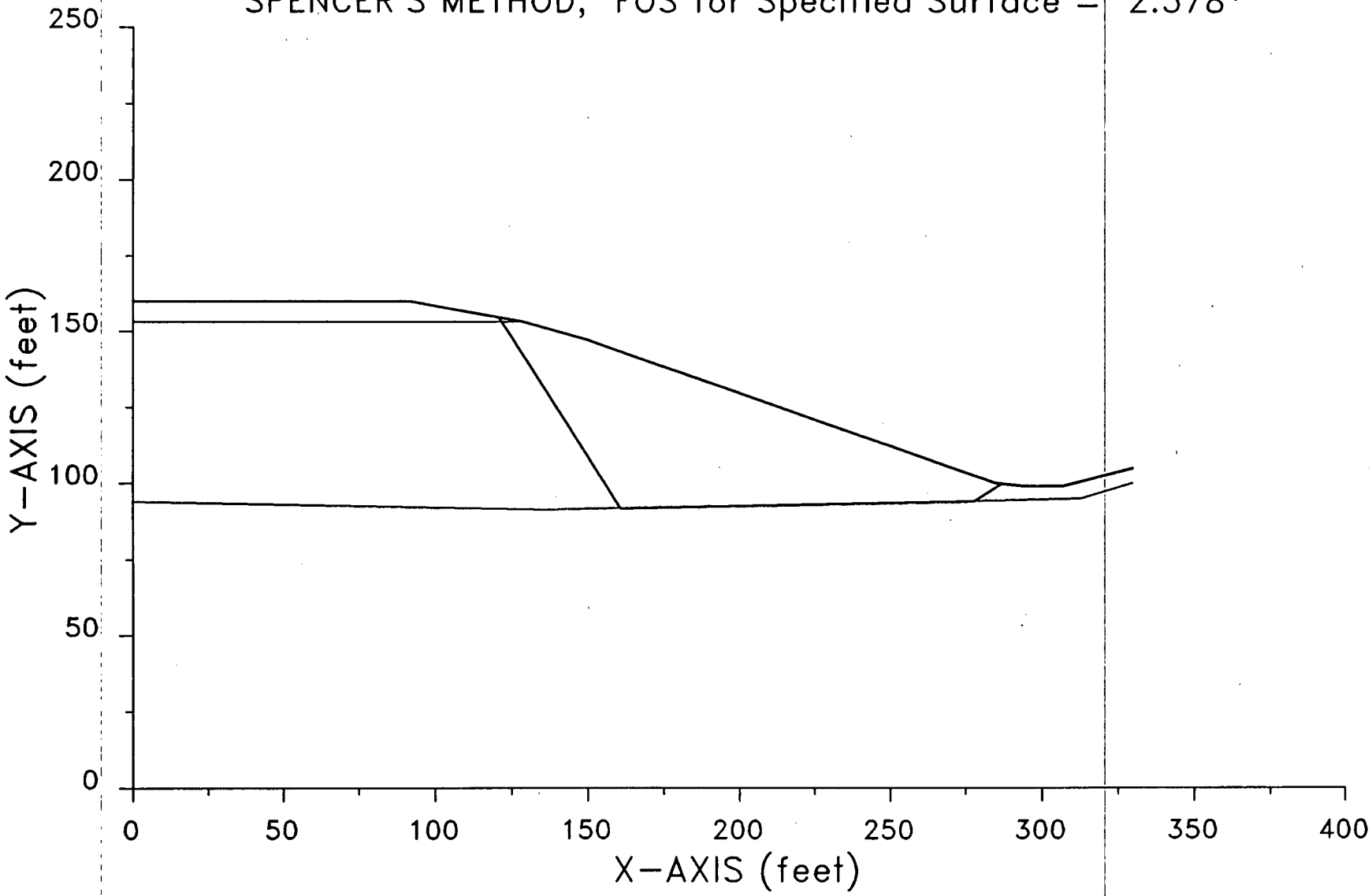
MCD Nov 7 1997
RAM 7 Nov 1997

APPENDIX C

NFTR04AS 11-03-97 13:17

OSDF Interim Closure/Short-Term,Peak

SPENCER'S METHOD, FOS for Specified Surface = 2.578



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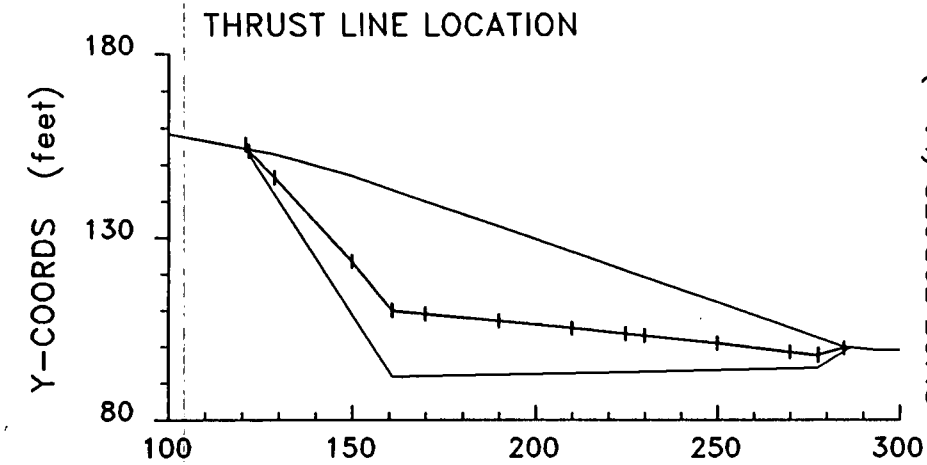

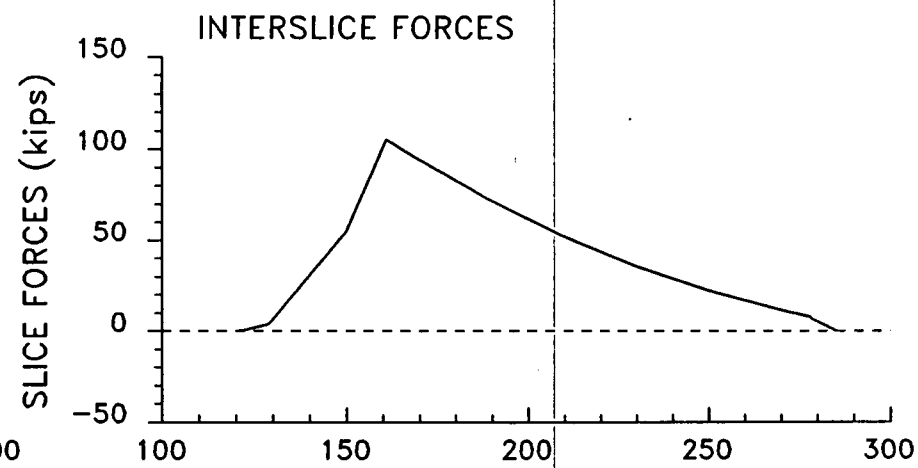

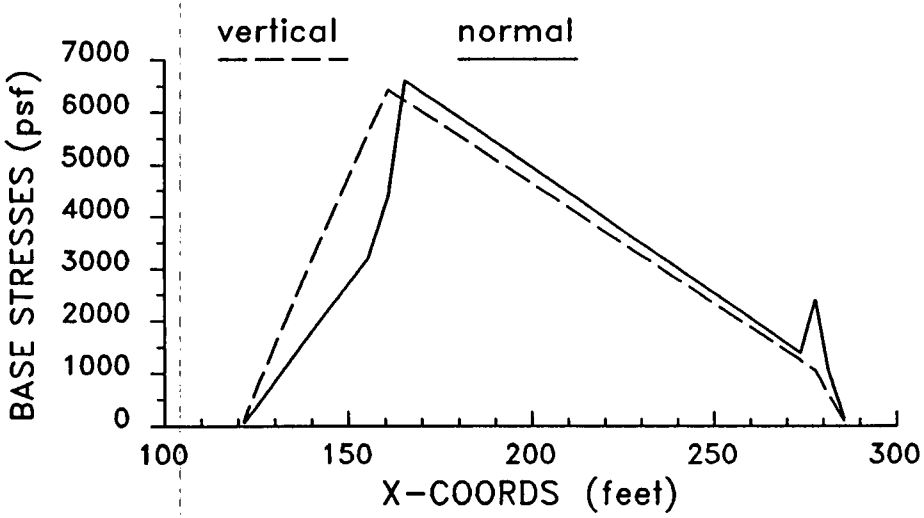

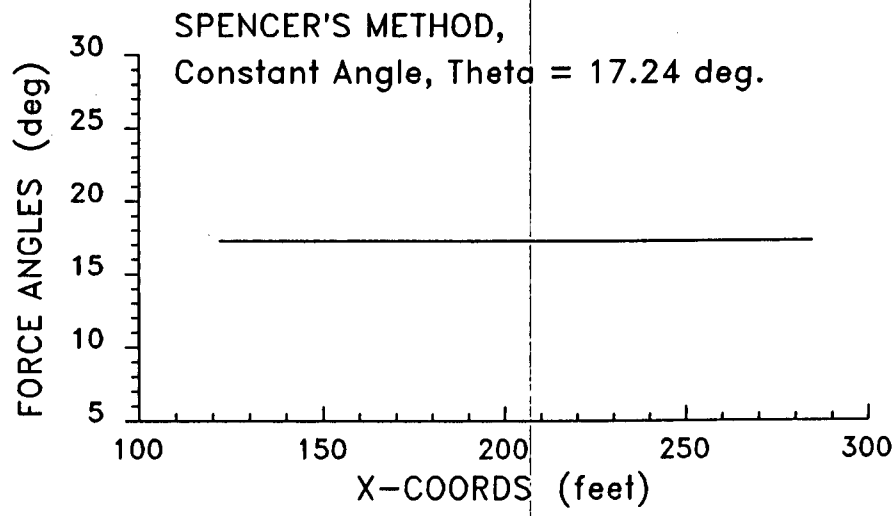

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.578 ✓

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16/42

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XSTABL File: NPPK04AS 11-03-97 13:17

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
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```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	849.6
4	2880.0	1467.4
5	6480.0	2661.1
6	10080.0	2661.1

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	286.72	99.81
2	278.01	94.26
3	277.80	94.06
4	224.80	93.00
5	161.06	91.73
6	160.90	91.90
7	121.97	153.00
8	121.11	154.49

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	285.86	99.26	.64	1.72	-32.50	6.34	138.
2	281.51	96.49	4.73	6.99	-32.50	19.12	4128.
3	277.90	94.16	8.30	.21	-43.60	19.12	218.
4	273.90	93.98	9.87	7.80	-1.15	19.12	9619.
5	260.00	93.70	15.00	20.00	-1.15	19.29	37490.
6	240.00	93.30	22.35	20.00	-1.15	19.03	55865.
7	227.40	93.05	26.96	5.20	-1.15	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.14	19.29	56716.
9	200.00	92.51	37.09	20.00	-1.14	19.29	92735.
10	180.00	92.11	44.44	20.00	-1.14	19.03	111107.
11	165.53	91.82	49.75	8.94	-1.14	19.29	55591.
12	160.98	91.82	51.34	.16	46.73	19.29	1027.
13	155.45	100.45	44.64	10.90	57.50	19.29	60820.
14	139.50	125.49	24.51	21.00	57.50	15.95	64347.
15	125.48	147.48	6.18	7.03	57.50	10.71	5432.
16	121.54	153.75	.66	.86	60.05	10.71	71.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.9146	2.5994	2.6657
3	17.0148	2.6041	2.5994
4	17.0114	2.6040	2.6041

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.1955	2.5819	2.5744
3	17.1925	2.5818	2.5819

Nonlinear M-C Iteration Number - 3

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment

2	17.2366	2.5774	2.5756
3	17.2359	2.5774	2.5774

Nonlinear M-C Iteration Number - 4

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	17.2359	2.5775	2.5774

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	17.2359	2.5775	2.5774

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	136.3	.0	30.00	0.	0.	0.	.00
2	1052.6	200.0	25.00	0.	0.	0.	.00
3	2396.5	643.7	15.96	0.	0.	0.	.00
4	1374.6	643.7	15.96	0.	0.	0.	.00
5	2044.6	643.7	15.96	0.	0.	0.	.00
6	3005.2	512.4	18.34	0.	0.	0.	.00
7	3611.2	512.4	18.34	0.	0.	0.	.00
8	4097.2	512.4	18.34	0.	0.	0.	.00
9	4942.9	512.4	18.34	0.	0.	0.	.00
10	5908.4	512.4	18.34	0.	0.	0.	.00
11	6599.8	2661.1	.00	0.	0.	0.	.00
12	4394.5	512.4	18.34	0.	0.	0.	.00
13	3197.1	200.0	25.00	0.	0.	0.	.00
14	1730.0	200.0	25.00	0.	0.	0.	.00
15	393.7	200.0	25.00	0.	0.	0.	.00
16	44.8	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	285.86	136.3	80.4	.0	30.5
2	281.51	1052.6	590.6	.0	268.0
3	277.90	2396.5	1037.4	.0	515.7
4	273.90	1374.6	1233.3	.0	402.3
5	260.00	2044.6	1874.5	.0	476.6
6	240.00	3005.2	2793.2	.0	585.4
7	227.40	3611.2	3369.8	.0	663.4

21/A2

8	217.40	4097.2	3832.2	.0	725.9
9	200.00	4942.9	4636.8	.0	834.7
10	180.00	5908.4	5555.3	.0	958.9
11	165.53	6599.8	6218.2	.0	1032.4
12	160.98	4394.5	6417.8	.0	764.1
13	155.45	3197.1	5579.9	.0	656.0
14	139.50	1730.0	3064.1	.0	390.6
15	125.48	393.7	772.7	.0	148.8
16	121.54	44.8	83.1	.0	10.0

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	17.24	211.	.81	1.29	.633
2	278.01	17.24	7080.	3.43	8.16	.421
3	277.80	17.24	7696.	3.42	8.44	.405
4	270.00	17.24	11205.	4.52	11.30	.400
5	250.00	17.24	22042.	7.28	18.70	.389
6	230.00	17.24	35559.	9.86	26.00	.379
7	224.80	17.24	39564.	10.49	27.92	.376
8	210.00	17.24	52077.	12.27	33.39	.367
9	190.00	17.24	71618.	14.62	40.79	.358
10	170.00	17.24	94163.	16.93	48.09	.352
11	161.06	17.24	105058.	17.98	51.40	.350
12	160.90	17.24	104404.	17.97	51.28	.350
13	150.00	17.24	54625.	14.36	37.99	.378
14	129.00	17.24	3513.	4.51	11.03	.409
15	121.97	17.24	61.	.61	1.33	.461
16	121.11	.00	0.	.93	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3051.10 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 579.00 (psf)

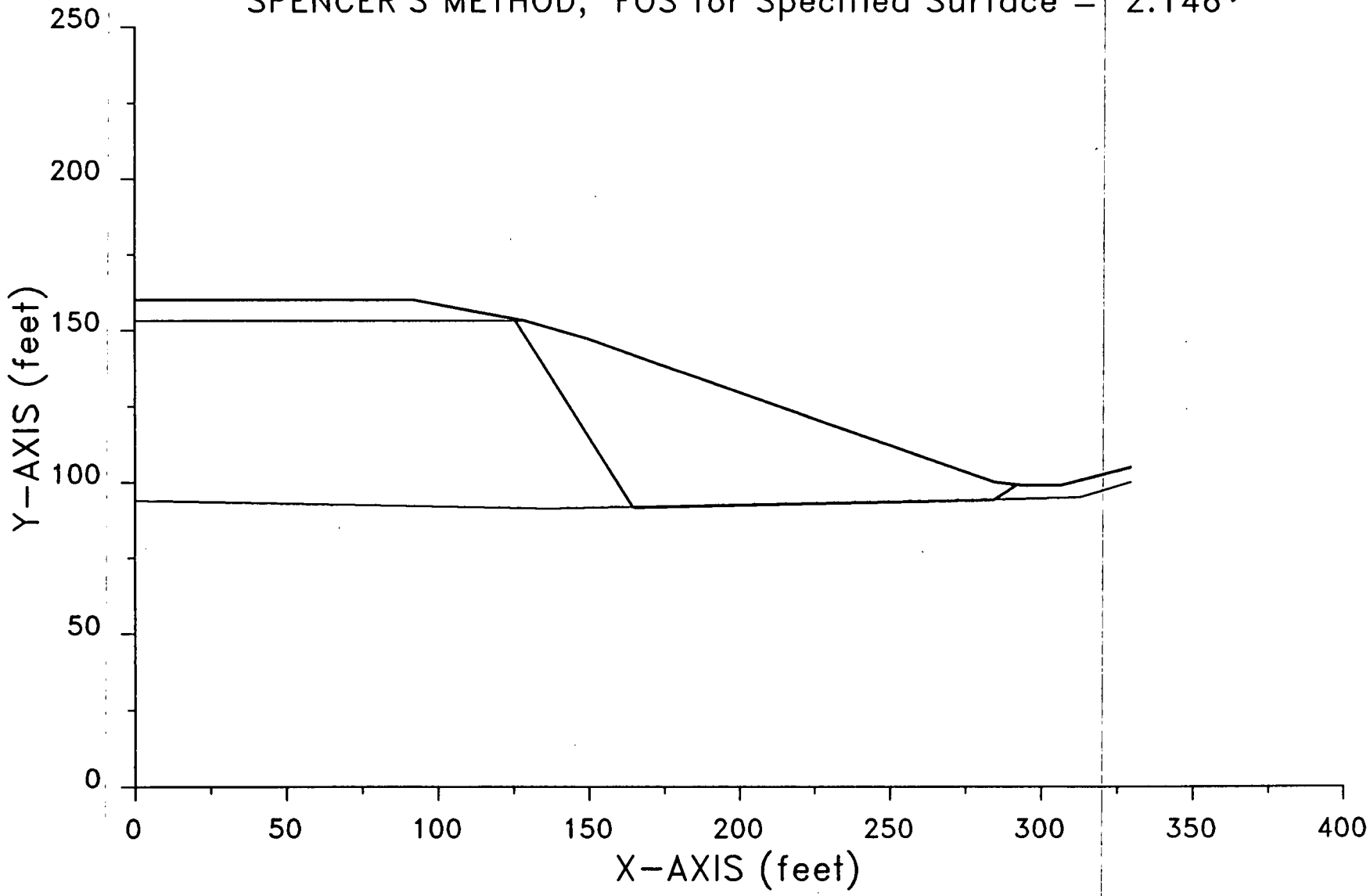
Total Length of failure surface = 201.79 feet

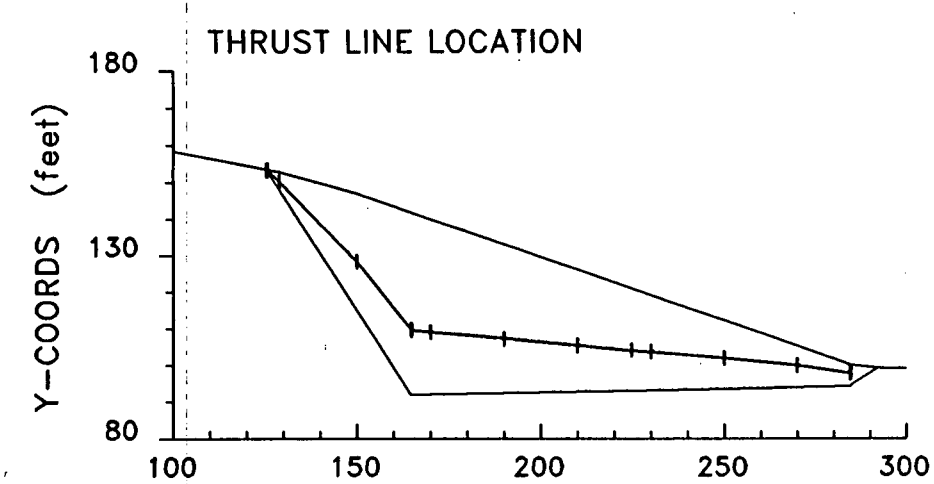
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

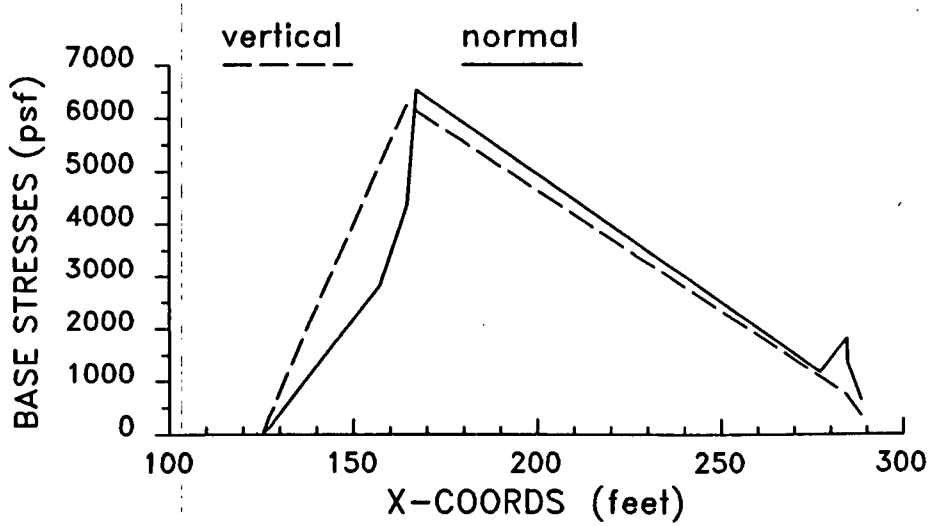
FACTOR OF SAFETY = 2.578

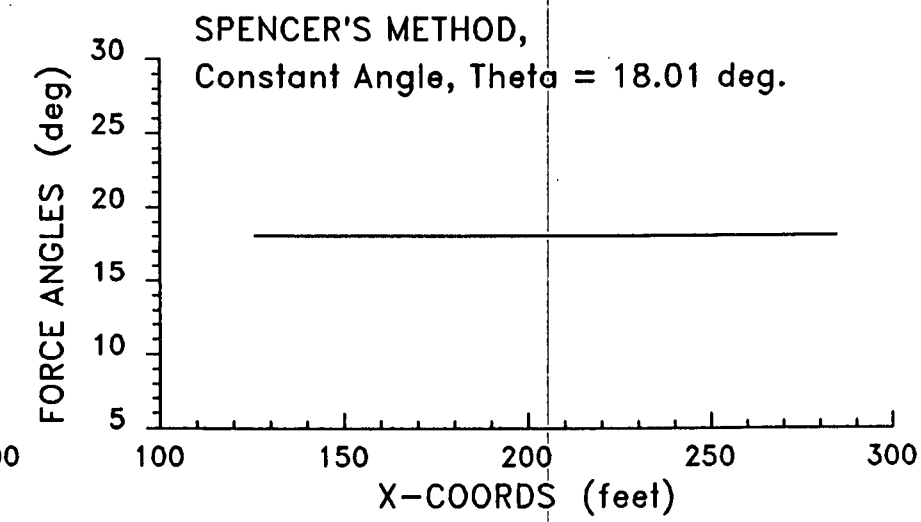
Total shear strength available along specified failure surface = 301.14E+03 lb

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.146









OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.146 ✓

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*              X S T A B L              *
*                                       *
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*              using the                *
*           Method of Slices            *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	331.2
4	2880.0	1108.8
5	6480.0	2160.0
6	10080.0	2160.0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	292.31	99.19
2	284.78	94.40
3	284.58	94.19
4	224.80	93.00
5	164.88	91.78
6	164.69	91.97
7	125.81	153.00
8	125.42	153.68

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.65	96.86	2.73	7.31	-32.45	6.34	2495.
2	284.89	94.47	5.57	.22	-32.45	19.12	156.
3	284.68	94.29	5.82	.20	-46.40	19.12	142.
4	277.29	94.04	8.63	14.58	-1.14	19.12	15724.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37498.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55869.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.17	19.29	56722.
9	200.00	92.50	37.10	20.00	-1.17	19.29	92762.
10	180.00	92.09	44.46	20.00	-1.17	19.03	111155.
11	167.44	91.83	49.06	5.12	-1.17	19.29	31401.
12	164.78	91.88	49.95	.19	45.00	19.29	1205.
13	157.34	103.50	40.93	14.69	57.50	19.29	75139.
14	139.50	131.51	18.49	21.00	57.50	15.95	48534.
15	127.40	150.50	2.81	3.19	57.50	10.71	1119.
16	125.61	153.34	.30	.39	60.07	10.71	15.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.9957	2.1482	2.1510
3	17.9995	2.1483	2.1482

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.0122	2.1457	2.1453

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	18.0122	2.1457	2.1453

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	638.2	.0	30.00	0.	0.	0.	.00
2	1344.7	200.0	25.00	0.	0.	0.	.00
3	1807.7	72.0	19.80	0.	0.	0.	.00
4	1165.1	72.0	19.80	0.	0.	0.	.00
5	2016.3	72.0	19.80	0.	0.	0.	.00
6	2996.6	267.8	16.28	0.	0.	0.	.00
7	3605.5	267.8	16.28	0.	0.	0.	.00
8	4095.4	267.8	16.28	0.	0.	0.	.00
9	4946.6	267.8	16.28	0.	0.	0.	.00
10	5918.4	267.8	16.28	0.	0.	0.	.00
11	6524.0	2160.0	.00	0.	0.	0.	.00
12	4346.8	267.8	16.28	0.	0.	0.	.00
13	2807.6	200.0	25.00	0.	0.	0.	.00
14	1232.6	200.0	25.00	0.	0.	0.	.00
15	131.8	200.0	25.00	0.	0.	0.	.00
16	19.9	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.65	638.2	341.3	.0	171.7
2	284.89	1344.7	696.3	.0	385.4
3	284.68	1807.7	727.4	.0	336.9
4	277.29	1165.1	1078.5	.0	229.0
5	260.00	2016.3	1874.9	.0	371.8
6	240.00	2996.6	2793.4	.0	532.6
7	227.40	3605.5	3369.8	.0	615.5
8	217.40	4095.4	3832.6	.0	682.2
9	200.00	4946.6	4638.1	.0	798.0
10	180.00	5918.4	5557.8	.0	930.3
11	167.44	6524.0	6133.0	.0	1006.7
12	164.78	4346.8	6243.7	.0	716.4
13	157.34	2807.6	5116.0	.0	703.4
14	139.50	1232.6	2311.2	.0	361.1
15	127.40	131.8	350.7	.0	121.8
16	125.61	19.9	37.7	.0	5.4

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	18.01	4439.	3.51	5.46	.643
2	284.78	18.01	4732.	3.50	5.68	.617
3	284.58	18.01	5192.	3.45	5.96	.579
4	270.00	18.01	9059.	5.93	11.30	.525
5	250.00	18.01	17723.	8.25	18.70	.441
6	230.00	18.01	30179.	10.32	26.00	.397

7	224.80	18.01	33937.	10.87	27.92	.389
8	210.00	18.01	45851.	12.50	33.40	.374
9	190.00	18.01	64752.	14.75	40.81	.361
10	170.00	18.01	86850.	17.03	48.12	.354
11	164.88	18.01	92985.	17.62	50.01	.352
12	164.69	18.01	92249.	17.63	49.89	.353
13	150.00	18.01	35048.	13.20	31.97	.413
14	129.00	18.01	296.	2.07	5.01	.414
15	125.81	18.01	11.	.28	.60	.456
16	125.42	.00	-1.	-.57	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 2869.84 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 545.64 (psf)

Total Length of failure surface = 202.35 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.146

Total shear strength available along specified failure surface = 236.90E+03 lb

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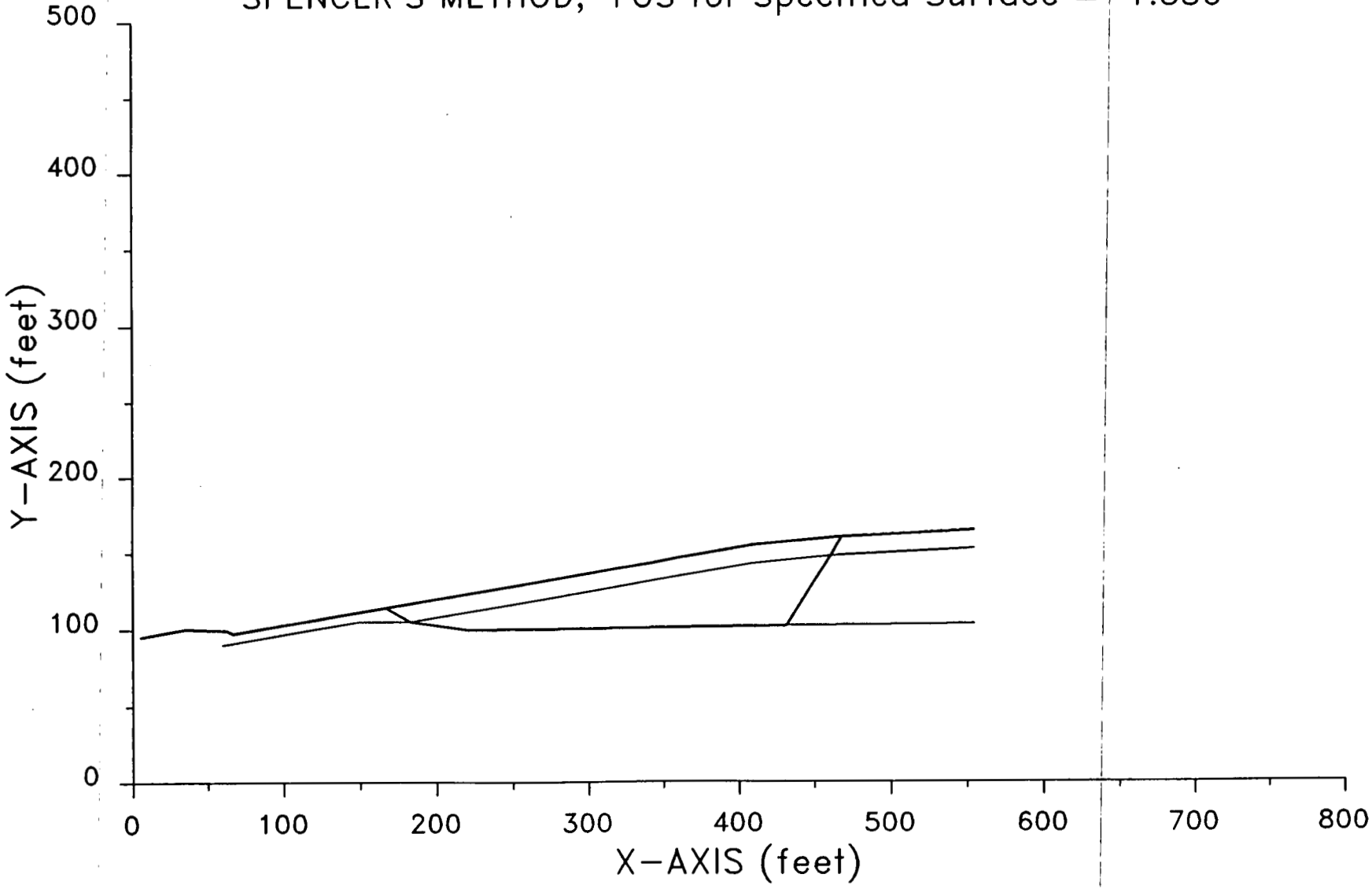
OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.556



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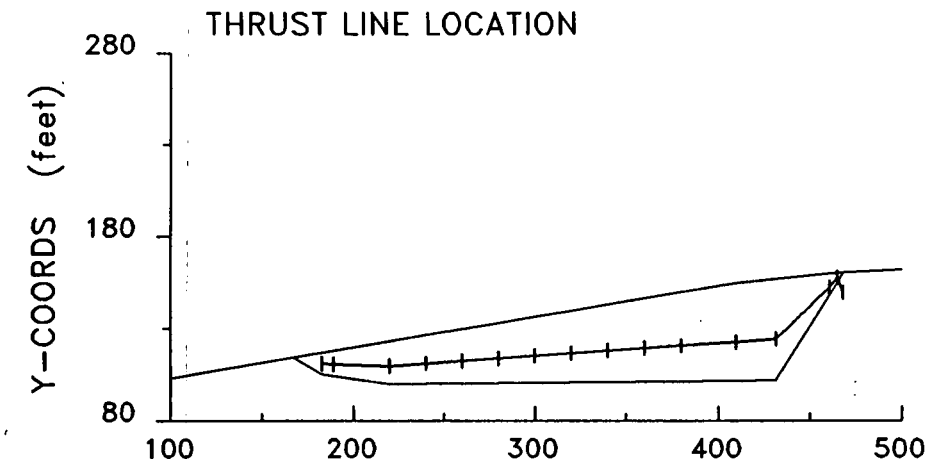

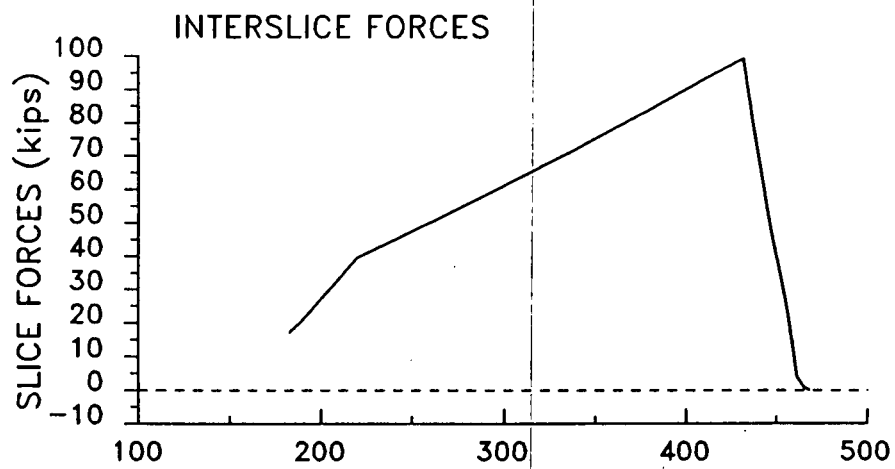

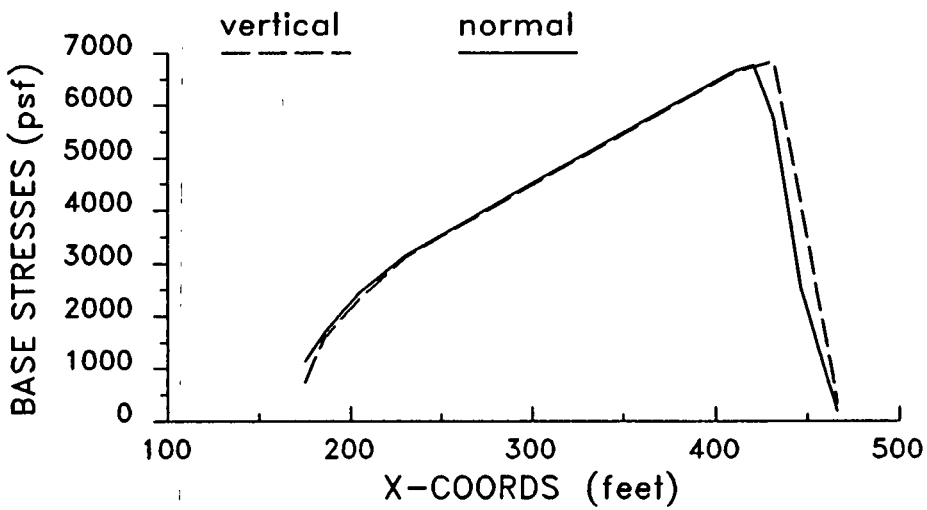

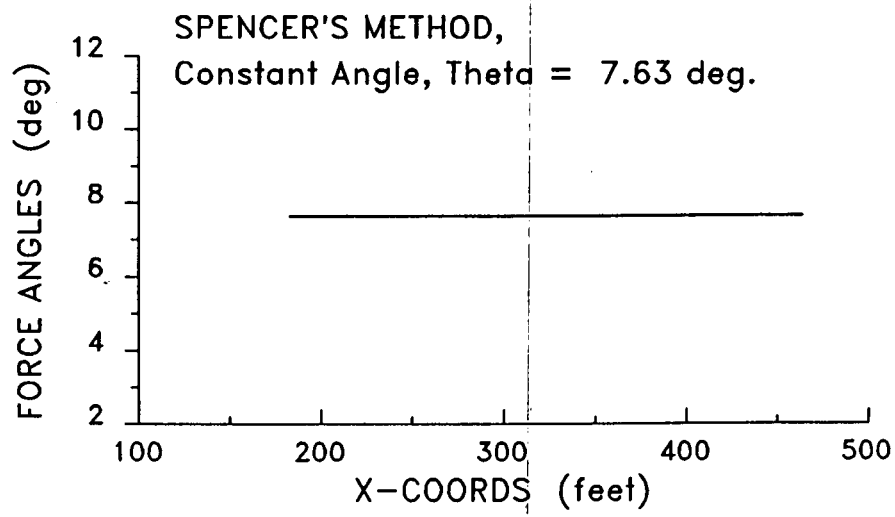

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.556 ✓

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*                                       *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	388.8
4	2880.0	439.2
5	6480.0	581.8
6	10080.0	581.8

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 9 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	409.90	101.80
6	431.64	102.08
7	431.79	102.23
8	460.88	147.89
9	468.07	160.35

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.63	9.37	93352.
9	330.00	100.93	40.42	20.00	.63	9.37	101056.
10	350.00	101.15	43.55	20.00	.63	9.65	108885.
11	370.00	101.36	46.69	20.00	.63	9.37	116714.
12	394.95	101.64	50.55	29.90	.63	9.46	188949.
13	409.95	101.80	52.89	.10	.74	9.46	661.
14	420.82	101.94	53.84	21.64	.74	5.71	145641.
15	431.72	102.16	54.72	.15	45.00	5.71	1026.
16	446.34	125.06	33.27	29.09	57.50	5.71	120991.
17	462.94	151.46	8.53	4.12	60.02	5.71	4395.
18	466.54	157.69	2.58	3.07	60.02	2.86	992.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.6015	1.5554	1.5783
3	7.6255	1.5559	1.5554

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.6255	1.5559	1.5554

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta

1	1122.8	.0	30.00	0.	0.	0.	.00
2	1698.9	372.0	1.34	0.	0.	0.	.00
3	2426.0	372.0	1.34	0.	0.	0.	.00
4	3131.6	325.1	2.27	0.	0.	0.	.00
5	3526.0	325.1	2.27	0.	0.	0.	.00
6	3914.2	325.1	2.27	0.	0.	0.	.00
7	4308.7	325.1	2.27	0.	0.	0.	.00
8	4701.1	325.1	2.27	0.	0.	0.	.00
9	5087.0	325.1	2.27	0.	0.	0.	.00
10	5479.1	325.1	2.27	0.	0.	0.	.00
11	5871.2	325.1	2.27	0.	0.	0.	.00
12	6355.7	325.1	2.27	0.	0.	0.	.00
13	6645.2	581.8	.00	0.	0.	0.	.00
14	6763.8	581.8	.00	0.	0.	0.	.00
15	5760.3	325.1	2.27	0.	0.	0.	.00
16	2535.4	.0	25.00	0.	0.	0.	.00
17	584.3	.0	30.00	0.	0.	0.	.00
18	177.0	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1122.8	739.6	.0	416.6
2	186.00	1698.9	1594.4	.0	264.6
3	204.50	2426.0	2304.8	.0	275.5
4	230.00	3131.6	3100.0	.0	288.7
5	250.00	3526.0	3493.8	.0	298.7
6	270.00	3914.2	3881.3	.0	308.6
7	290.00	4308.7	4275.0	.0	318.6
8	310.00	4701.1	4667.6	.0	328.6
9	330.00	5087.0	5052.8	.0	338.5
10	350.00	5479.1	5444.3	.0	348.4
11	370.00	5871.2	5835.7	.0	358.4
12	394.95	6355.7	6319.4	.0	370.8
13	409.95	6645.2	6611.4	.0	373.9
14	420.82	6763.8	6730.2	.0	373.9
15	431.72	5760.3	6839.6	.0	355.6
16	446.34	2535.4	4159.2	.0	759.9
17	462.94	584.3	1066.6	.0	216.8
18	466.54	177.0	323.0	.0	65.7

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.63	17087.	5.66	11.83	.478
2	189.00	7.63	20134.	6.33	13.68	.463
3	220.00	7.63	39413.	9.67	23.20	.417

4	240.00	7.63	44607.	10.88	26.40	.412
5	260.00	7.63	49923.	12.08	29.50	.409
6	280.00	7.63	55360.	13.25	32.60	.407
7	300.00	7.63	60921.	14.42	35.80	.403
8	320.00	7.63	66516.	15.57	38.88	.400
9	340.00	7.63	72225.	16.71	41.96	.398
10	360.00	7.63	78049.	17.84	45.14	.395
11	380.00	7.63	83988.	18.96	48.23	.393
12	409.90	7.63	93079.	20.61	52.88	.390
13	410.00	7.63	93108.	20.62	52.90	.390
14	431.64	7.63	99370.	21.86	54.78	.399
15	431.79	7.63	98552.	21.91	54.65	.401
16	460.88	7.63	4053.	4.35	11.90	.366
17	465.00	7.63	744.	2.45	5.17	.475
18	468.07	.00	-3.	-10.87	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3893.75 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 393.53 (psf)

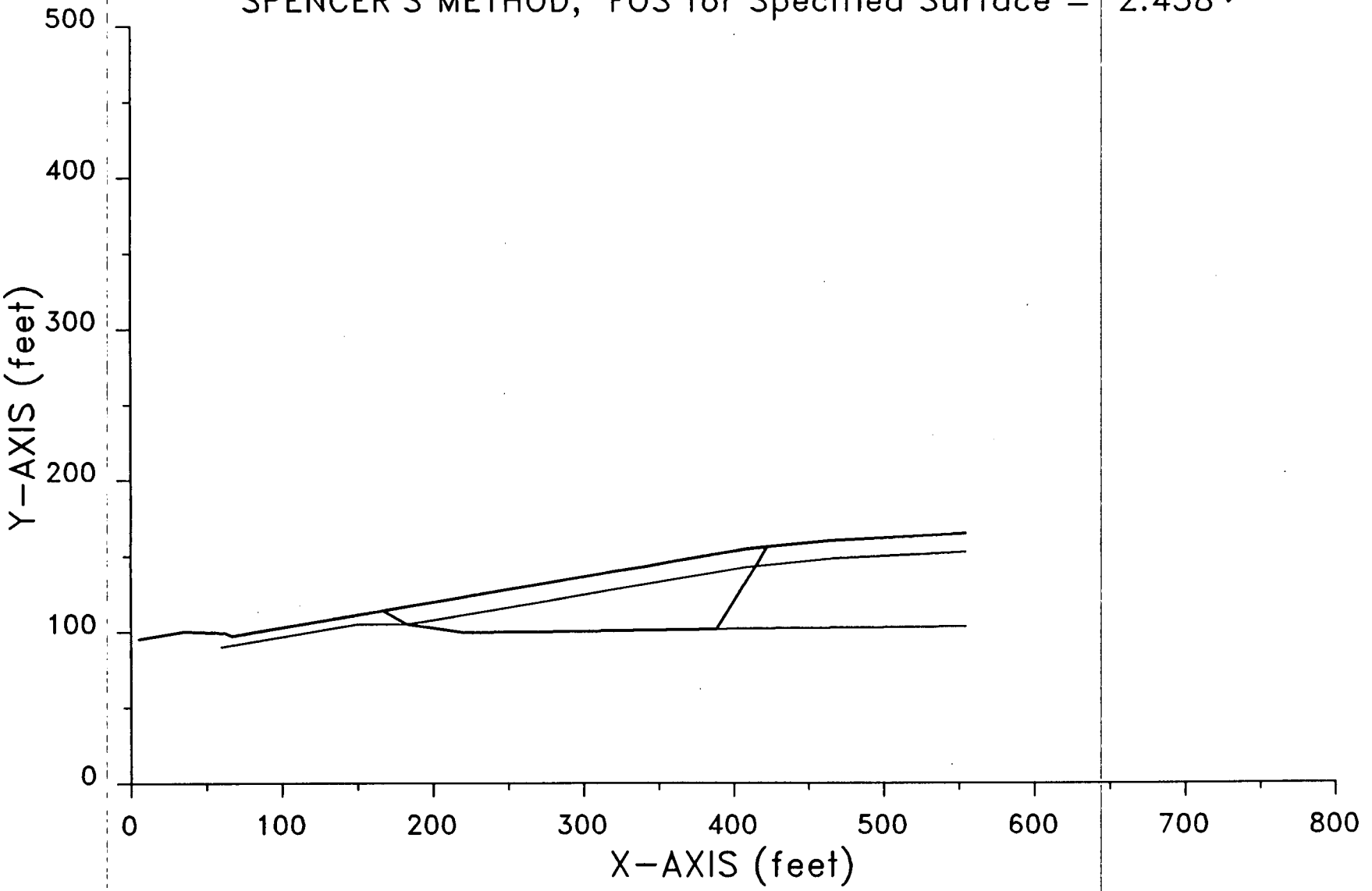
Total Length of failure surface = 336.12 feet

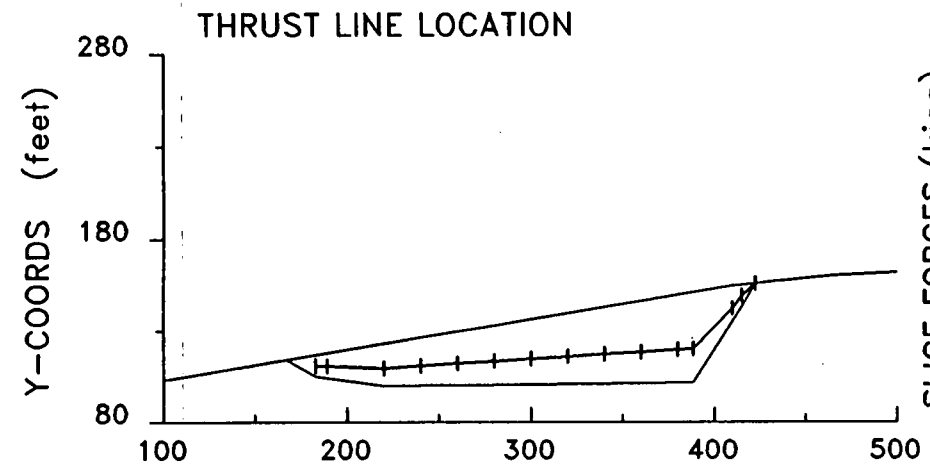
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

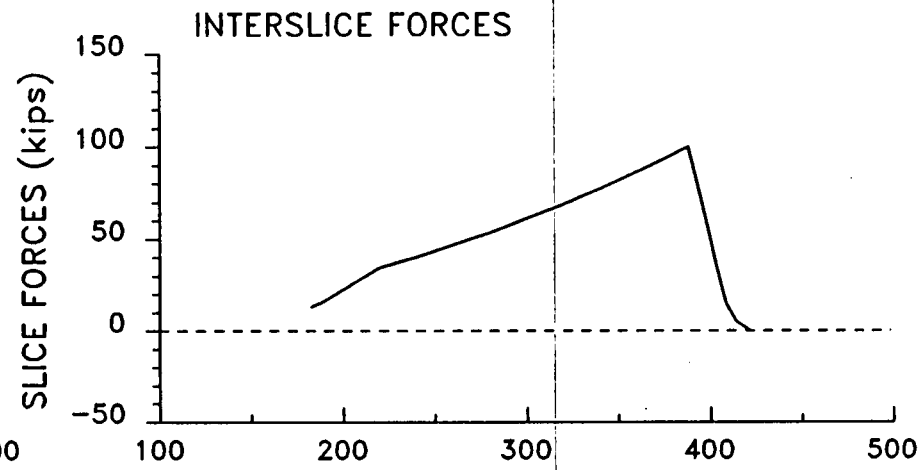
FACTOR OF SAFETY = 1.556 ✓

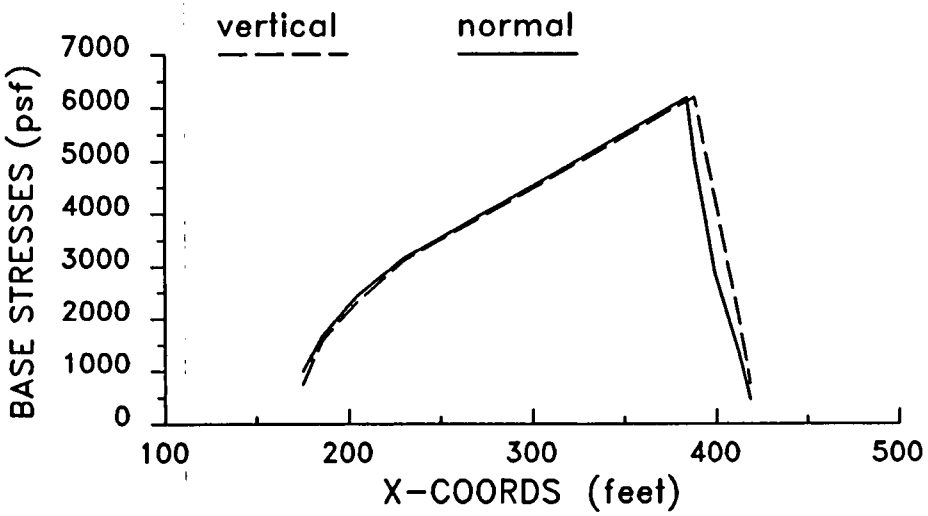
Total shear strength available along specified failure surface = 205.81E+03 lb

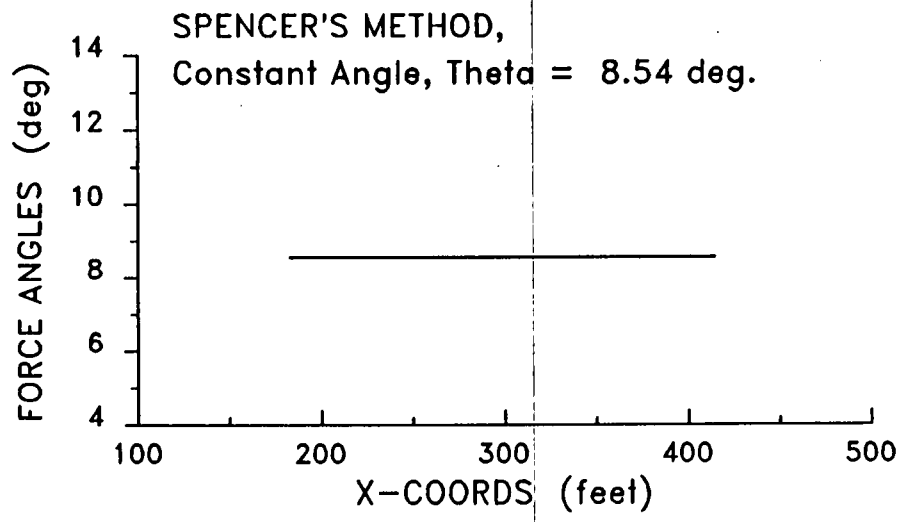
OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.458 ✓











OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.458

1269

37/42

000040

XSTABL File: NLD04BS 10-27-97 10:42

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	244.8
4	2880.0	734.4
5	6480.0	1440.0
6	10080.0	1440.0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	388.52	101.60
6	388.69	101.77
7	415.16	143.32
8	422.46	155.95

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.65	9.37	93343.
9	330.00	100.94	40.41	20.00	.65	9.37	101028.
10	350.00	101.16	43.54	20.00	.65	9.65	108838.
11	370.00	101.39	46.66	20.00	.65	9.37	116648.
12	384.26	101.55	48.86	8.52	.65	9.46	52034.
13	388.60	101.68	49.45	.17	45.00	9.46	1051.
14	399.35	118.50	34.43	21.31	57.50	9.46	91710.
15	412.58	139.27	15.69	5.16	57.50	5.71	10119.
16	418.81	149.63	5.95	7.30	59.96	5.71	5428.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	8.5194	2.4574	2.4893
3	8.5382	2.4582	2.4574

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	8.5382	2.4582	2.4574

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	996.2	.0	30.00	0.	0.	0.	.00
2	1684.7	81.6	12.77	0.	0.	0.	.00

3	2430.9	81.6	12.77	0.	0.	0.	.00
4	3140.1	169.9	11.09	0.	0.	0.	.00
5	3537.7	169.9	11.09	0.	0.	0.	.00
6	3928.9	169.9	11.09	0.	0.	0.	.00
7	4326.5	169.9	11.09	0.	0.	0.	.00
8	4721.0	169.9	11.09	0.	0.	0.	.00
9	5108.9	169.9	11.09	0.	0.	0.	.00
10	5503.1	169.9	11.09	0.	0.	0.	.00
11	5897.3	169.9	11.09	0.	0.	0.	.00
12	6174.7	169.9	11.09	0.	0.	0.	.00
13	5027.1	169.9	11.09	0.	0.	0.	.00
14	2859.7	.0	25.00	0.	0.	0.	.00
15	1303.0	.0	25.00	0.	0.	0.	.00
16	456.0	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	996.2	739.6	.0	234.0
2	186.00	1684.7	1594.4	.0	188.5
3	204.50	2430.9	2304.8	.0	257.3
4	230.00	3140.1	3100.0	.0	319.5
5	250.00	3537.7	3493.8	.0	351.2
6	270.00	3928.9	3881.3	.0	382.4
7	290.00	4326.5	4275.0	.0	414.1
8	310.00	4721.0	4667.1	.0	445.5
9	330.00	5108.9	5051.4	.0	476.5
10	350.00	5503.1	5441.9	.0	507.9
11	370.00	5897.3	5832.4	.0	539.3
12	384.26	6174.7	6107.3	.0	561.5
13	388.60	5027.1	6181.1	.0	470.0
14	399.35	2859.7	4303.6	.0	542.5
15	412.58	1303.0	1961.0	.0	247.2
16	418.81	456.0	743.5	.0	107.1

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	8.54	13013.	5.79	11.83	.489
2	189.00	8.54	15594.	6.43	13.68	.470
3	220.00	8.54	34370.	9.47	23.20	.408
4	240.00	8.54	40197.	10.71	26.40	.406
5	260.00	8.54	46584.	11.85	29.50	.402
6	280.00	8.54	53523.	12.94	32.60	.397
7	300.00	8.54	61022.	13.99	35.80	.391
8	320.00	8.54	68954.	15.00	38.87	.386
9	340.00	8.54	77423.	15.99	41.95	.381
10	360.00	8.54	86438.	16.96	45.12	.376

11	380.00	8.54	95998.	17.92	48.20	.372
12	388.52	8.54	100234.	18.32	49.52	.370
13	388.69	8.54	99451.	18.32	49.38	.371
14	410.00	8.54	14412.	6.95	19.48	.357
15	415.16	8.54	5029.	5.76	11.90	.485
16	422.46	.00	-2.	-.26	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3517.70 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 390.42 (psf)

Total Length of failure surface = 288.34 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.458

Total shear strength available along specified failure surface = 276.73E+03 lb

GCL 05

COMPUTATION COVER SHEET

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 05 - Compliance Package

Computations By: (Cognizant Engineer)
Signature: M. Orozco — Date: Nov 6 1997
Printed Name and Title: M. CATALINA OROZCO, STAFF ENGINEER

Assumptions and Procedures Checked By: (Checker)
Signature: Robert A. Morgan III — Date: 7 Nov 1997
Printed Name and Title: ROBERT A. MORGAN III, SR. STAFF ENGINEER

Computations Checked by:
Signature: Robert A. Morgan III — Date: 7 Nov 1997
Printed Name and Title: ROBERT A. MORGAN III, SR. STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: M. Orozco — Date: Nov 7 1997
Printed Name and Title: M. CATALINA OROZCO, STAFF ENGINEER

Approved by: (PDP)
Signature: Gary R. Schmertmann — Date: 7 Nov 97
Printed Name and Title: Gary R. Schmertmann, Sr. Project Engineer

Approved by: (DTL and TETL)
Signature: K. W. Cargill — Date: 10 Nov 97
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

000046A

Written By : MCO Date: 11 / 6 / 97 Reviewed by: RAM Date: 11 / 7 / 97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 05 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 05 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample No.	Case	Test Type	Measured Shear Strengths		
			5 psi	20 psi	45 psi
05	Peak	GCL Internal	0[1] psi	11.8psi	15.3psi
		GCL/GMB Interface	0[1]	6.4	14.2
05	Large-displacement	GCL Internal	0[1]	5.2	6.1
		GCL/GMB Interface	0[1]	3.9	8.0

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix B.

QA Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
05	GCL Internal	NPK05AS	2.4	YES
	GCL/GMB Interface	NPK05BS	2.0	YES
Baseline	Large-displacement	NA	1.6	NA
05	GCL Internal	NLD05AS	2.0	YES
	GCL/GMB Interface	NLD05BS	2.1	YES

[1] Shear strength values for QA sample 05 at 5 psi normal stress were not available at the time that this calculation package was prepared. These values were assumed to equal zero. This assumption is conservative in the context of RCI 1702-006R.

YCO NOV 6 1997
RAM 7 NOV 1997

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 5I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-05). GCL's initial moisture content was 9.7%. GCL's final moisture content ranged from 77% to 80% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20 and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 5G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

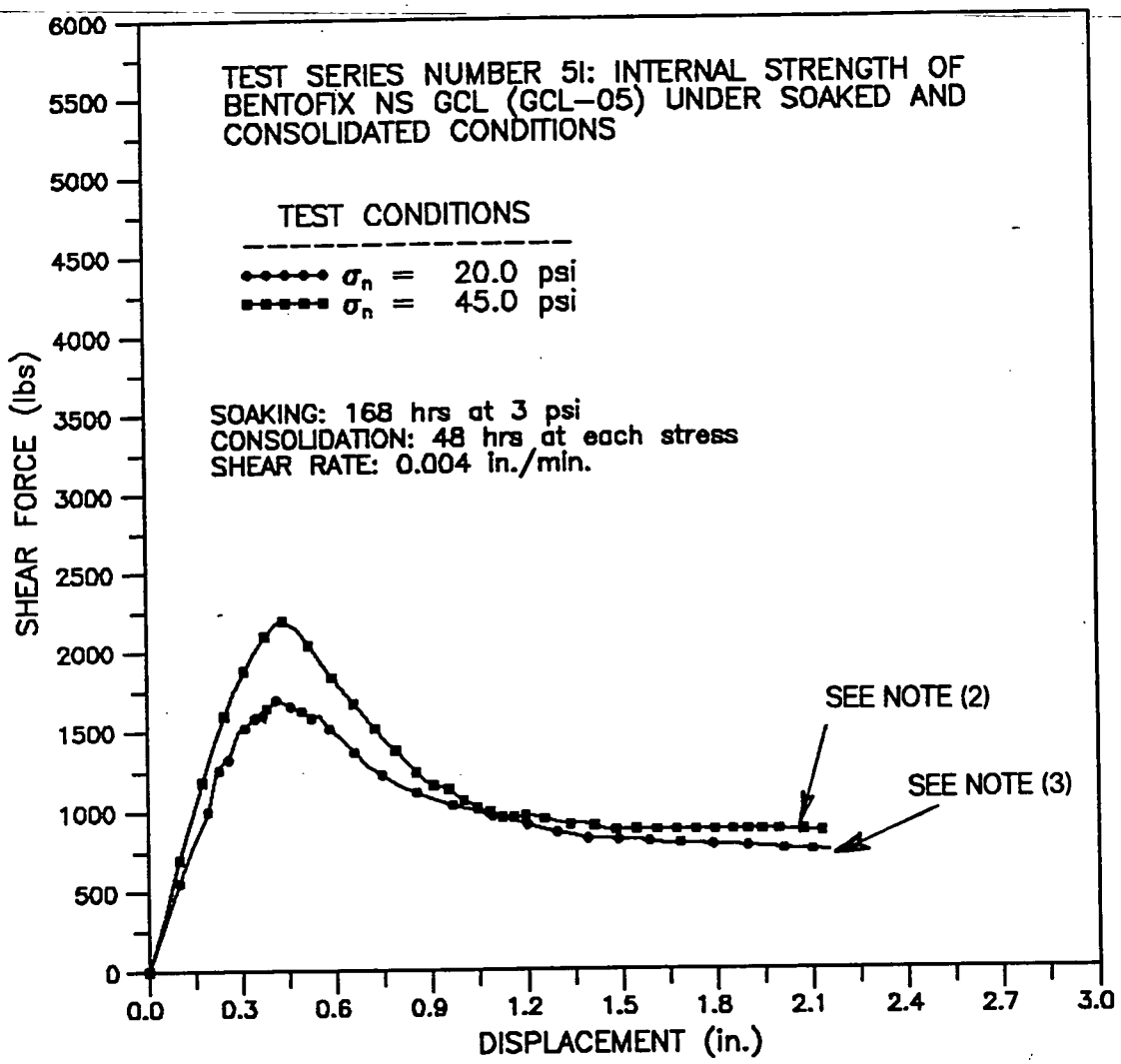
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-05) with woven geotextile against geomembrane. GCL's initial moisture content was 9.9%. GCL's final moisture content ranged from 65 to 69% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-10); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20 and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



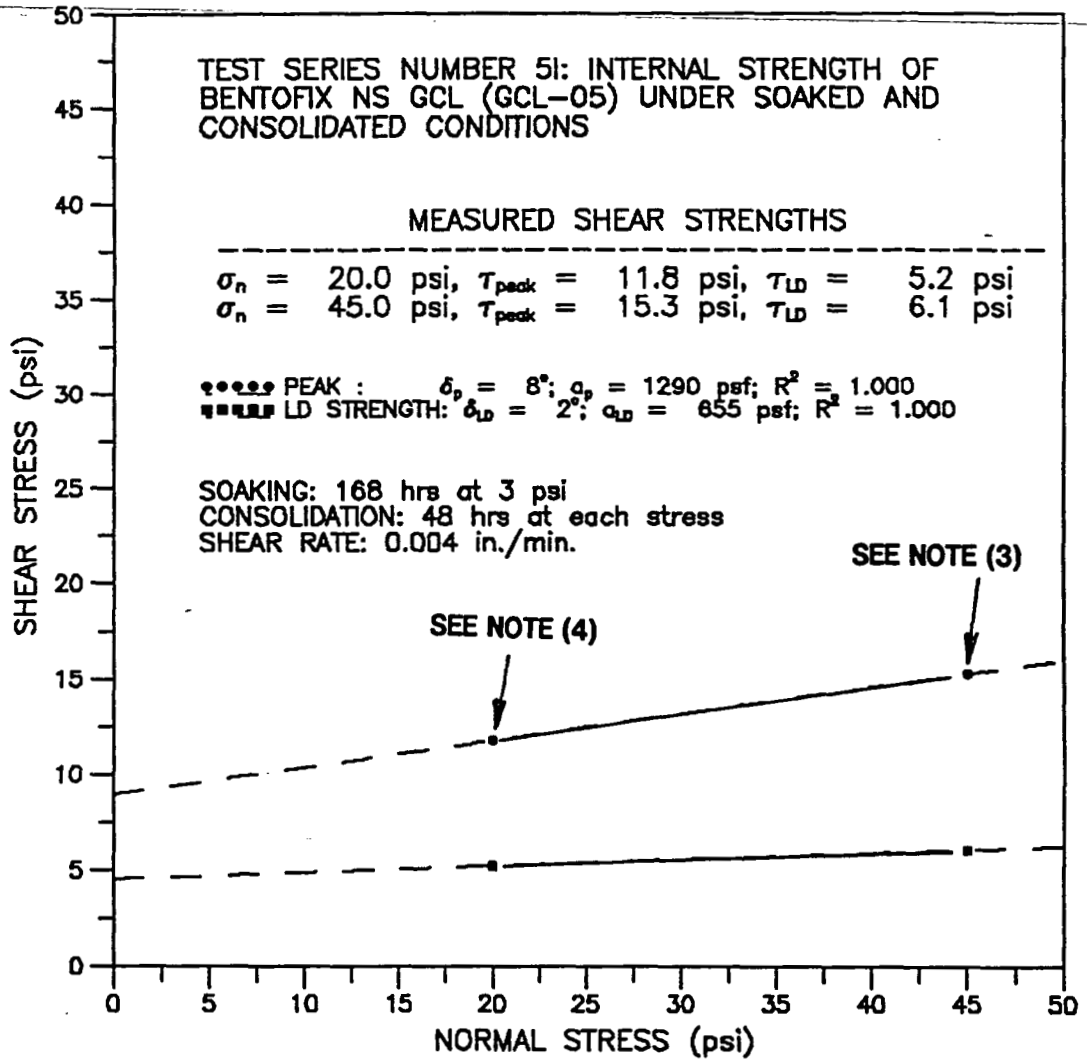
NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.
(2) Internal shear failure within GCL was observed.
(3) Partial internal shear failure within GCL was observed.

DATE TESTED: 18 TO 27 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730116
FILE NO.	000051

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



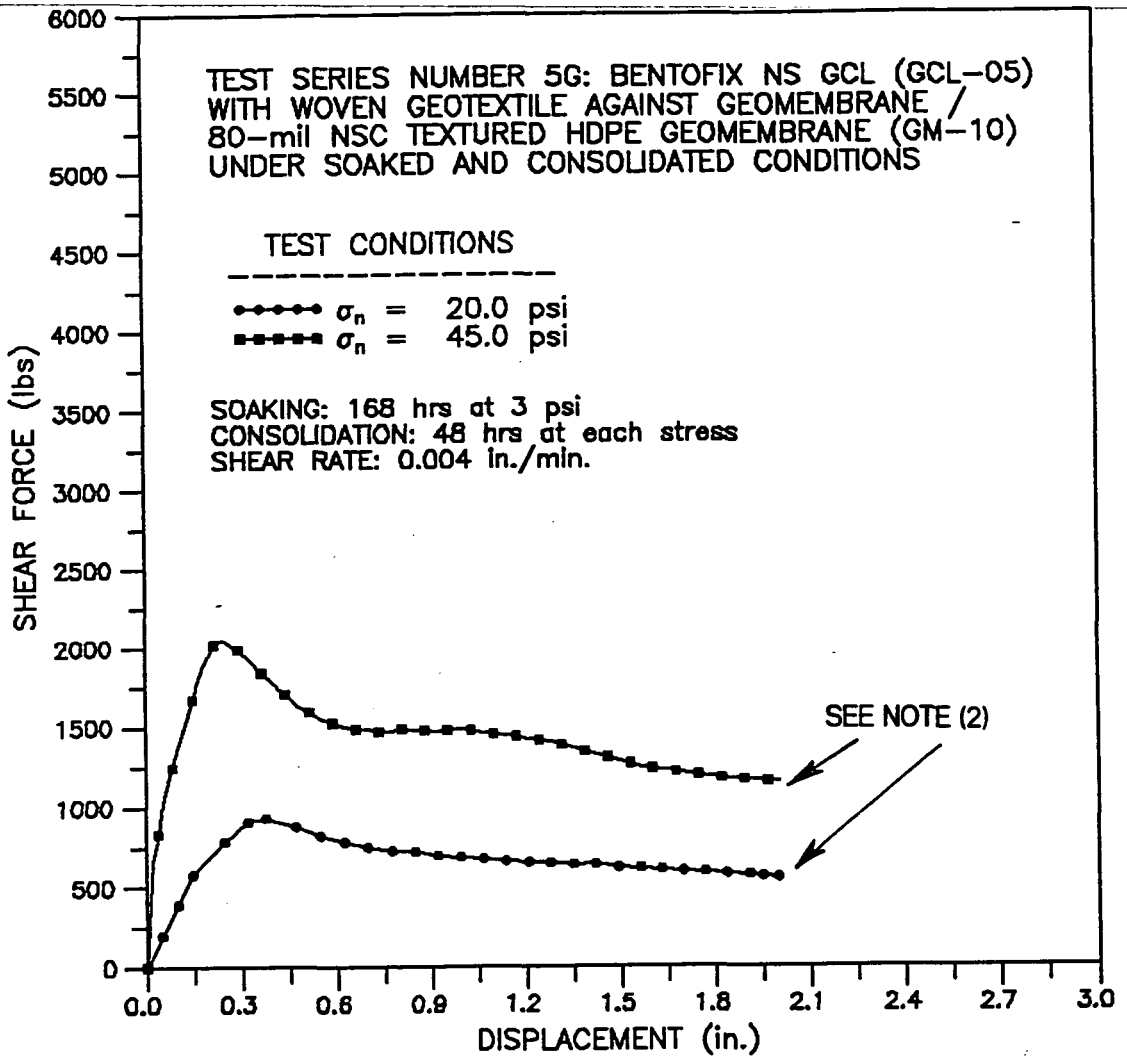
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Internal shear failure within GCL was observed.
(4) Partial internal failure within GCL was observed.

DATE TESTED: 18 TO 27 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730116
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

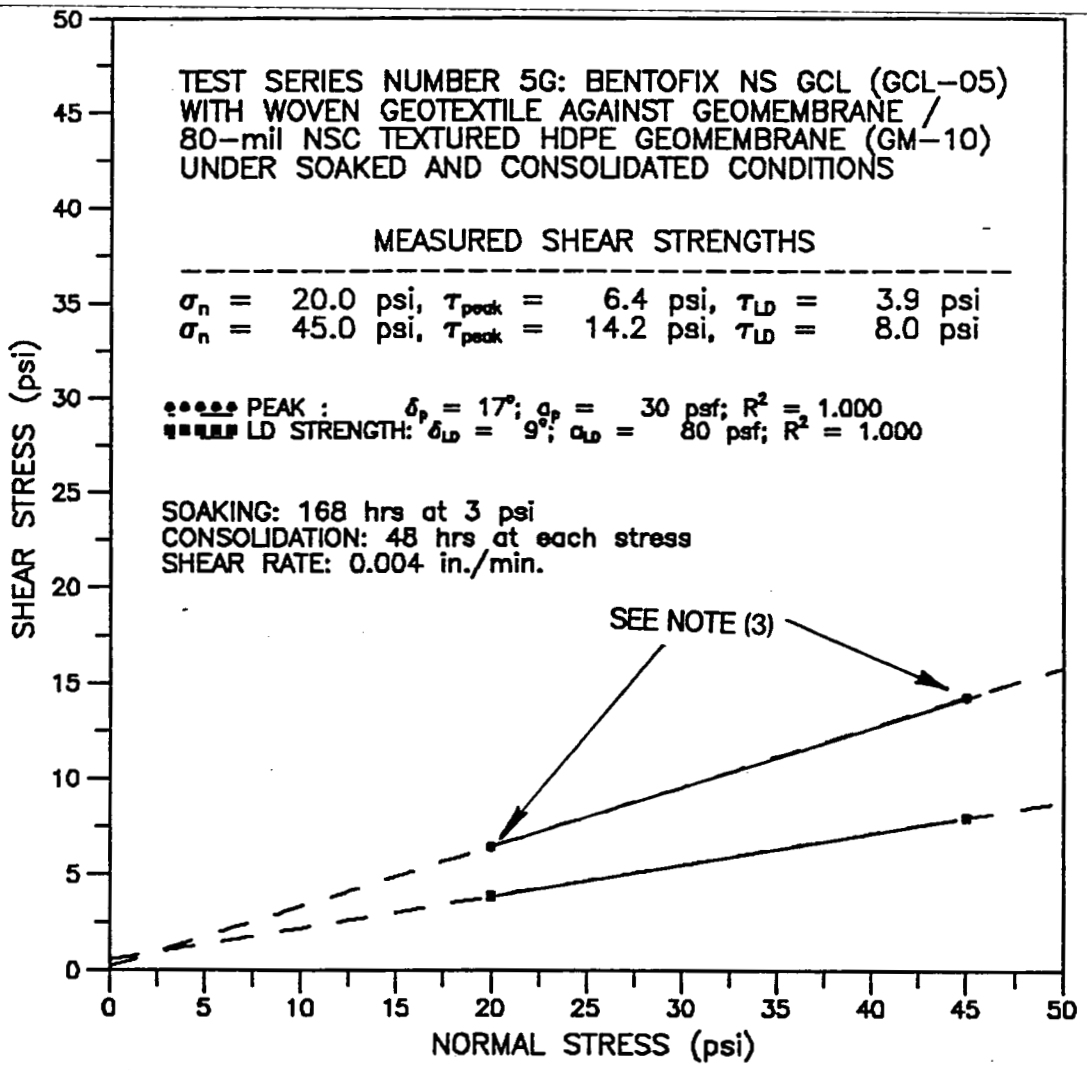
DATE TESTED: 18 TO 28 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730116
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 18 TO 28 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

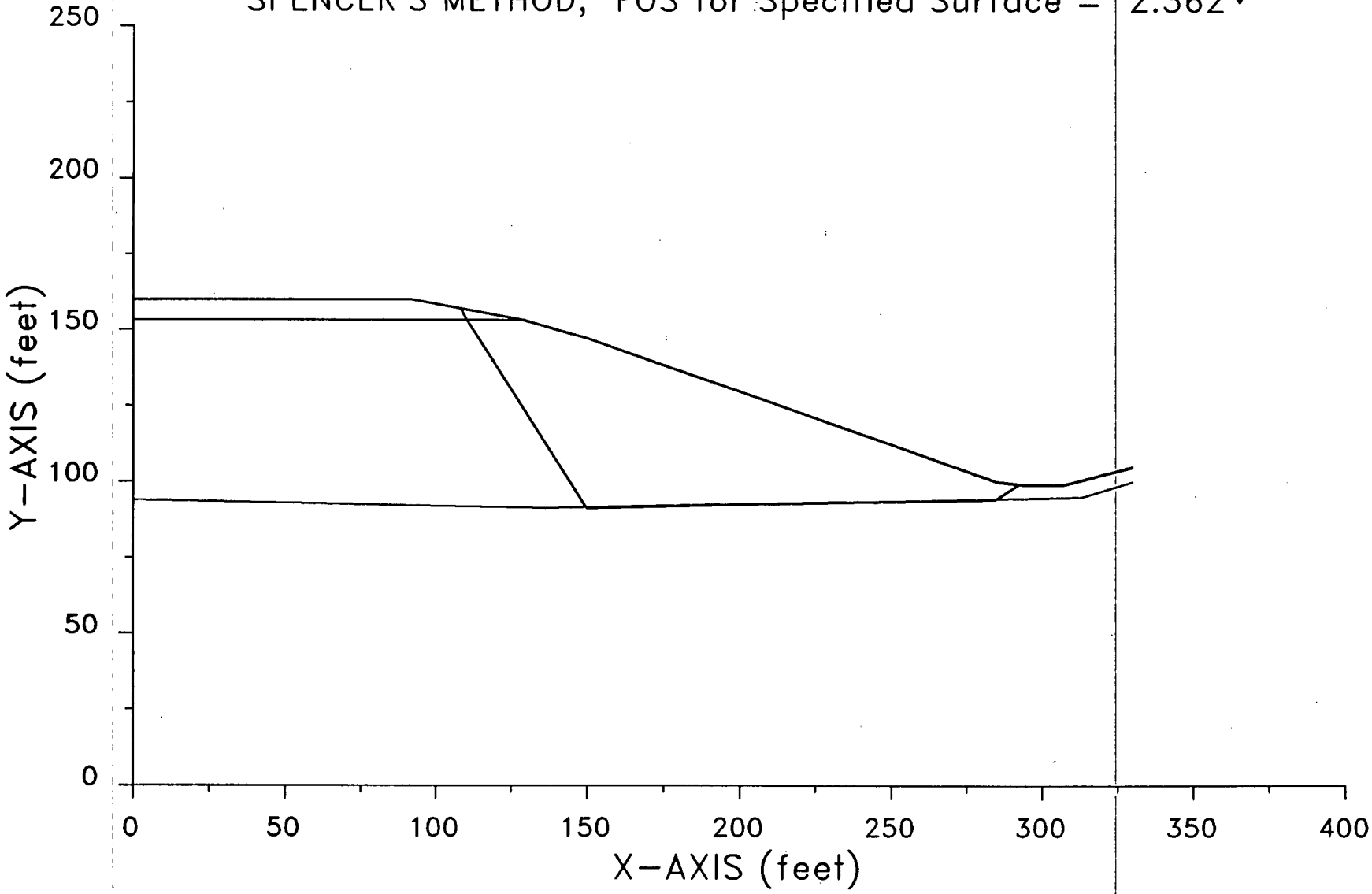
FIGURE NO.	A-4
PROJECT NO.	G00166-04.1
DOCUMENT NO.	F9730116
FILE NO.	000054

MCO NOV 6 1997
RAM 7 NOV 1997

APPENDIX B

NPROSAS 10-30-97 11:59

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.362 ✓



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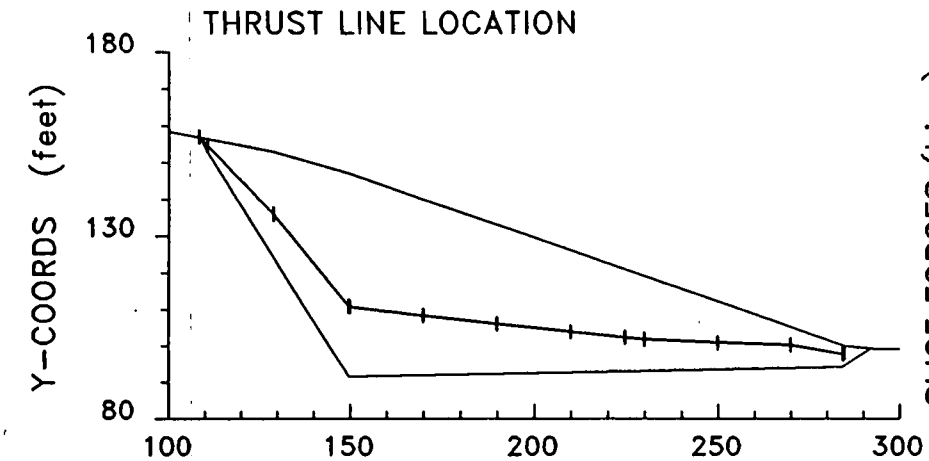

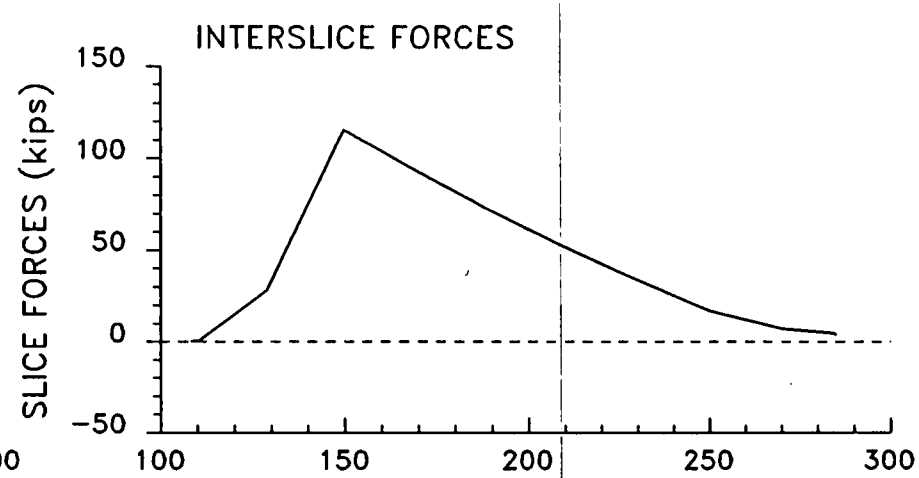

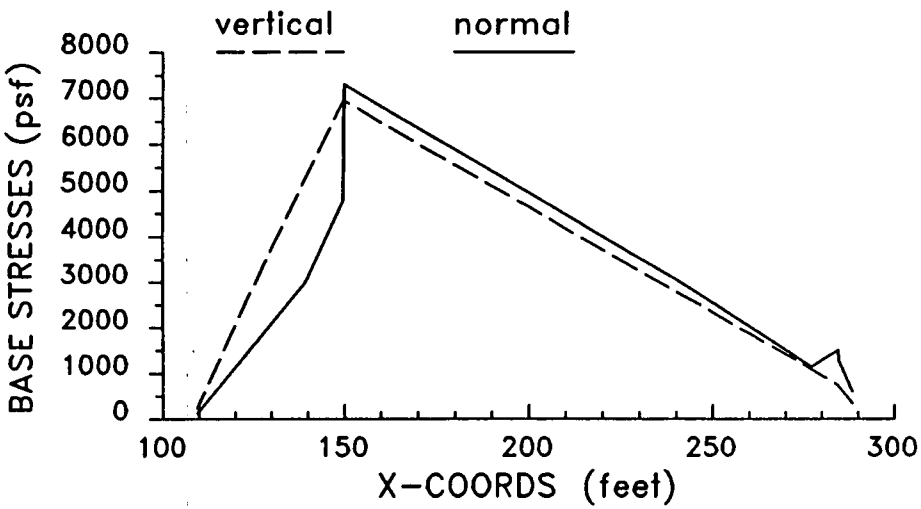

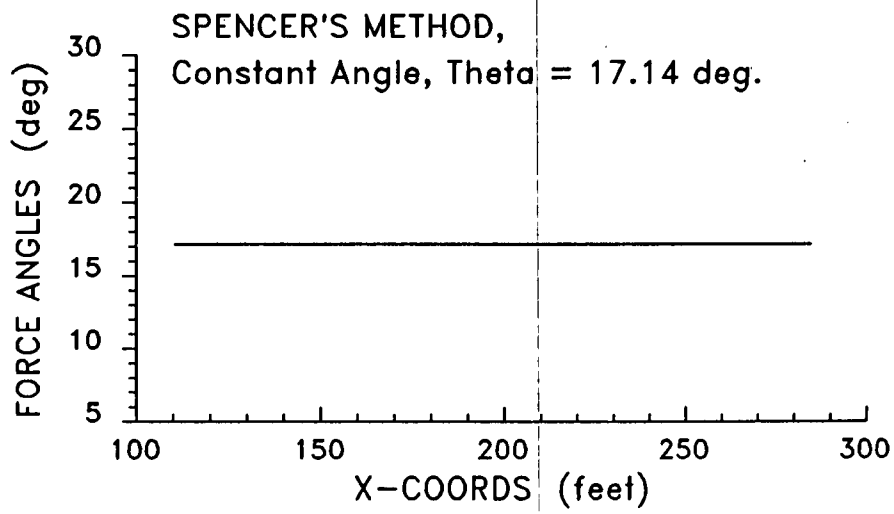

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.362 ✓

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*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	1699.2
5	6480.0	2203.2
6	10080.0	2203.2

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	292.24	99.20
2	284.70	94.39
3	284.49	94.19
4	224.80	93.00
5	149.87	91.47
6	149.68	91.67
7	110.61	153.00
8	108.35	156.91

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.62	96.89	2.71	7.24	-32.51	6.34	2452.
2	284.85	94.49	5.57	.30	-32.51	19.12	209.
3	284.60	94.29	5.85	.21	-43.60	19.12	154.
4	277.24	94.05	8.64	14.49	-1.14	19.12	15654.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37496.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55867.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.17	19.29	56723.
9	200.00	92.49	37.11	20.00	-1.17	19.29	92766.
10	180.00	92.09	44.46	20.00	-1.17	19.03	111162.
11	160.00	91.68	51.82	20.00	-1.17	19.29	129558.
12	149.93	91.47	55.55	.13	-1.17	15.95	903.
13	149.77	91.57	55.49	.19	46.47	15.95	1318.
14	139.34	107.90	42.14	20.68	57.50	15.95	108944.
15	119.80	138.57	16.17	18.39	57.50	10.71	37179.
16	109.48	154.95	1.74	2.26	59.95	10.71	491.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.1288	2.3838	2.3945
3	17.1380	2.3842	2.3838

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.1389	2.3620	2.3619

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	17.1389	2.3620	2.3619

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	591.8	.0	30.00	0.	0.	0.	.00
2	1258.0	200.0	25.00	0.	0.	0.	.00
3	1497.5	-566.4	38.19	0.	0.	0.	.00
4	1132.4	-566.4	38.19	0.	0.	0.	.00
5	2030.6	-566.4	38.19	0.	0.	0.	.00
6	3051.7	1296.0	7.97	0.	0.	0.	.00
7	3643.2	1296.0	7.97	0.	0.	0.	.00
8	4119.3	1296.0	7.97	0.	0.	0.	.00
9	4946.3	1296.0	7.97	0.	0.	0.	.00
10	5890.4	1296.0	7.97	0.	0.	0.	.00
11	6827.6	2203.2	.00	0.	0.	0.	.00
12	7296.1	2203.2	.00	0.	0.	0.	.00
13	4769.7	1296.0	7.97	0.	0.	0.	.00
14	2978.0	200.0	25.00	0.	0.	0.	.00
15	1104.9	200.0	25.00	0.	0.	0.	.00
16	115.7	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.62	591.8	338.7	.0	144.7
2	284.85	1258.0	695.8	.0	333.0
3	284.60	1497.5	731.3	.0	259.0
4	277.24	1132.4	1080.4	.0	137.4
5	260.00	2030.6	1874.8	.0	436.5
6	240.00	3051.7	2793.4	.0	729.6
7	227.40	3643.2	3369.8	.0	764.6
8	217.40	4119.3	3832.6	.0	792.9
9	200.00	4946.3	4638.3	.0	841.9
10	180.00	5890.4	5558.1	.0	897.8
11	160.00	6827.6	6477.9	.0	932.8
12	149.93	7296.1	6943.4	.0	932.8
13	149.77	4769.7	6936.8	.0	831.4
14	139.34	2978.0	5268.1	.0	672.6
15	119.80	1104.9	2021.7	.0	302.8
16	109.48	115.7	217.4	.0	28.3

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	17.14	3954.	3.42	5.42	.632
2	284.70	17.14	4310.	3.41	5.71	.597
3	284.49	17.14	4680.	3.40	5.99	.567
4	270.00	17.14	7105.	6.18	11.30	.547
5	250.00	17.14	17088.	7.22	18.70	.386
6	230.00	17.14	33631.	8.62	26.00	.332

7	224.80	17.14	38187.	9.20	27.92	.329
8	210.00	17.14	51770.	11.01	33.40	.330
9	190.00	17.14	71503.	13.64	40.81	.334
10	170.00	17.14	92812.	16.33	48.12	.339
11	150.00	17.14	115252.	19.09	55.53	.344
12	149.87	17.14	115400.	19.11	55.57	.344
13	149.68	17.14	114567.	19.10	55.42	.345
14	129.00	17.14	27956.	11.79	28.87	.408
15	110.61	17.14	406.	1.61	3.48	.462
16	108.35	.00	0.	-.06	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3218.61 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 599.22 (psf)

Total Length of failure surface = 221.39 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.362

Total shear strength available along specified failure surface = 313.33E+03 lb

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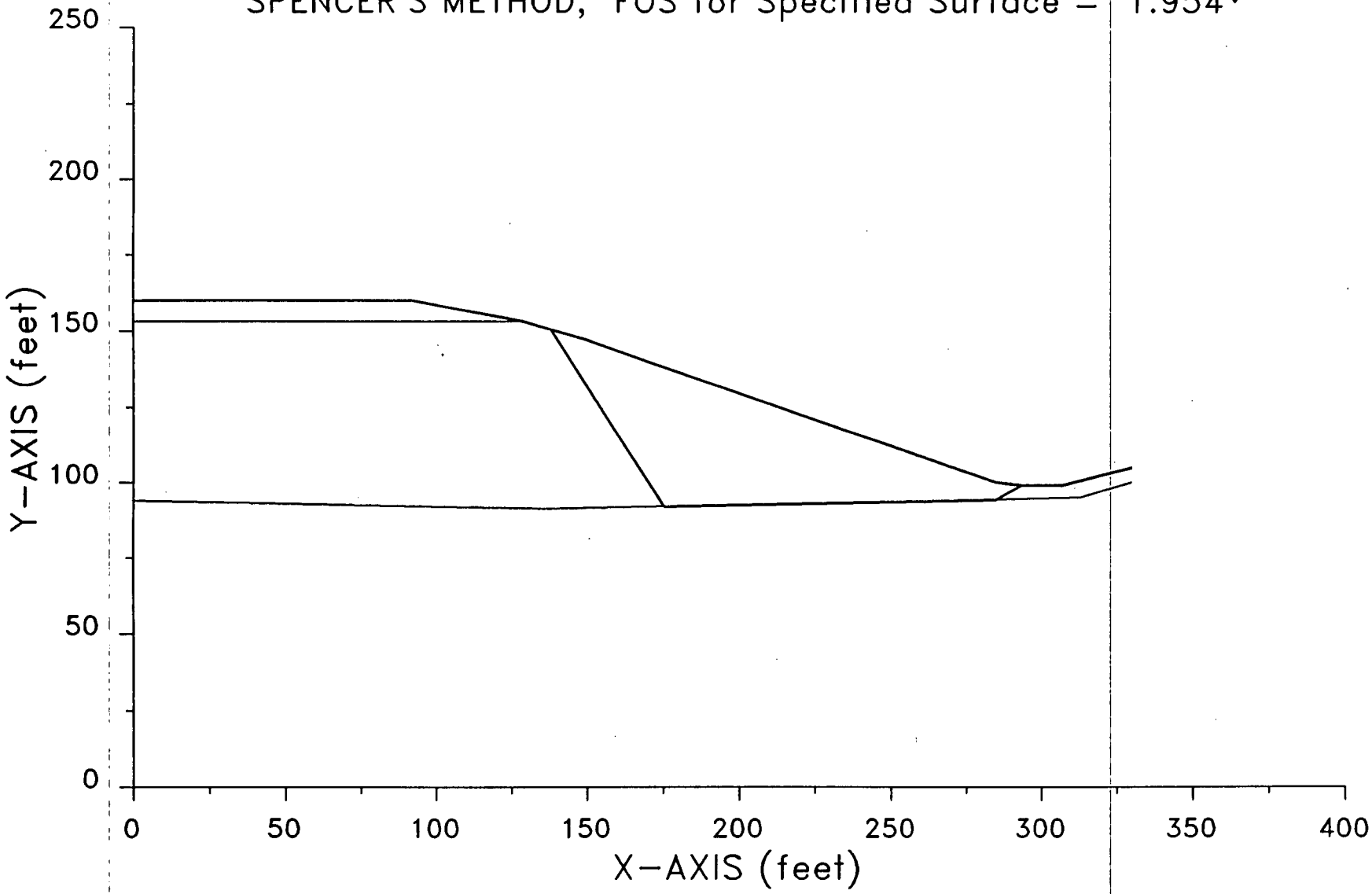
OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 1.954



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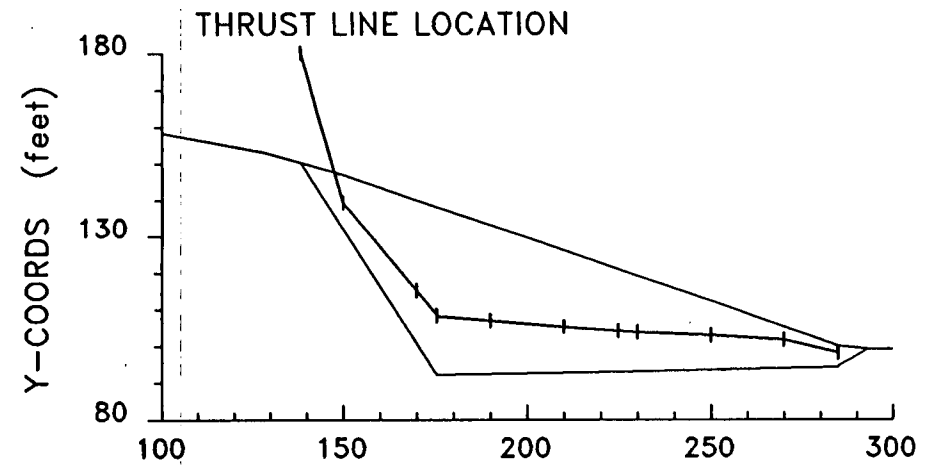

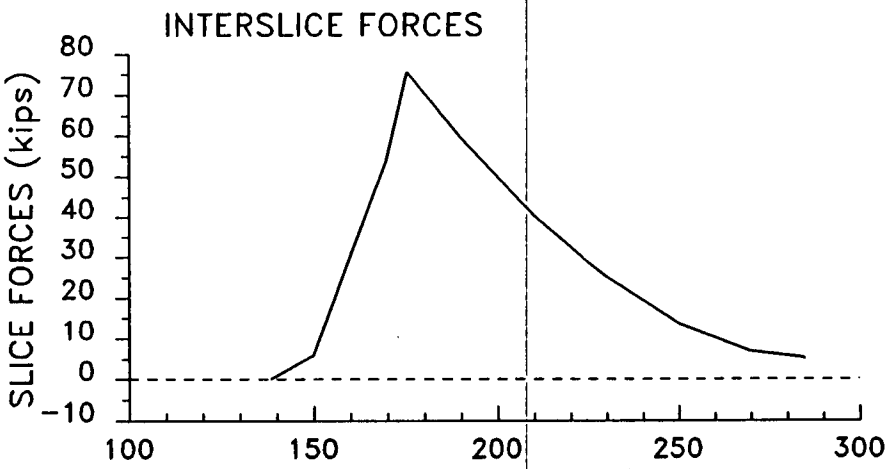

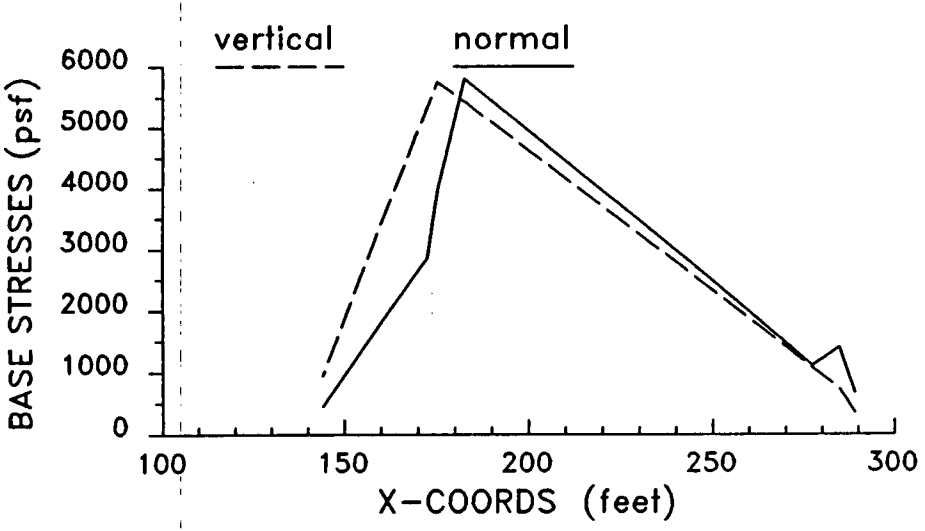

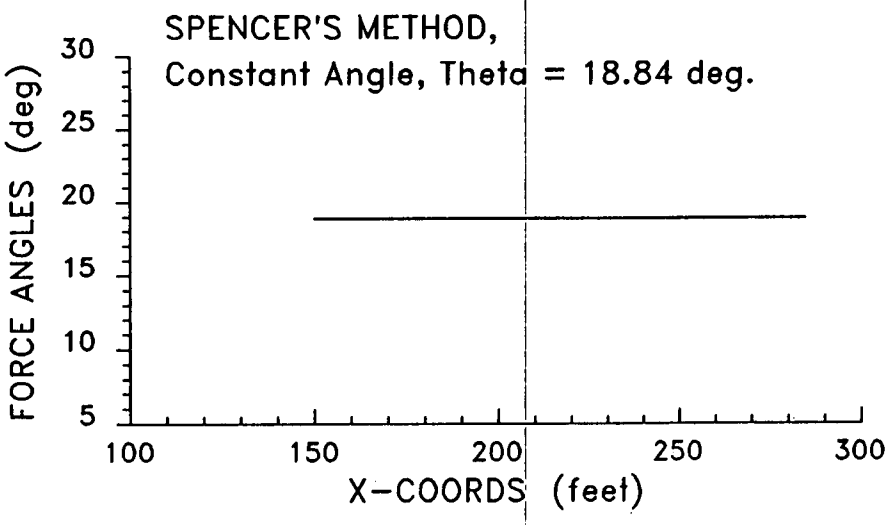

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 1.954 ✓

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*****************************************
*              X S T A B L              *
*                                       *
*       Slope Stability Analysis        *
*              using the                *
*           Method of Slices            *
*                                       *
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```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	921.6
5	6480.0	2044.8
6	10080.0	2044.8

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 7 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	293.27	99.08
2	285.17	94.40
3	284.97	94.20
4	224.80	93.00
5	175.56	92.03
6	175.40	92.19
7	138.37	150.32

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	289.22	96.74	2.79	8.10	-30.02	6.34	2825.
2	285.09	94.31	5.68	.17	-45.00	6.34	121.
3	284.98	94.21	5.79	.03	-45.00	19.12	22.
4	277.48	94.05	8.55	14.97	-1.14	19.12	16008.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37495.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55867.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.13	19.29	56713.
9	200.00	92.51	37.09	20.00	-1.13	19.29	92721.
10	182.78	92.17	43.42	14.44	-1.13	19.03	78371.
11	175.48	92.11	46.00	.16	45.00	19.03	931.
12	172.70	96.43	42.64	5.40	57.50	19.03	28771.
13	160.00	116.37	27.13	20.00	57.50	19.29	67834.
14	144.18	141.19	7.47	11.63	57.50	15.95	10856.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.8783	1.9564	1.9404
3	18.8660	1.9560	1.9564

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.8384	1.9539	1.9547

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	18.8384	1.9539	1.9547

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	656.6	.0	30.00	0.	0.	0.	.00

2	1362.3	-307.2	23.11	0.	0.	0.	.00
3	1401.5	-307.2	23.11	0.	0.	0.	.00
4	1107.4	-307.2	23.11	0.	0.	0.	.00
5	1988.3	-307.2	23.11	0.	0.	0.	.00
6	2990.4	23.0	17.33	0.	0.	0.	.00
7	3606.5	23.0	17.33	0.	0.	0.	.00
8	4100.0	23.0	17.33	0.	0.	0.	.00
9	4959.4	23.0	17.33	0.	0.	0.	.00
10	5805.1	23.0	17.33	0.	0.	0.	.00
11	3970.0	23.0	17.33	0.	0.	0.	.00
12	2845.6	200.0	25.00	0.	0.	0.	.00
13	1785.8	200.0	25.00	0.	0.	0.	.00
14	441.7	200.0	25.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	289.22	656.6	348.8	.0	194.0
2	285.09	1362.3	709.4	.0	140.3
3	284.98	1401.5	723.8	.0	148.8
4	277.48	1107.4	1069.3	.0	84.6
5	260.00	1988.3	1874.7	.0	276.9
6	240.00	2990.4	2793.4	.0	489.3
7	227.40	3606.5	3369.8	.0	587.7
8	217.40	4100.0	3832.0	.0	666.5
9	200.00	4959.4	4636.1	.0	803.7
10	182.78	5805.1	5427.3	.0	938.7
11	175.48	3970.0	5749.8	.0	645.7
12	172.70	2845.6	5329.8	.0	781.5
13	160.00	1785.8	3391.7	.0	528.5
14	144.18	441.7	933.4	.0	207.8

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.17	18.84	4908.	3.72	5.58	.667
2	285.00	18.84	5178.	3.75	5.77	.650
3	284.97	18.84	5227.	3.75	5.81	.646
4	270.00	18.84	6914.	7.59	11.30	.671
5	250.00	18.84	13605.	9.30	18.70	.498
6	230.00	18.84	25205.	10.58	26.00	.407
7	224.80	18.84	28829.	11.01	27.92	.394
8	210.00	18.84	40514.	12.41	33.39	.372
9	190.00	18.84	59562.	14.50	40.79	.356
10	175.56	18.84	75630.	16.08	46.05	.349
11	175.40	18.84	75061.	16.09	45.95	.350
12	170.00	18.84	54039.	14.43	39.33	.367
13	150.00	18.84	5965.	7.14	14.93	.478

14	138.37	.00	-3.	59.50	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 2607.29 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 495.06 (psf)

Total Length of failure surface = 188.22 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.954

Total shear strength available along specified failure surface = 182.07E+03 lb

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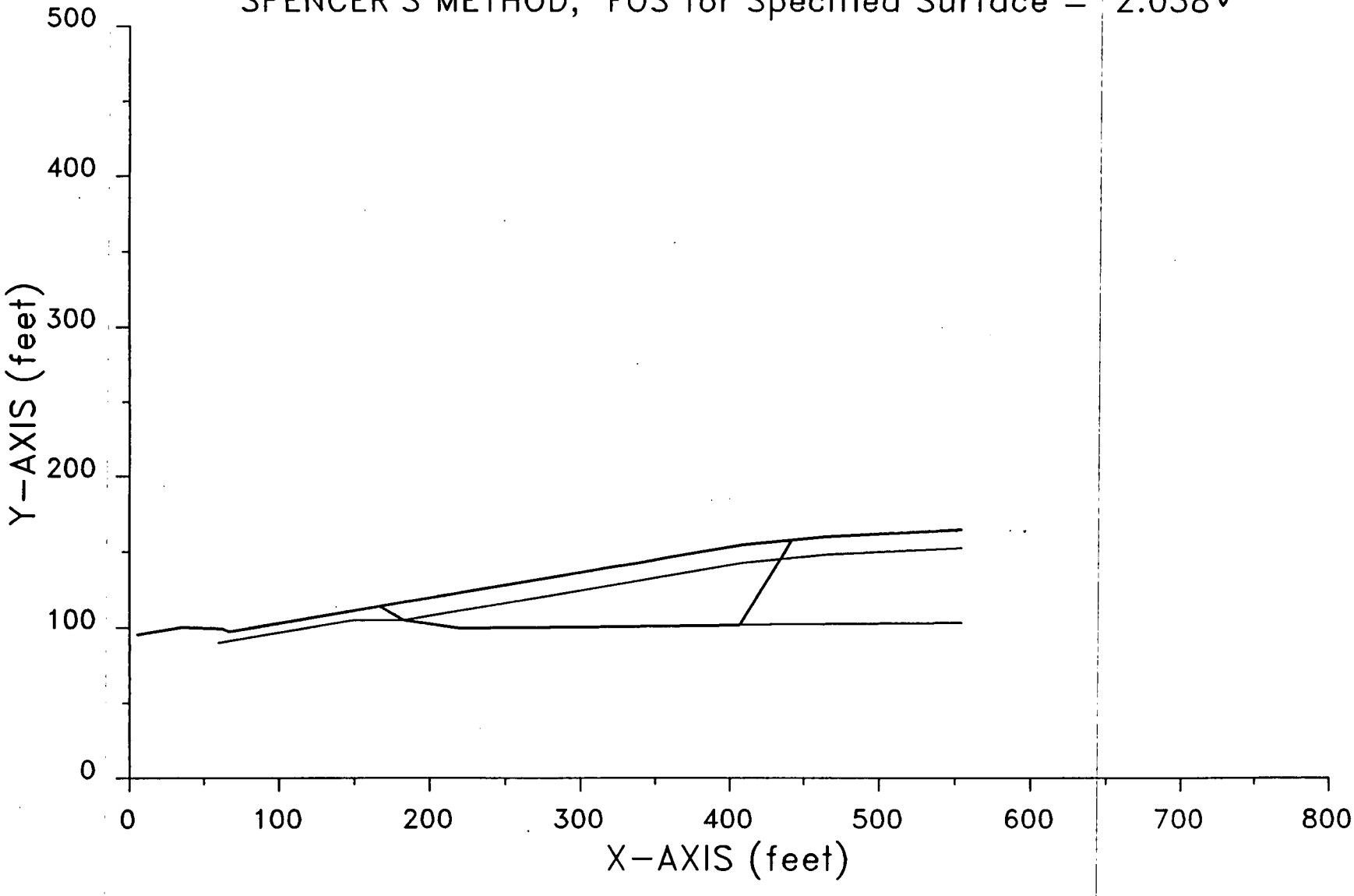
OSDF Final Long Term – Large Displ.

SPENCER'S METHOD, FOS for Specified Surface = 2.038 ✓



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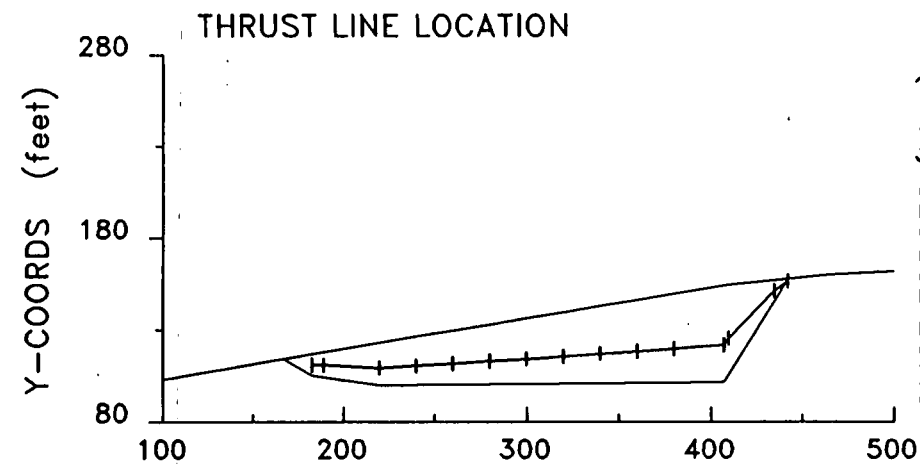

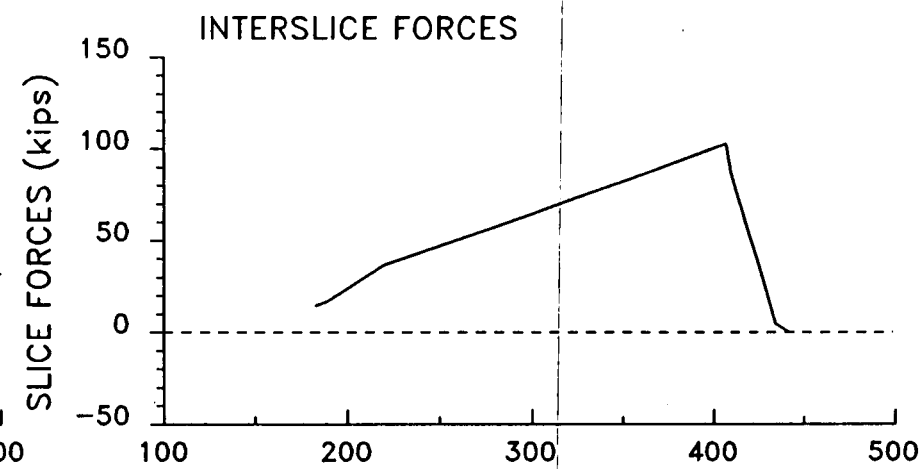

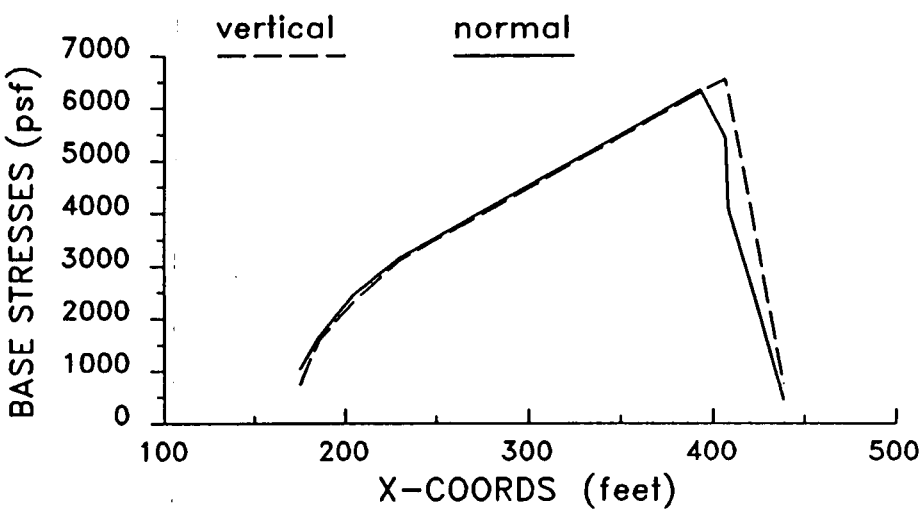

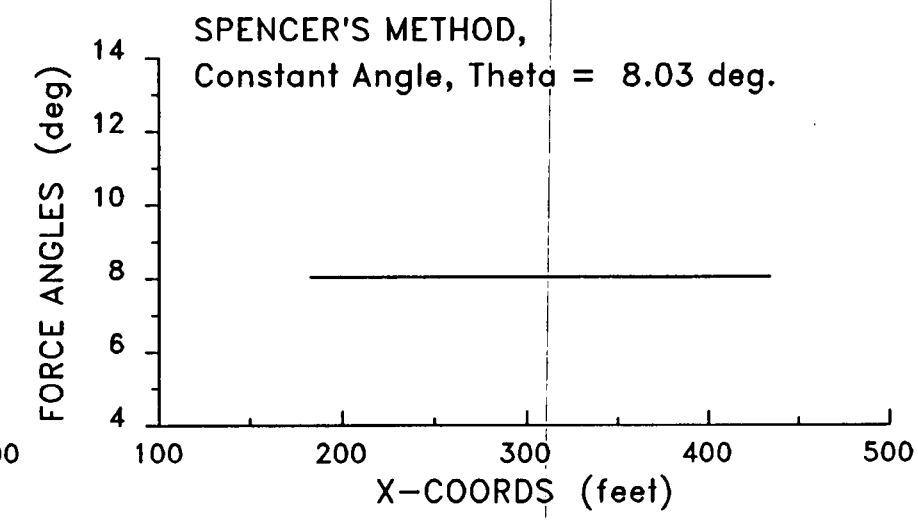

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.038 ✓

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*            Method of Slices           *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	748.8
5	6480.0	878.4
6	10080.0	878.4

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	407.12	101.72
6	407.37	101.97
7	434.97	145.30
8	442.26	157.93

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.70	37.35	20.00	.60	9.37	93364.
9	330.00	100.91	40.44	20.00	.60	9.37	101091.
10	350.00	101.12	43.58	20.00	.60	9.65	108943.
11	370.00	101.33	46.72	20.00	.60	9.37	116795.
12	393.56	101.58	50.38	27.12	.60	9.46	170794.
13	407.25	101.85	52.40	.25	45.00	9.46	1643.
14	408.69	104.04	50.45	2.63	57.50	9.46	16579.
15	422.48	125.70	30.25	24.97	57.50	5.71	94415.
16	438.61	151.61	5.95	7.29	60.00	5.71	5421.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	8.0052	2.0371	2.0690
3	8.0278	2.0378	2.0371

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	8.0278	2.0378	2.0371

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1034.5	.0	30.00	0.	0.	0.	.00
2	1673.2	-249.6	19.12	0.	0.	0.	.00

3	2435.2	-249.6	19.12	0.	0.	0.	.00
4	3144.3	645.1	2.06	0.	0.	0.	.00
5	3538.4	645.1	2.06	0.	0.	0.	.00
6	3926.3	645.1	2.06	0.	0.	0.	.00
7	4320.4	645.1	2.06	0.	0.	0.	.00
8	4713.4	645.1	2.06	0.	0.	0.	.00
9	5100.1	645.1	2.06	0.	0.	0.	.00
10	5493.1	645.1	2.06	0.	0.	0.	.00
11	5886.0	645.1	2.06	0.	0.	0.	.00
12	6344.3	645.1	2.06	0.	0.	0.	.00
13	5429.4	645.1	2.06	0.	0.	0.	.00
14	4072.4	.0	25.00	0.	0.	0.	.00
15	2442.0	.0	25.00	0.	0.	0.	.00
16	438.7	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1034.5	739.6	.0	293.1
2	186.00	1673.2	1594.4	.0	162.2
3	204.50	2435.2	2304.8	.0	291.8
4	230.00	3144.3	3100.0	.0	372.1
5	250.00	3538.4	3493.8	.0	379.1
6	270.00	3926.3	3881.3	.0	385.9
7	290.00	4320.4	4275.0	.0	392.9
8	310.00	4713.4	4668.2	.0	399.8
9	330.00	5100.1	5054.5	.0	406.7
10	350.00	5493.1	5447.2	.0	413.6
11	370.00	5886.0	5839.8	.0	420.6
12	393.56	6344.3	6297.7	.0	428.7
13	407.25	5429.4	6549.4	.0	412.5
14	408.69	4072.4	6305.7	.0	931.9
15	422.48	2442.0	3781.1	.0	558.8
16	438.61	438.7	743.6	.0	124.3

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	8.03	14300.	5.72	11.83	.483
2	189.00	8.03	16707.	6.46	13.68	.473
3	220.00	8.03	36557.	9.32	23.20	.402
4	240.00	8.03	43438.	10.26	26.40	.389
5	260.00	8.03	50380.	11.30	29.50	.383
6	280.00	8.03	57383.	12.39	32.60	.380
7	300.00	8.03	64446.	13.51	35.80	.377
8	320.00	8.03	71527.	14.67	38.89	.377
9	340.00	8.03	78664.	15.84	41.98	.377
10	360.00	8.03	85858.	17.02	45.17	.377

11	380.00	8.03	93109.	18.21	48.26	.377
12	407.12	8.03	103033.	19.84	52.50	.378
13	407.37	8.03	101762.	19.87	52.29	.380
14	410.00	8.03	87261.	19.10	48.60	.393
15	434.97	8.03	4677.	5.80	11.90	.487
16	442.26	.00	-2.	-1.50	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3692.78 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 397.96 (psf)

Total Length of failure surface = 309.16 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.038

Total shear strength available along specified failure surface = 250.72E+03 lb

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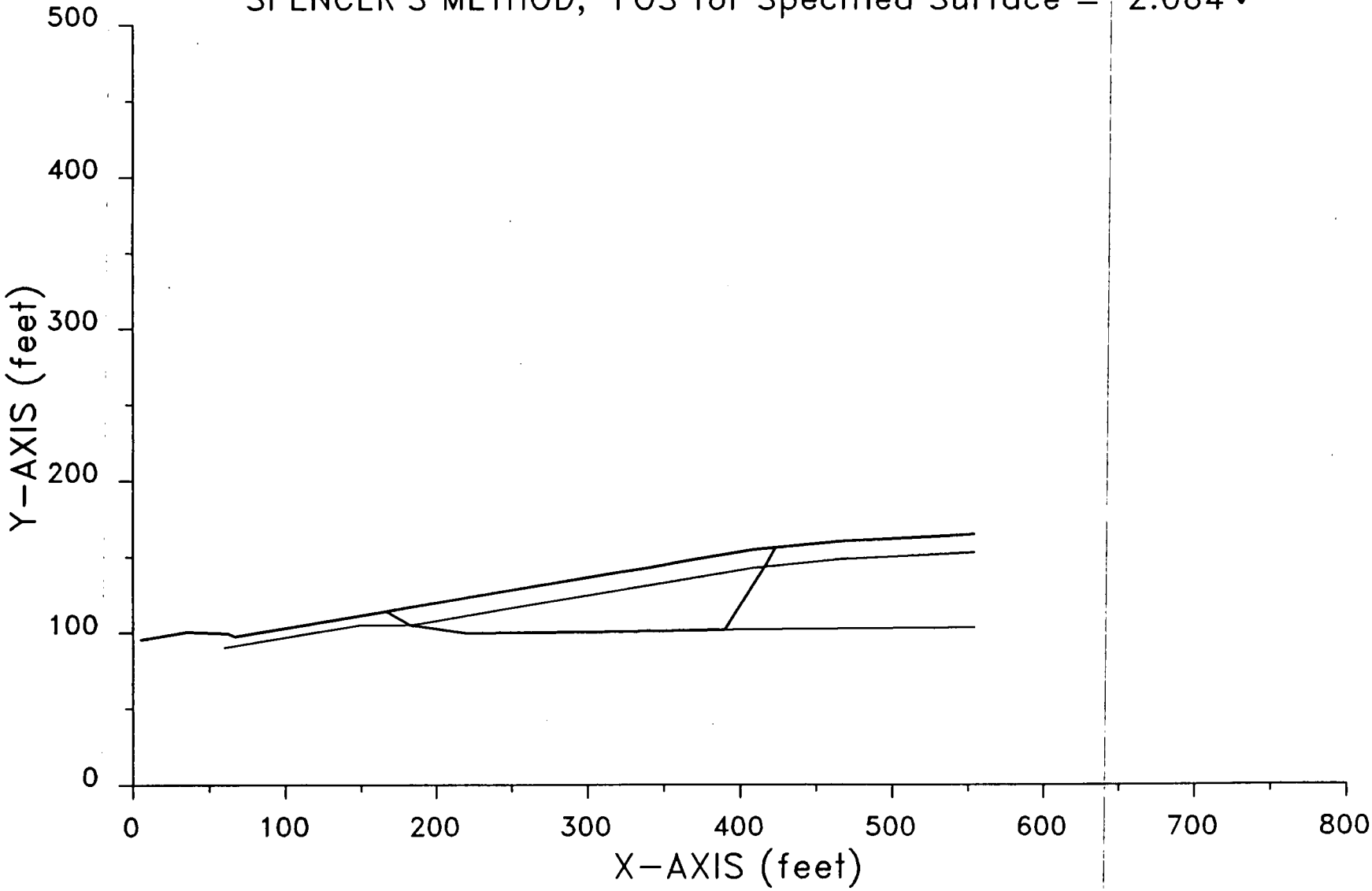
OSDF Final Long Term – Large Displ.

SPENCER'S METHOD, FOS for Specified Surface = 2.064 ✓



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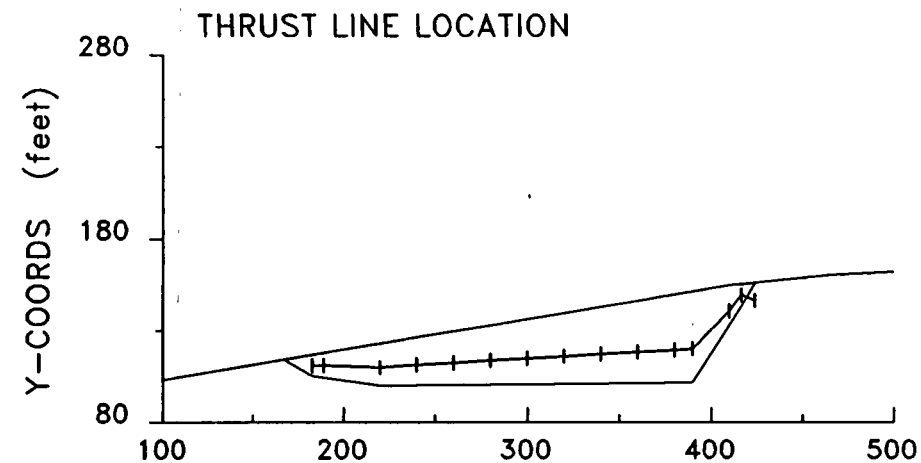

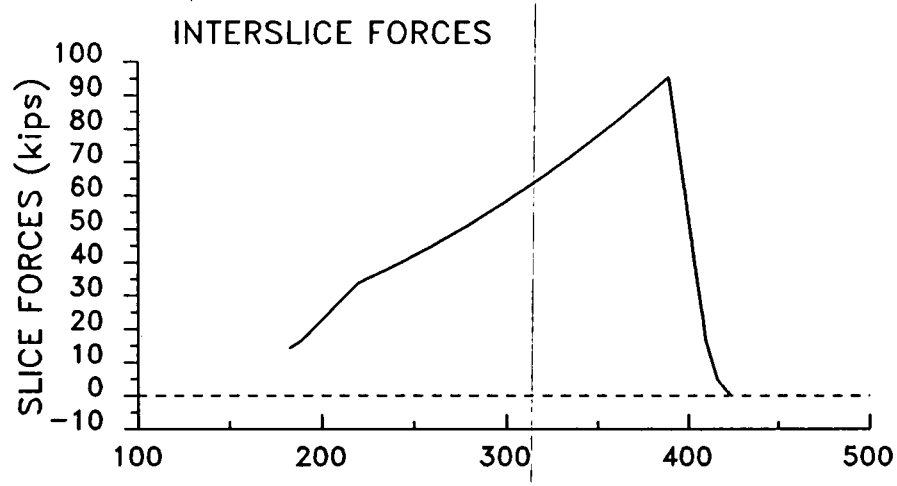

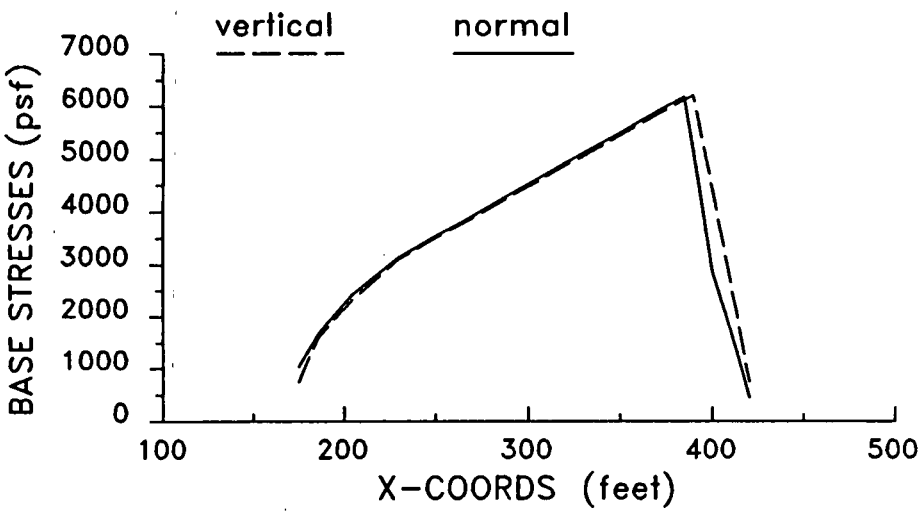

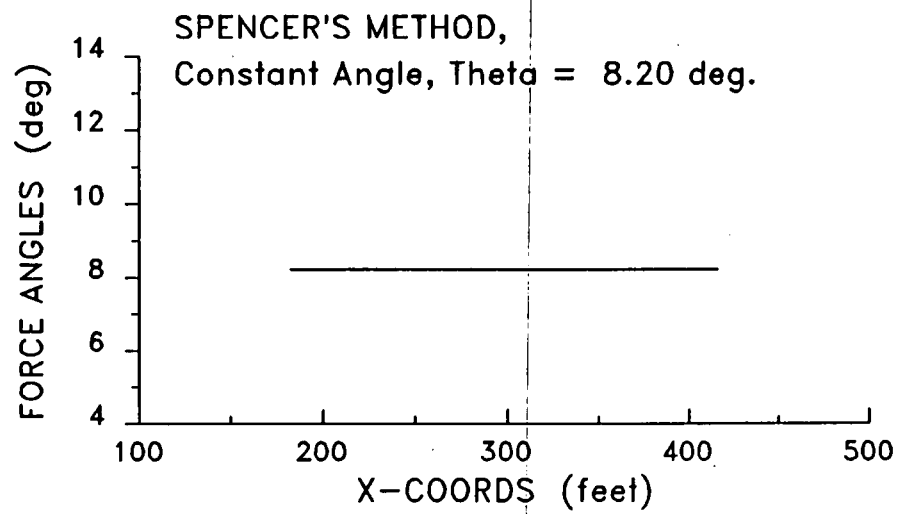

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.064

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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	561.6
5	6480.0	1152.0
6	10080.0	1152.0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	389.94	101.63
6	390.10	101.78
7	416.65	143.47
8	423.95	156.10

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.66	9.37	93339.
9	330.00	100.94	40.41	20.00	.66	9.37	101016.
10	350.00	101.17	43.53	20.00	.66	9.65	108818.
11	370.00	101.40	46.65	20.00	.66	9.37	116621.
12	384.97	101.57	48.96	9.94	.66	9.46	60827.
13	390.02	101.71	49.66	.16	43.15	9.46	1005.
14	400.05	117.41	35.64	19.90	57.51	9.46	88637.
15	413.33	138.25	16.78	6.65	57.51	5.71	13951.
16	420.30	149.78	5.95	7.30	59.96	5.71	5427.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	8.1738	2.0633	2.0994
3	8.2017	2.0642	2.0633

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	8.2017	2.0642	2.0633

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1034.5	.0	30.00	0.	0.	0.	.00
2	1661.8	-187.2	14.57	0.	0.	0.	.00

3	2414.4	-187.2	14.57	0.	0.	0.	.00
4	3134.7	89.3	9.31	0.	0.	0.	.00
5	3532.1	89.3	9.31	0.	0.	0.	.00
6	3923.2	89.3	9.31	0.	0.	0.	.00
7	4320.6	89.3	9.31	0.	0.	0.	.00
8	4714.6	89.3	9.31	0.	0.	0.	.00
9	5101.9	89.3	9.31	0.	0.	0.	.00
10	5495.5	89.3	9.31	0.	0.	0.	.00
11	5889.1	89.3	9.31	0.	0.	0.	.00
12	6180.1	89.3	9.31	0.	0.	0.	.00
13	5152.7	89.3	9.31	0.	0.	0.	.00
14	2876.7	.0	25.00	0.	0.	0.	.00
15	1354.8	.0	25.00	0.	0.	0.	.00
16	439.2	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1034.5	739.6	.0	289.4
2	186.00	1661.8	1594.4	.0	118.6
3	204.50	2414.4	2304.8	.0	213.4
4	230.00	3134.7	3100.0	.0	292.3
5	250.00	3532.1	3493.8	.0	323.9
6	270.00	3923.2	3881.3	.0	354.9
7	290.00	4320.6	4275.0	.0	386.5
8	310.00	4714.6	4666.9	.0	417.8
9	330.00	5101.9	5050.8	.0	448.6
10	350.00	5495.5	5440.9	.0	479.9
11	370.00	5889.1	5831.0	.0	511.1
12	384.97	6180.1	6119.4	.0	534.3
13	390.02	5152.7	6208.0	.0	452.6
14	400.05	2876.7	4454.6	.0	649.9
15	413.33	1354.8	2097.9	.0	306.1
16	420.30	439.2	743.4	.0	122.9

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	8.20	14247.	5.74	11.83	.485
2	189.00	8.20	16382.	6.59	13.68	.482
3	220.00	8.20	33694.	9.77	23.20	.421
4	240.00	8.20	38967.	10.96	26.40	.415
5	260.00	8.20	44798.	12.05	29.50	.408
6	280.00	8.20	51177.	13.07	32.60	.401
7	300.00	8.20	58114.	14.04	35.80	.392
8	320.00	8.20	65466.	14.98	38.87	.385
9	340.00	8.20	73350.	15.89	41.94	.379
10	360.00	8.20	81775.	16.78	45.11	.372

11	380.00	8.20	90740.	17.65	48.18	.366
12	389.94	8.20	95395.	18.08	49.73	.364
13	390.10	8.20	94679.	18.09	49.60	.365
14	410.00	8.20	16931.	7.66	21.67	.353
15	416.65	8.20	4694.	5.78	11.89	.486
16	423.95	.00	-3.	-9.92	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3515.81 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 386.62 (psf)

Total Length of failure surface = 289.90 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.064

Total shear strength available along specified failure surface = 231.36E+03 lb

GCL 06

COMPUTATION COVER SHEET

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) QA06 and QC03 - Compliance Package

Computations By: (Cognizant Engineer)
Signature [signature] Date Dec 18 1997
Printed Name and Title MARIA CATALINA OROZCO, STAFF ENGINEER

Assumptions and Procedures Checked By: (Checker)
Signature [signature] Date 19 DEC 1997
Printed Name and Title ROBERT A. MORGAN III, SR. STAFF ENGINEER

Computations Checked by:
Signature [signature] Date 19 DEC 1997
Printed Name and Title ROBERT A. MORGAN III, SR. STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date Dec 19 1997
Printed Name and Title MARIA CATALINA OROZCO, STAFF ENGINEER

Approved by: (PDP)
Signature [signature] Date 19 Dec 97
Printed Name and Title Gary R. Schmertmann, Sr. Project Engr.

Approved by: (DTL and TETL)
Signature [signature] Date 20 Dec 97
Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

Written By : YCO Date: 12/18/97 Reviewed by: RAM Date: 12/19/97

Client: FDF Project: OSDF Project/Proposal No.: GQ-0409 Task No.: 04

PURPOSE

Evaluate whether GCL lot number 97082502 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3). The evaluation is based on the shear test results from GCL QA sample no. 06 and GCL QC sample no. 03.

METHOD

The method for evaluating the GCL samples is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL samples to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 06 and the results of the GCL internal shear tests performed on QC sample no. 03 are shown in the following table. The results of the GCL internal shear tests for QA sample no. 06 were averaged with the results of the GCL internal shear tests for QC sample no. 03. The averaged values for the GCL internal shear tests were used in the stability analyses. The laboratory test results for GCL QA sample no. 06 are presented in Appendix A. The laboratory test results for GCL QC sample no. 03 are presented in Appendix B.

Test Type	Case	Sample No.	Measured Shear Strengths (psi)		
			5 psi	20 psi	45 psi
GCL Internal	Peak	QA 06	3.8	7.7	9.8
		QC 03	(2)	(2)	15.76
		Average QA06-QC03	**3.8**	**7.7**	**12.780**
	Large-displacement	QA 06	1.3	3.4	4.2
		QC 03	(2)	(2)	3.35
		Average QA06-QC03	**1.3**	**3.4**	**3.775**
GCL/GMB Interface	Peak	QA 06	**0**(1)	**7.0**	**14.9**
	Large-displacement	QA 06	**0**(1)	**3.3**	**6.4**

(1) Interface shear strength values for QA sample 06 at 5 psi normal stress were not available at the time that this calculation package was prepared. These values were assumed to equal zero. This assumption is conservative in the context of RCI 1702-006R.

(2) GeoSyntec requested that the shear strength values measured for QC sample 03 at 5 and 20 psi normal stress be verified. A response from AGP Laboratories dated October 23 1997 indicated that these values might be not representative (included in Appendix B). These values were not included in the slope stability analysis performed.

Written By.: MCO Date: 12/18/97 Reviewed by: RAM Date: 12/19/97

Client: FDF Project: OSDF Project/Proposal No.: GQ-0409 Task No.: 04

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix C.

Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
Average QA06-QC03	GCL Internal	NPPK06AS ✓	2.0 ✓	YES ✓
QA 06	GCL/GMB Interface	NPK06BS ✓	2.0 ✓	YES ✓
Baseline	Large-displacement	NA	1.6	NA
Average QA06-QC03	GCL Internal	NPL06ADS ✓	1.5 ✓	NO ✓
QA 06	GCL/GMB Interface	NLD06BS ✓	1.8 ✓	YES ✓

YMCO Doc 18/97

RAM 19 DEC 97

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 6I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-6). GCL's initial moisture content was 9.4%. GCL's final moisture content ranged from 87% to 108% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 6G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

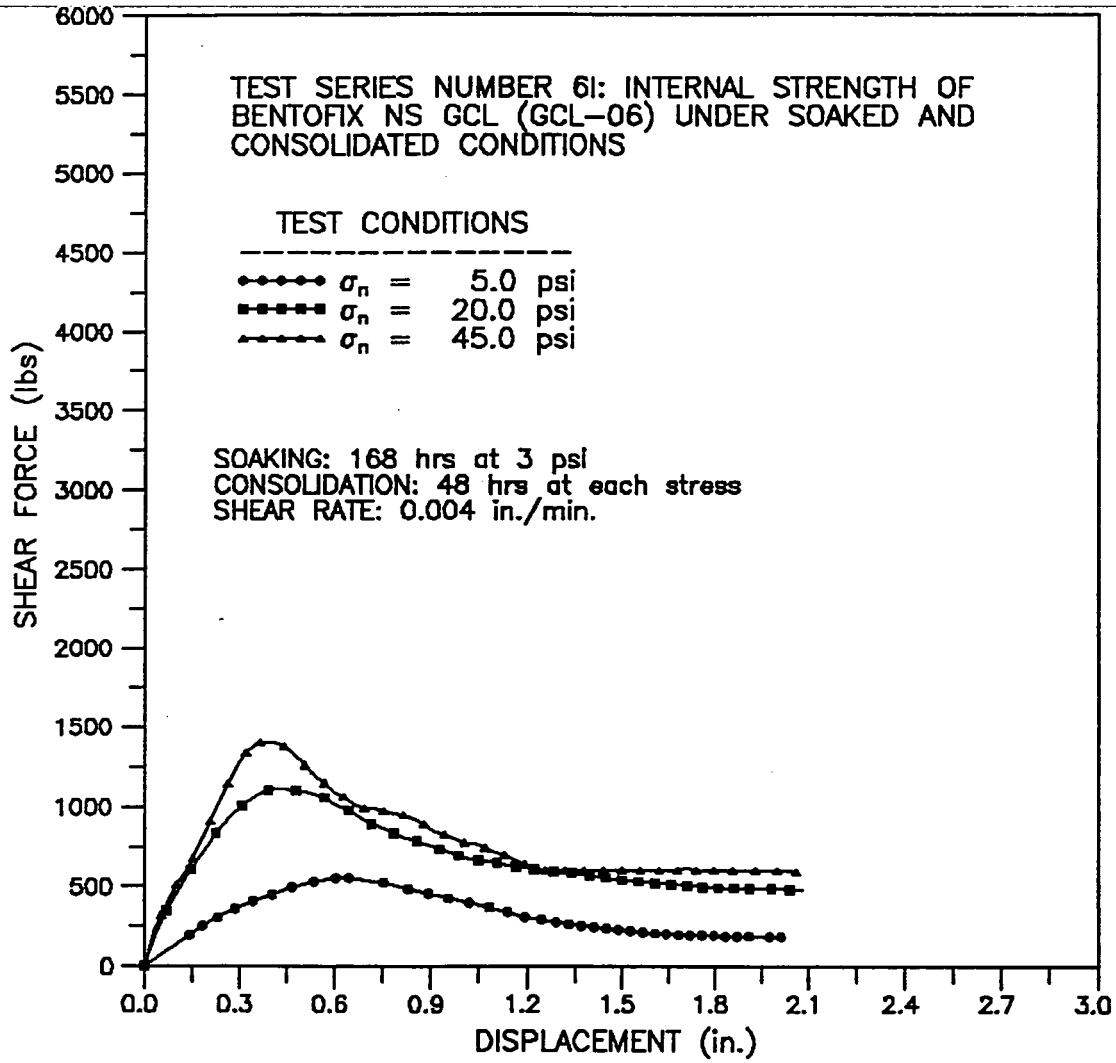
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-6) with woven geotextile against geomembrane. GCL's initial moisture content was 9.6%. GCL's final moisture content ranged from 60 to 91% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-8); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20 and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.

(2) For each test, sliding (i.e., internal shear failure) was observed to occur within the GCL.

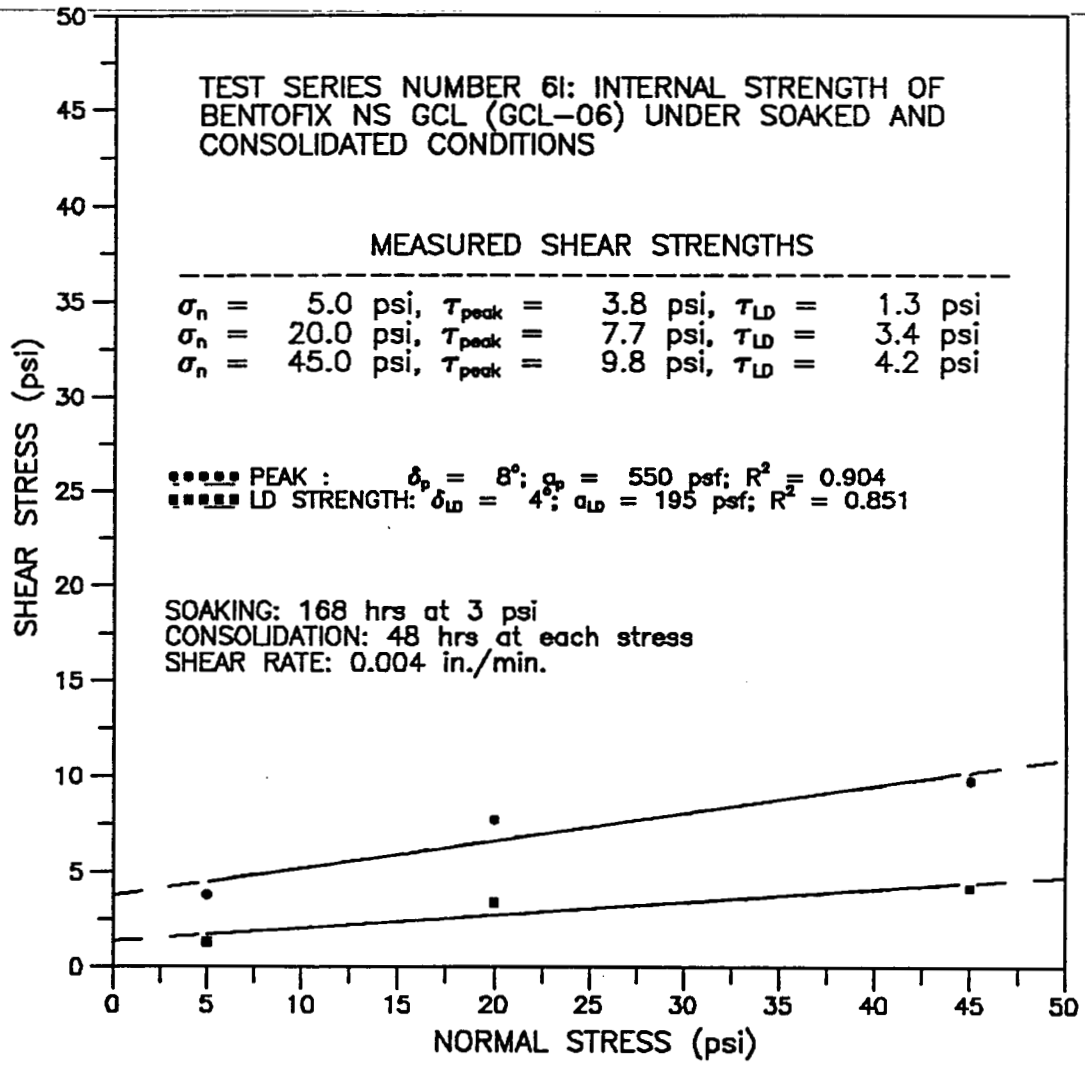
DATE TESTED: 29 SEPTEMBER TO 12 NOVEMBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730109
FILE NO.	000091

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



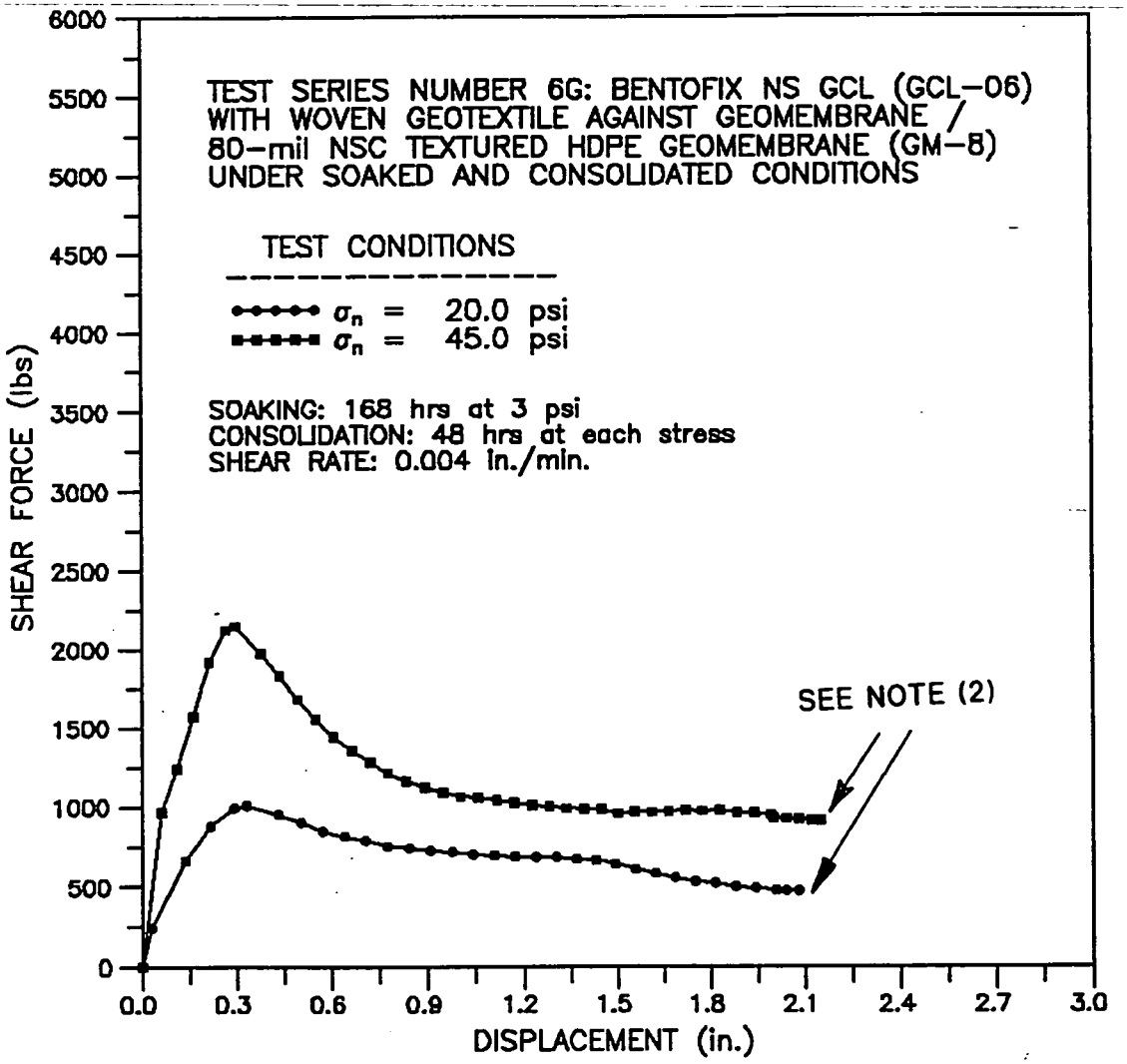
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) For each test, sliding (i.e, internal shear failure) was observed to occur within the GCL.

DATE TESTED: 29 SEPTEMBER TO 12 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730109
FILE NO.	

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

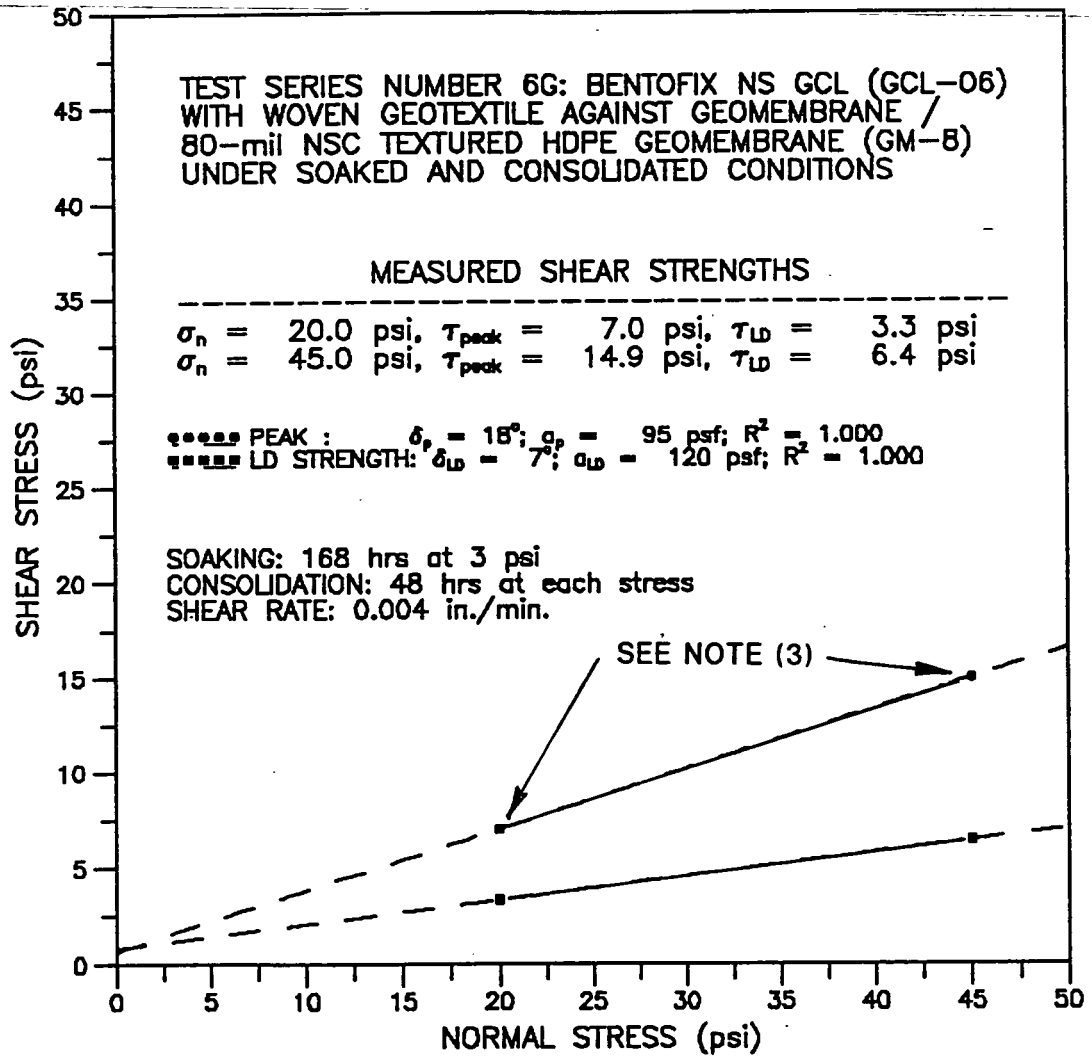
DATE TESTED: 29 SEPTEMBER TO 8 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730109
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 29 SEPTEMBER TO 8 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730109
FILE NO.	

YMCD Doc 18/97
RAM 19 DEC 97

APPENDIX B

AGP Laboratories, Inc.
2004 E. Randol Mill, Suite 512
Arlington, Texas 76011
(817) 861-9090 • (800) AGP-6030
Fax: (817) 861-5400

October 16, 1997

Petro Environmental Technologies
Attn: Mr. Steve Brandstetter
7400 Wiley Rd., Mail Stop 44
Harrison, OH 45038

RE: Client Project Number WC7-024
AGP Project Number: PET3101.001

Dear Mr. Brandstetter:

One (1) sample was received for testing 10/01/97. The sample was identified as follows:

SAMPLE I.D.	AGP COMMENTS
Roll # 36114	GCL

The sample was tested in accordance with the test methods listed below:

ASTM D 5321 "Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method"

All tests were performed at 73° F ± 3° with a relative humidity of 50% ± 5. Conditioning of the samples, before testing, is standard 40 hours at test temperature and relative humidity unless waived by the client.

The sample material was submitted by Petro Environmental Technologies. AGP Laboratories, Inc. has no specific knowledge as to conditioning, origin, sampling procedure, special use of material, or purpose of material. The testing listed herein is based upon accepted industry practice as well as by the test method listed. AGP Laboratories, neither accepts nor makes claim as to final use and purpose of the material. Results presented apply only to the items tested.

DIRECT SHEAR
ASTM D 5321

12-in. x 12-in. boxes
Hydraulic loading ram with load gauges for normal force
Load cell with dial indication for shear force
Bolted flat plate clamping device
Friction table attached to CRE

Tested
10/15/97

Configuration:

1. Steel Plate
2. GCL - Roll #36114
3. Steel Plate

Internal shear of Geosynthetic clay liner.

Strain Rate, in. /min.	0.04	0.04
Normal Stress, psi	5.0	20.0
Peak Shear Stress, psi	3.20	7.53
Adhesion, psi	1.681	
Friction Angle, deg.	24.2	
Residual Shear Stress, psi	2.79	5.58
Adhesion, psi	1.585	
Friction Angle, deg.	16.1	

Plot of results are presented in Figure 1.
Force - displacement plots are shown in Figure 2.

SPECIAL TEST CONDITION: The GCL specimens were hydrated for a 7- day period prior to testing of normal stress of 3 psi. After hydration, the specimens were consolidated for 48 hours at the specified normal stress which is 5 psi and 20 psi.

Figure 1: Friction Angle Plot
Interface: GCL Internal Shear Strenth - Roll# 36114

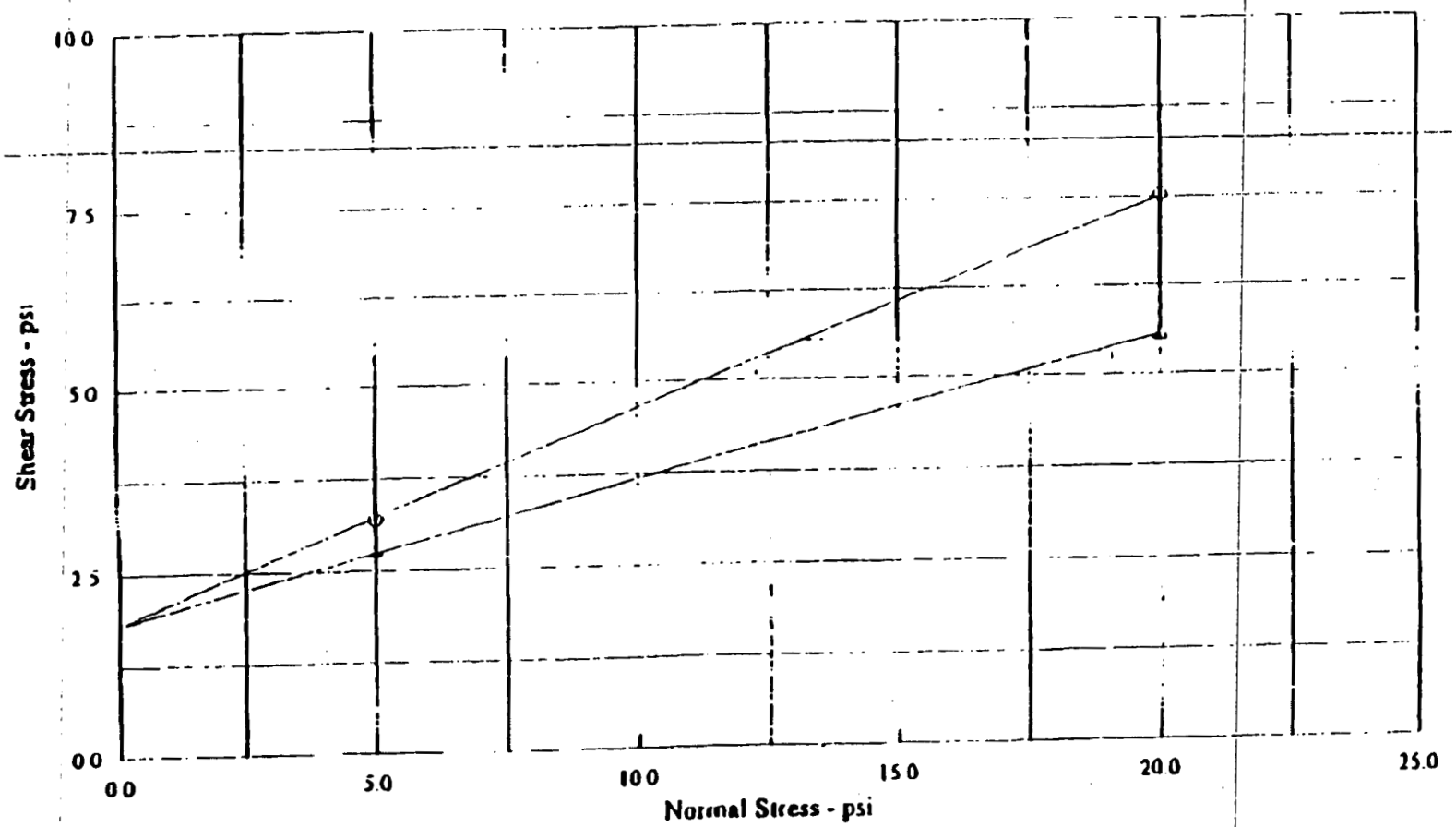
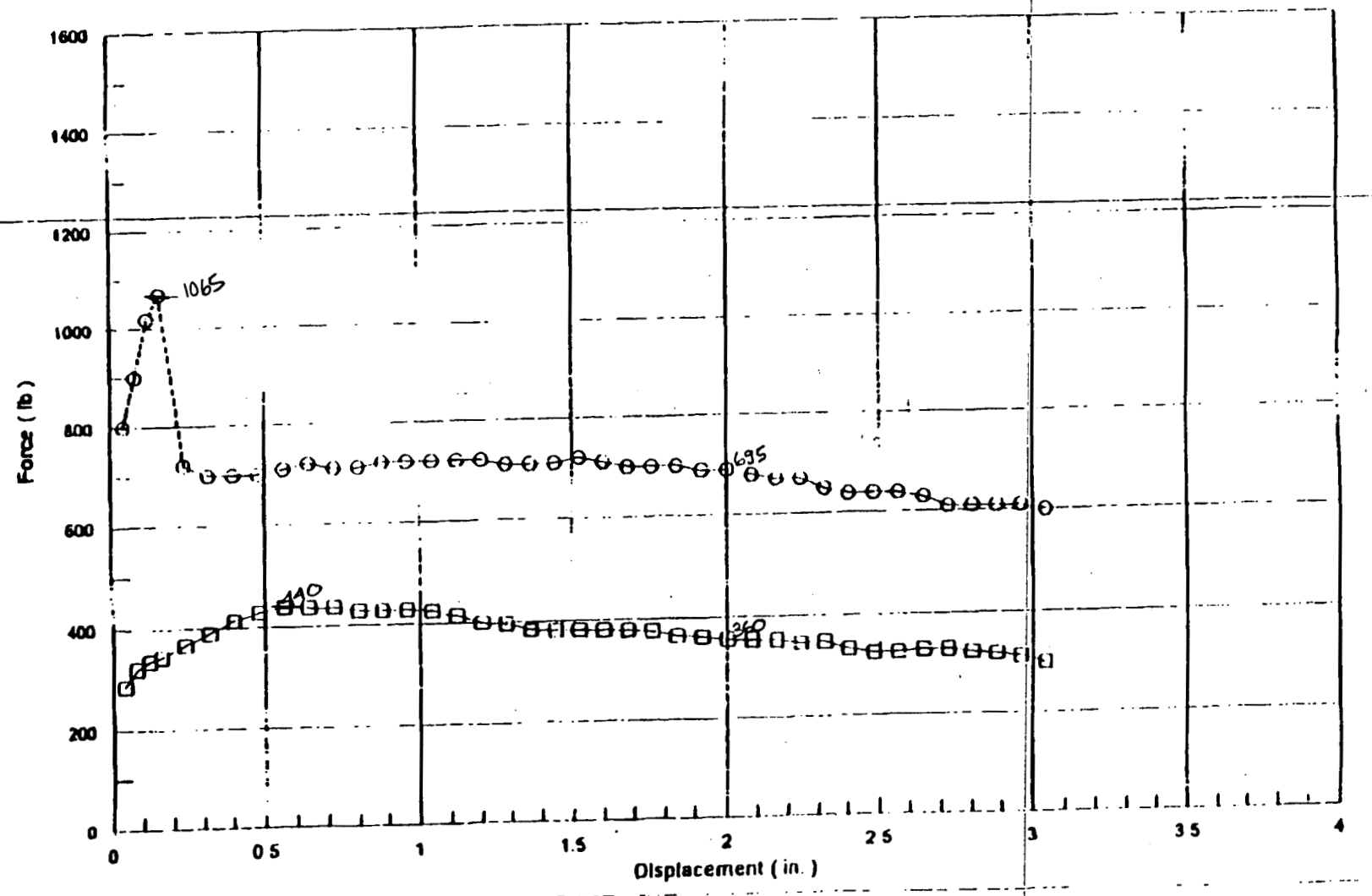


Figure 2: Force vs. Displacement
Interface: GCL Internal Shear Strenth - Roll# 36114



.15/48

This report shall not be reproduced except in full, without written approval from this laboratory.

If there are any questions, please contact us.

Respectfully,

Neelam Asher

Neelam Asher
Laboratory Supervisor

NTH Consultants, Ltd.
Professional Engineering and Environmental Services

Farmington Hills, MI • (810) 553-6800
Exton, PA • (610) 524-2300
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Lansing, MI • (517) 321-6800
Grand Rapids, MI • (616) 957-1690

JOB Petro-Fernald Site PROJECT NO 54 7637 SHEET NO. 1
SUBJECT Direct Shear Testing BY RMS DATE 9/29/97
CHK. BY DATE 10/6/97 update

Summary of Test Results

Internal Strength of Hydrated GCL

Peak Strength

Normal Stress (psi)		Measured Shear Strength (psi)	Calculated Secant Angle (°)
Roll #03575 (57)	5	3.81	37.3
	45	17.18	20.9
	45 (*)	18.06	21.9
# 36344	5 (*)	3.55	35.4 ✓
Roll # 36344	20 (*)	9.12	24.5
# 37386	45 (*)	18.85	22.7
Roll # 36114	45 (*)	15.76	19.3
Roll # 36344	45 (*)	17.46	21.2
Roll # 036262	45 (*)	14.46	17.8
Roll # 37061	45 (*)	9.20	11.6

Neu Dec 10/14/97

Residual Strength @ 2 inches displacement

Normal Stress (psi)		Measured Shear Strength (psi)	Calculated Secant Angle (°)
Roll # 03575 (57)	5	3.25	33.0
	45	3.10	4.0
	45 (*)	3.98	5.1
# 36344	5 (*)	2.53	26.8 ✓
# 36344	20 (*)	2.40	6.9
Roll # 37386	45 (*)	4.51	5.7
Roll # 36114	45 (*)	3.35	4.3
Roll # 36344	45 (*)	4.17	5.3
Roll # 036262	45 (*)	3.73	4.7
Roll # 37061	45 (*)	2.92	3.7

Neu Dec 10/14/97

(*) Speed for testing = 0.005 inches/minute

Other speed = 0.04 inches/minute

PETRO
environmental
technologies

October 24, 1997

Mr. Bill Zebick
Fluor Daniel Fernald
P. O. Box 538704, Mail Stop 64
Cincinnati, Ohio 45253-8704

Letter No. 069

RE: Direct Shear Test Data for
Petro Environmental Samples PET-03 and PET-07
Subcontract No. FSC 597
Petro Environmental Project WC7-024

Dear Mr. Zebick:

Please find attached copies of formal written responses to the shear testing concerns raised in the referenced letter. If beneficial, please do not hesitate to contact, or have GeoSyntec contact either lab. Direct discussions between those well versed in the test procedure may assist in the understanding of the issues.

Lastly, please be aware that Petro Environmental has not sent, and does not intend to send any other samples from this project to either of these labs.

Please do not hesitate to contact me if you should have any question, or require additional information.

Respectfully submitted,

PETRO ENVIRONMENTAL TECHNOLOGIES, INC.

S C Brandstetter

Steven C. Brandstetter
Project Manager

cc: Mike Godber, FDF
Dan Bodine, GeoSyntec
WC7-024 Correspondence

F:\CUR_JOBS\WC7-024\CORRES\FDF-069.DOC

Fernald Site Office PO. Box 538704 • Mail Stop 44 • Cincinnati, Ohio 45253-8704 • 513.648.3402 • Fax 648.3407
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AGP Laboratories, Inc.
2004 E. Randol Mill, Suite 512
Arlington, Texas 76011
(817) 861-9090 • (800) AGP-6030
Fax: (817) 861-5400

23 October 1997

Steve Branstetter
PETRO environmental technologies
P.O. Box 5.8704
Mail Stop 44
Cincinnati, OH 45253-8704

Re: Commets and clairification to fax received 22 October 1997

Dear Mr. Branstetter:

Whenever you and Rick Schailbaum? contacted Ms. Asher, she informed you that the lowest speed that our apparatus could go was 0.04 ipm. This information was upfront and she suggested that if this speed was a requirement of your specification that you should go to another lab.

When AGP received the samples for the test they were precut in twelve (12) inch by twenty (20) inch specimens. These specimens were not secured via the use of tape on any side of the specimen to prevent loss of bentonite. The received package of GCL specimen has loose bentonite in the package significant enough to indicate samples are inconsistent and not represented of the material that may have been received in the field or manufactured for the project.

I did not examine the specimen tested in the twenty psi so my comments that will be made to statement 2 of the fax from Ken Cargill will done so based on past test experience on interface GCL specimens. Whenever a GCL specimen is tested for internal shear and the process used to intertwine the bentonite with the two geotextiles is a needlepunch process, a high point shear occurs within the shear plane of the needlepunched threads. This is more evident whenever depletion of bentonite is significant enough that the "cushion" between the two geotextiles exist. In simple terms the test is how well the GCL two geotextile are interlocked together. If bentonite is depleted between the two geotextile the threads interlocking the two by the needlepunched process are allowed to take up tension. If the bentonite is present a immediate shear plane is present. Again AGP did not prepare or shipped the samples.

In our experience of hydrated GCLs it is usually necessary to hydrate the test specimen at the test pressure. Whenever hydration occurs at lower psi the specimen tends to swell more and a true value of internal shear is not represented when you compress a specimen that was hydrated at lower pressures than actual test.

Statement three about maintaining constant speed with test apparatus can be consistently acheived to 0.01 ipm. However, any speed below that is not consistent. That is why you were informed that the 0.004 ipm could not be acheived with AGP's equipment.

Statement four is not proper when final reporting ASTM D 5321. In ASTM D 5321, paragraph 12.2.1 requres corrected values to be plotted to accompany the final report. Your request to Ms. Asher was to perform internal shear of the GCL according to ASTM D 5321 which she did.

Statement number five may have had some validity if AGP had the specification before performing the test. AGP did not receive a copy of the specifcation until after testing had begun. However, residual as well as shear values are obtained before the two (2) or three (3) inch displacement is reached.

AGP can recalculate the peak shear values at 2 inch displacement, since your data from other labs was presented. The need and presenting of data should have been passed on to Ms. Asher before actual test began. **The changed report will show ASTM D 5321 modified to site specification.**

AGP tries to accomondate its clients in providing test data that would benifit and support the client with the specification they are monitoring. In such the testing occurs without written specification based upon information supplied via verbal communication between client and AGP. This especially occurs when a time table is involved, and the client is under the "gun". If a client requests a certain test, that test will be adhered too without any modification.

If you require other comments pertaining to this test method or report, please contact me.

Respectfully yours,

Wayne Youngblood

TOTAL P.03

TOTAL P.05

MCO DOC 18/97
RAM 19 DEC 97

APPENDIX C

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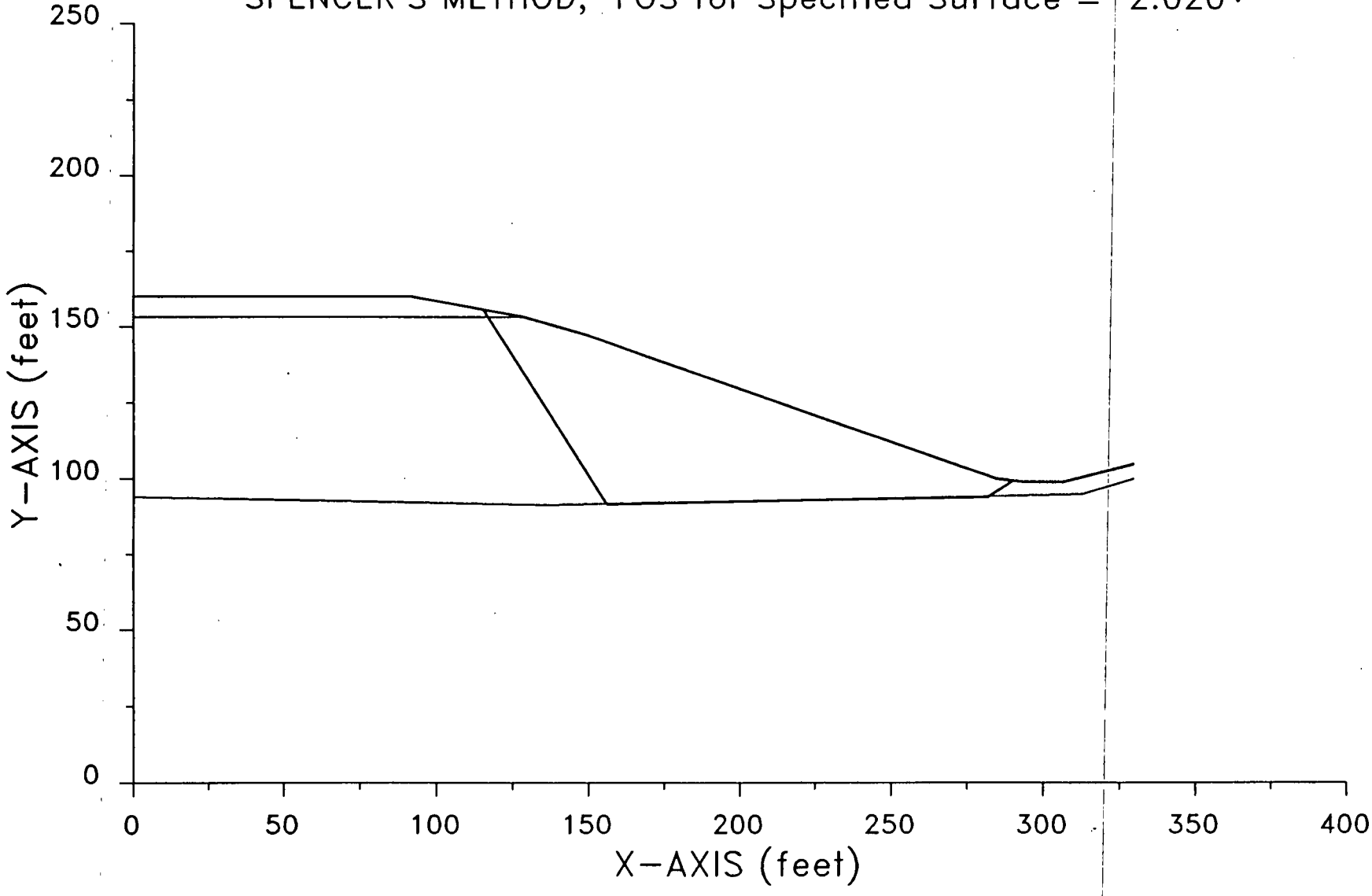
OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.020



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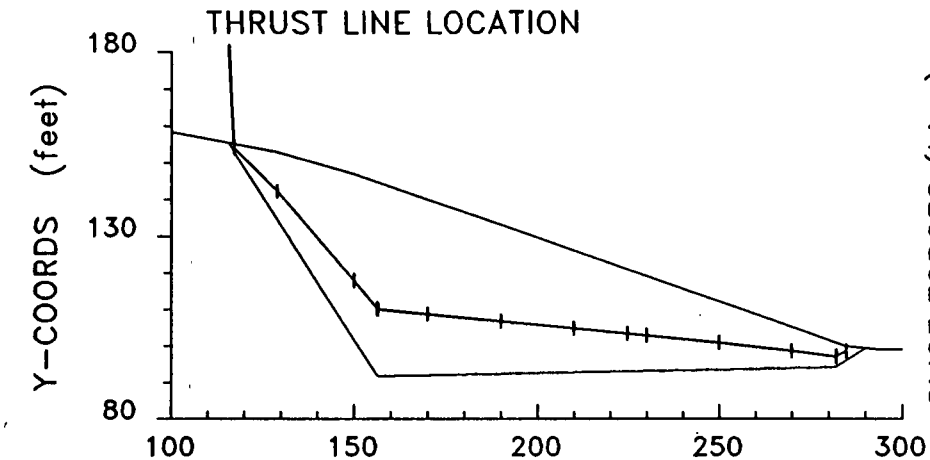

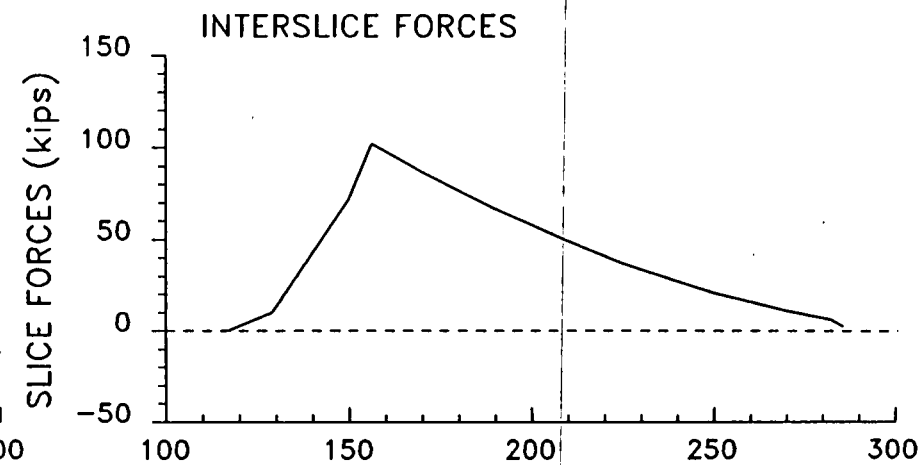

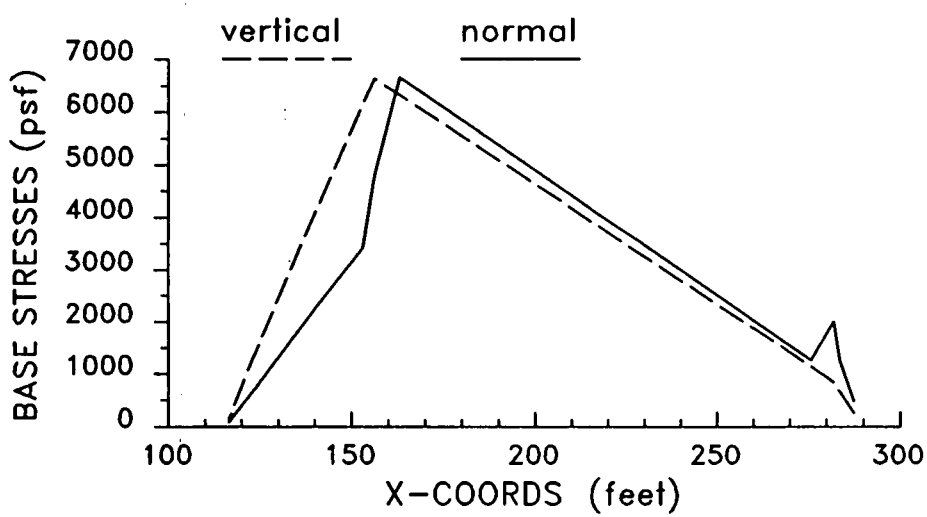

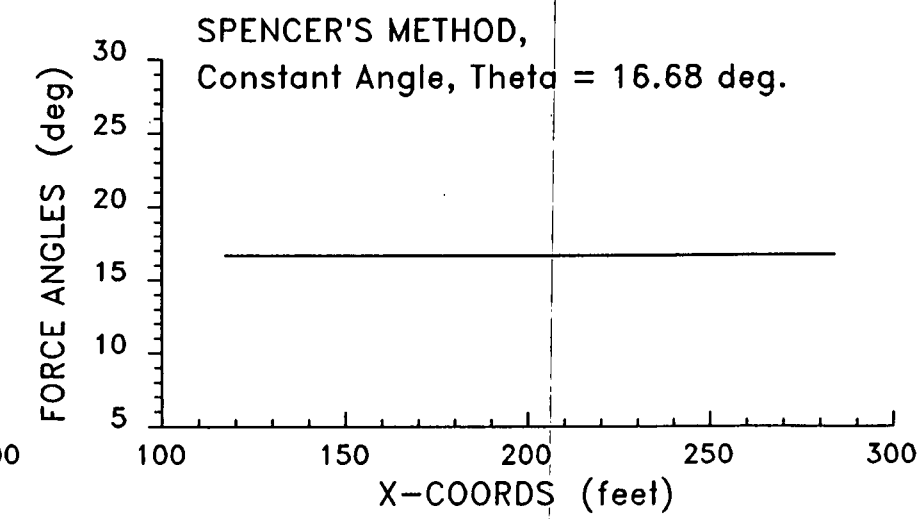

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.020

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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*  Ver. 5.201                 96 á 1202 *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	547.2
4	2880.0	1108.8
5	6480.0	1840.3
6	10080.0	1840.3

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	290.33	99.41
2	282.39	94.35
3	282.18	94.14
4	224.80	93.00
5	156.43	91.65
6	156.27	91.80
7	117.28	153.00
8	115.85	155.49

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	287.66	97.71	1.99	5.33	-32.50	6.34	1328.
2	283.69	95.18	5.27	2.61	-32.50	19.12	1721.
3	282.28	94.24	6.70	.21	-45.00	19.12	174.
4	276.09	94.02	9.07	12.18	-1.14	19.12	13809.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37502.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55870.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.13	19.29	56714.
9	200.00	92.51	37.09	20.00	-1.13	19.29	92724.
10	180.00	92.12	44.43	20.00	-1.13	19.03	111087.
11	163.21	91.78	50.59	13.57	-1.13	19.29	85815.
12	156.35	91.73	53.05	.16	43.15	19.29	1074.
13	153.13	96.72	49.18	6.27	57.50	19.29	38534.
14	139.50	118.12	31.88	21.00	57.50	15.95	83678.
15	123.14	143.80	10.31	11.72	57.50	10.71	15099.
16	116.57	154.24	1.11	1.43	60.11	10.71	198.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.5647	2.0308	2.0686
3	16.6180	2.0324	2.0308
4	16.6170	2.0323	2.0324

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.6843	2.0204	2.0185
3	16.6833	2.0204	2.0204

Nonlinear M-C Iteration Number - 3

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment

1	16.6833	2.0201	2.0204

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.6833	2.0201	2.0204

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	460.3	.0	30.00	0.	0.	0.	.00
2	1268.0	200.0	25.00	0.	0.	0.	.00
3	2005.0	360.0	14.57	0.	0.	0.	.00
4	1249.5	360.0	14.57	0.	0.	0.	.00
5	2027.5	360.0✓	14.57✓	0.	0.	0.	.00
6	2990.3	523.6✓	11.49✓	0.	0.	0.	.00
7	3589.4	523.6	11.49	0.	0.	0.	.00
8	4069.7	523.6	11.49	0.	0.	0.	.00
9	4905.7	523.6	11.49	0.	0.	0.	.00
10	5860.1	523.6	11.49	0.	0.	0.	.00
11	6654.2	1840.3✓	.00✓	0.	0.	0.	.00
12	4807.0	523.6	11.49	0.	0.	0.	.00
13	3414.6	200.0	25.00	0.	0.	0.	.00
14	2188.1	200.0	25.00	0.	0.	0.	.00
15	659.2	200.0	25.00	0.	0.	0.	.00
16	71.8	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	287.66	460.3	249.2	.0	131.6
2	283.69	1268.0	659.0	.0	391.7
3	282.28	2005.0	837.2	.0	436.3
4	276.09	1249.5	1133.7	.0	339.0
5	260.00	2027.5	1875.1	.0	439.2
6	240.00	2990.3	2793.5	.0	560.0
7	227.40	3589.4	3369.8	.0	620.2
8	217.40	4069.7	3832.0	.0	668.5
9	200.00	4905.7	4636.2	.0	752.6
10	180.00	5860.1	5554.3	.0	848.6
11	163.21	6654.2	6323.8	.0	911.0
12	156.35	4807.0	6631.5	.0	742.7
13	153.13	3414.6	6147.6	.0	887.2
14	139.50	2188.1	3984.7	.0	604.1
15	123.14	659.2	1288.3	.0	251.2
16	116.57	71.8	138.6	.0	20.5

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	16.68	2364.	2.50	3.99	.626
2	282.39	16.68	5634.	2.78	6.56	.425
3	282.18	16.68	6164.	2.79	6.84	.409
4	270.00	16.68	10791.	4.66	11.30	.412
5	250.00	16.68	20801.	7.27	18.70	.389
6	230.00	16.68	33733.	9.65	26.00	.371
7	224.80	16.68	37487.	10.27	27.92	.368
8	210.00	16.68	49058.	12.02	33.39	.360
9	190.00	16.68	66795.	14.37	40.79	.352
10	170.00	16.68	86929.	16.69	48.08	.347
11	156.43	16.68	101696.	18.29	53.10	.344
12	156.27	16.68	101060.	18.30	53.00	.345
13	150.00	16.68	71794.	16.17	45.36	.357
14	129.00	16.68	9742.	7.58	18.40	.412
15	117.28	16.68	155.	1.03	2.22	.466
16	115.85	.00	-1.	89.88	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3071.98 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 584.79 (psf)

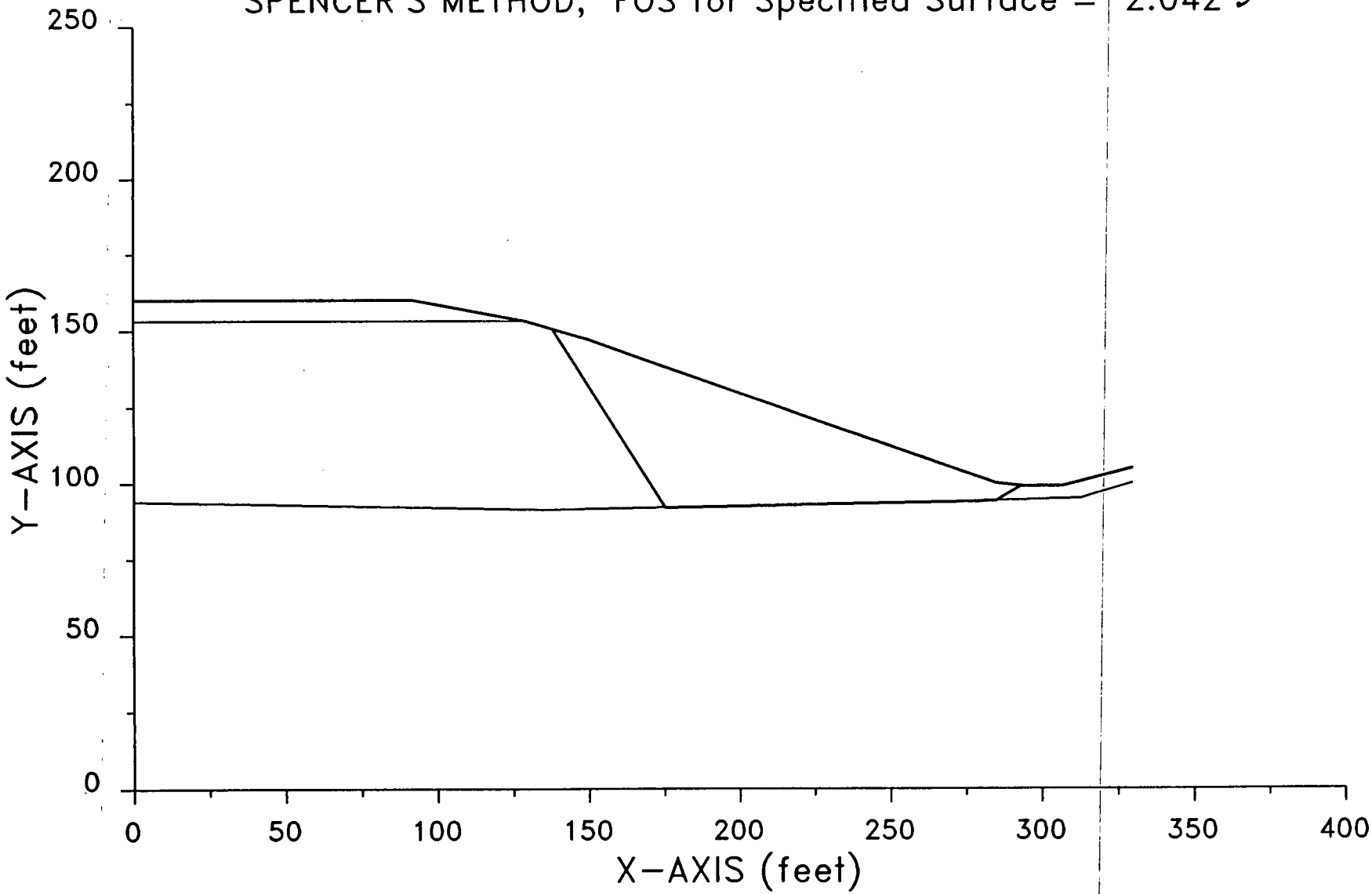
Total Length of failure surface = 211.14 feet

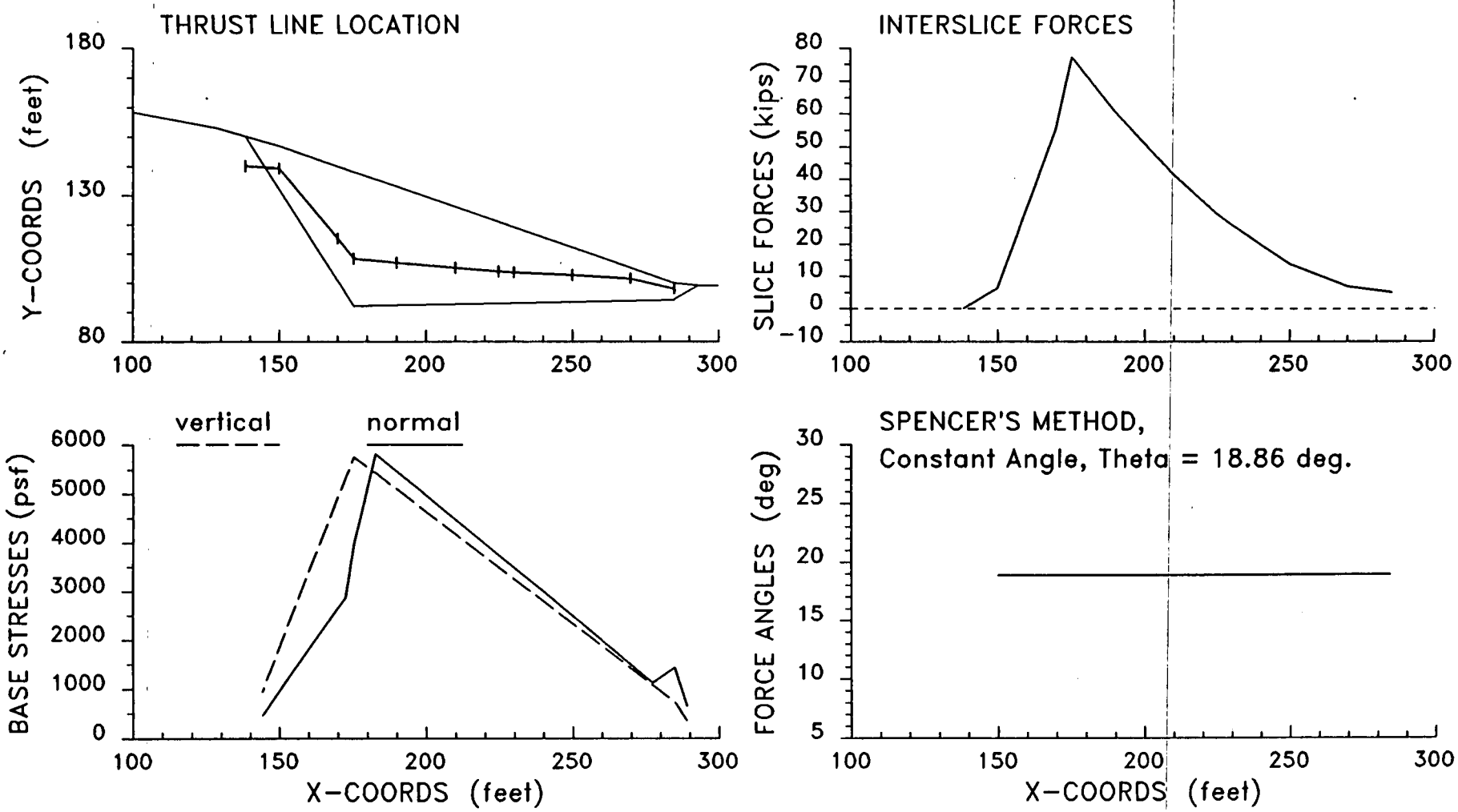
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.020 ✓

Total shear strength available along specified failure surface = 249.42E+03 lb

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.042





OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.042

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	1008.0
5	6480.0	2145.6
6	10080.0	2145.6

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 7 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	293.27	99.08
2	285.17	94.40
3	284.97	94.20
4	224.80	93.00
5	175.56	92.03
6	175.40	92.19
7	138.37	150.32

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	289.22	96.74	2.79	8.10	-30.02	6.34	2825.
2	285.09	94.31	5.68	.17	-45.00	6.34	121.
3	284.98	94.21	5.79	.03	-45.00	19.12	22.
4	277.48	94.05	8.55	14.97	-1.14	19.12	16008.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37495.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55867.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.13	19.29	56713.
9	200.00	92.51	37.09	20.00	-1.13	19.29	92721.
10	182.78	92.17	43.42	14.44	-1.13	19.03	78371.
11	175.48	92.11	46.00	.16	45.00	19.03	931.
12	172.70	96.43	42.64	5.40	57.50	19.03	28771.
13	160.00	116.37	27.13	20.00	57.50	19.29	67834.
14	144.18	141.19	7.47	11.63	57.50	15.95	10856.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.8962	2.0451	2.0276
3	18.8841	2.0448	2.0451

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.8586	2.0417	2.0424

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	18.8586	2.0417	2.0424

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	642.9	.0	30.00	0.	0.	0.	.00

2	1389.0	-336.0	25.02	0.	0.	0.	.00
3	1429.7	-336.0	25.02	0.	0.	0.	.00
4	1109.0	-336.0	25.02	0.	0.	0.	.00
5	1993.6	-336.0	25.02	0.	0.	0.	.00
6	2998.9	97.9	17.54	0.	0.	0.	.00
7	3613.9	97.9	17.54	0.	0.	0.	.00
8	4106.5	97.9	17.54	0.	0.	0.	.00
9	4964.4	97.9	17.54	0.	0.	0.	.00
10	5808.5	97.9	17.54	0.	0.	0.	.00
11	3961.5	97.9	17.54	0.	0.	0.	.00
12	2867.5	200.0	25.00	0.	0.	0.	.00
13	1800.7	200.0	25.00	0.	0.	0.	.00
14	447.6	200.0	25.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	289.22	642.9	348.8	.0	181.8
2	285.09	1389.0	709.4	.0	152.9
3	284.98	1429.7	723.8	.0	162.2
4	277.48	1109.0	1069.3	.0	88.9
5	260.00	1993.6	1874.7	.0	291.1
6	240.00	2998.9	2793.4	.0	512.1
7	227.40	3613.9	3369.8	.0	607.3
8	217.40	4106.5	3832.0	.0	683.5
9	200.00	4964.4	4636.1	.0	816.3
10	182.78	5808.5	5427.3	.0	947.0
11	175.48	3961.5	5749.8	.0	661.1
12	172.70	2867.5	5329.8	.0	752.9
13	160.00	1800.7	3391.7	.0	509.2
14	144.18	447.6	933.4	.0	200.2

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.17	18.86	4736.	3.72	5.58	.667
2	285.00	18.86	5013.	3.74	5.77	.648
3	284.97	18.86	5064.	3.74	5.81	.644
4	270.00	18.86	6820.	7.49	11.30	.663
5	250.00	18.86	13813.	9.10	18.70	.487
6	230.00	18.86	25900.	10.40	26.00	.400
7	224.80	18.86	29633.	10.85	27.92	.389
8	210.00	18.86	41588.	12.31	33.39	.369
9	190.00	18.86	60908.	14.49	40.79	.355
10	175.56	18.86	77104.	16.11	46.05	.350
11	175.40	18.86	76539.	16.12	45.95	.351
12	170.00	18.86	55155.	14.46	39.33	.368
13	150.00	18.86	6173.	7.14	14.93	.478

14	138.37	.00	-2.	-10.35	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 2614.53 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 496.40 (psf)

Total Length of failure surface = 188.22 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.042

Total shear strength available along specified failure surface = 190.76E+03 lb

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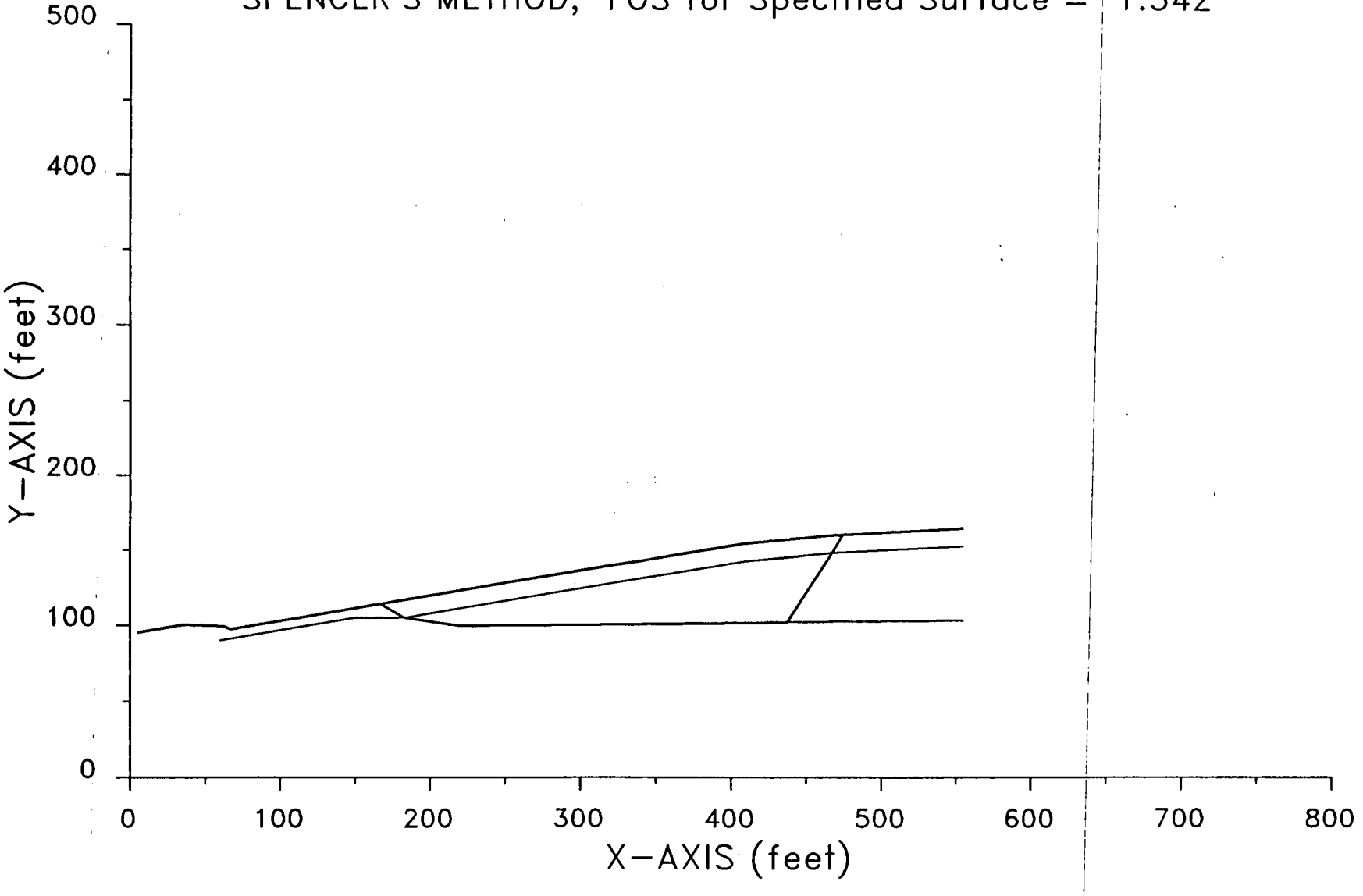
OSDF Final Long Term – Large Displ.

SPENCER'S METHOD, FOS for Specified Surface = 1.542



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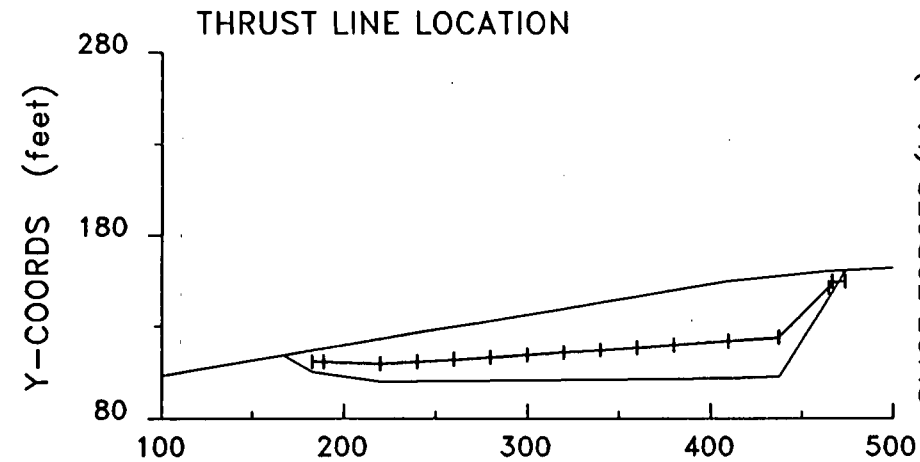

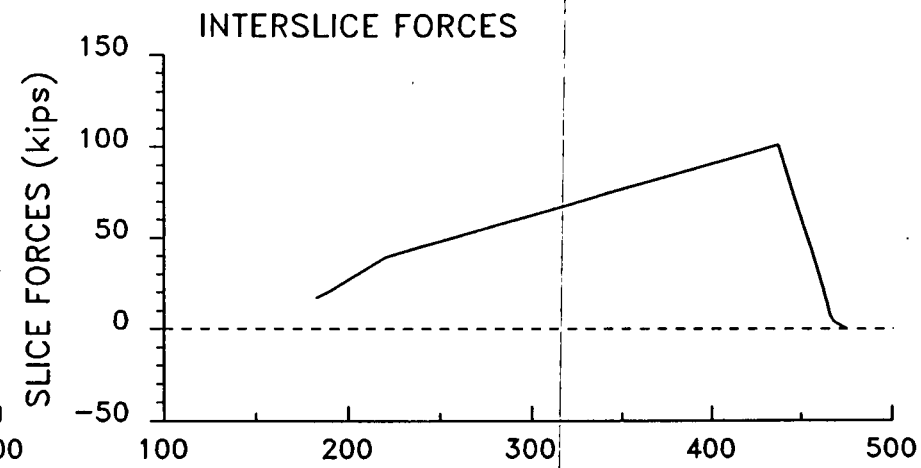

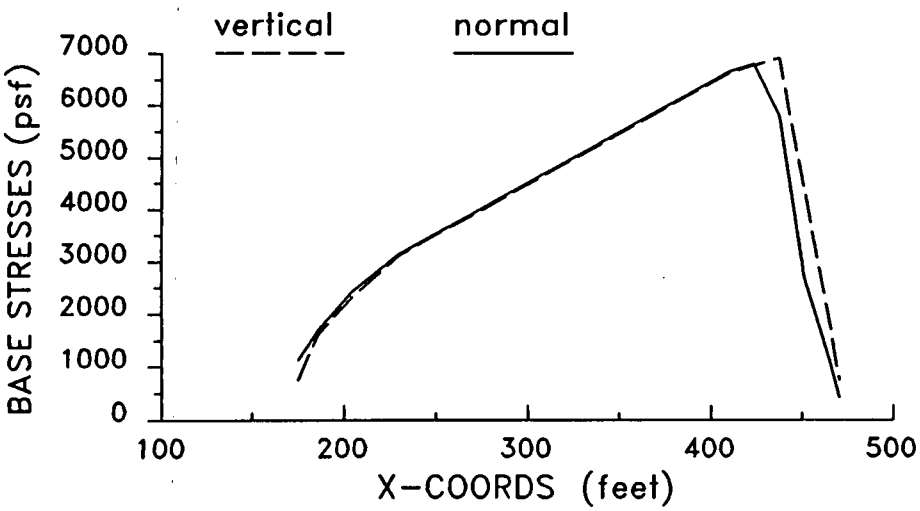

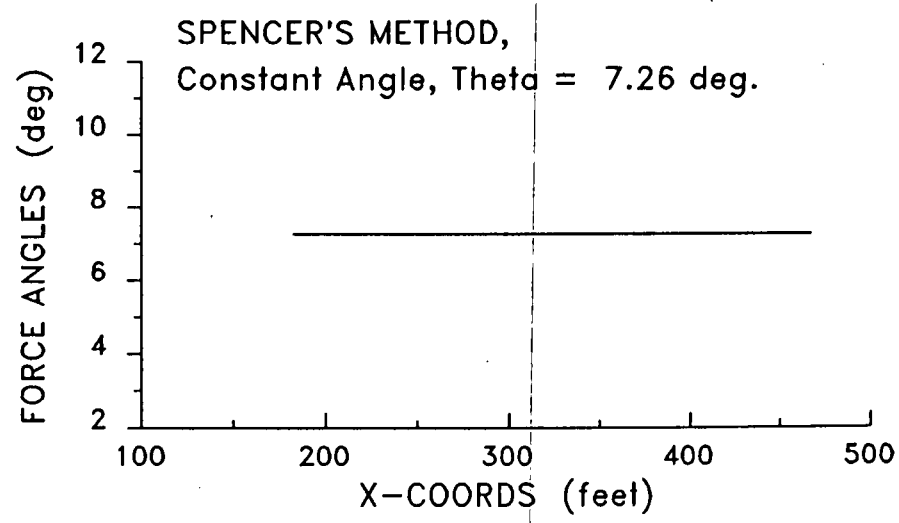

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.542 ✓

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0001121

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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```

Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	187.2
4	2880.0	489.6
5	6480.0	543.6
6	10080.0	543.6

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 9 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	409.90	101.80
6	437.47	102.14
7	437.61	102.29
8	467.05	148.50
9	474.07	160.65

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.63	9.37	93352.
9	330.00	100.93	40.42	20.00	.63	9.37	101056.
10	350.00	101.15	43.55	20.00	.63	9.65	108885.
11	370.00	101.36	46.69	20.00	.63	9.37	116714.
12	394.95	101.64	50.55	29.90	.63	9.46	188949.
13	409.95	101.80	52.89	.10	.71	9.46	661.
14	423.73	101.97	54.10	27.47	.71	5.71	185776.
15	437.54	102.21	55.24	.14	46.98	5.71	967.
16	451.30	123.79	35.04	27.39	57.50	5.71	119983.
17	466.00	146.85	13.40	2.00	57.50	2.86	3350.
18	467.03	148.46	11.84	.05	57.50	2.86	76.
19	470.56	154.58	5.90	7.02	59.99	2.86	5176.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.2336	1.5413	1.5690
3	7.2619	1.5419	1.5413

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.2619	1.5419	1.5413

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	1116.5	.0	30.00	0.	0.	0.	.00
2	1680.4	86.4	7.97	0.	0.	0.	.00
3	2422.1	86.4	7.97	0.	0.	0.	.00
4	3133.6	446.4	.86	0.	0.	0.	.00
5	3527.3	446.4	.86	0.	0.	0.	.00
6	3914.7	446.4	.86	0.	0.	0.	.00
7	4308.4	446.4	.86	0.	0.	0.	.00
8	4700.1	446.4	.86	0.	0.	0.	.00
9	5085.2	446.4	.86	0.	0.	0.	.00
10	5476.6	446.4	.86	0.	0.	0.	.00
11	5867.9	446.4	.86	0.	0.	0.	.00
12	6351.5	446.4	.86	0.	0.	0.	.00
13	6641.5	543.6	.00	0.	0.	0.	.00
14	6792.8	543.6	.00	0.	0.	0.	.00
15	5788.0	446.4	.86	0.	0.	0.	.00
16	2677.3	.0	25.00	0.	0.	0.	.00
17	1023.6	.0	25.00	0.	0.	0.	.00
18	904.5	.0	25.00	0.	0.	0.	.00
19	405.0	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1116.5	739.6	.0	418.0
2	186.00	1680.4	1594.4	.0	208.6
3	204.50	2422.1	2304.8	.0	276.0
4	230.00	3133.6	3100.0	.0	320.0
5	250.00	3527.3	3493.8	.0	323.8
6	270.00	3914.7	3881.3	.0	327.6
7	290.00	4308.4	4275.0	.0	331.4
8	310.00	4700.1	4667.6	.0	335.2
9	330.00	5085.2	5052.8	.0	339.0
10	350.00	5476.6	5444.3	.0	342.8
11	370.00	5867.9	5835.7	.0	346.6
12	394.95	6351.5	6319.4	.0	351.3
13	409.95	6641.5	6611.4	.0	352.5
14	423.73	6792.8	6762.9	.0	352.5
15	437.54	5788.0	6904.9	.0	345.8
16	451.30	2677.3	4380.5	.0	809.7
17	466.00	1023.6	1674.8	.0	309.6
18	467.03	904.5	1479.9	.0	273.5
19	470.56	405.0	737.5	.0	151.6

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio

1	183.00	7.26	17037.	5.61	11.83	.474
2	189.00	7.26	19727.	6.34	13.68	.464
3	220.00	7.26	38988.	9.48	23.20	.408
4	240.00	7.26	44808.	10.45	26.40	.396
5	260.00	7.26	50626.	11.47	29.50	.389
6	280.00	7.26	56441.	12.53	32.60	.384
7	300.00	7.26	62255.	13.60	35.80	.380
8	320.00	7.26	67979.	14.70	38.88	.378
9	340.00	7.26	73694.	15.81	41.96	.377
10	360.00	7.26	79399.	16.93	45.14	.375
11	380.00	7.26	85095.	18.06	48.23	.374
12	409.90	7.26	93594.	19.76	52.88	.374
13	410.00	7.26	93621.	19.76	52.90	.374
14	437.47	7.26	101064.	21.37	55.31	.386
15	437.61	7.26	100238.	21.41	55.17	.388
16	465.00	7.26	6559.	5.69	14.92	.381
17	467.00	7.26	3944.	5.62	11.88	.473
18	467.05	7.26	3884.	5.63	11.80	.477
19	474.07	.00	-3.	-6.40	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3948.30 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 396.76 (psf)

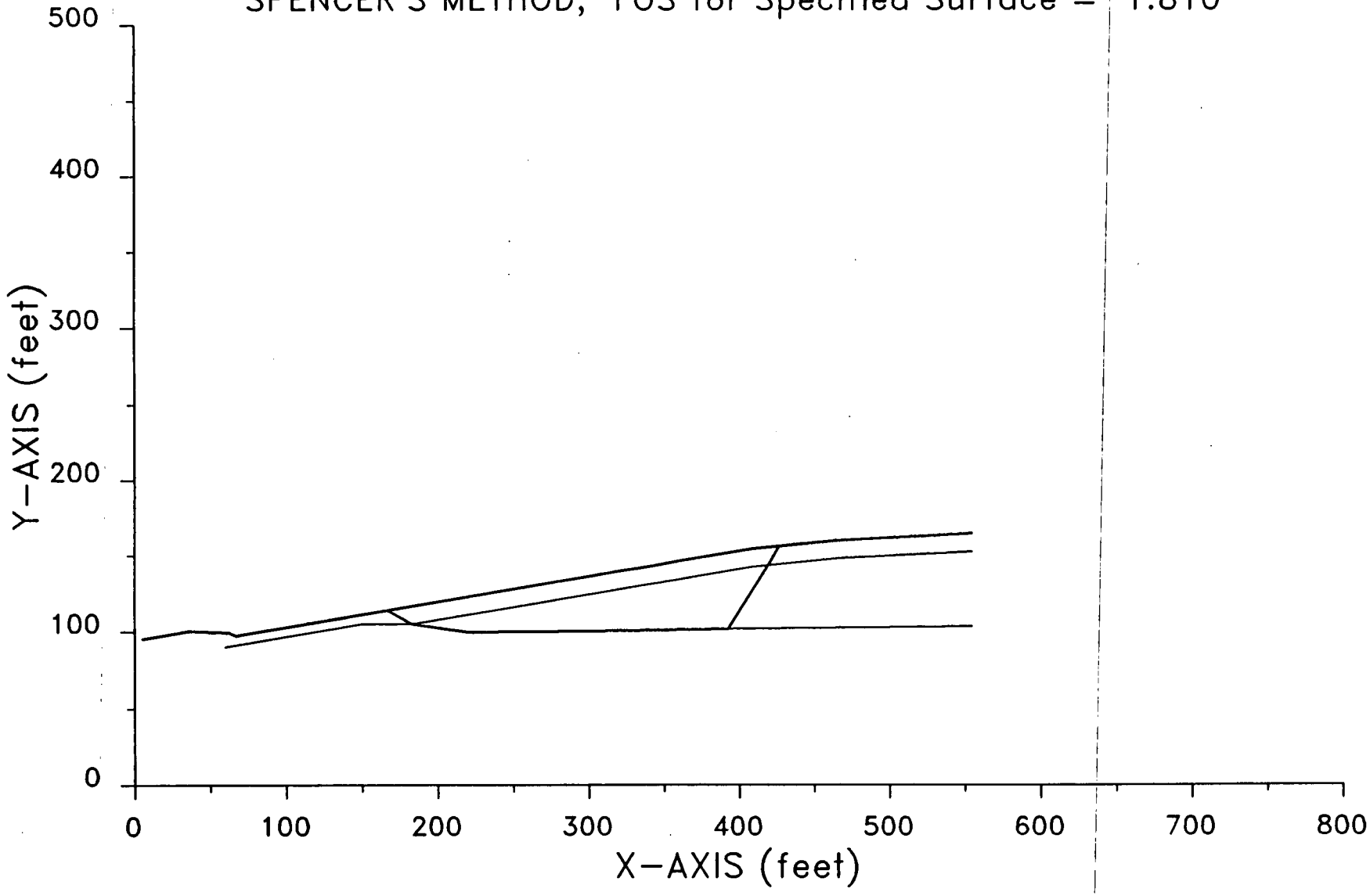
Total Length of failure surface = 342.24 feet

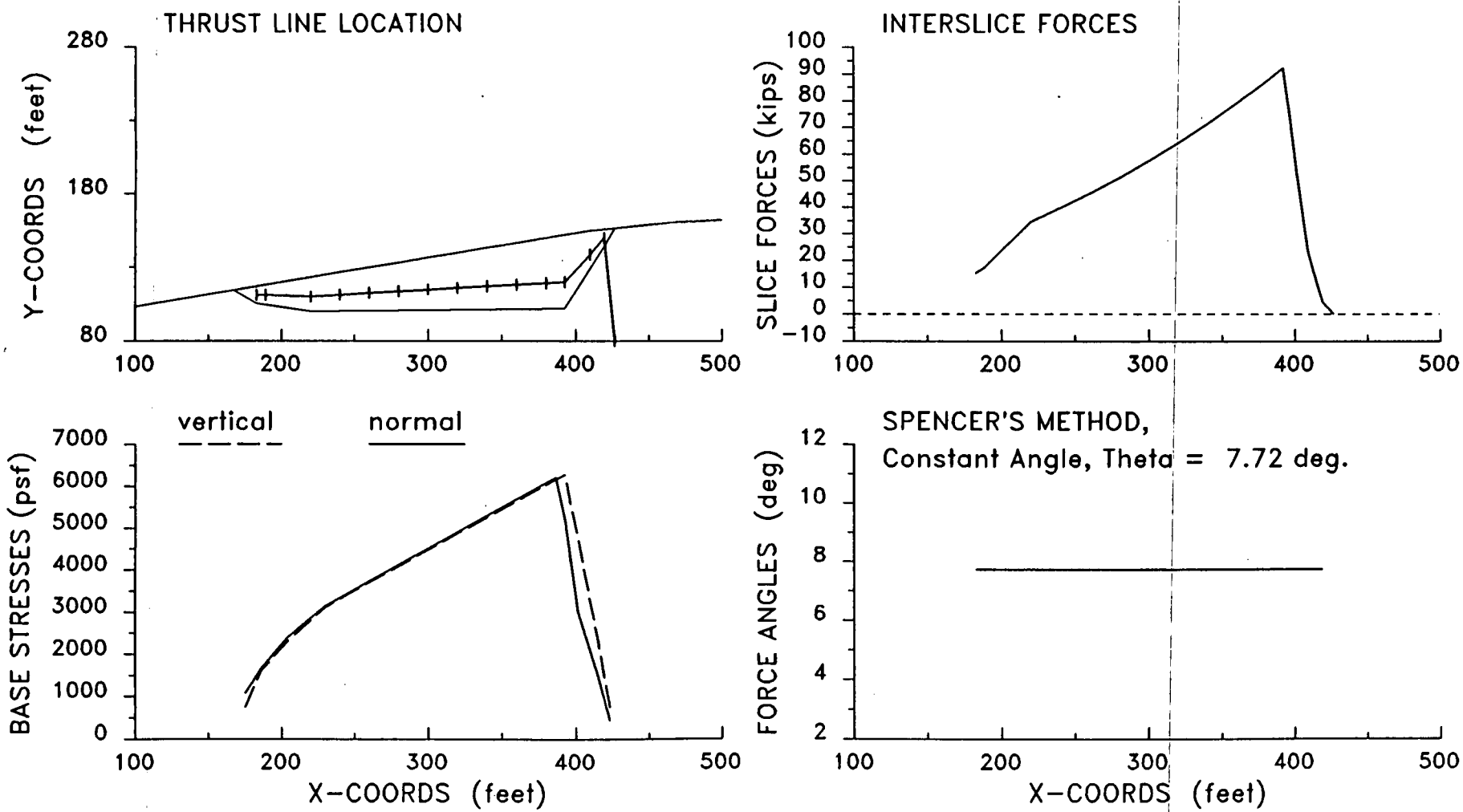
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.542 ✓

Total shear strength available along specified failure surface = 209.37E+03 lb

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.810





OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.810 ✓

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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```

Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	475.2
5	6480.0	921.6
6	10080.0	921.6

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	392.70	101.65
6	392.86	101.81
7	419.58	143.76
8	426.87	156.39

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.65	9.37	93342.
9	330.00	100.94	40.41	20.00	.65	9.37	101026.
10	350.00	101.17	43.53	20.00	.65	9.65	108834.
11	370.00	101.39	46.66	20.00	.65	9.37	116643.
12	386.35	101.58	49.18	12.70	.65	9.46	78074.
13	392.78	101.73	50.10	.16	45.00	9.46	1014.
14	401.43	115.27	38.01	17.14	57.50	9.46	81418.
15	414.79	136.24	18.94	9.58	57.50	5.71	22680.
16	423.22	150.07	5.95	7.29	60.00	5.71	5421.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.6453	1.8083	1.8519
3	7.7243	-----	1.8083
3	7.6848	1.8093	-----
4	7.7224	1.8104	1.8093
5	7.7215	1.8103	1.8104

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.7215	1.8103	1.8104

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta

1	1065.3	.0	30.00	0.	0.	0.	.00
2	1657.4	-158.4	12.41	0.	0.	0.	.00
3	2407.3	-158.4	12.41	0.	0.	0.	.00
4	3130.9	118.1	7.07	0.	0.	0.	.00
5	3527.5	118.1	7.07	0.	0.	0.	.00
6	3917.8	118.1	7.07	0.	0.	0.	.00
7	4314.5	118.1	7.07	0.	0.	0.	.00
8	4708.0	118.1	7.07	0.	0.	0.	.00
9	5094.9	118.1	7.07	0.	0.	0.	.00
10	5488.1	118.1	7.07	0.	0.	0.	.00
11	5881.3	118.1	7.07	0.	0.	0.	.00
12	6198.9	118.1	7.07	0.	0.	0.	.00
13	5194.1	118.1	7.07	0.	0.	0.	.00
14	3002.3	.0	25.00	0.	0.	0.	.00
15	1496.1	.0	25.00	0.	0.	0.	.00
16	426.4	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1065.3	739.6	.0	339.7
2	186.00	1657.4	1594.4	.0	113.9
3	204.50	2407.3	2304.8	.0	205.0
4	230.00	3130.9	3100.0	.0	279.7
5	250.00	3527.5	3493.8	.0	306.8
6	270.00	3917.8	3881.3	.0	333.6
7	290.00	4314.5	4275.0	.0	360.7
8	310.00	4708.0	4667.1	.0	387.7
9	330.00	5094.9	5051.3	.0	414.2
10	350.00	5488.1	5441.7	.0	441.1
11	370.00	5881.3	5832.1	.0	468.1
12	386.35	6198.9	6147.5	.0	489.8
13	392.78	5194.1	6262.4	.0	421.0
14	401.43	3002.3	4750.7	.0	773.3
15	414.79	1496.1	2367.4	.0	385.4
16	423.22	426.4	743.6	.0	136.0

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.72	15324.	5.67	11.83	.479
2	189.00	7.72	17424.	6.54	13.68	.478
3	220.00	7.72	34422.	9.76	23.20	.421
4	240.00	7.72	39435.	10.87	26.40	.412
5	260.00	7.72	44916.	11.90	29.50	.403
6	280.00	7.72	50858.	12.88	32.60	.395
7	300.00	7.72	57269.	13.81	35.80	.386

8	320.00	7.72	64017.	14.70	38.87	.378
9	340.00	7.72	71212.	15.58	41.95	.371
10	360.00	7.72	78861.	16.43	45.12	.364
11	380.00	7.72	86964.	17.27	48.19	.358
12	392.70	7.72	92342.	17.80	50.17	.355
13	392.86	7.72	91562.	17.81	50.03	.356
14	410.00	7.72	23416.	9.27	25.98	.357
15	419.58	7.72	4433.	5.82	11.90	.489
16	426.87	.00	0.	-85.81	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3532.20 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 385.81 (psf)

Total Length of failure surface = 292.98 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.810

Total shear strength available along specified failure surface = 204.63E+03 lb

GCL 07

COMPUTATION COVER SHEET

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 07 - Compliance Package

Computations By: (Cognizant Engineer)
Signature Robert A. Morgan III — Date 13 OCT 1997
Printed Name and Title ROBERT A. MORGAN III, SR. STAFF ENGINEER

Assumptions and Procedures Checked By: (Checker)
Signature [illegible] — Date 14 Oct 97
Printed Name and Title Gary R. Schmertmann, Senior Project Engineer

Computations Checked by:
Signature [illegible] — Date 14 Oct 97
Printed Name and Title Gary R. Schmertmann, Senior Project Engineer

Computations Backchecked by: (Cognizant Engineer)
Signature Robert A. Morgan III — Date 15 OCT 1997
Printed Name and Title ROBERT A. MORGAN III, SR. STAFF ENGINEER

Approved by: (PDP)
Signature [illegible] — Date 15 Oct 97
Printed Name and Title Gary R. Schmertmann, Senior Project Engineer

Approved by: (DTL and TETL)
Signature [illegible] — Date 15 Oct 97
Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

Written By: RAM Date: 10 / 13 / 97 Reviewed by: GRS Date: 10 / 14 / 97

Client: FDF Project: OSDF Project/Proposal No.: GQ0160 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 07 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 07 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample No.	Case	Test Type	Measured Shear Strengths		
			5 psi *	20 psi	45 psi
07	Peak	GCL Internal	0 psi	9.7 psi	11.6 psi
		GCL/GMB Interface	0	8.3	12.6
07	Large-displacement	GCL Internal	0	3.2	5.6
		GCL/GMB Interface	0	5.6	6.2

* Note: Measured shear strengths at 5 psi normal stress are assumed to be equal to zero. This is a conservative assumption in the context of RCI no. 1702-006R.

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix B.

QA Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
07	GCL Internal	NPK07AS	2.0	YES
	GCL/GMB Interface	NPK07BS	2.0	YES
Baseline	Large-displacement	NA	1.6	NA
07	GCL Internal	NLD07AS	1.7	YES
	GCL/GMB Interface	NLD07BS	2.1	YES

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RAM 10/14/97

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 7I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-07). GCL's initial moisture content was 9.0%. GCL's final moisture content ranged from 60% to 90% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20 and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 7G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

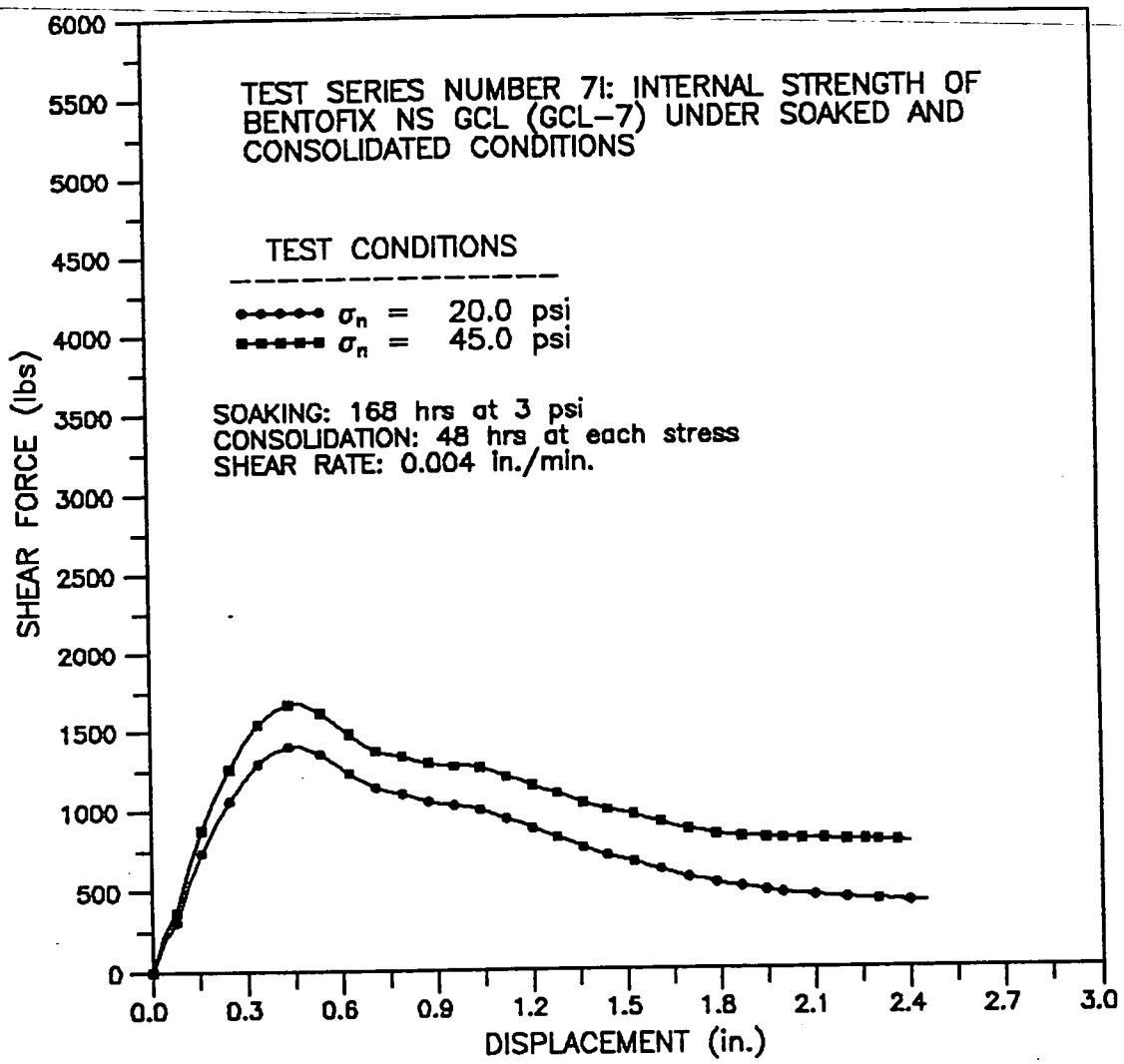
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-07) with woven geotextile against geomembrane. GCL's initial moisture content was 8.5%. GCL's final moisture content ranged from 52 to 75% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-7); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20 and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.

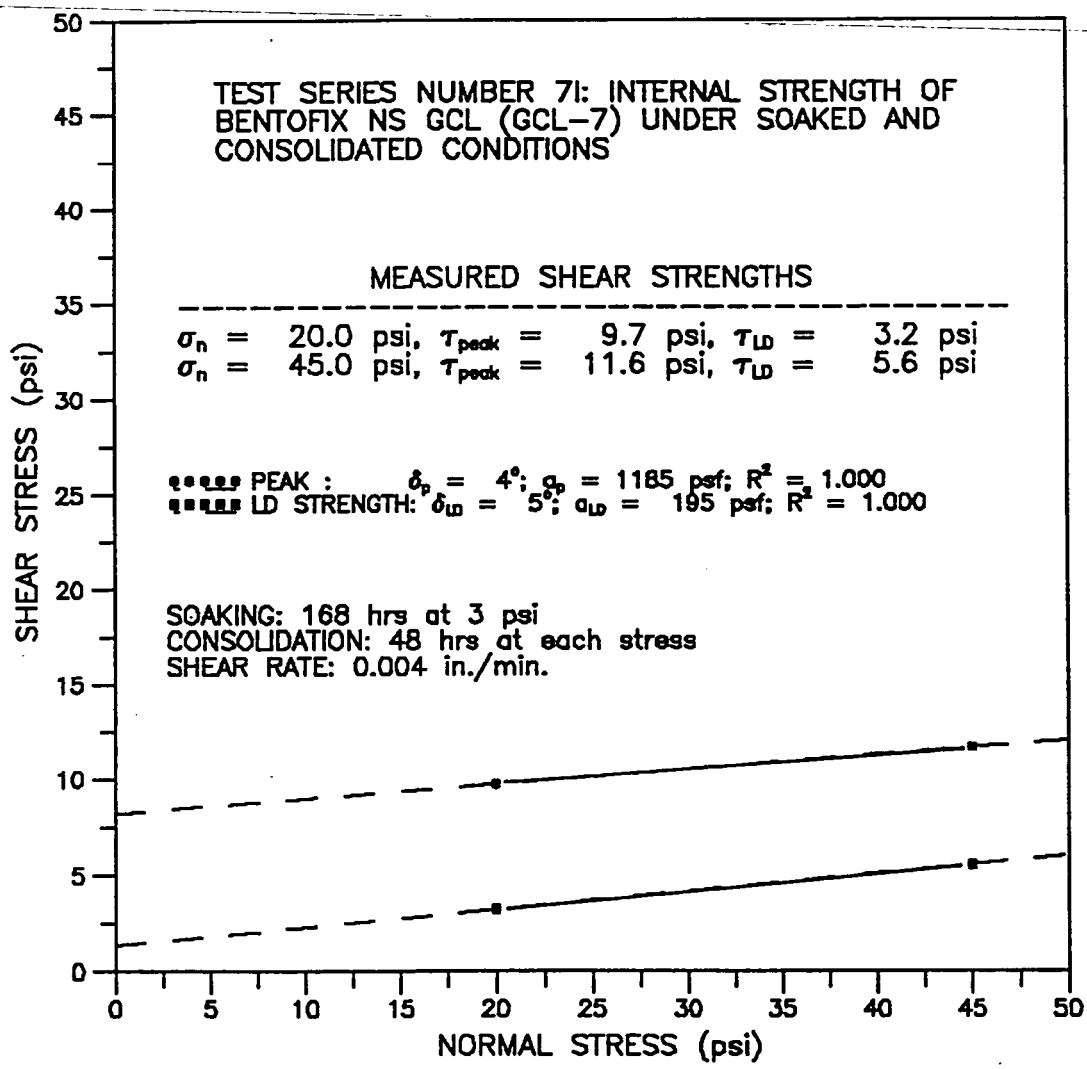
(2) For each test, sliding (i.e., internal shear failure) was observed to occur within the GCL.

DATE TESTED: 27 SEPTEMBER TO 6 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	G00166-04.1
DOCUMENT NO.	F9730089
FILE NO.	000140

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



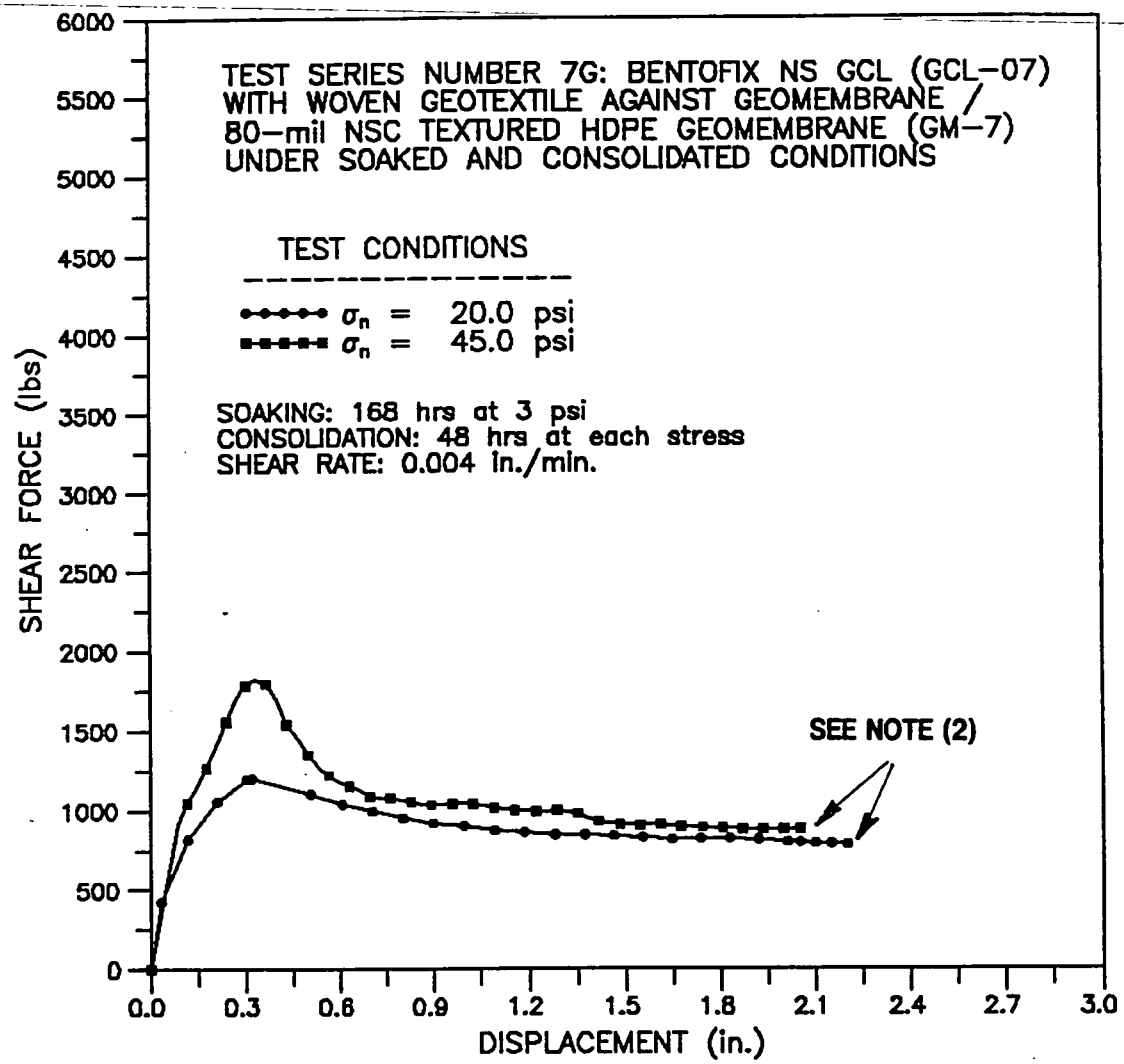
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) For each test, sliding (i.e, internal shear failure) was observed to occur within the GCL.

DATE TESTED: 27 SEPTEMBER TO 6 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730089
FILE NO.	000141

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

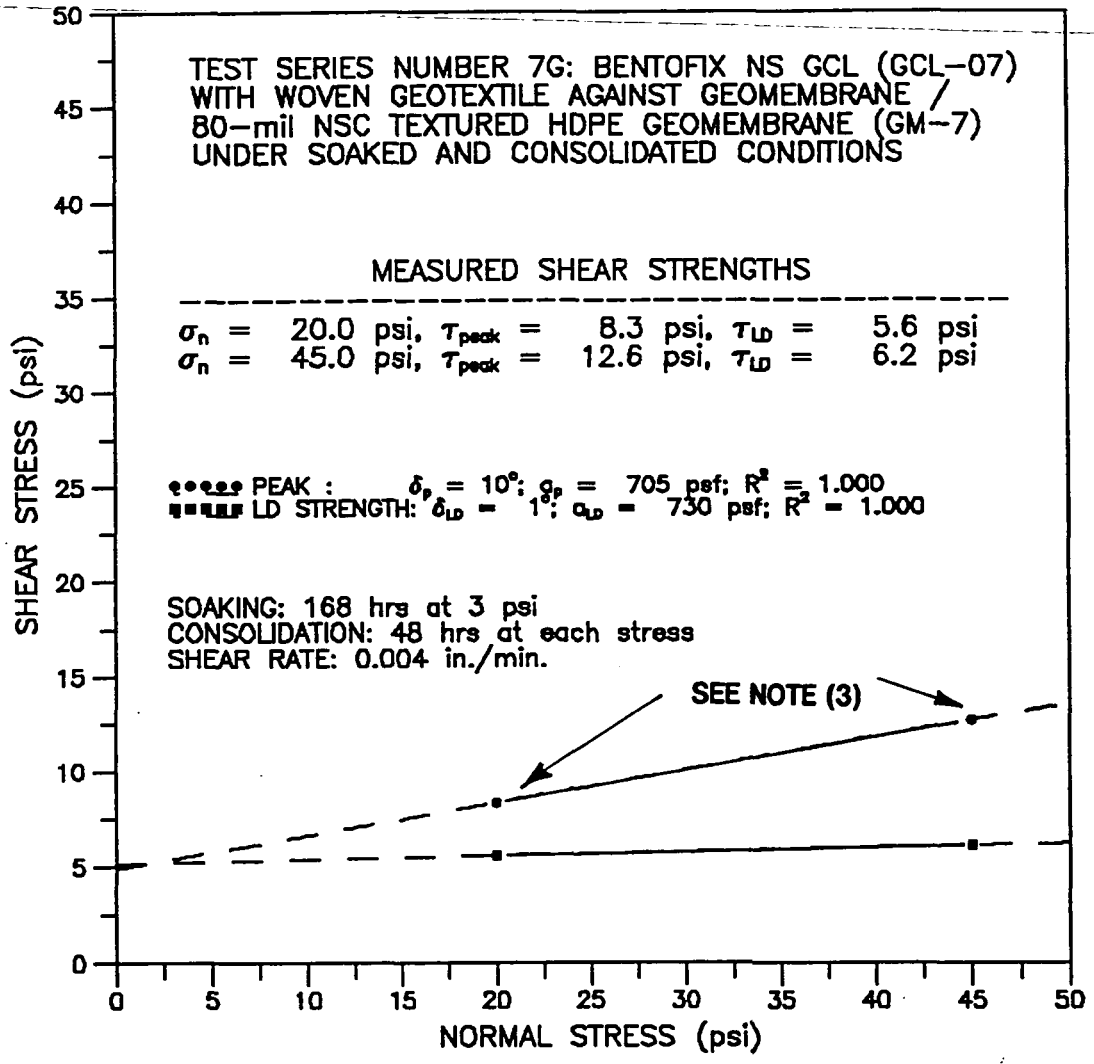
(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 27 SEPTEMBER TO 6 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730089
FILE NO.	000142

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 27 SEPTEMBER TO 6 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730089
FILE NO.	

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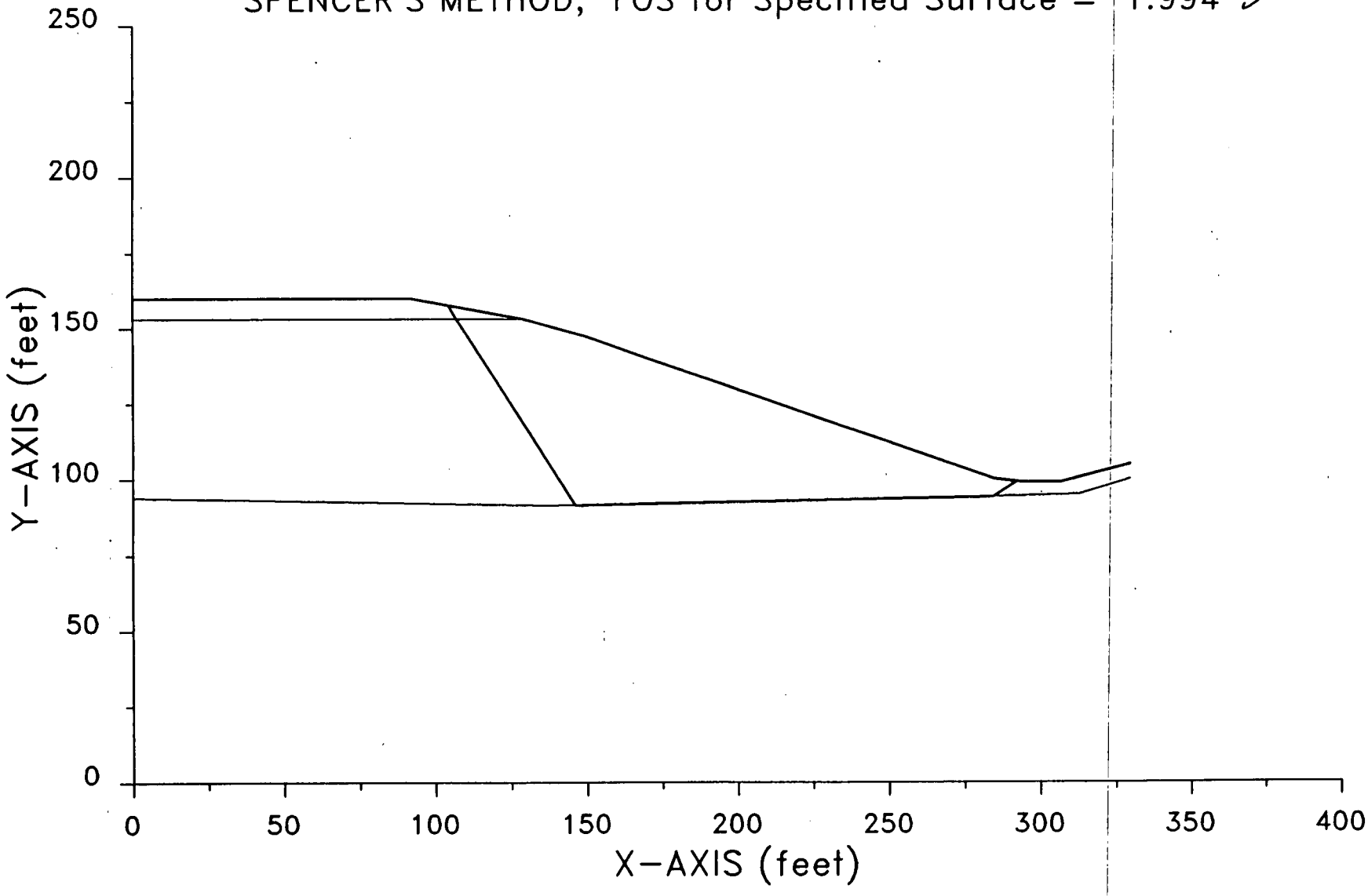
APPENDIX B

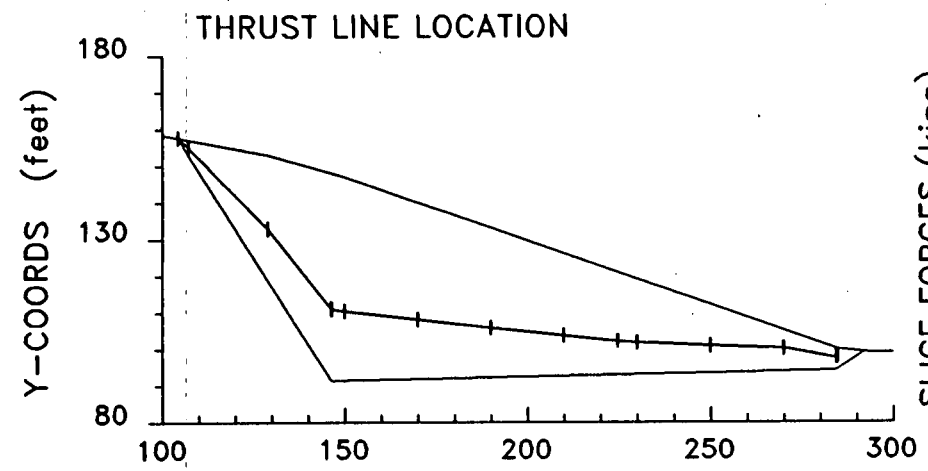
NPK07AS 10-13-97 18:01

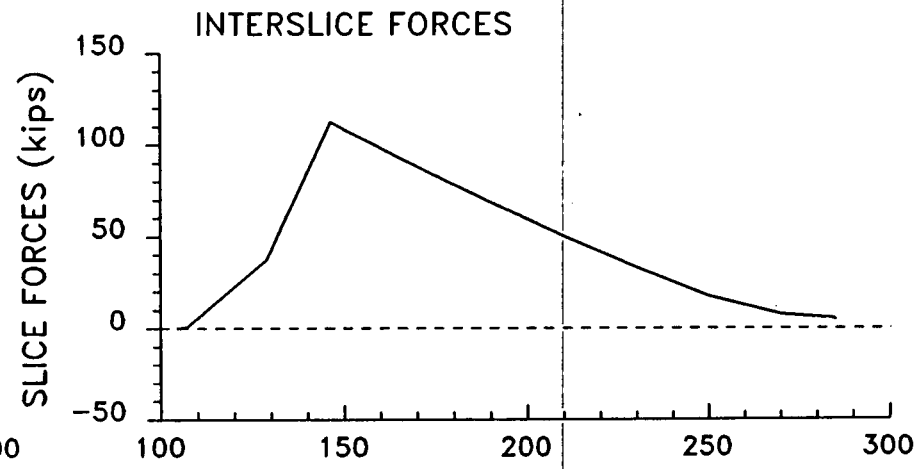
OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 1.994

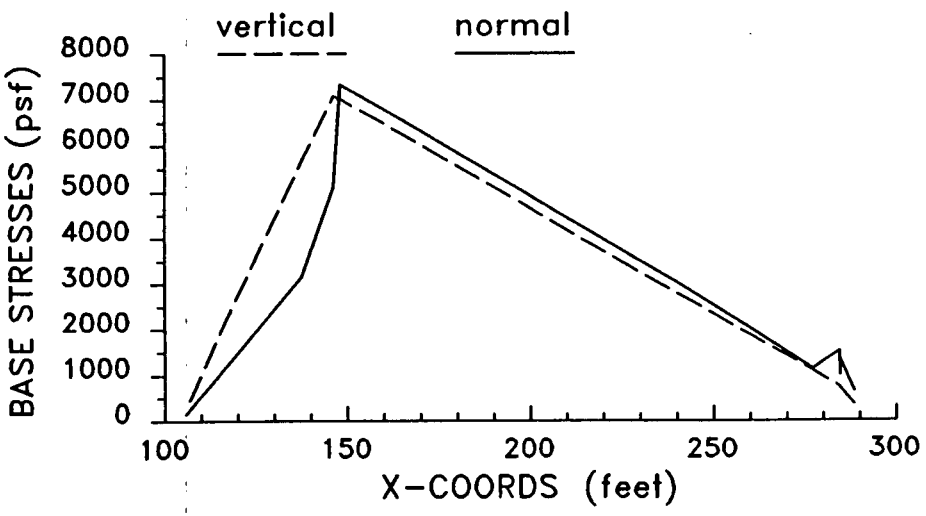


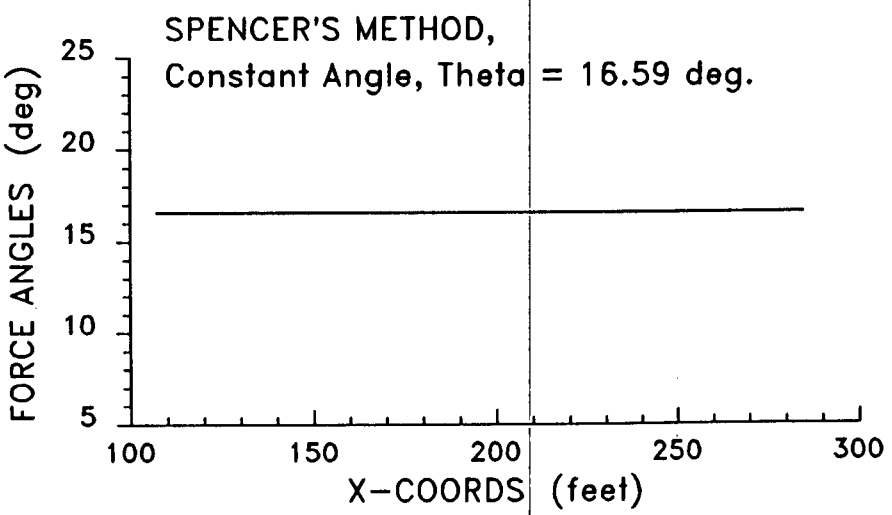
1269 10/31

000145









OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 1.994

1269

11/37

000146

XSTABL File: NPK07AS 10-13-97 18:01

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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*  Ver. 5.201                 96 á 1202 *
*****************************************
```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	1396.8
5	6480.0	1670.4
6	10080.0	1670.4

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	292.25	99.19
2	284.72	94.39
3	284.52	94.19
4	224.80	93.00
5	146.52	91.37
6	146.28	91.60
7	107.17	153.00
8	104.49	157.64

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.63	96.88	2.72	7.25	-32.54	6.34	2461.
2	284.86	94.48	5.57	.27	-32.54	19.12	190.
3	284.72	94.39	5.70	.01	-32.54	19.12	5.
4	284.62	94.29	5.84	.20	-45.00	19.12	146.
5	277.26	94.05	8.64	14.52	-1.14	19.12	15678.
6	260.00	93.70	15.00	20.00	-1.14	19.29	37496.
7	240.00	93.30	22.35	20.00	-1.14	19.03	55868.
8	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
9	217.40	92.85	30.66	14.80	-1.19	19.29	56729.
10	200.00	92.48	37.12	20.00	-1.19	19.29	92791.
11	180.00	92.07	44.48	20.00	-1.19	19.03	111207.
12	160.00	91.65	51.85	20.00	-1.19	19.29	129623.
13	148.26	91.41	56.09	3.48	-1.19	15.95	24400.
14	146.40	91.49	56.54	.24	43.78	15.95	1696.
15	137.64	105.16	45.37	17.28	57.50	15.95	97993.
16	118.08	135.86	19.20	21.83	57.50	10.71	52394.
17	105.83	155.32	2.07	2.68	59.97	10.71	692.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.5466	2.0076	2.0283
3	16.5714	2.0083	2.0076

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.5854	1.9937	1.9933

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.5854	1.9937	1.9933

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	629.9	.0	30.00	0.	0.	0.	.00
2	1335.9	200.0	25.00	0.	0.	0.	.00
3	976.2	-465.6	32.89	0.	0.	0.	.00
4	1518.7	-465.6	32.89	0.	0.	0.	.00
5	1128.5	-465.6	32.89	0.	0.	0.	.00
6	2020.9	-465.6	32.89	0.	0.	0.	.00
7	3035.9	1177.9	4.35	0.	0.	0.	.00
8	3622.9	1177.9	4.35	0.	0.	0.	.00
9	4096.5	1177.9	4.35	0.	0.	0.	.00
10	4918.1	1177.9	4.35	0.	0.	0.	.00
11	5856.1	1177.9	4.35	0.	0.	0.	.00
12	6790.3	1670.4	.00	0.	0.	0.	.00
13	7323.8	1670.4	.00	0.	0.	0.	.00
14	5095.2	1177.9	4.35	0.	0.	0.	.00
15	3140.5	200.0	25.00	0.	0.	0.	.00
16	1287.4	200.0	25.00	0.	0.	0.	.00
17	133.8	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.63	629.9	339.5	.0	182.4
2	284.86	1335.9	695.7	.0	412.8
3	284.72	976.2	712.9	.0	83.1
4	284.62	1518.7	730.2	.0	259.1
5	277.26	1128.5	1079.7	.0	132.5
6	260.00	2020.9	1874.8	.0	422.0
7	240.00	3035.9	2793.4	.0	706.6
8	227.40	3622.9	3369.8	.0	728.9
9	217.40	4096.5	3833.0	.0	747.0
10	200.00	4918.1	4639.6	.0	778.3
11	180.00	5856.1	5560.4	.0	814.1
12	160.00	6790.3	6481.2	.0	837.9
13	148.26	7323.8	7011.4	.0	837.9
14	146.40	5095.2	7067.9	.0	785.1
15	137.64	3140.5	5670.9	.0	834.9
16	118.08	1287.4	2400.1	.0	401.4
17	105.83	133.8	258.1	.0	38.8

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	16.59	4420.	3.39	5.43	.625
2	284.73	16.59	4780.	3.38	5.70	.593
3	284.72	16.59	4785.	3.39	5.71	.593

4	284.52	16.59	5156.	3.39	5.98	.568
5	270.00	16.59	7505.	6.22	11.30	.551
6	250.00	16.59	17151.	7.29	18.70	.390
7	230.00	16.59	33158.	8.59	26.00	.330
8	224.80	16.59	37504.	9.15	27.92	.328
9	210.00	16.59	50357.	10.93	33.41	.327
10	190.00	16.59	68736.	13.53	40.82	.331
11	170.00	16.59	88269.	16.20	48.14	.337
12	150.00	16.59	108704.	18.93	55.56	.341
13	146.52	16.59	112300.	19.42	56.62	.343
14	146.28	16.59	111274.	19.44	56.46	.344
15	129.00	16.59	37432.	14.11	34.27	.412
16	107.17	16.59	538.	1.92	4.13	.465
17	104.49	.00	-1.	-.14	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3260.13 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 603.77 (psf)

Total Length of failure surface = 225.73 feet

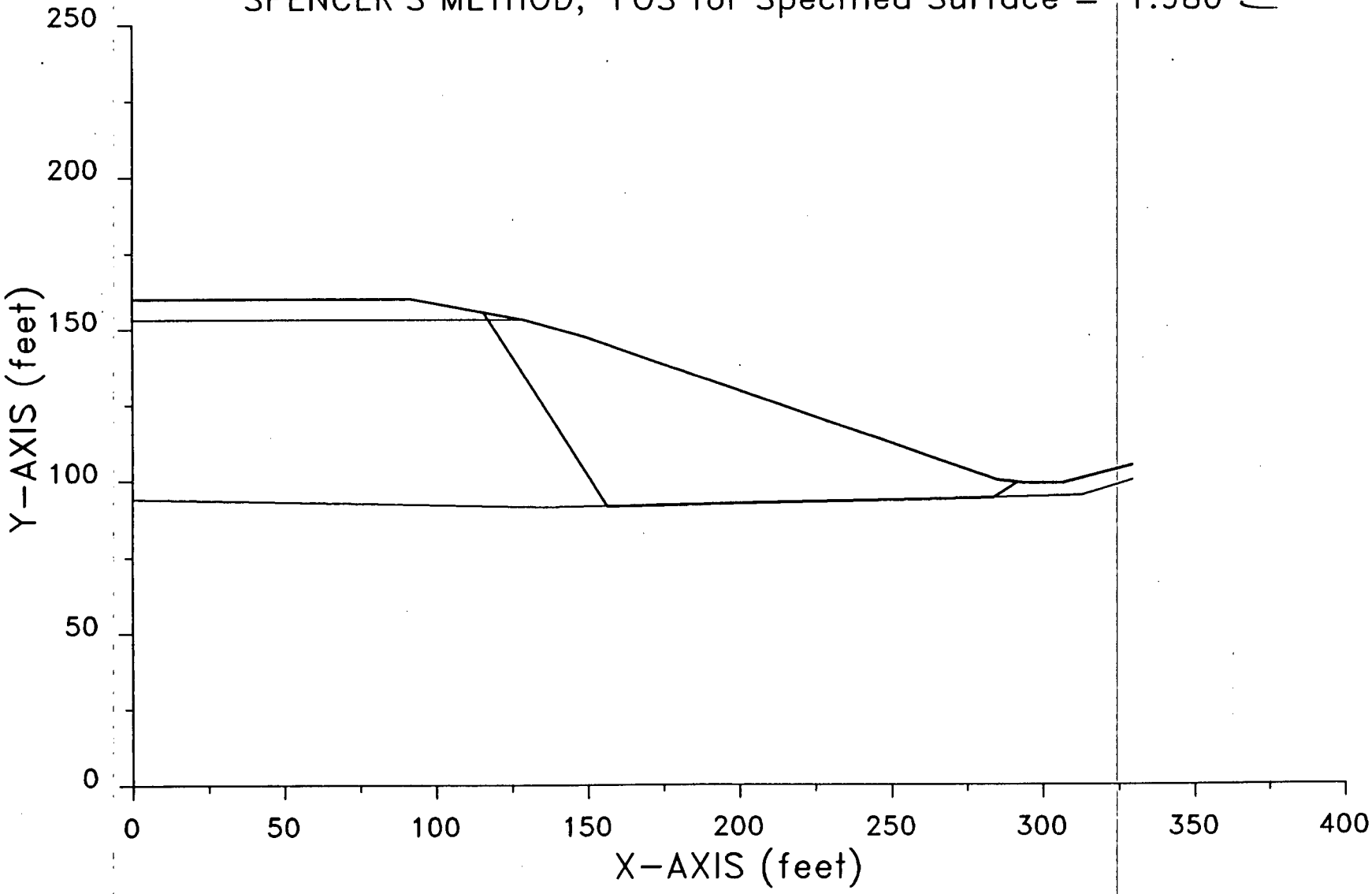
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

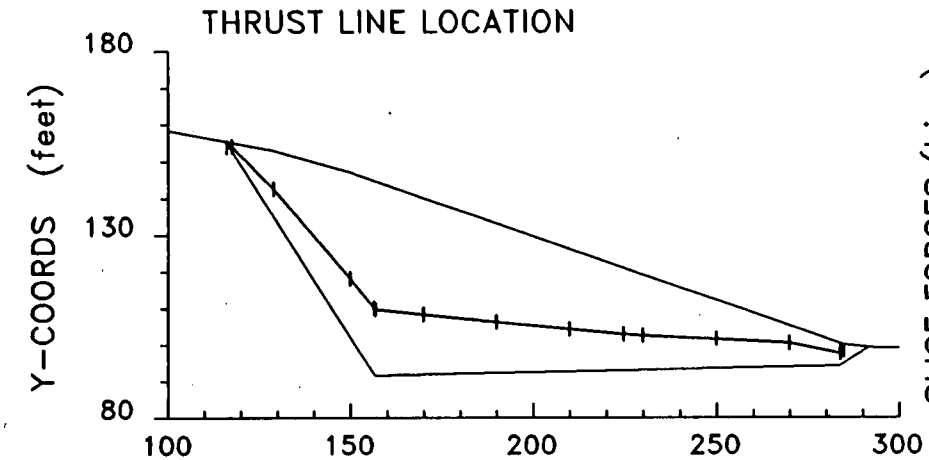
FACTOR OF SAFETY = 1.994 ✓

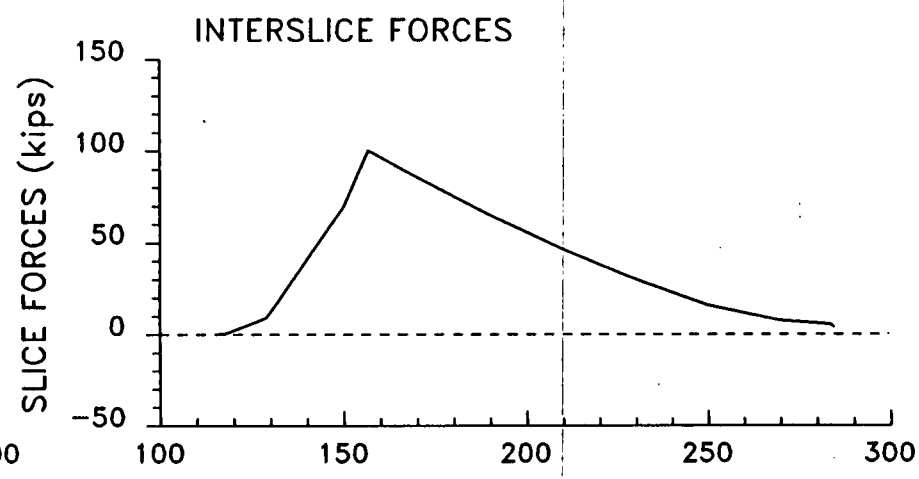
Total shear strength available
along specified failure surface = 271.72E+03 lb

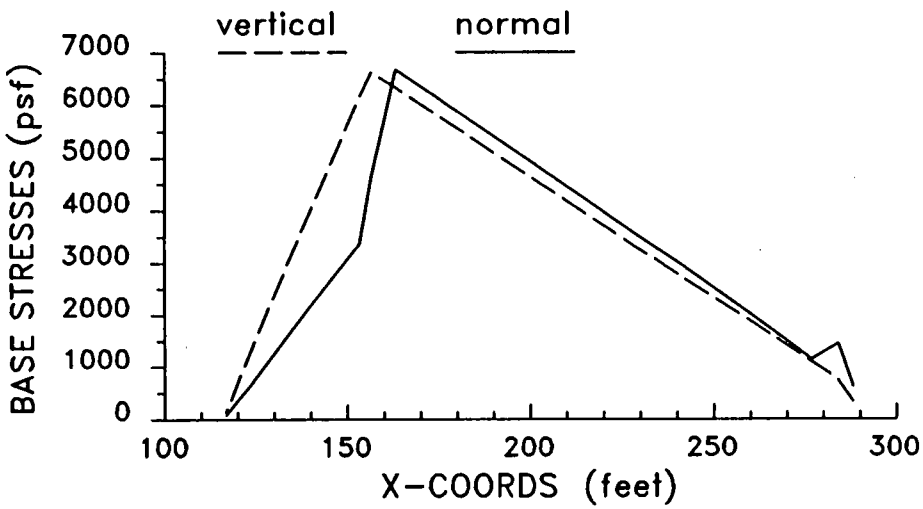
NPK07BS 10-10-97 13:34

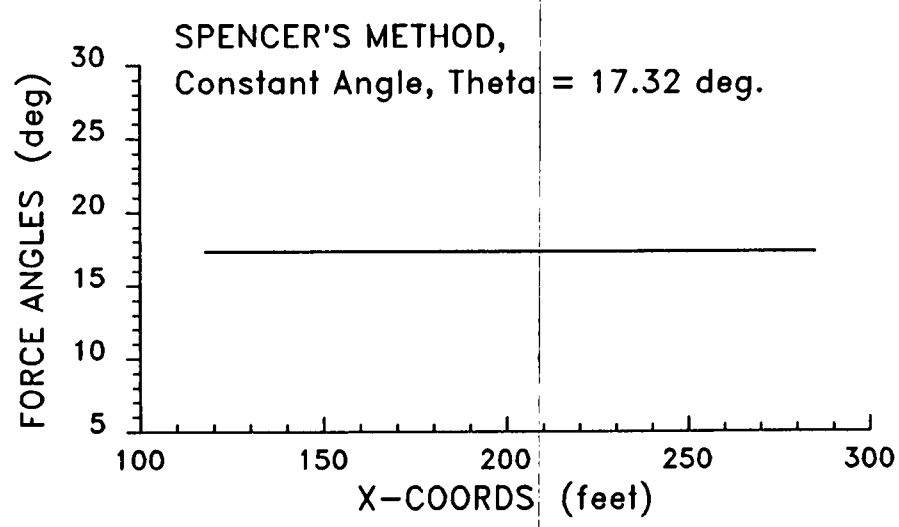
OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 1.980











OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 1.980

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*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	1195.2
5	6480.0	1814.4
6	10080.0	1814.4

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	291.80	99.24
2	284.17	94.38
3	283.96	94.18
4	224.80	93.00
5	156.82	91.58
6	156.59	91.81
7	117.61	153.00
8	116.21	155.42

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.40	97.08	2.55	6.80	-32.52	6.34	2164.
2	284.59	94.64	5.50	.83	-32.52	19.12	571.
3	284.07	94.28	6.04	.21	-43.60	19.12	159.
4	276.98	94.04	8.74	13.96	-1.14	19.12	15250.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37495.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55867.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.20	19.29	56729.
9	200.00	92.48	37.12	20.00	-1.20	19.29	92795.
10	180.00	92.06	44.49	20.00	-1.20	19.03	111215.
11	163.41	91.72	50.59	13.18	-1.20	19.29	83345.
12	156.71	91.69	52.96	.23	45.00	19.29	1523.
13	153.29	96.98	48.86	6.59	57.50	19.29	40252.
14	139.50	118.64	31.36	21.00	57.50	15.95	82327.
15	123.30	144.06	10.02	11.39	57.50	10.71	14262.
16	116.91	154.21	1.08	1.40	59.95	10.71	189.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.3139	1.9907	2.0027
3	17.3295	1.9912	1.9907

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.3196	1.9803	1.9806

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	17.3196	1.9803	1.9806

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	606.7	.0	30.00	0.	0.	0.	.00
2	1356.0	200.0	25.00	0.	0.	0.	.00
3	1432.7	-398.4	28.96	0.	0.	0.	.00
4	1138.3	-398.4	28.96	0.	0.	0.	.00
5	2006.5	-398.4	28.96	0.	0.	0.	.00
6	3016.3	699.8	9.76	0.	0.	0.	.00
7	3613.6	699.8	9.76	0.	0.	0.	.00
8	4095.7	699.8	9.76	0.	0.	0.	.00
9	4932.0	699.8	9.76	0.	0.	0.	.00
10	5886.8	699.8	9.76	0.	0.	0.	.00
11	6671.9	1814.4	.00	0.	0.	0.	.00
12	4649.1	699.8	9.76	0.	0.	0.	.00
13	3349.3	200.0	25.00	0.	0.	0.	.00
14	2124.2	200.0	25.00	0.	0.	0.	.00
15	630.1	200.0	25.00	0.	0.	0.	.00
16	69.1	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.40	606.7	318.2	.0	176.9
2	284.59	1356.0	687.4	.0	420.3
3	284.07	1432.7	755.5	.0	199.1
4	276.98	1138.3	1092.4	.0	116.9
5	260.00	2006.5	1874.7	.0	359.5
6	240.00	3016.3	2793.4	.0	615.4
7	227.40	3613.6	3369.8	.0	667.3
8	217.40	4095.7	3833.1	.0	709.1
9	200.00	4932.0	4639.8	.0	781.8
10	180.00	5886.8	5560.7	.0	864.7
11	163.41	6671.9	6323.6	.0	916.2
12	156.71	4649.1	6619.8	.0	757.2
13	153.29	3349.3	6108.0	.0	889.7
14	139.50	2124.2	3920.3	.0	601.2
15	123.30	630.1	1252.2	.0	249.4
16	116.91	69.1	134.7	.0	20.1

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	17.32	4015.	3.23	5.09	.634
2	284.17	17.32	5132.	3.23	5.91	.546
3	283.96	17.32	5476.	3.28	6.18	.531
4	270.00	17.32	7517.	6.39	11.30	.566
5	250.00	17.32	15887.	7.91	18.70	.423
6	230.00	17.32	30039.	9.26	26.00	.356

7	224.80	17.32	34066.	9.79	27.92	.351
8	210.00	17.32	46386.	11.46	33.41	.343
9	190.00	17.32	64922.	13.89	40.83	.340
10	170.00	17.32	85614.	16.38	48.14	.340
11	156.82	17.32	100187.	18.07	53.03	.341
12	156.59	17.32	99249.	18.08	52.88	.342
13	150.00	17.32	69097.	15.87	44.85	.354
14	129.00	17.32	8970.	7.30	17.88	.408
15	117.61	17.32	145.	.99	2.15	.460
16	116.21	.00	-1.	-1.70	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3044.56 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 575.05 (psf)

Total Length of failure surface = 212.18 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.980 ✓

Total shear strength available along specified failure surface = 241.62E+03 lb

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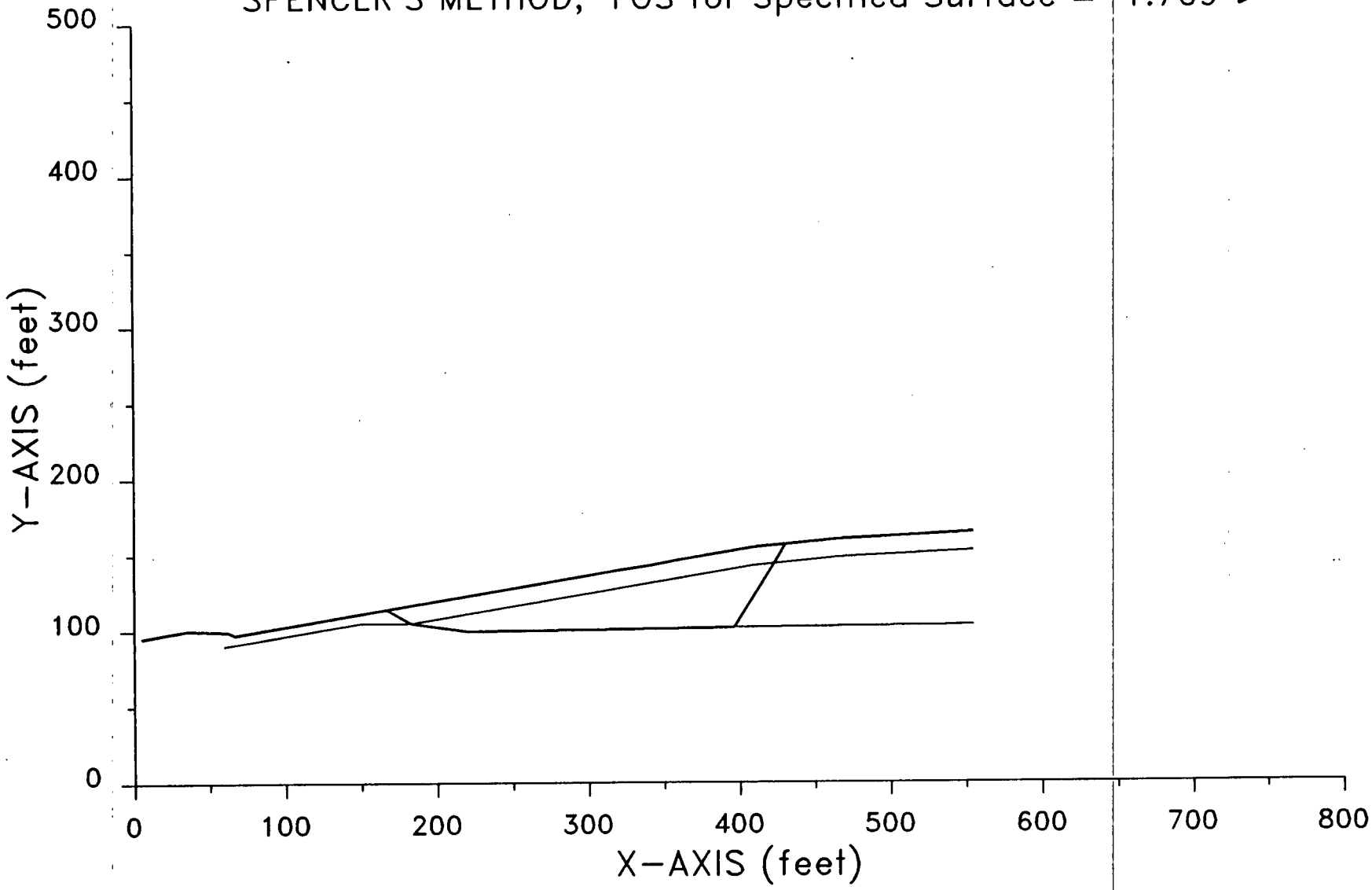
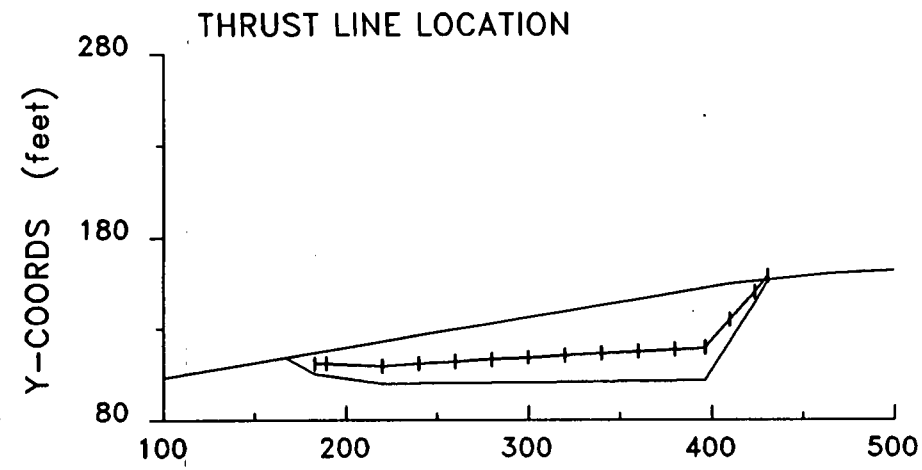
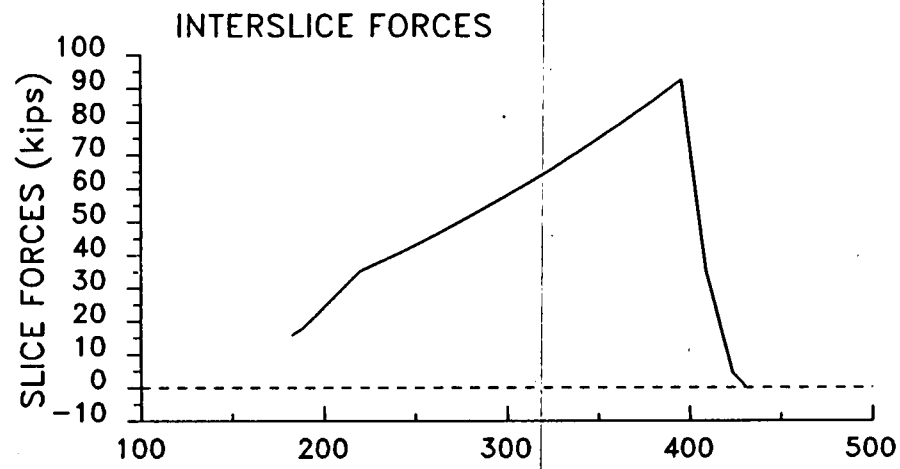
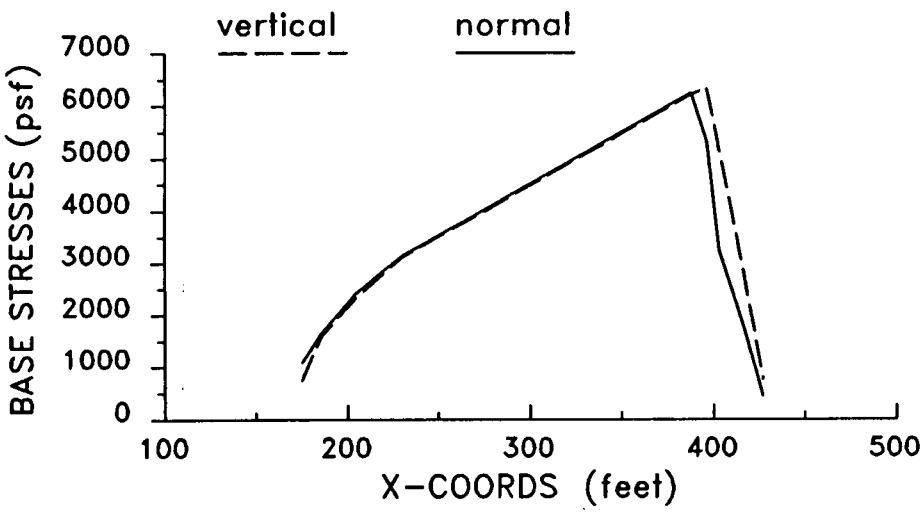
OSDF Final Long Term – Large Displ.

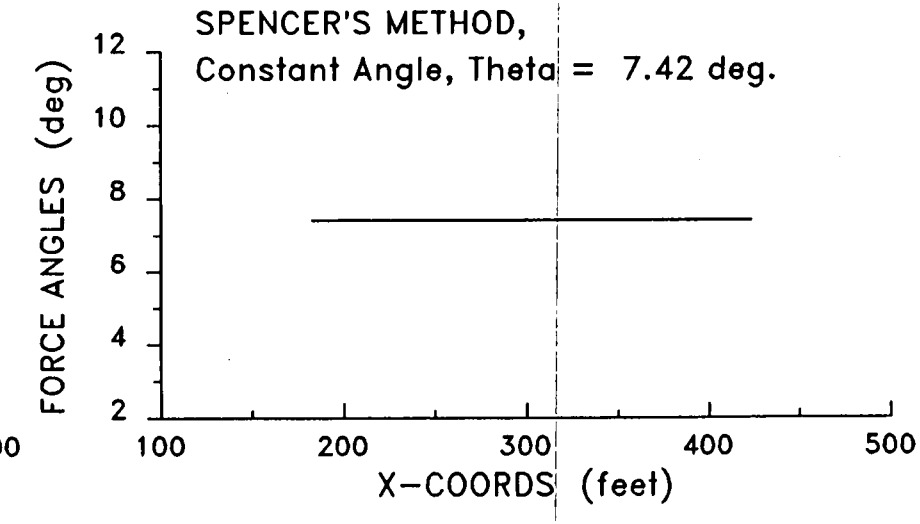
SPENCER'S METHOD, FOS for Specified Surface = 1.709











OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.709

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*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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```

Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	460.8
5	6480.0	806.4
6	10080.0	806.4

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	396.44	101.60
6	396.69	101.85
7	423.64	144.16
8	430.93	156.79

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.70	37.35	20.00	.59	9.37	93366.
9	330.00	100.91	40.44	20.00	.59	9.37	101097.
10	350.00	101.12	43.58	20.00	.59	9.65	108954.
11	370.00	101.33	46.72	20.00	.59	9.37	116810.
12	388.22	101.51	49.56	16.44	.59	9.46	101836.
13	396.57	101.73	50.73	.25	45.00	9.46	1605.
14	403.35	112.30	41.29	13.31	57.50	9.46	68681.
15	416.82	133.45	21.93	13.64	57.50	5.71	37393.
16	427.29	150.48	5.95	7.29	60.01	5.71	5420.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.3295	1.7070	1.7539
3	7.4185	1.7092	1.7070
4	7.4164	1.7092	1.7092

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.4164	1.7092	1.7092

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1078.5	.0	30.00	0.	0.	0.	.00

2	1656.3	-153.6	12.04	0.	0.	0.	.00
3	2405.8	-153.6	12.04	0.	0.	0.	.00
4	3130.0	184.3	5.48	0.	0.	0.	.00
5	3525.9	184.3	5.48	0.	0.	0.	.00
6	3915.5	184.3	5.48	0.	0.	0.	.00
7	4311.4	184.3	5.48	0.	0.	0.	.00
8	4706.5	184.3	5.48	0.	0.	0.	.00
9	5095.2	184.3	5.48	0.	0.	0.	.00
10	5490.1	184.3	5.48	0.	0.	0.	.00
11	5885.1	184.3	5.48	0.	0.	0.	.00
12	6240.9	184.3	5.48	0.	0.	0.	.00
13	5299.3	184.3	5.48	0.	0.	0.	.00
14	3231.6	.0	25.00	0.	0.	0.	.00
15	1716.1	.0	25.00	0.	0.	0.	.00
16	420.9	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1078.5	739.6	.0	364.3
2	186.00	1656.3	1594.4	.0	116.9
3	204.50	2405.8	2304.8	.0	210.4
4	230.00	3130.0	3100.0	.0	283.6
5	250.00	3525.9	3493.8	.0	305.9
6	270.00	3915.5	3881.3	.0	327.8
7	290.00	4311.4	4275.0	.0	350.0
8	310.00	4706.5	4668.3	.0	372.2
9	330.00	5095.2	5054.9	.0	394.0
10	350.00	5490.1	5447.7	.0	416.2
11	370.00	5885.1	5840.5	.0	438.4
12	388.22	6240.9	6194.4	.0	458.4
13	396.57	5299.3	6341.8	.0	405.5
14	403.35	3231.6	5161.3	.0	881.7
15	416.82	1716.1	2740.9	.0	468.2
16	427.29	420.9	743.7	.0	142.2

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.42	15829.	5.63	11.83	.475
2	189.00	7.42	17945.	6.49	13.68	.475
3	220.00	7.42	35092.	9.66	23.20	.416
4	240.00	7.42	40182.	10.69	26.40	.405
5	260.00	7.42	45640.	11.67	29.50	.396
6	280.00	7.42	51461.	12.62	32.60	.387
7	300.00	7.42	57650.	13.53	35.80	.378
8	320.00	7.42	64173.	14.43	38.89	.371
9	340.00	7.42	71054.	15.31	41.99	.365

10	360.00	7.42	78300.	16.18	45.18	.358
11	380.00	7.42	85911.	17.04	48.27	.353
12	396.44	7.42	92438.	17.73	50.84	.349
13	396.69	7.42	91189.	17.75	50.63	.351
14	410.00	7.42	34940.	11.76	31.95	.368
15	423.64	7.42	4315.	5.84	11.90	.491
16	430.93	.00	0.	1.89	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3567.89 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 387.62 (psf)

Total Length of failure surface = 297.28 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

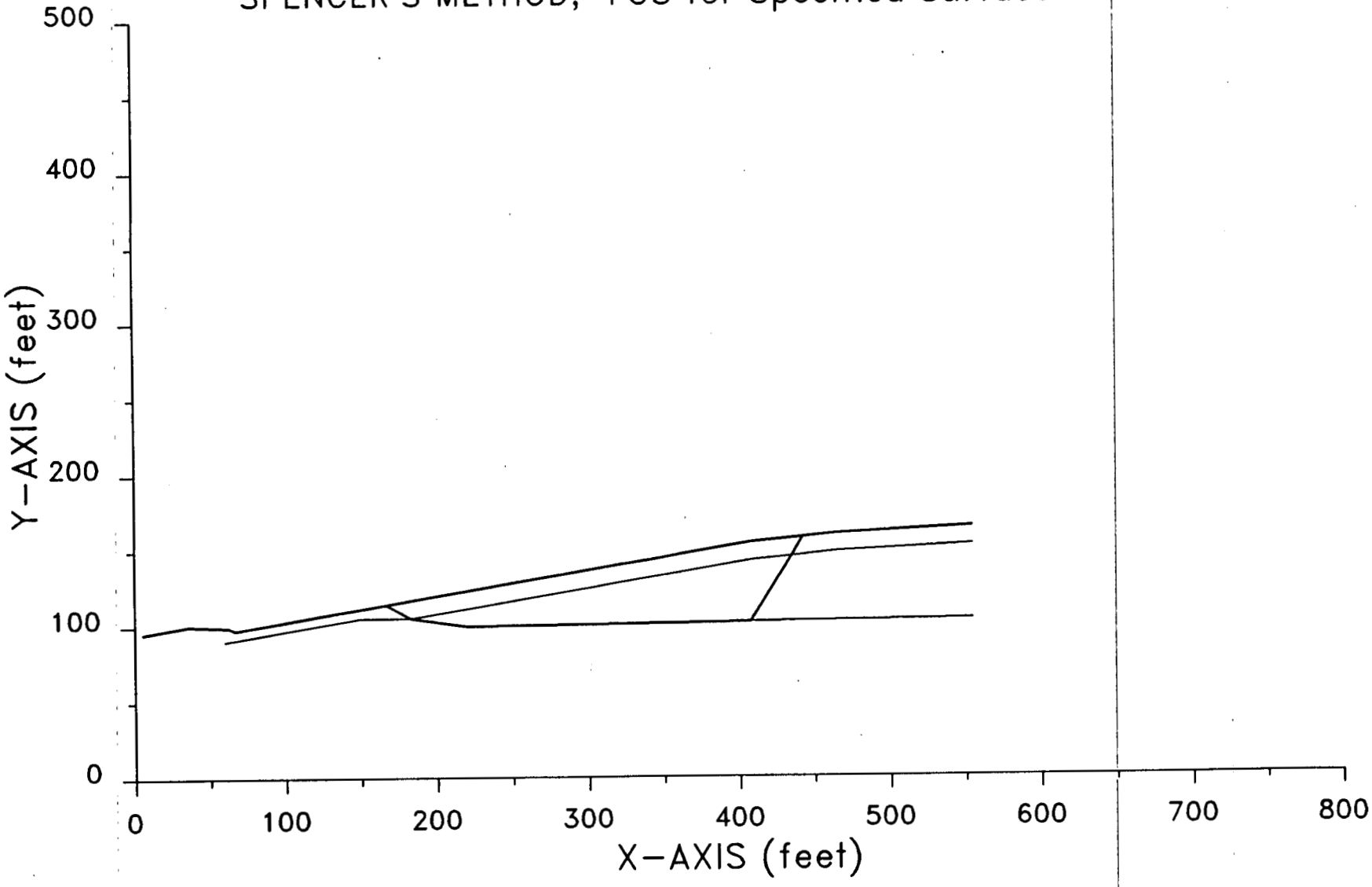
FACTOR OF SAFETY = 1.709

Total shear strength available along specified failure surface = 196.95E+03 lb

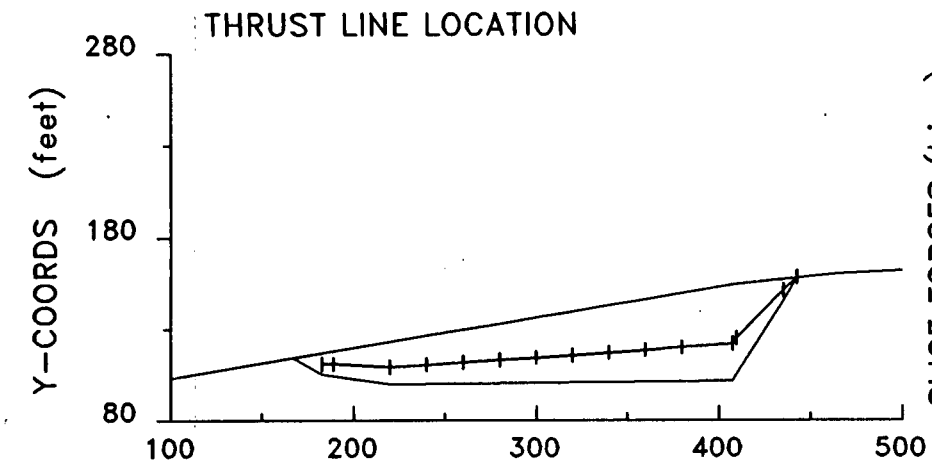
NLD07BS 10-10-97 13:37

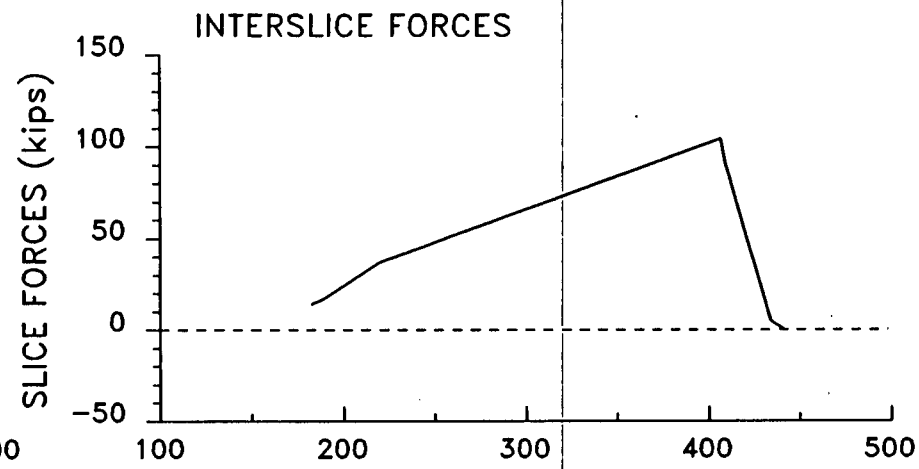
OSDF Final Long Term – Large Displ.

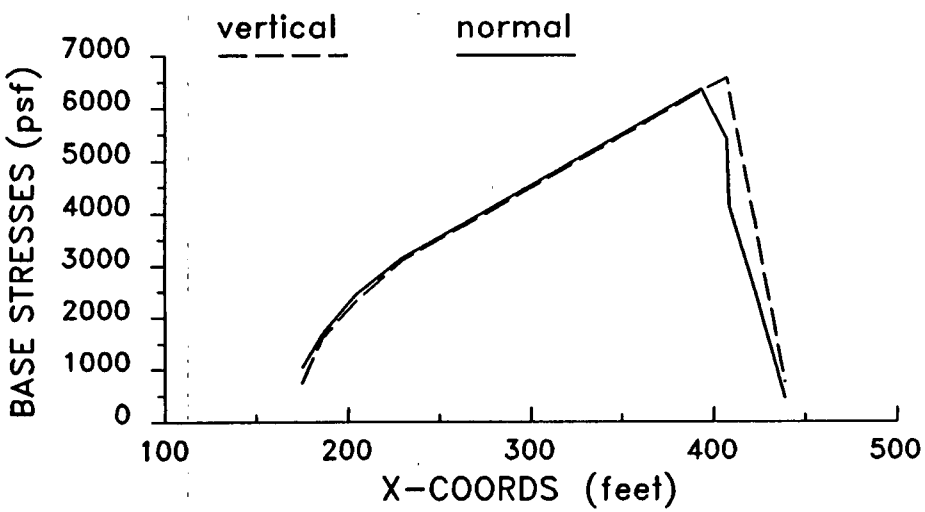
SPENCER'S METHOD, FOS for Specified Surface = 2.101

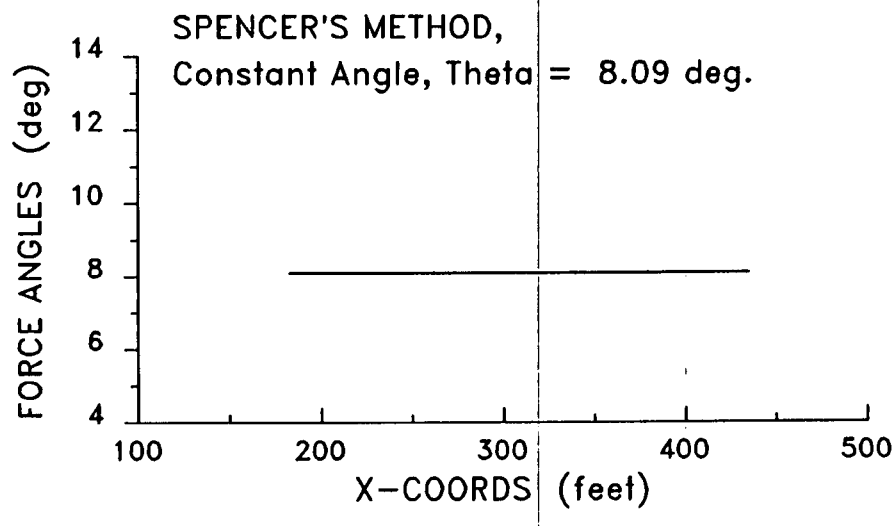


31/37









OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.101

32/37

12669

000167

XSTABL File: NLD07BS 10-10-97 13:37

```
*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.201                96 á 1202  *
*****************************************
```

Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

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5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	806.4
5	6480.0	892.8
6	10080.0	892.8

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	407.64	101.72
6	407.89	101.98
7	435.53	145.35
8	442.82	157.98

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.70	37.35	20.00	.60	9.37	93365.
9	330.00	100.91	40.44	20.00	.60	9.37	101095.
10	350.00	101.12	43.58	20.00	.60	9.65	108949.
11	370.00	101.33	46.72	20.00	.60	9.37	116804.
12	393.82	101.58	50.43	27.64	.60	9.46	174226.
13	407.77	101.85	52.48	.25	46.12	9.46	1640.
14	408.95	103.64	50.89	2.11	57.49	9.46	13422.
15	422.77	125.32	30.65	25.53	57.49	5.71	97834.
16	439.18	151.67	5.95	7.29	60.01	5.71	5420.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	8.0662	2.1003	2.1313
3	8.0871	2.1010	2.1003

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	8.0871	2.1010	2.1003

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1027.0	.0	30.00	0.	0.	0.	.00
2	1675.8	-268.8	20.47	0.	0.	0.	.00

3	2439.9	-268.8	20.47	0.	0.	0.	.00
4	3146.6	737.3	1.37	0.	0.	0.	.00
5	3540.4	737.3	1.37	0.	0.	0.	.00
6	3927.9	737.3	1.37	0.	0.	0.	.00
7	4321.7	737.3	1.37	0.	0.	0.	.00
8	4714.6	737.3	1.37	0.	0.	0.	.00
9	5101.1	737.3	1.37	0.	0.	0.	.00
10	5493.8	737.3	1.37	0.	0.	0.	.00
11	5886.6	737.3	1.37	0.	0.	0.	.00
12	6349.8	737.3	1.37	0.	0.	0.	.00
13	5392.4	737.3	1.37	0.	0.	0.	.00
14	4131.4	.0	25.00	0.	0.	0.	.00
15	2488.7	.0	25.00	0.	0.	0.	.00
16	441.8	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1027.0	739.6	.0	282.2
2	186.00	1675.8	1594.4	.0	169.8
3	204.50	2439.9	2304.8	.0	305.6
4	230.00	3146.6	3100.0	.0	386.9
5	250.00	3540.4	3493.8	.0	391.4
6	270.00	3927.9	3881.3	.0	395.8
7	290.00	4321.7	4275.0	.0	400.3
8	310.00	4714.6	4668.2	.0	404.8
9	330.00	5101.1	5054.7	.0	409.2
10	350.00	5493.8	5447.5	.0	413.7
11	370.00	5886.6	5840.2	.0	418.2
12	393.82	6349.8	6303.4	.0	423.5
13	407.77	5392.4	6559.7	.0	412.5
14	408.95	4131.4	6361.1	.0	917.0
15	422.77	2488.7	3831.8	.0	552.4
16	439.18	441.8	743.7	.0	121.4

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	8.09	14058.	5.72	11.83	.484
2	189.00	8.09	16514.	6.44	13.68	.471
3	220.00	8.09	36820.	9.24	23.20	.398
4	240.00	8.09	44000.	10.17	26.40	.385
5	260.00	8.09	51190.	11.20	29.50	.380
6	280.00	8.09	58392.	12.31	32.60	.377
7	300.00	8.09	65605.	13.46	35.80	.376
8	320.00	8.09	72791.	14.64	38.89	.376
9	340.00	8.09	79985.	15.84	41.98	.377
10	360.00	8.09	87187.	17.07	45.18	.378

11	380.00	8.09	94397.	18.30	48.27	.379
12	407.64	8.09	104374.	20.03	52.59	.381
13	407.89	8.09	103062.	20.06	52.37	.383
14	410.00	8.09	91201.	19.46	49.41	.394
15	435.53	8.09	4740.	5.80	11.90	.487
16	442.82	.00	-2.	.24	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3701.19 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 399.19 (psf)

Total Length of failure surface = 309.75 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.101

Total shear strength available along specified failure surface = 259.78E+03 lb

GCL 08 – Not Approved for Phase I. Pending Approval for Phase II

GCL 09

COMPUTATION COVER SHEET

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) QA09 and QC04 - Compliance Package

Computations By: (Cognizant Engineer)
Signature: M. Orozco — Date: 22 OCT 1997
Printed Name and Title: M. CATALINA OROZCO, STAFF ENGINEER

Assumptions and Procedures Checked By: (Checker)
Signature: Robert A. Morgan III — Date: 23 OCT 1997
Printed Name and Title: ROBERT A. MORGAN III, SR. STAFF ENGINEER

Computations Checked by:
Signature: Robert A. Morgan III — Date: 23 OCT 1997
Printed Name and Title: ROBERT A. MORGAN III, SR. STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: M. Orozco — Date: 23 OCT 1997
Printed Name and Title: M. CATALINA OROZCO, STAFF ENGINEER

Approved by: (PDP)
Signature: Gary R. Schmertmann — Date: 23 Oct 97
Printed Name and Title: Gary R. Schmertmann, Senior Project Engineer

Approved by: (DTL and TETL)
Signature: K W C — Date: 27 Oct 97
Printed Name and Title: Kenneth W. Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

GEOSYNTEC CONSULTANTS

Written By : YCO Date: 10/22/97 Reviewed by: RAM Date: 10/23/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL lot number 97082702 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3). The evaluation is based on the shear test results from GCL QA sample no. 09 and GCL QC sample no. 04 ✓

METHOD

The method for evaluating the GCL samples is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL samples to establish the envelopes of measured peak and large-displacement ✓ internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 09 and the results of the GCL internal shear tests performed on QC sample no. 04 are shown in the following table. The results of the GCL internal shear tests for QA sample no. 09 were averaged with the results of the GCL internal shear tests for QC sample no. 04. The averaged values for the GCL internal shear tests were used in the stability analyses. The laboratory test results for GCL QA sample no. 09 ✓ are presented in Appendix A. The laboratory test results for GCL QC sample no. 04 ✓ are presented in Appendix B. ✓

Test Type	Case	Sample No.	Measured Shear Strengths (psi)		
			5 psi	20 psi	45 psi
GCL Internal	Peak	QA 09	6.5 ✓	10.1 ✓	13.7 ✓
		QC 04	3.55 ✓	9.12 ✓	17.46 ✓
		Average QA09-QC04	**5.025** ✓	**9.61** ✓	**15.58** ✓
	Large-displacement	QA 09	2.6 ✓	2.9 ✓	5.2 ✓
		QC 04	2.53 ✓	2.40 ✓	4.17 ✓
		Average QA09-QC04	**2.565** ✓	**2.65** ✓	**4.685** ✓
GCL/GMB Interface	Peak	QA 09	**3.0** ✓	**9.7** ✓	**14.9** ✓
	Large-displacement	QA 09	**1.7** ✓	**6.1** ✓	**6.4** ✓

Written By : YMO Date: 10/22/97 Reviewed by: RM Date: 10/23/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix C.

Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
Average QA09-QC04	GCL Internal	NPPK09AS ✓	2.3 ✓	YES ✓
QA 09	GCL/GMB Interface	NPK09BS ✓	2.3 ✓	YES ✓
Baseline	Large-displacement	NA	1.6	NA
Average QA09-QC04	GCL Internal	NPLD09AS ✓	1.6 ✓	YES ✓
QA 09	GCL/GMB Interface	NLD09BDS ✓	2.2 ✓	YES ✓

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MCO 10/22/97
RAM 10/23/97

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 9I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-09). GCL's initial moisture content was 8.7%. GCL's final moisture content ranged from 57% to 105% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 9G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

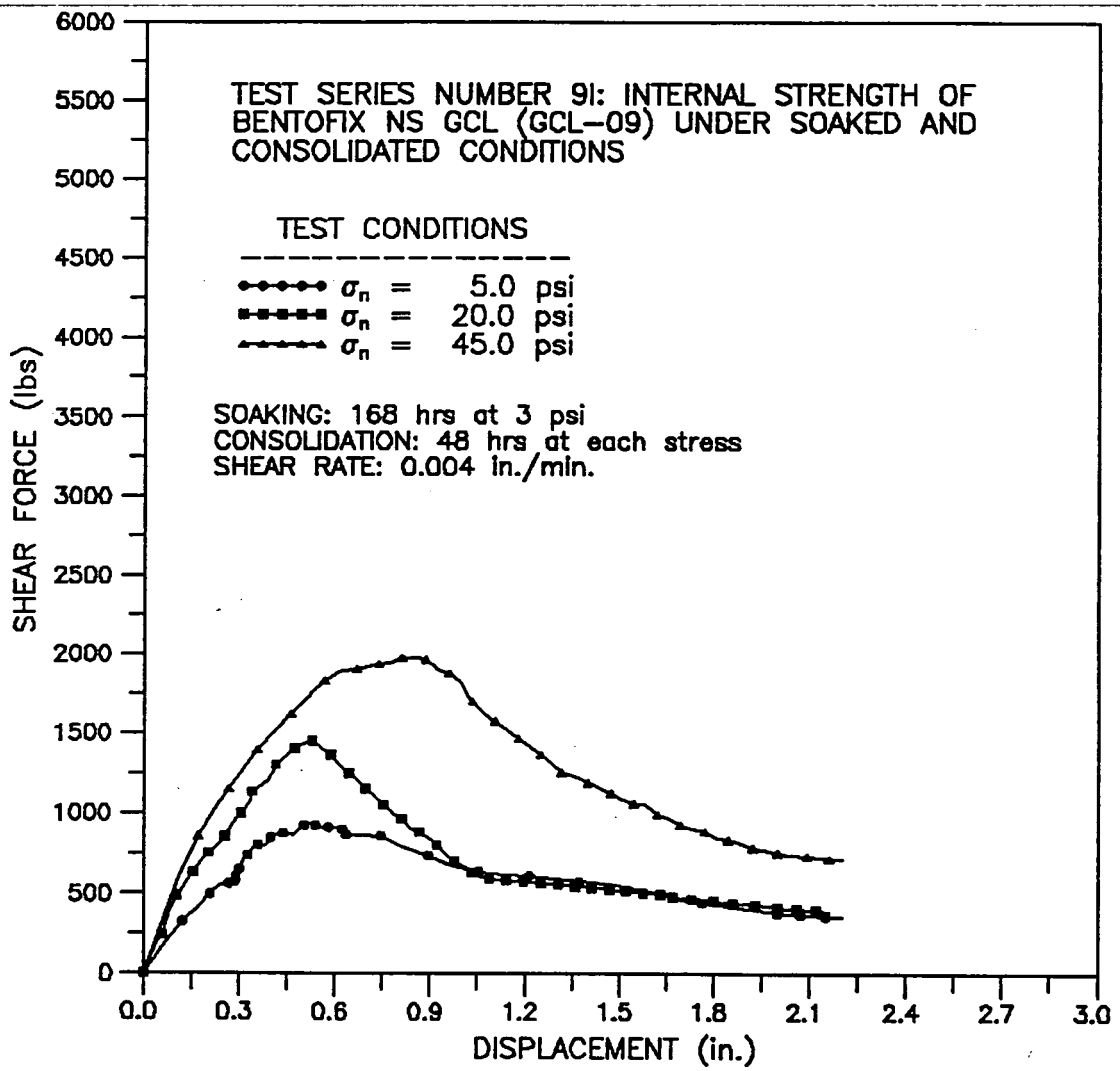
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-09) with woven geotextile against geomembrane. GCL's initial moisture content was 8.9%. GCL's final moisture content ranged from 62 to 107% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-10); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.

(2) For each test, sliding (i.e., internal shear failure) was observed to occur within the GCL.

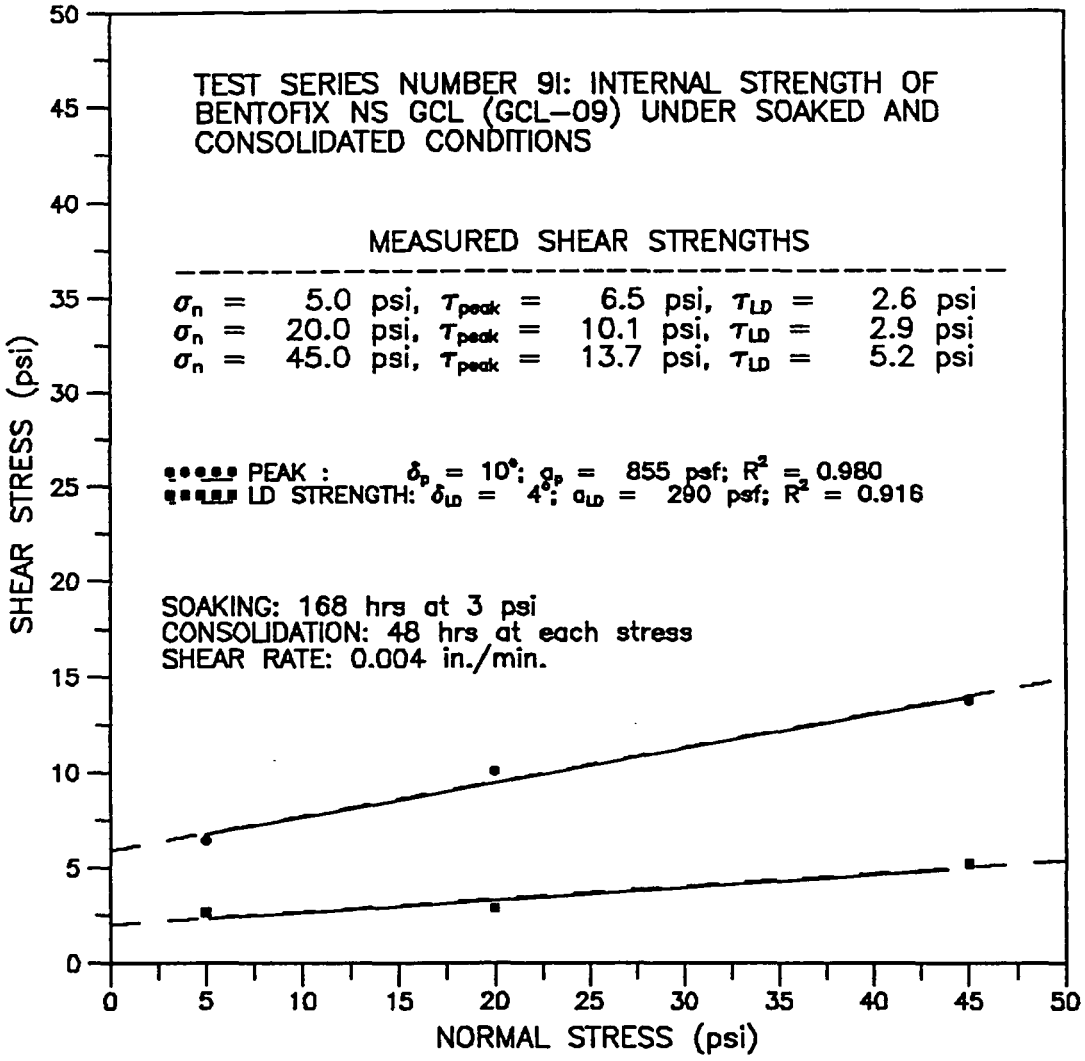
DATE TESTED: 8 TO 17 SEPTEMBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730099
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



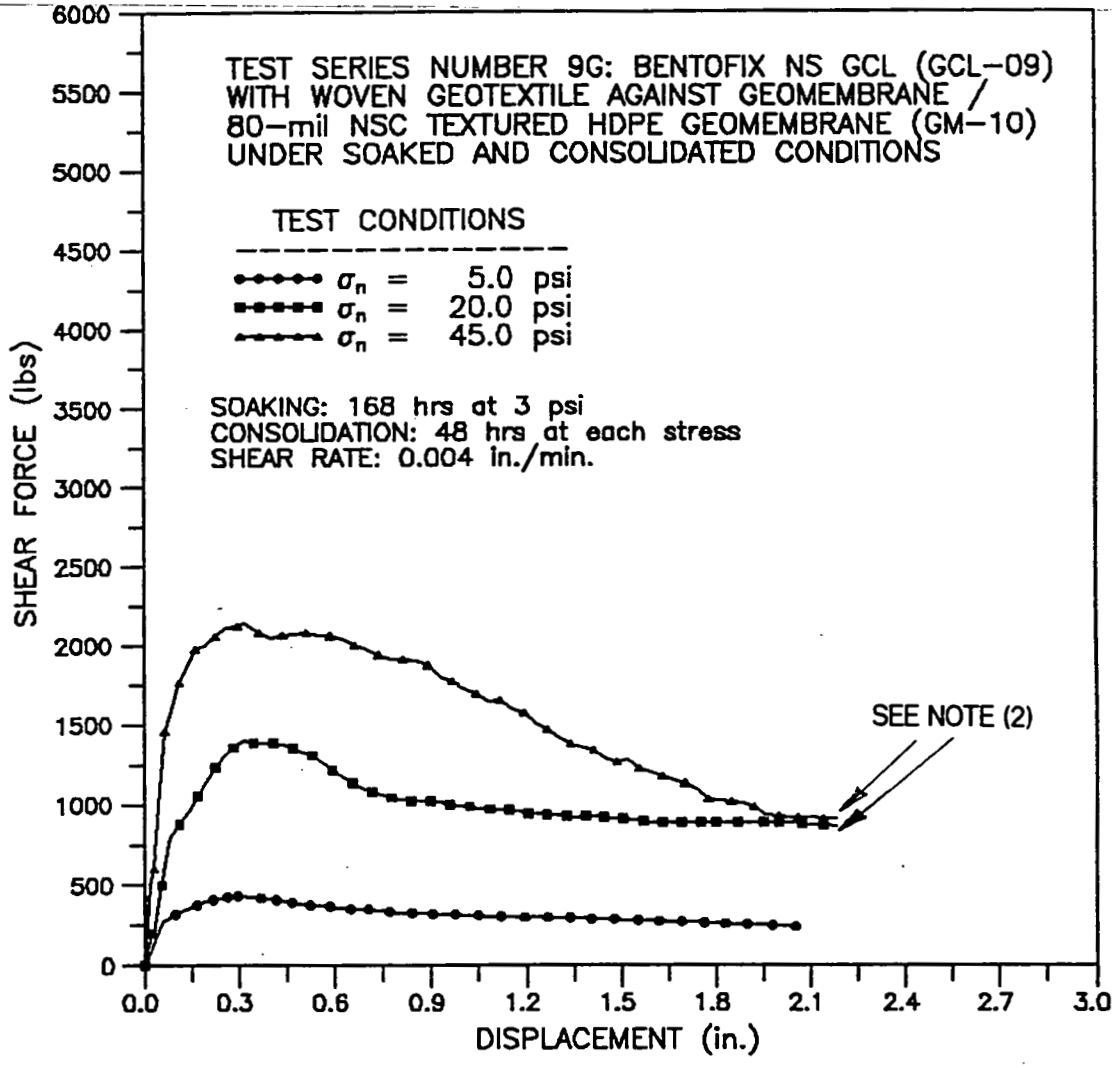
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) For each test, sliding (i.e, internal shear failure) was observed to occur within the GCL.

DATE TESTED: 8 TO 17 SEPTEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730099
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

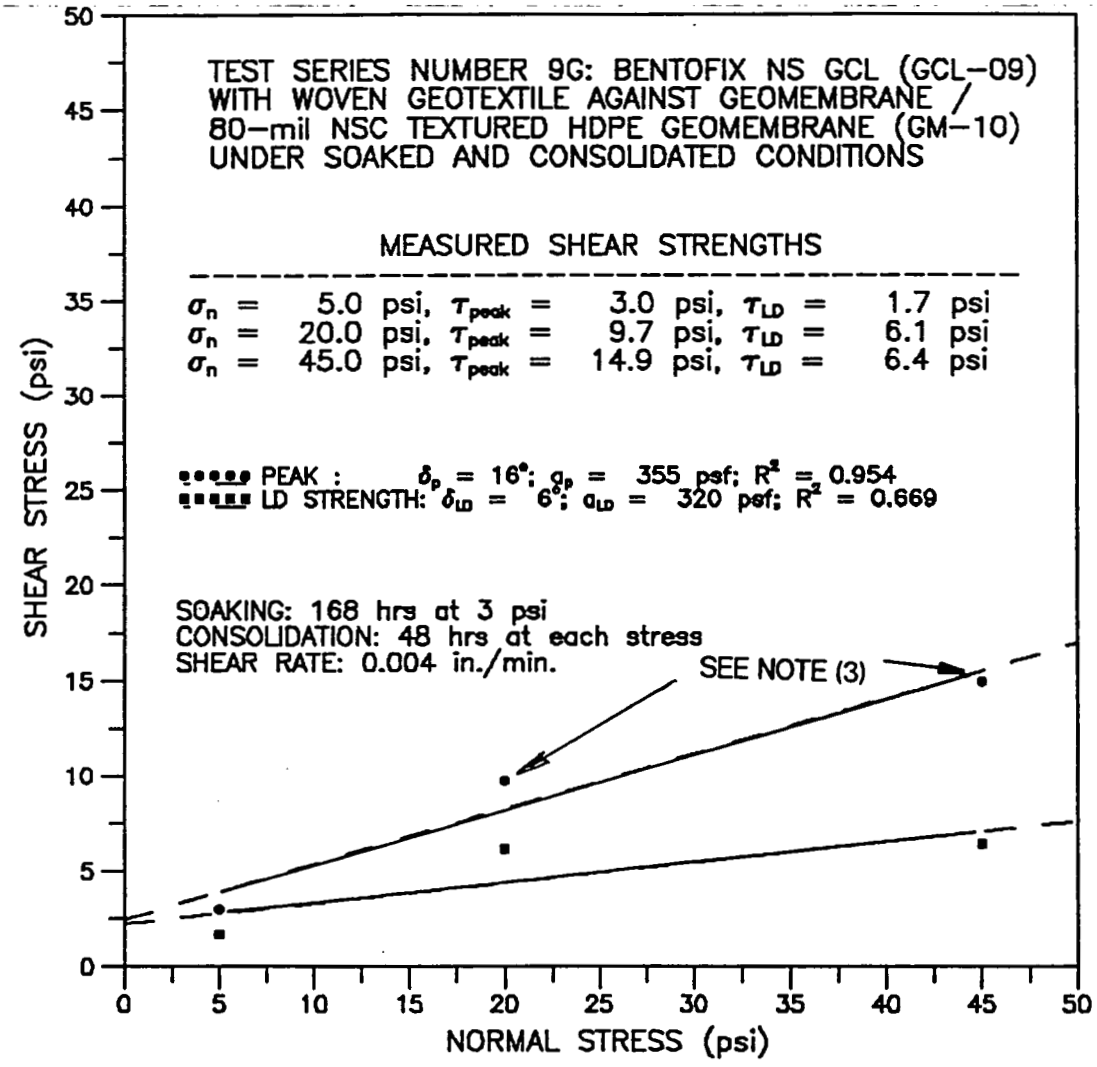
DATE TESTED: 12 TO 21 SEPTEMBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730099
FILE NO.	000183

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 12 TO 21 SEPTEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730099
FILE NO.	

YCO 10/22/97
RAM 10/23/97

APPENDIX B

NTH Consultants, Ltd.
Professional Engineering and Environmental Services

Farmington Hills, MI • (810) 553-6800
Exton PA • (610) 524-2300
Detroit, MI • (313) 965-0036
Lansing, MI • (517) 321-6900
Grand Rapids, MI • (616) 957-1690

JOB Fernald Site PROJECT NO. 54 7639 SHEET NO. 1
SUBJECT Direct Shear Testing BY RMS DATE 9/29/97
CHK. BY DATE 10/6/97 update

Summary of Test Results

Internal Strength of Hydrated GCL

Peak Strength

Normal Stress (psi)		Measured Shear Strength (psi)	Calculated Secant Angle (°)
Roll #03575 (57)	.5	3.81	37.3
	.45	17.18	20.9
	.45 (*)	18.06	21.9
# 36344	5 (*)	3.55	35.4
Roll # 36344	20 (*)	9.12	24.5
# 37386	45 (*)	18.85	22.7
Roll # 36114	45 (*)	15.76	19.3
Roll # 36344	45 (*)	17.46	21.2
Roll # 036262	45 (*)	14.46	17.8
Roll # 37061	45 (*)	9.20	11.6

New Data 10/14/97

Residual Strength @ 2 inches displacement

Normal Stress (psi)		Measured Shear Strength (psi)	Calculated Secant Angle (°)
Roll # 03575 (57)	5	3.25	33.0
	45	3.10	4.0
	45 (*)	3.98	5.1
# 36344	5 (*)	2.53	26.8
# 36344	20 (*)	2.40	6.9
Roll # 37386	45 (*)	4.51	5.7
Roll # 36114	45 (*)	3.35	4.3
Roll # 36344	45 (*)	4.17	5.3
Roll # 036262	45 (*)	3.73	4.7
Roll # 37061	45 (*)	2.92	3.7

New Data 10/14/97

(*) Speed for testing = 0.005 inches/minute

other speed = 0.04 inches/minute

PETRO
environmental technologies

Date: October 17, 1997

Destination Fax: (404) 705 - 9400

To: Gary Schmertmann

Company: Geo Synthetics

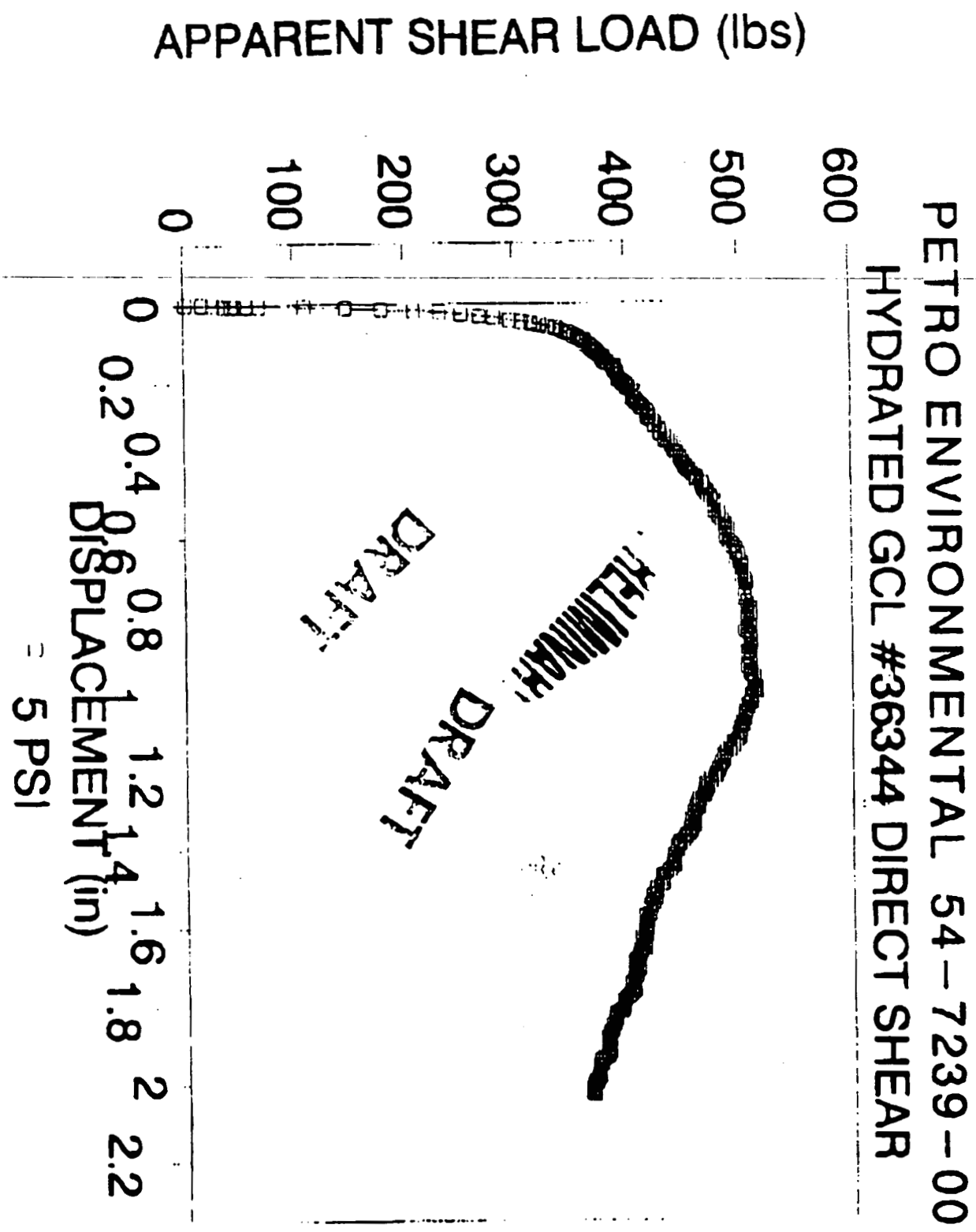
From: Rick Schaubaum

Total Number of Pages (Including Cover): 4

Comments: Graphs from NTH for Roll # 36344.

Fluor Daniel Fernald Project Office: 513.648.3402 • Fax 648.3407
Mailing: P. O. Box 538704, Mail Stop 44, Cincinnati, OH 45253-8704
Shipping: 7400 Willey Road, Cincinnati, OH 45030

7951 Palace Drive • Cincinnati, Ohio 45249 • 513.489.6789 • Fax 489.7208
8200 Seville Road • Seville, Ohio 44273 • 330.948.1494 • Fax 948.1933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HYDRATED GCL #36344 DIRECT SHEAR
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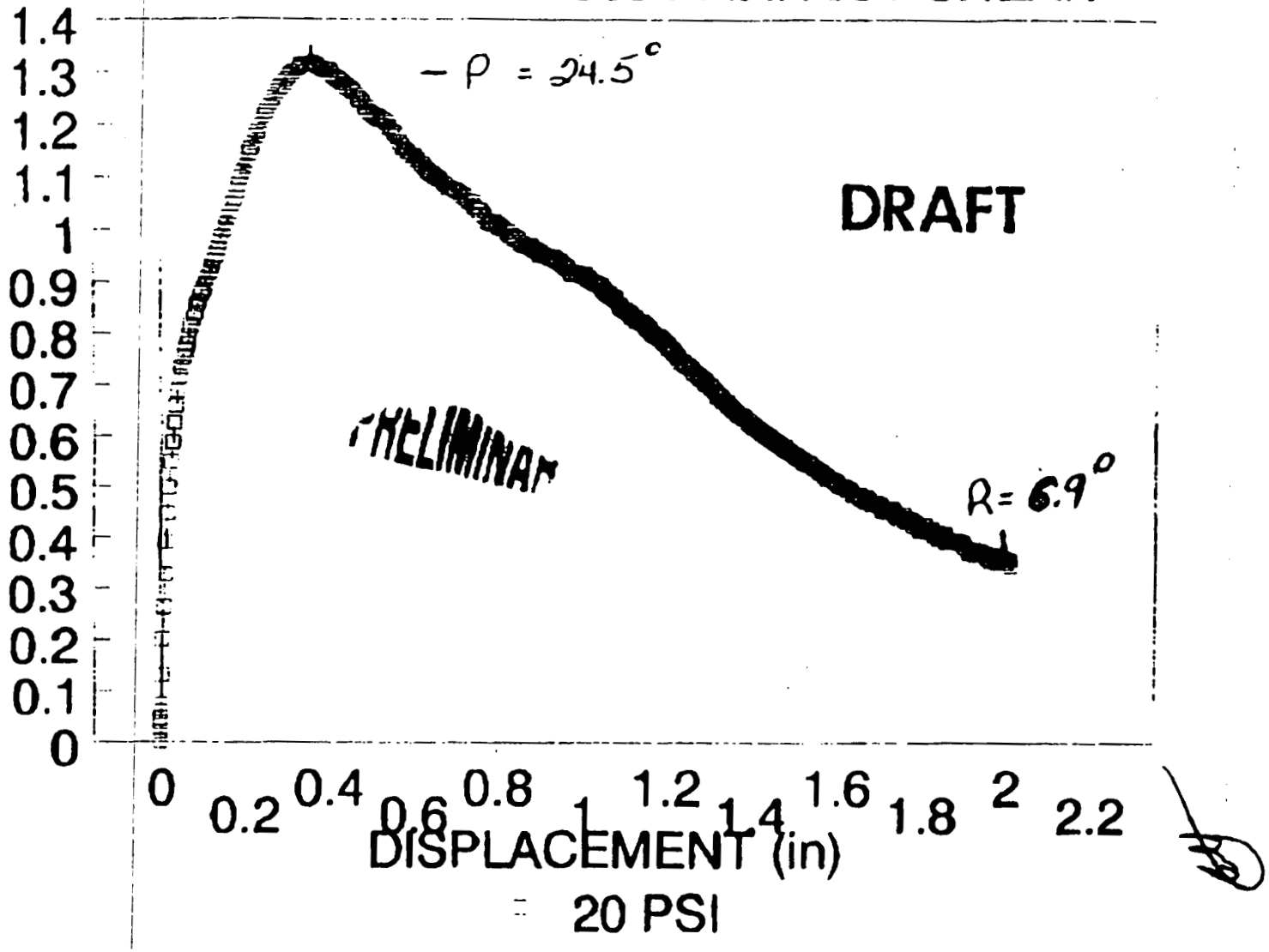
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
DISPLACEMENT (in)
5 PSI
PRELIMINARY DRAFT
DRAFT

PETRO ENVIRONMENTAL 54-7239-00
HYDRATED GCL #36344 DIRECT SHEAR



DRAFT

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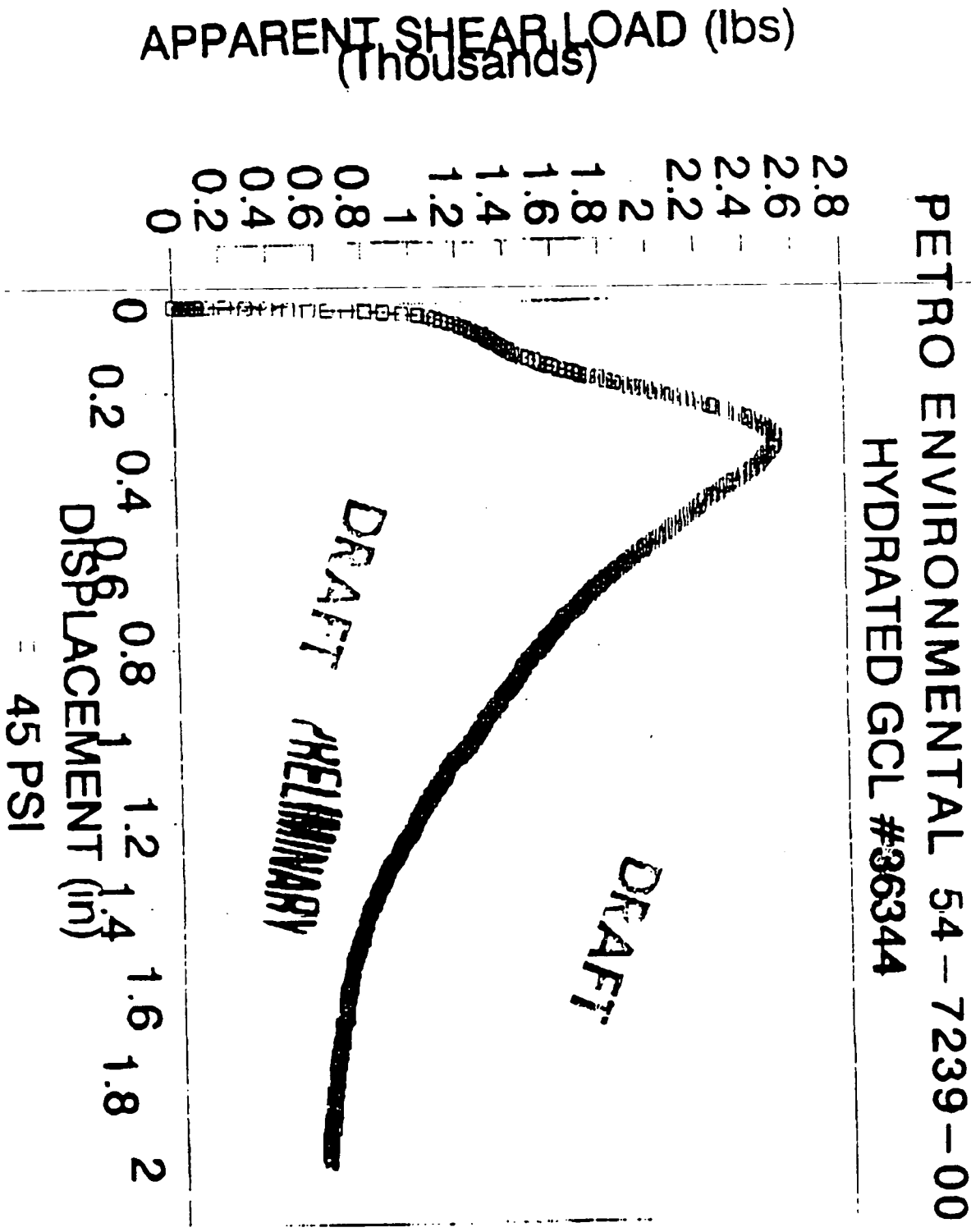
PETRO ENVIRONMENTAL 54-7239-00
HYDRATED GCL #36344
APPARENT SHEAR LOAD (lbs)
(Thousands)
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2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
DISPLACEMENT (in)
45 PSI
DRAFT
PRELIMINARY
DRAFT

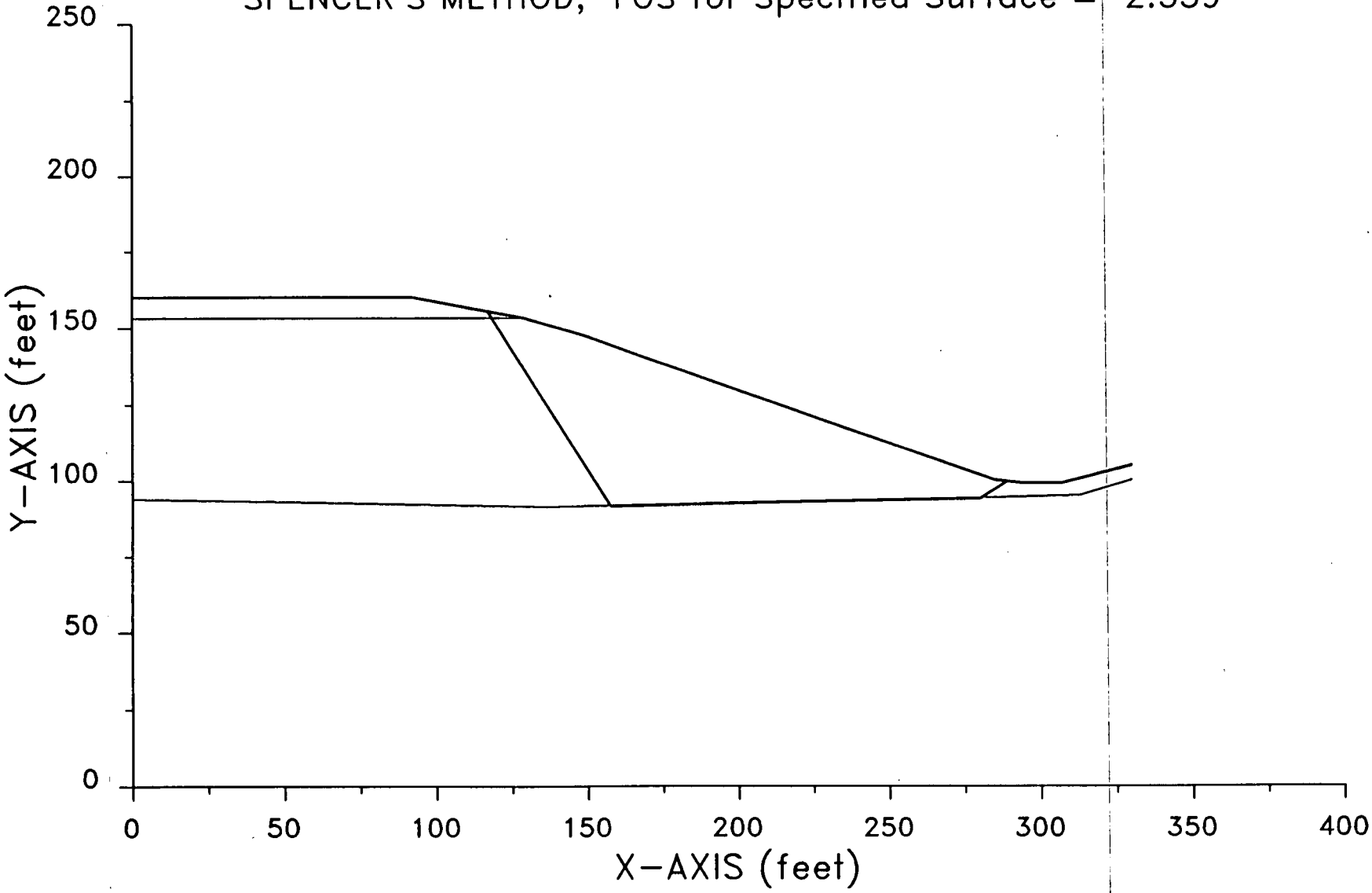
4/44

YMCO 10/22/97
RAM 10/23/97

APPENDIX C

N 09AS 10-20-97 8:30

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.339



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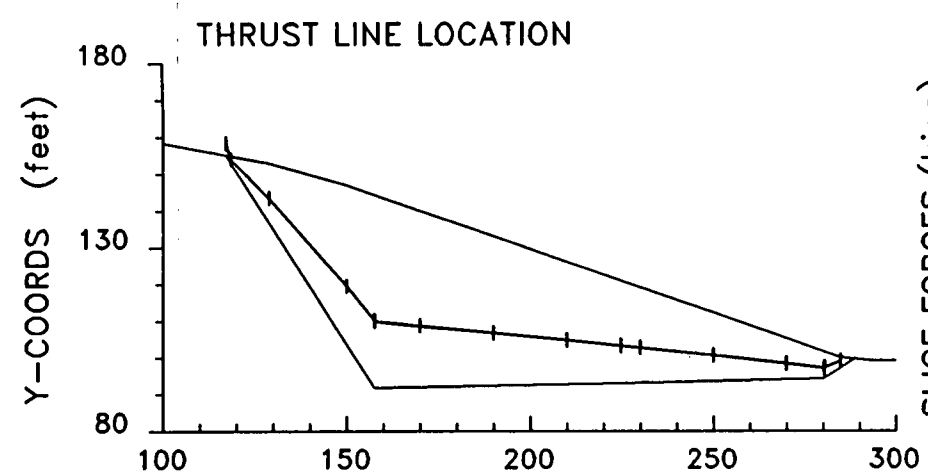

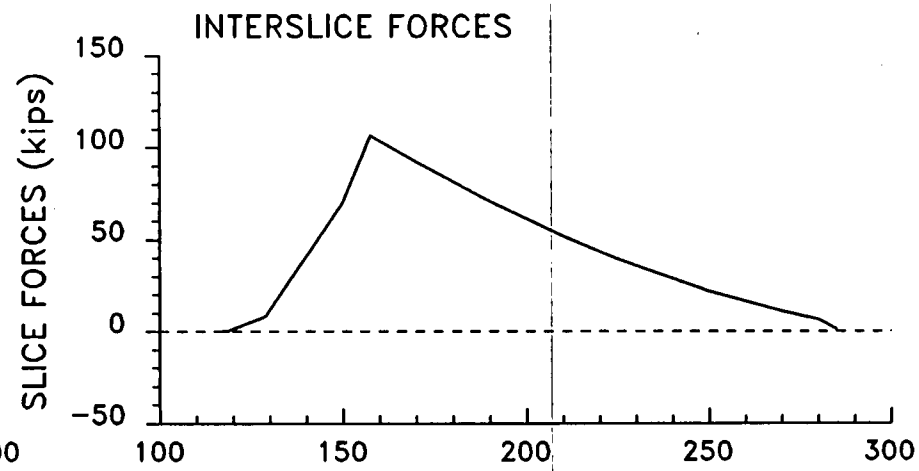

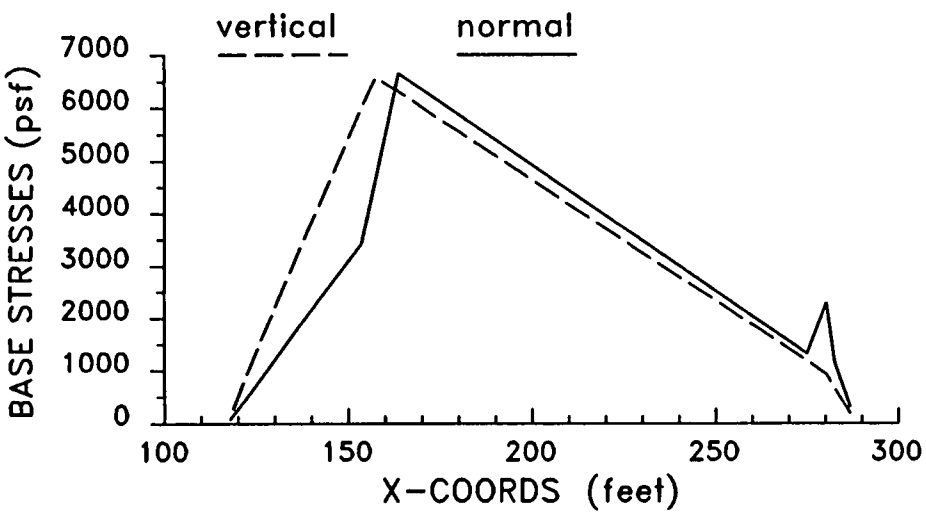

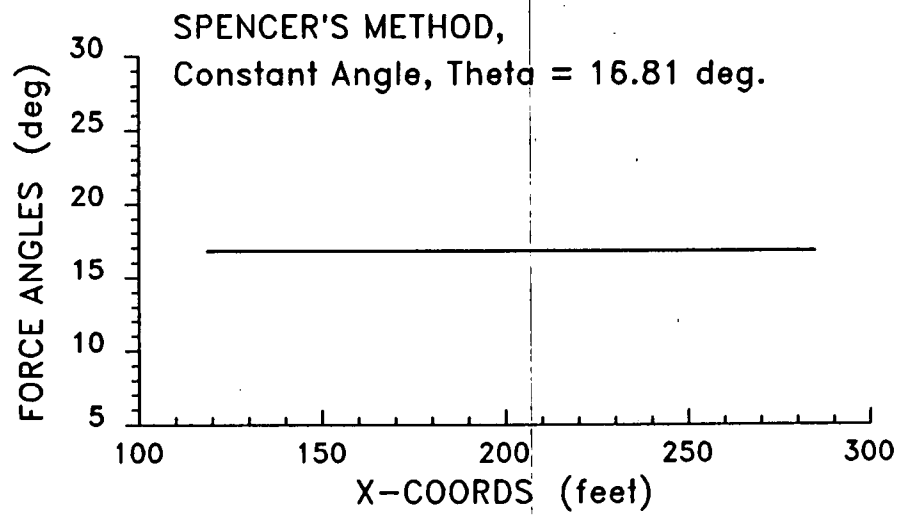

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.339 ✓

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*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	723.6
4	2880.0	1383.8
5	6480.0	2243.5
6	10080.0	2243.5

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	288.81	99.58
2	280.54	94.31
3	280.34	94.11
4	224.80	93.00
5	157.74	91.63
6	157.54	91.83
7	118.57	153.00
8	117.29	155.22

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	286.90	98.36	1.42	3.81	-32.49	6.34	679.
2	282.77	95.73	5.04	4.46	-32.49	19.12	2811.
3	280.44	94.21	7.37	.20	-45.00	19.12	184.
4	275.17	94.01	9.40	10.34	-1.14	19.12	12151.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37491.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55866.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.17	19.29	56723.
9	200.00	92.49	37.11	20.00	-1.17	19.29	92767.
10	180.00	92.08	44.47	20.00	-1.17	19.03	111163.
11	163.87	91.76	50.39	12.26	-1.17	19.29	77223.
12	157.64	91.73	52.60	.20	45.00	19.29	1315.
13	153.77	97.75	47.93	7.54	57.50	19.29	45177.
14	139.50	120.15	29.85	21.00	57.50	15.95	78365.
15	123.79	144.81	9.17	10.43	57.50	10.71	11959.
16	117.93	154.11	.99	1.28	59.98	10.71	158.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.5626	2.3575	2.4146
3	16.6489	2.3608	2.3575
4	16.6465	2.3607	2.3608

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.8076	2.3393	2.3337
3	16.8053	2.3392	2.3393

Nonlinear M-C Iteration Number - 3

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment

1	16.8053	2.3390	2.3393

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.8053	2.3390	2.3393

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	309.3	.0	30.00	0.	0.	0.	.00
2	1145.3	200.0	25.00	0.	0.	0.	.00
3	2276.4	503.5	17.00	0.	0.	0.	.00
4	1307.4	503.5	17.00	0.	0.	0.	.00
5	2042.1	503.5	17.00	0.	0.	0.	.00
6	3006.1	696.0	13.43	0.	0.	0.	.00
7	3605.9	696.0	13.43	0.	0.	0.	.00
8	4088.4	696.0	13.43	0.	0.	0.	.00
9	4926.9	696.0	13.43	0.	0.	0.	.00
10	5884.1	696.0	13.43	0.	0.	0.	.00
11	6649.1	2243.5	.00	0.	0.	0.	.00
12	4636.3	696.0	13.43	0.	0.	0.	.00
13	3407.0	200.0	25.00	0.	0.	0.	.00
14	2098.3	200.0	25.00	0.	0.	0.	.00
15	601.2	200.0	25.00	0.	0.	0.	.00
16	65.9	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	286.90	309.3	178.1	.0	76.3
2	282.77	1145.3	630.4	.0	313.8
3	280.44	2276.4	921.3	.0	512.7
4	275.17	1307.4	1175.1	.0	386.1
5	260.00	2042.1	1874.6	.0	482.1
6	240.00	3006.1	2793.3	.0	604.5
7	227.40	3605.9	3369.8	.0	665.7
8	217.40	4088.4	3832.6	.0	715.0
9	200.00	4926.9	4638.3	.0	800.6
10	180.00	5884.1	5558.2	.0	898.3
11	163.87	6649.1	6298.8	.0	959.2
12	157.64	4636.3	6574.5	.0	770.9
13	153.77	3407.0	5991.6	.0	764.7
14	139.50	2098.3	3731.6	.0	503.8
15	123.79	601.2	1146.6	.0	205.4
16	117.93	65.9	123.3	.0	16.3

23/4A

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	16.81	1088.	1.79	2.85	.628
2	280.54	16.81	5948.	2.80	7.24	.387
3	280.34	16.81	6531.	2.80	7.51	.373
4	270.00	16.81	10983.	4.32	11.30	.382
5	250.00	16.81	21909.	7.00	18.70	.374
6	230.00	16.81	35793.	9.48	26.00	.365
7	224.80	16.81	39801.	10.11	27.92	.362
8	210.00	16.81	52146.	11.93	33.40	.357
9	190.00	16.81	70976.	14.36	40.81	.352
10	170.00	16.81	92255.	16.75	48.12	.348
11	157.74	16.81	106279.	18.23	52.66	.346
12	157.54	16.81	105471.	18.23	52.53	.347
13	150.00	16.81	69373.	15.67	43.33	.362
14	129.00	16.81	8174.	6.73	16.37	.411
15	118.57	16.81	130.	.91	1.97	.463
16	117.29	.00	-1.	3.08	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3088.42 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 587.95 (psf)

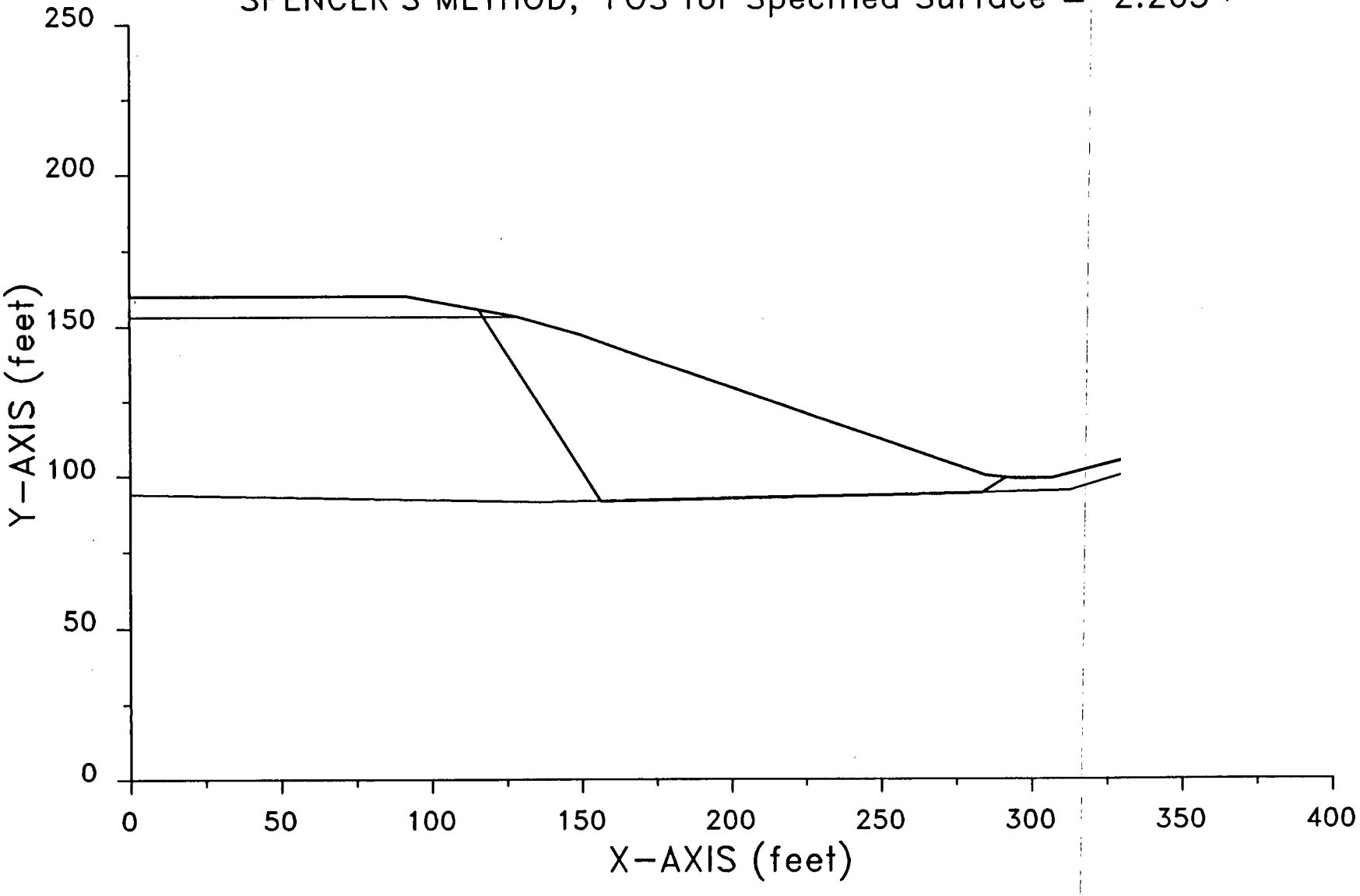
Total Length of failure surface = 208.08 feet

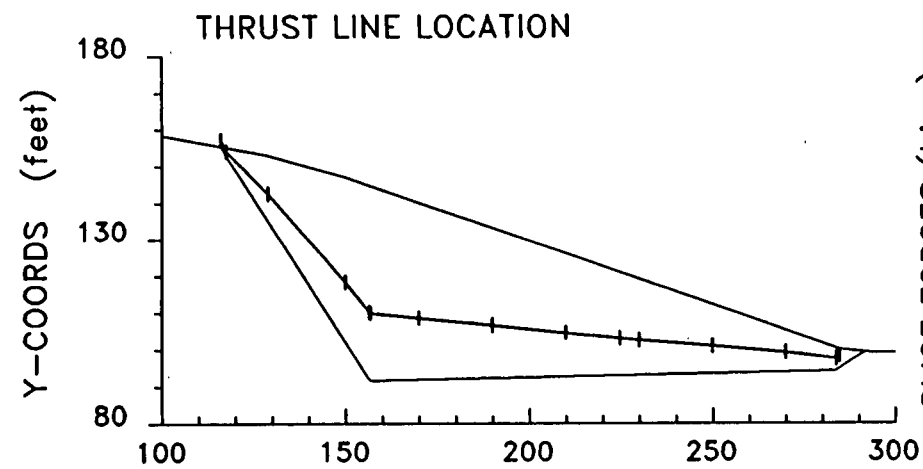
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

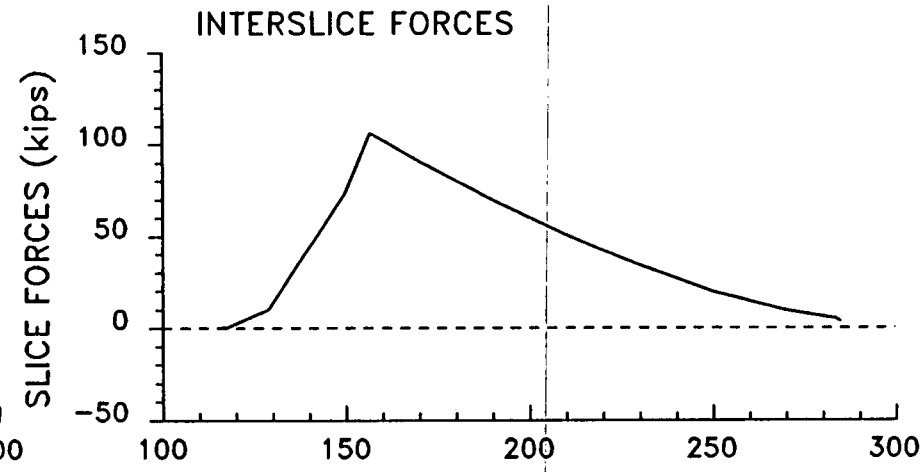
FACTOR OF SAFETY = 2.339

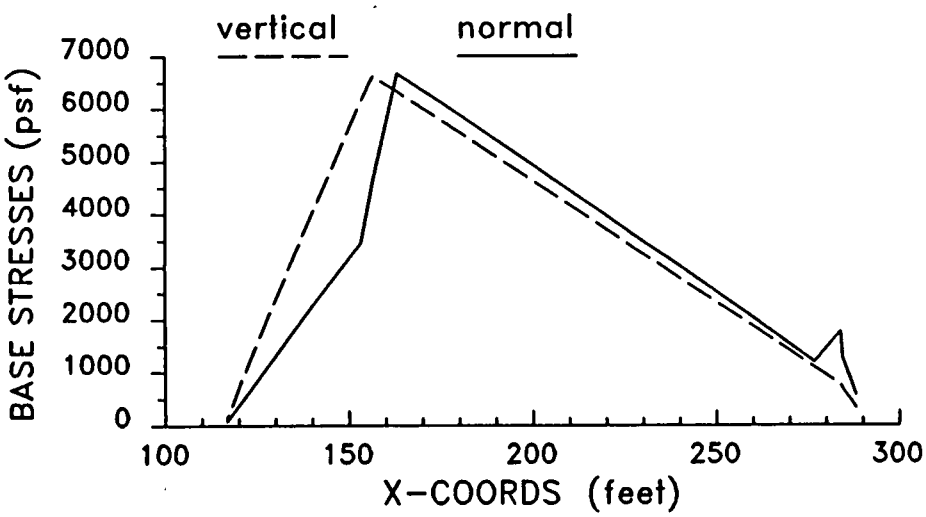
Total shear strength available along specified failure surface = 286.16E+03 lb

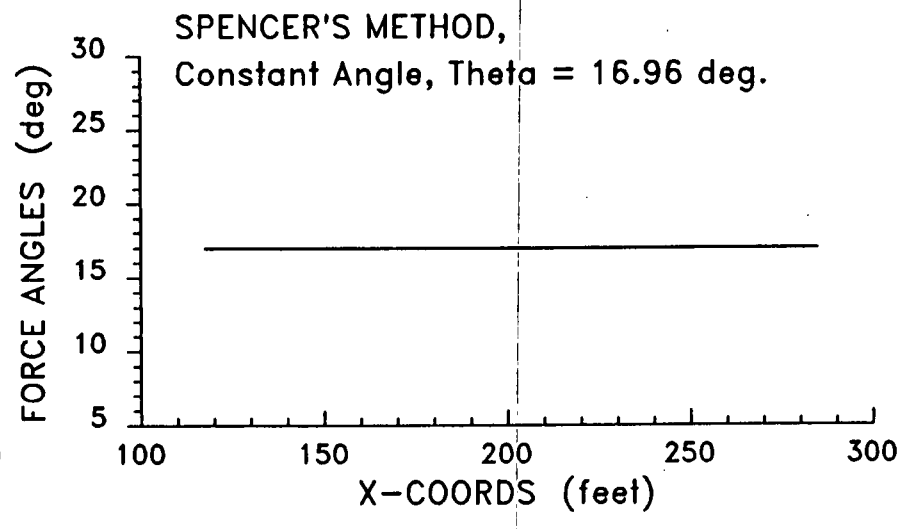
OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.265 ✓











OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.265

26/A

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*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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*****************************************
```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	432.0
4	2880.0	1396.8
5	6480.0	2145.6
6	10080.0	2145.6

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	291.80	99.24
2	284.17	94.38
3	283.96	94.18
4	224.80	93.00
5	156.82	91.58
6	156.59	91.81
7	117.61	153.00
8	116.21	155.42

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.40	97.08	2.55	6.80	-32.52	6.34	2164.
2	284.59	94.64	5.50	.83	-32.52	19.12	571.
3	284.07	94.28	6.04	.21	-43.60	19.12	159.
4	276.98	94.04	8.74	13.96	-1.14	19.12	15250.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37495.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55867.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.20	19.29	56729.
9	200.00	92.48	37.12	20.00	-1.20	19.29	92795.
10	180.00	92.06	44.49	20.00	-1.20	19.03	111215.
11	163.41	91.72	50.59	13.18	-1.20	19.29	83345.
12	156.71	91.69	52.96	.23	45.00	19.29	1523.
13	153.29	96.98	48.86	6.59	57.50	19.29	40252.
14	139.50	118.64	31.36	21.00	57.50	15.95	82327.
15	123.30	144.06	10.02	11.39	57.50	10.71	14262.
16	116.91	154.21	1.08	1.40	59.95	10.71	189.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.9307	2.2745	2.3020
3	16.9539	2.2753	2.2745

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.9551	2.2646	2.2645

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.9551	2.2646	2.2645

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	562.8	.0	30.00	0.	0.	0.	.00
2	1260.1	200.0	25.00	0.	0.	0.	.00
3	1769.1	110.4	24.07	0.	0.	0.	.00
4	1191.9	110.4	24.07	0.	0.	0.	.00
5	2033.2	110.4	24.07	0.	0.	0.	.00
6	3016.1	797.8	11.75	0.	0.	0.	.00
7	3614.0	797.8	11.75	0.	0.	0.	.00
8	4096.5	797.8	11.75	0.	0.	0.	.00
9	4933.6	797.8	11.75	0.	0.	0.	.00
10	5889.2	797.8	11.75	0.	0.	0.	.00
11	6674.8	2145.6	.00	0.	0.	0.	.00
12	4657.7	797.8	11.75	0.	0.	0.	.00
13	3448.1	200.0	25.00	0.	0.	0.	.00
14	2190.0	200.0	25.00	0.	0.	0.	.00
15	655.8	200.0	25.00	0.	0.	0.	.00
16	71.3	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.40	562.8	318.2	.0	143.5
2	284.59	1260.1	687.4	.0	347.8
3	284.07	1769.1	755.5	.0	397.7
4	276.98	1191.9	1092.4	.0	283.8
5	260.00	2033.2	1874.7	.0	449.8
6	240.00	3016.1	2793.4	.0	629.3
7	227.40	3614.0	3369.8	.0	684.2
8	217.40	4096.5	3833.1	.0	728.5
9	200.00	4933.6	4639.8	.0	805.4
10	180.00	5889.2	5560.7	.0	893.2
11	163.41	6674.8	6323.6	.0	947.5
12	156.71	4657.7	6619.8	.0	780.1
13	153.29	3448.1	6108.0	.0	798.3
14	139.50	2190.0	3920.3	.0	539.3
15	123.30	655.8	1252.2	.0	223.4
16	116.91	71.3	134.7	.0	18.2

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	16.96	3571.	3.20	5.09	.629
2	284.17	16.96	4570.	3.20	5.91	.542
3	283.96	16.96	5027.	3.16	6.18	.512
4	270.00	16.96	9516.	5.13	11.30	.454
5	250.00	16.96	19769.	7.28	18.70	.390
6	230.00	16.96	34185.	9.34	26.00	.359

7	224.80	16.96	38296.	9.93	27.92	.356
8	210.00	16.96	50892.	11.70	33.41	.350
9	190.00	16.96	69888.	14.15	40.83	.347
10	170.00	16.96	91136.	16.61	48.14	.345
11	156.82	16.96	106112.	18.25	53.03	.344
12	156.59	16.96	105180.	18.25	52.88	.345
13	150.00	16.96	73389.	16.02	44.85	.357
14	129.00	16.96	9752.	7.33	17.88	.410
15	117.61	16.96	154.	1.00	2.15	.463
16	116.21	.00	0.	1.56	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3069.99 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 583.89 (psf)

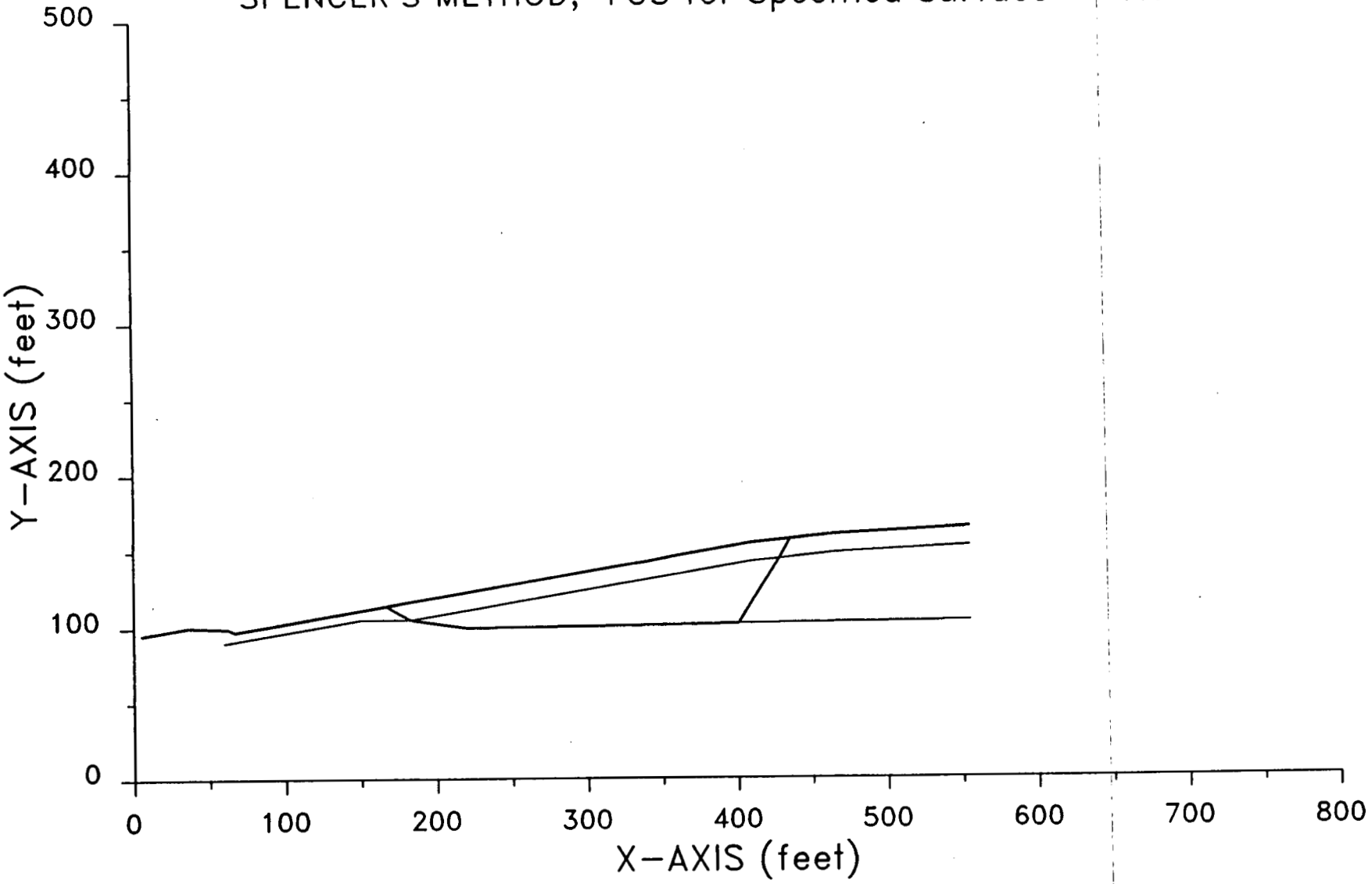
Total Length of failure surface = 212.18 feet

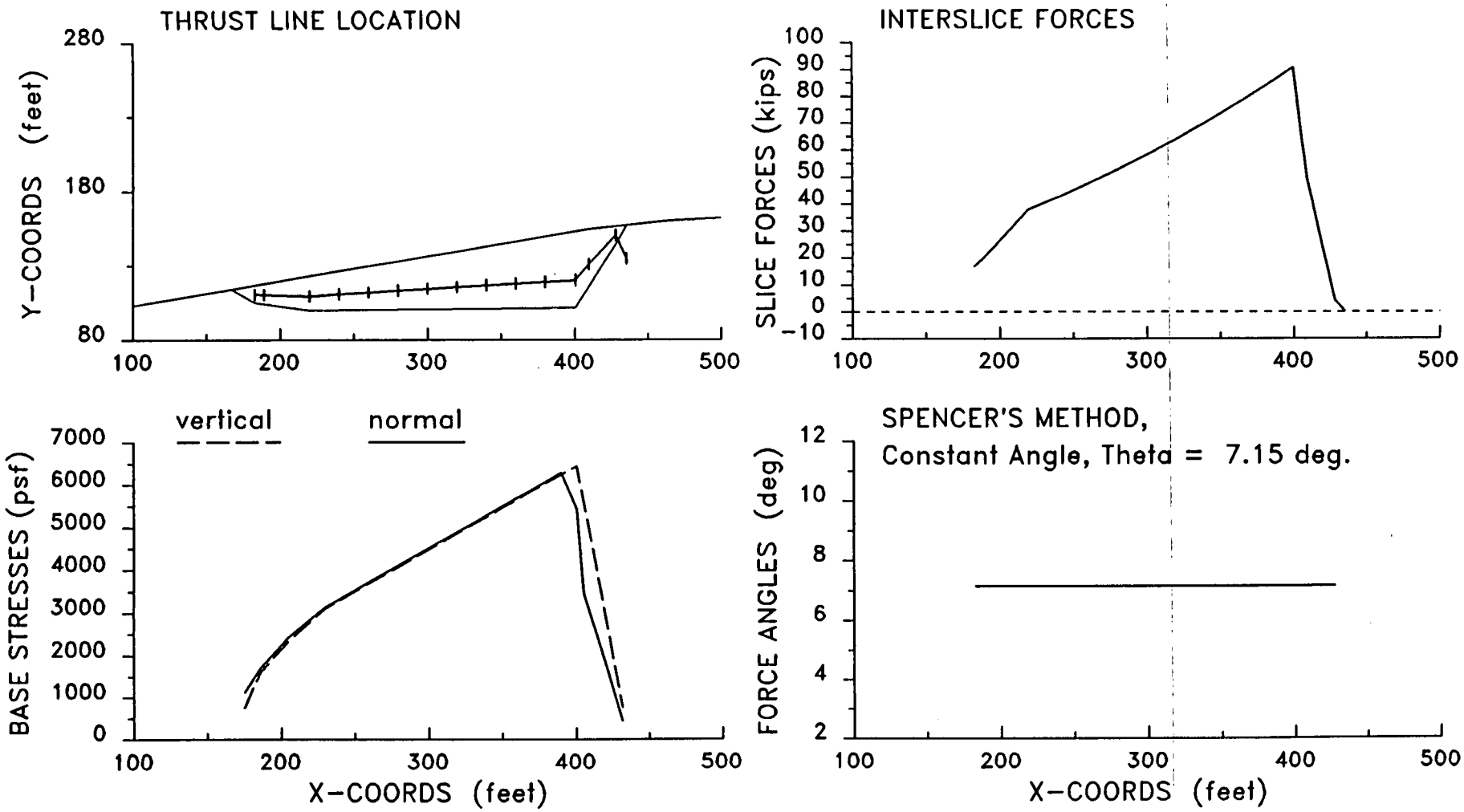
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.265

Total shear strength available along specified failure surface = 280.55E+03 lb

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.566 ✓





OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.566 ✓

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	369.4
4	2880.0	381.6
5	6480.0	674.6
6	10080.0	674.6

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	400.64	101.66
6	400.88	101.90
7	428.09	144.61
8	435.38	157.24

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.60	9.37	93362.
9	330.00	100.92	40.43	20.00	.60	9.37	101085.
10	350.00	101.13	43.57	20.00	.60	9.65	108933.
11	370.00	101.34	46.71	20.00	.60	9.37	116782.
12	390.32	101.55	49.87	20.64	.60	9.46	128661.
13	400.76	101.78	51.38	.24	45.00	9.46	1543.
14	405.44	109.06	44.88	9.12	57.50	9.46	51164.
15	419.04	130.41	25.19	18.09	57.50	5.71	56965.
16	431.73	150.92	5.95	7.29	60.00	5.71	5422.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.0569	1.5645	1.6099
3	7.1496	1.5665	1.5645
4	7.1476	1.5665	1.5665

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.1476	1.5665	1.5665

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1106.4	.0	30.00	0.	0.	0.	.00

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2	1687.8	365.3	.32	0.	0.	0.	.00
3	2411.6	365.3	.32	0.	0.	0.	.00
4	3125.7	147.2	4.65	0.	0.	0.	.00
5	3521.3	147.2	4.65	0.	0.	0.	.00
6	3910.6	147.2	4.65	0.	0.	0.	.00
7	4306.3	147.2	4.65	0.	0.	0.	.00
8	4700.7	147.2	4.65	0.	0.	0.	.00
9	5088.7	147.2	4.65	0.	0.	0.	.00
10	5482.9	147.2	4.65	0.	0.	0.	.00
11	5877.2	147.2	4.65	0.	0.	0.	.00
12	6273.5	147.2	4.65	0.	0.	0.	.00
13	5415.1	147.2	4.65	0.	0.	0.	.00
14	3448.7	.0	25.00	0.	0.	0.	.00
15	1935.7	.0	25.00	0.	0.	0.	.00
16	411.0	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1106.4	739.6	.0	407.8
2	186.00	1687.8	1594.4	.0	239.3
3	204.50	2411.6	2304.8	.0	241.9
4	230.00	3125.7	3100.0	.0	256.4
5	250.00	3521.3	3493.8	.0	276.9
6	270.00	3910.6	3881.3	.0	297.2
7	290.00	4306.3	4275.0	.0	317.7
8	310.00	4700.7	4668.1	.0	338.2
9	330.00	5088.7	5054.3	.0	358.4
10	350.00	5482.9	5446.7	.0	378.8
11	370.00	5877.2	5839.1	.0	399.3
12	390.32	6273.5	6233.6	.0	419.9
13	400.76	5415.1	6422.5	.0	375.3
14	405.44	3448.7	5610.3	.0	1026.6
15	419.04	1935.7	3149.0	.0	576.2
16	431.73	411.0	743.7	.0	151.5

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.15	16774.	5.59	11.83	.472
2	189.00	7.15	19655.	6.25	13.68	.457
3	220.00	7.15	37803.	9.51	23.20	.410
4	240.00	7.15	42340.	10.68	26.40	.404
5	260.00	7.15	47213.	11.76	29.50	.399
6	280.00	7.15	52414.	12.79	32.60	.392
7	300.00	7.15	57950.	13.76	35.80	.384
8	320.00	7.15	63769.	14.70	38.89	.378
9	340.00	7.15	69912.	15.60	41.98	.372

10	360.00	7.15	76384.	16.48	45.17	.365
11	380.00	7.15	83186.	17.34	48.26	.359
12	400.64	7.15	90546.	18.20	51.48	.354
13	400.88	7.15	89326.	18.24	51.28	.356
14	410.00	7.15	49008.	14.65	38.48	.381
15	428.09	7.15	4118.	5.86	11.90	.492
16	435.38	.00	0.	-22.72	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3601.34 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 386.84 (psf)

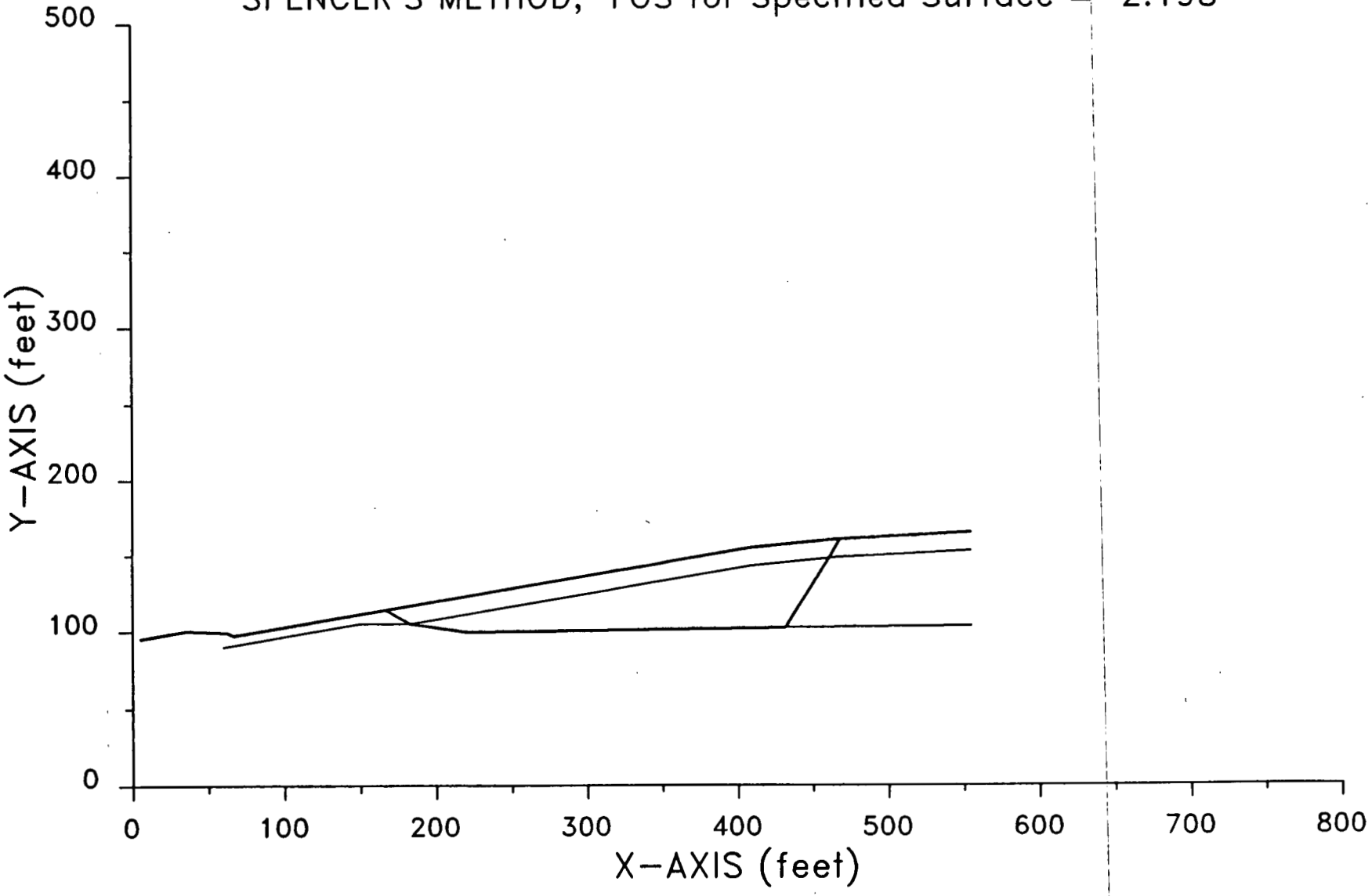
Total Length of failure surface = 301.94 feet

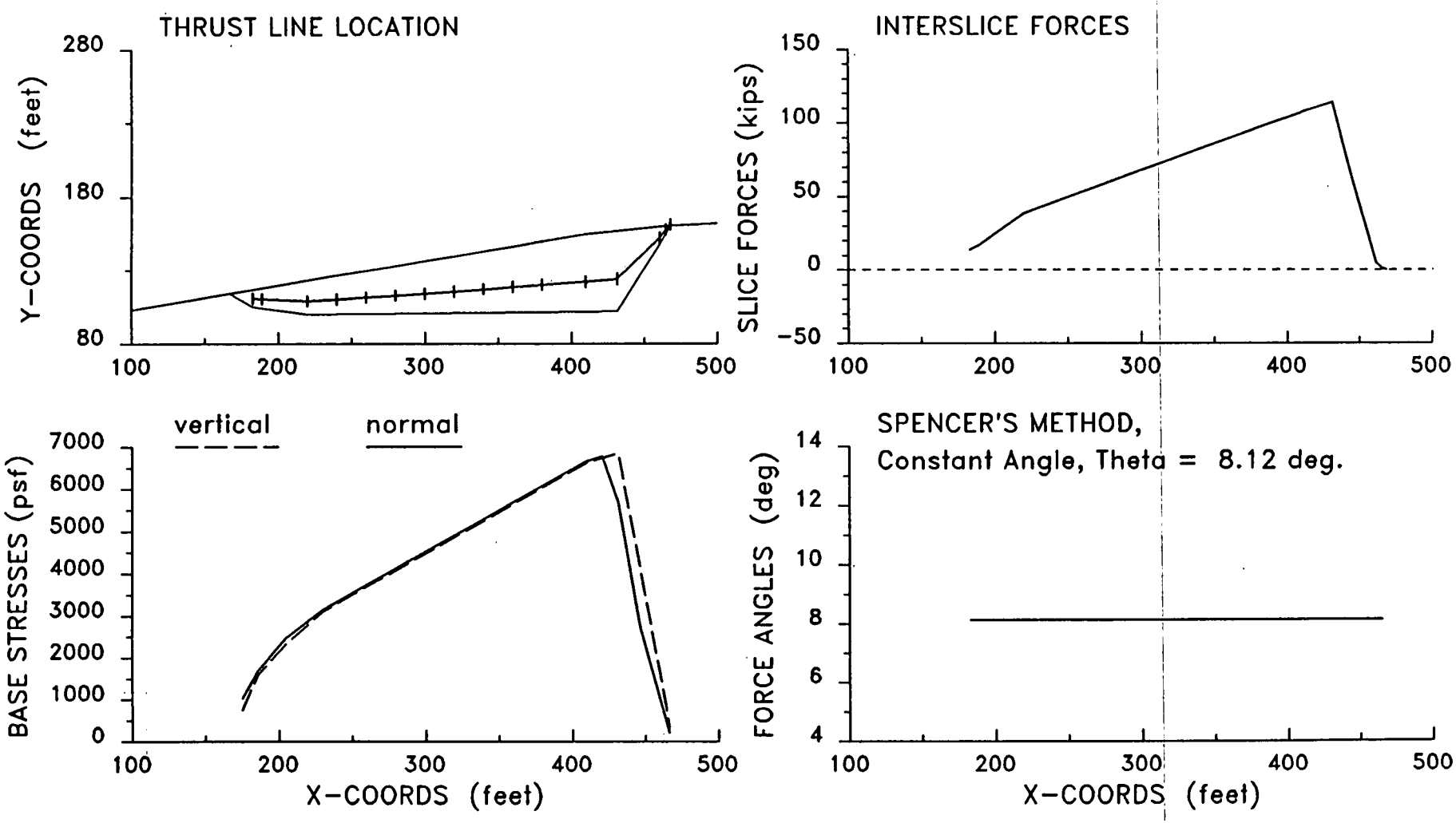
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.566

Total shear strength available along specified failure surface = 182.96E+03 lb

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.198





OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.198 ✓

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	244.8
4	2880.0	878.4
5	6480.0	921.6
6	10080.0	921.6

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 9 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	409.90	101.80
6	431.64	102.08
7	431.79	102.23
8	460.88	147.89
9	468.07	160.35

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.63	9.37	93352.
9	330.00	100.93	40.42	20.00	.63	9.37	101056.
10	350.00	101.15	43.55	20.00	.63	9.65	108885.
11	370.00	101.36	46.69	20.00	.63	9.37	116714.
12	394.95	101.64	50.55	29.90	.63	9.46	188949.
13	409.95	101.80	52.89	.10	.74	9.46	661.
14	420.82	101.94	53.84	21.64	.74	5.71	145641.
15	431.72	102.16	54.72	.15	45.00	5.71	1026.
16	446.34	125.06	33.27	29.09	57.50	5.71	120991.
17	462.94	151.46	8.53	4.12	60.02	5.71	4395.
18	466.54	157.69	2.58	3.07	60.02	2.86	992.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	8.1106	2.1981	2.2181
3	8.1225	2.1985	2.1981

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	8.1225	2.1985	2.1981

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta

1	1015.3	.0	30.00	0.	0.	0.	.00
2	1696.9	33.6	16.35	0.	0.	0.	.00
3	2450.9	33.6	16.35	0.	0.	0.	.00
4	3148.7	843.8	.69	0.	0.	0.	.00
5	3542.2	843.8	.69	0.	0.	0.	.00
6	3929.4	843.8	.69	0.	0.	0.	.00
7	4322.9	843.8	.69	0.	0.	0.	.00
8	4714.2	843.8	.69	0.	0.	0.	.00
9	5099.1	843.8	.69	0.	0.	0.	.00
10	5490.2	843.8	.69	0.	0.	0.	.00
11	5881.4	843.8	.69	0.	0.	0.	.00
12	6364.6	843.8	.69	0.	0.	0.	.00
13	6653.6	921.6	.00	0.	0.	0.	.00
14	6772.1	921.6	.00	0.	0.	0.	.00
15	5674.1	843.8	.69	0.	0.	0.	.00
16	2724.4	.0	25.00	0.	0.	0.	.00
17	640.6	.0	30.00	0.	0.	0.	.00
18	194.0	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1015.3	739.6	.0	266.6
2	186.00	1696.9	1594.4	.0	241.7
3	204.50	2450.9	2304.8	.0	342.3
4	230.00	3148.7	3100.0	.0	401.0
5	250.00	3542.2	3493.8	.0	403.2
6	270.00	3929.4	3881.3	.0	405.3
7	290.00	4322.9	4275.0	.0	407.4
8	310.00	4714.2	4667.6	.0	409.6
9	330.00	5099.1	5052.8	.0	411.7
10	350.00	5490.2	5444.3	.0	413.8
11	370.00	5881.4	5835.7	.0	415.9
12	394.95	6364.6	6319.4	.0	418.6
13	409.95	6653.6	6611.4	.0	419.2
14	420.82	6772.1	6730.2	.0	419.2
15	431.72	5674.1	6839.6	.0	414.8
16	446.34	2724.4	4159.2	.0	577.8
17	462.94	640.6	1066.6	.0	168.2
18	466.54	194.0	323.0	.0	51.0

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	8.12	13701.	5.73	11.83	.484
2	189.00	8.12	16611.	6.28	13.68	.459
3	220.00	8.12	38116.	9.04	23.20	.390

4	240.00	8.12	45582.	10.00	26.40	.379
5	260.00	8.12	53011.	11.07	29.50	.375
6	280.00	8.12	60405.	12.21	32.60	.375
7	300.00	8.12	67763.	13.40	35.80	.374
8	320.00	8.12	74997.	14.62	38.88	.376
9	340.00	8.12	82189.	15.87	41.96	.378
10	360.00	8.12	89337.	17.13	45.14	.379
11	380.00	8.12	96443.	18.41	48.23	.382
12	409.90	8.12	106986.	20.35	52.88	.385
13	410.00	8.12	107020.	20.36	52.90	.385
14	431.64	8.12	114276.	21.79	54.78	.398
15	431.79	8.12	113479.	21.81	54.65	.399
16	460.88	8.12	4805.	4.33	11.90	.364
17	465.00	8.12	884.	2.44	5.17	.473
18	468.07	.00	-1.	.49	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3930.07 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 408.01 (psf)

Total Length of failure surface = 336.12 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.198 ✓

Total shear strength available along specified failure surface = 301.50E+03 lb

GCL 10

COMPUTATION COVER SHEET

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 10 - Compliance Package

Computations By: (Cognizant Engineer)
Signature [signature] Date 30 OCT 1997
Printed Name and Title M. CATALINA OROZCO, STAFF ENGINEER

Assumptions and Procedures Checked By: (Checker)
Signature [signature] Date 30 OCT 1997
Printed Name and Title ROBERT A. MORGAN III, SR. STAFF ENGINEER

Computations Checked by:
Signature [signature] Date 30 OCT 1997
Printed Name and Title ROBERT A. MORGAN III, SR. STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 30 OCT 1997
Printed Name and Title M. CATALINA OROZCO, STAFF ENGINEER

Approved by: (PDP)
Signature [signature] Date 30 Oct 97
Printed Name and Title Gary R. Schmertmann, Sr. Project Engineer

Approved by: (DTL and TETL)
Signature [signature] Date 10 Nov 97
Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

GEOSYNTEC CONSULTANTS

Written By : MCO Date: 10 / 30 / 97 Reviewed by: RAM Date: 10 / 30 / 97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 10 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 10 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample No.	Case	Test Type	Measured Shear Strengths		
			5 psi	20 psi	45 psi
10	Peak	GCL Internal	3.3psi	7.8psi	9.8, 13.3 psi[1] (average 11.55)
		GCL/GMB Interface	2.3	7.4	9.6, 8.9[1] (average 9.25)
10	Large-displacement	GCL Internal	2.1	2.7	3.5, 6.8[1] (average 5.15)
		GCL/GMB Interface	1.8	5.1	8.0, 7.2[1] (average 7.60)

[1] The shear test at 45 psi normal stress for the GCL/GMB interface (and for GCL internal shear) for GCL QA sample no. 10 was performed twice. The two values obtained for both peak and large displacement are presented in the table. The average of those values is used for the slope stability analyses.

Written By : MCO Date: 10/30/97 Reviewed by: RAM Date: 10/30/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix B.

QA Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
10	GCL Internal	NPK10A2S ✓	1.9 ✓	YES ✓
	GCL/GMB Interface	NP10B2S ✓	1.8 ✓	NO ✓
Baseline	Large-displacement	NA	1.6	NA
10	GCL Internal	NLD10A2S ✓	1.6 ✓	YES ✓
	GCL/GMB Interface	NLD10B2S ✓	2.2 ✓	YES

3/35

MCO 30 OCT 1997
RAM 30 OCT 1997

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 10I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-10). GCL's initial moisture content was 8.0%. GCL's final moisture content ranged from 51% to 95% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, 45, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 10G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

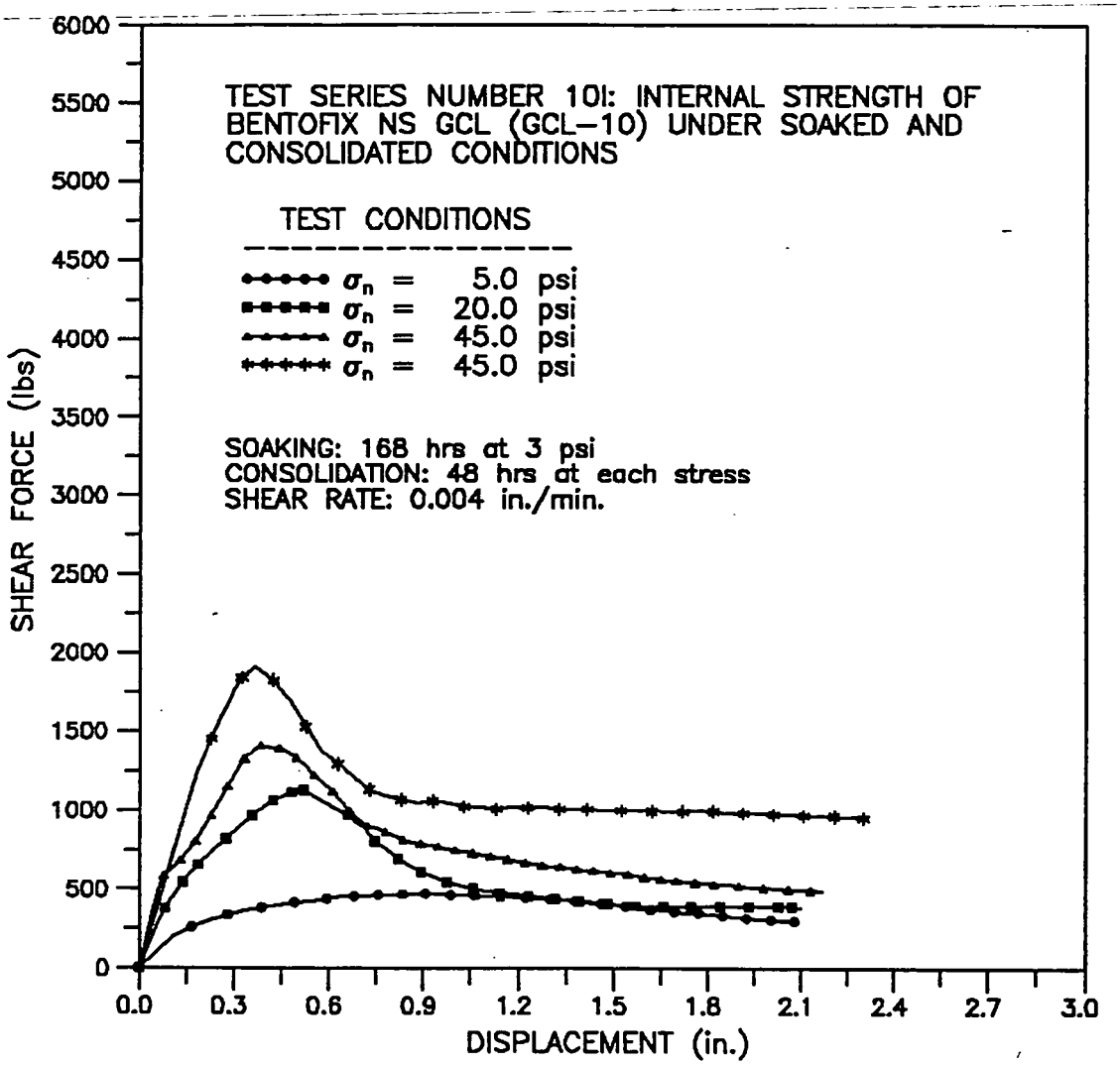
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-10) with woven geotextile against geomembrane. GCL's initial moisture content was 8.2%. GCL's final moisture content ranged from 60 to 101% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-15); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, 45, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.

(2) For each test, sliding (i.e., internal shear failure) was observed to occur within the GCL.

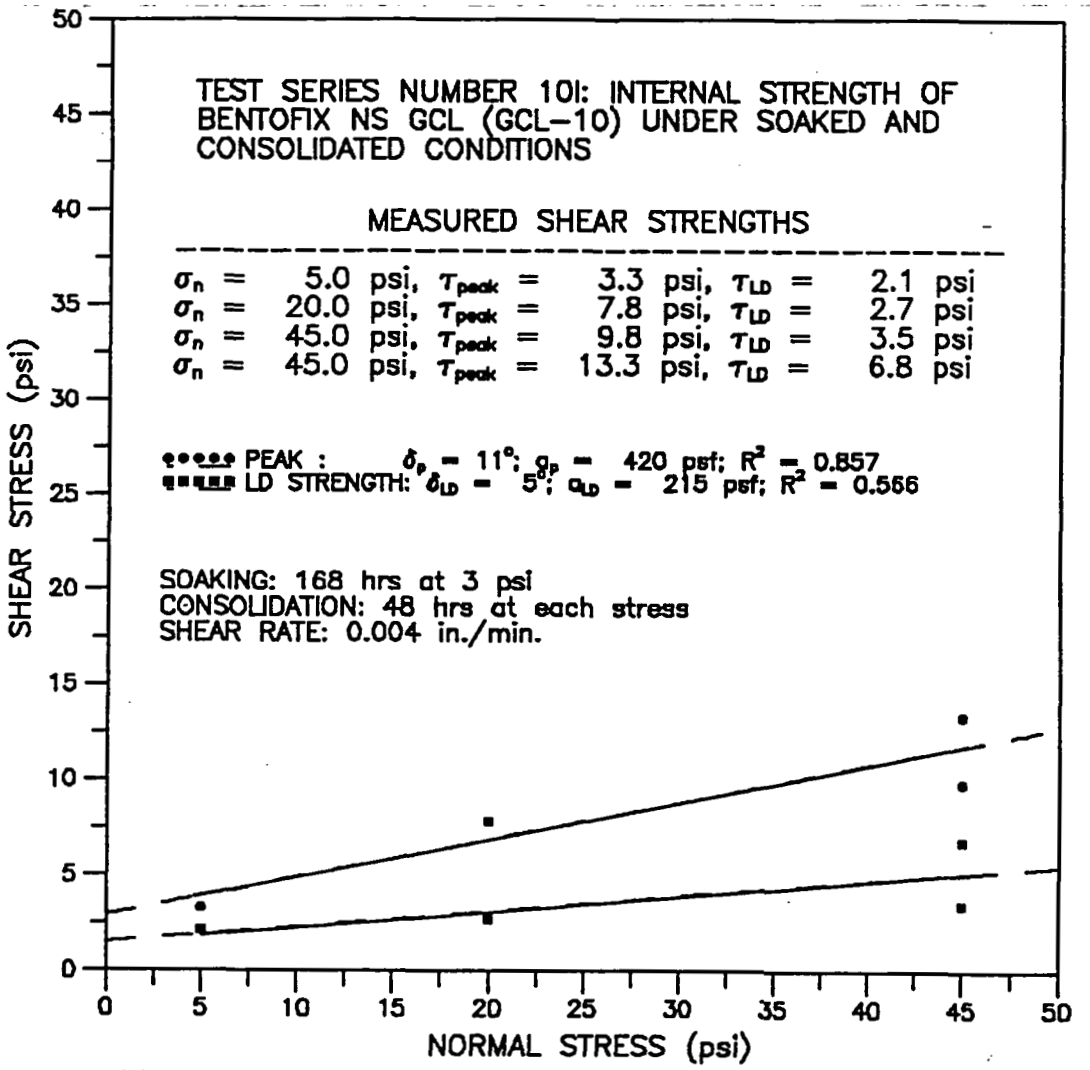
DATE TESTED: 11 SEPTEMBER TO 1 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730108
FILE NO.	000227

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



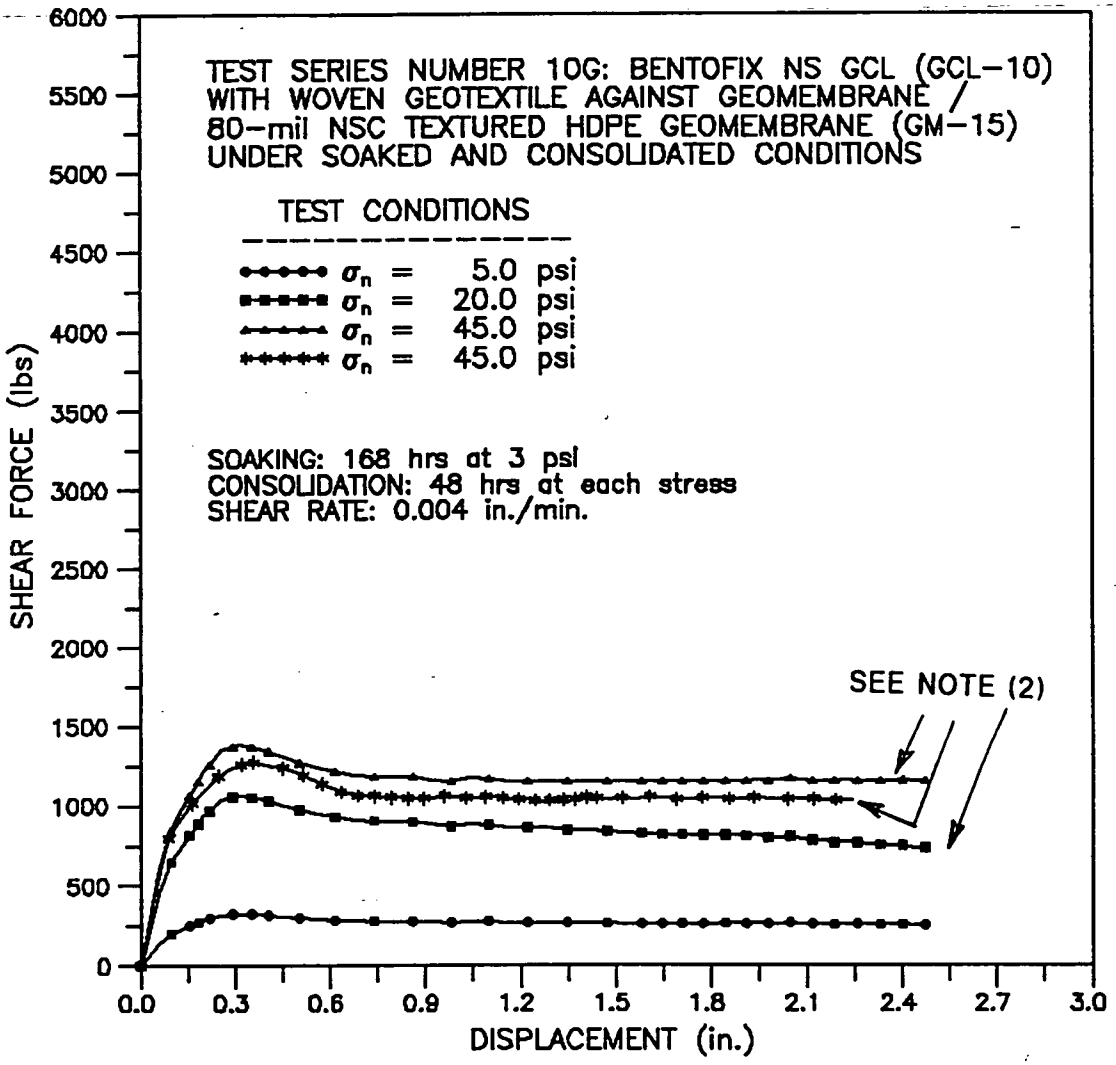
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) For each test, sliding (i.e, internal shear failure) was observed to occur within the GCL.

DATE TESTED: 11 SEPTEMBER TO 1 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730108
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

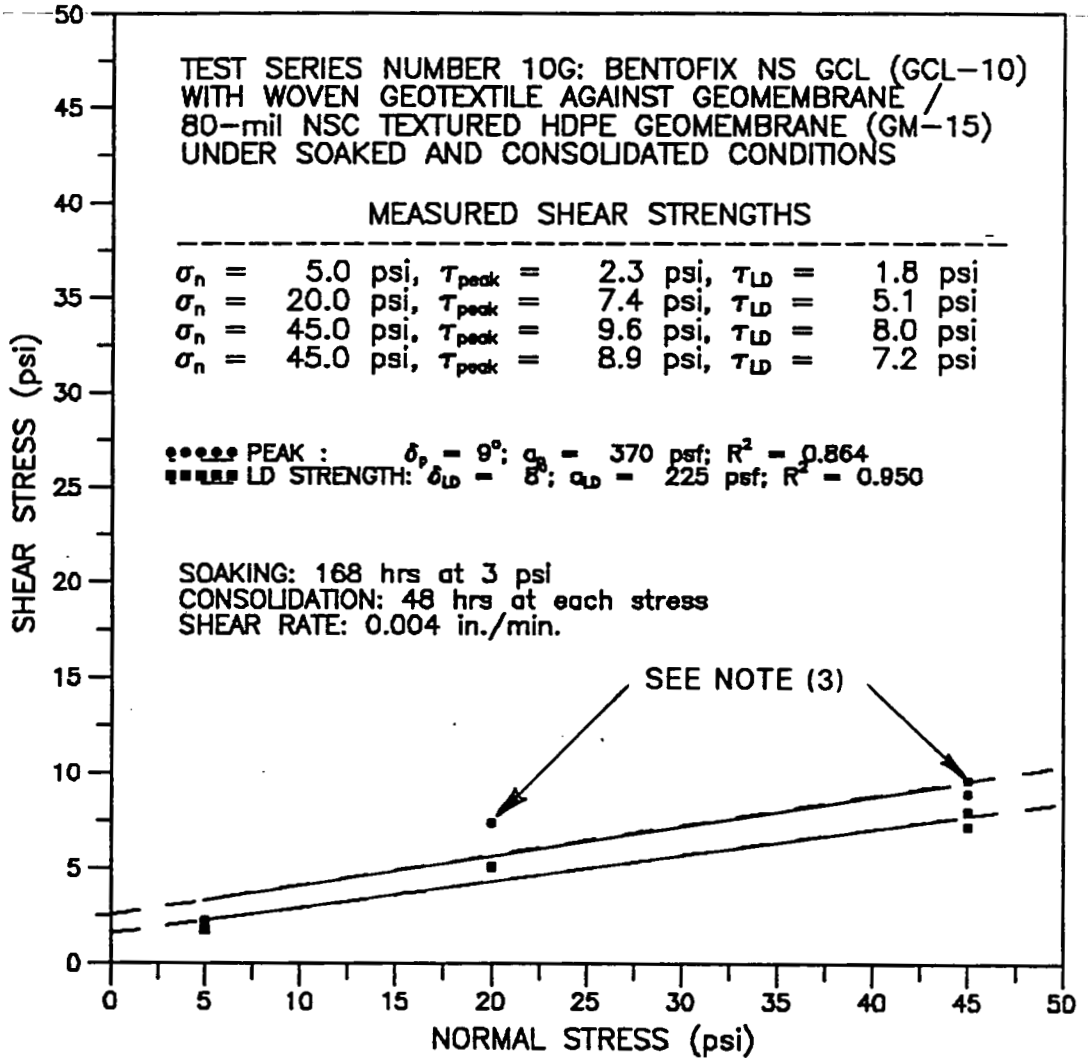
DATE TESTED: 13 TO 24 SEPTEMBER AND 6 TO 15 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730108
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 13 TO 24 SEPTEMBER AND 6 TO 15 OCTOBER 1997

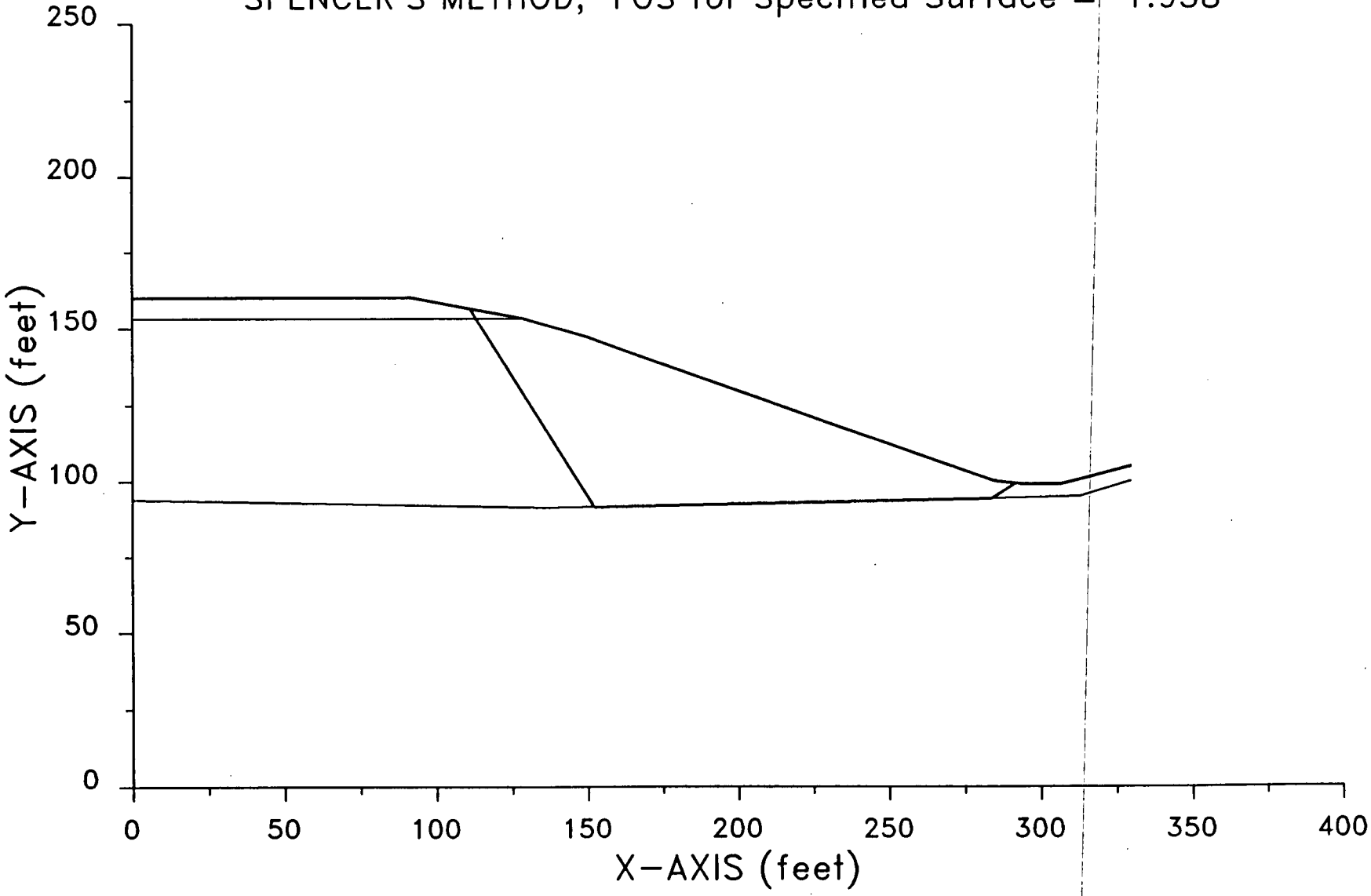
GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

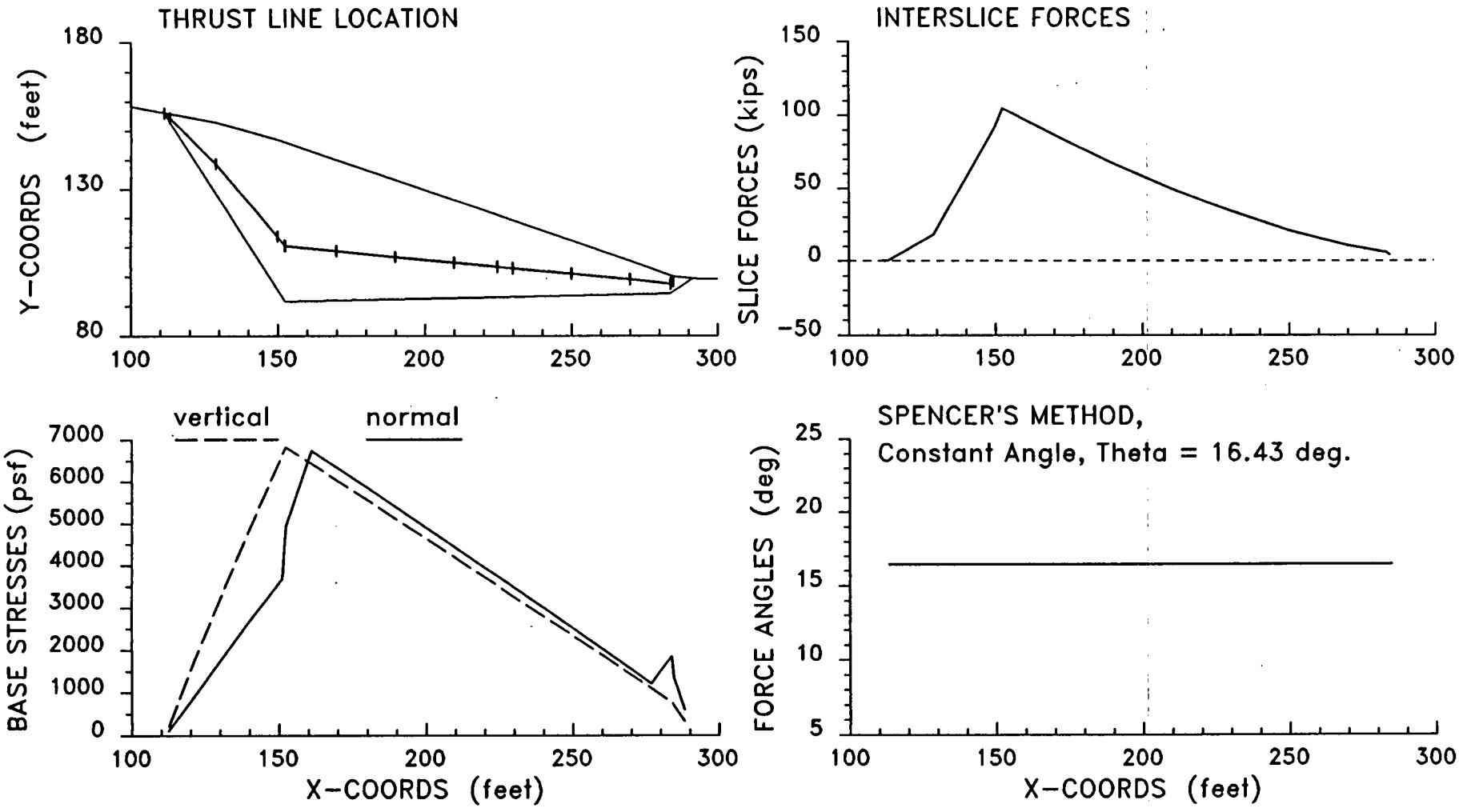
FIGURE NO.	A-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730108
FILE NO.	

MCO 30 OCT 1997
RAM 30 OCT 1997

APPENDIX B

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 1.938





OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 1.938 ✓

12699

0002233

XSTABL File: NPK10A2S 10-27-97 10:57

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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*        Moscow, ID 83843, U.S.A.       *
*                                       *
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*                                       *
*  Ver. 5.201                 96 - 1202 *
*****************************************
```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	475.2
4	2880.0	1123.2
5	6480.0	1663.2
6	10080.0	1663.2

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	291.74	99.25
2	284.10	94.38
3	283.90	94.18
4	224.80	93.00
5	152.67	91.49
6	152.43	91.72
7	113.39	153.00
8	111.48	156.31

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.37	97.10	2.52	6.74	-32.52	6.34	2126.
2	284.55	94.67	5.49	.90	-32.52	19.12	618.
3	284.00	94.28	6.07	.20	-45.00	19.12	152.
4	276.95	94.04	8.75	13.90	-1.14	19.12	15202.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37493.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55866.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.20	19.29	56730.
9	200.00	92.48	37.12	20.00	-1.20	19.29	92798.
10	180.00	92.06	44.49	20.00	-1.20	19.03	111220.
11	161.33	91.67	51.36	17.33	-1.20	19.29	111262.
12	152.55	91.61	54.50	.24	43.78	19.29	1655.
13	151.21	93.63	52.95	2.43	57.50	19.29	16063.
14	139.50	112.02	37.98	21.00	57.50	15.95	99708.
15	121.20	140.75	13.73	15.61	57.50	10.71	26787.
16	112.43	154.66	1.48	1.91	60.05	10.71	353.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.3764	1.9490	1.9814
3	16.4173	1.9501	1.9490
4	16.4166	1.9501	1.9501

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.4345	1.9385	1.9380

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.4345	1.9385	1.9380

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	590.4	.0	30.00	0.	0.	0.	.00
2	1331.4	200.0	25.00	0.	0.	0.	.00
3	1845.8	259.2	16.70	0.	0.	0.	.00
4	1201.4	259.2	16.70	0.	0.	0.	.00
5	2027.5	259.2	16.70	0.	0.	0.	.00
6	2996.3	691.2	8.53	0.	0.	0.	.00
7	3590.7	691.2	8.53	0.	0.	0.	.00
8	4070.4	691.2	8.53	0.	0.	0.	.00
9	4902.7	691.2	8.53	0.	0.	0.	.00
10	5852.8	691.2	8.53	0.	0.	0.	.00
11	6732.8	1663.2	.00	0.	0.	0.	.00
12	4929.6	691.2	8.53	0.	0.	0.	.00
13	3665.6	200.0	25.00	0.	0.	0.	.00
14	2608.7	200.0	25.00	0.	0.	0.	.00
15	895.4	200.0	25.00	0.	0.	0.	.00
16	95.2	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.37	590.4	315.4	.0	175.8
2	284.55	1331.4	686.1	.0	423.4
3	284.00	1845.8	758.3	.0	419.4
4	276.95	1201.4	1093.7	.0	319.6
5	260.00	2027.5	1874.6	.0	447.5
6	240.00	2996.3	2793.3	.0	588.4
7	227.40	3590.7	3369.8	.0	634.4
8	217.40	4070.4	3833.1	.0	671.5
9	200.00	4902.7	4639.9	.0	735.9
10	180.00	5852.8	5561.0	.0	809.5
11	161.33	6732.8	6420.2	.0	858.0
12	152.55	4929.6	6812.7	.0	738.0
13	151.21	3665.6	6618.2	.0	984.9
14	139.50	2608.7	4748.0	.0	730.7
15	121.20	895.4	1716.0	.0	318.6
16	112.43	95.2	184.6	.0	28.4

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	16.43	3881.	3.14	5.05	.623
2	284.10	16.43	5075.	3.14	5.93	.530
3	283.90	16.43	5547.	3.12	6.20	.504
4	270.00	16.43	10527.	4.99	11.30	.441
5	250.00	16.43	20702.	7.29	18.70	.390

6	230.00	16.43	34219.	9.46	26.00	.364
7	224.80	16.43	38047.	10.07	27.92	.361
8	210.00	16.43	49724.	11.83	33.41	.354
9	190.00	16.43	67210.	14.25	40.83	.349
10	170.00	16.43	86644.	16.66	48.15	.346
11	152.67	16.43	104693.	18.79	54.58	.344
12	152.43	16.43	103683.	18.81	54.43	.346
13	150.00	16.43	91616.	17.99	51.47	.350
14	129.00	16.43	17960.	10.12	24.50	.413
15	113.39	16.43	271.	1.38	2.95	.466
16	111.48	.00	-2.	-.36	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3133.18 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 592.36 (psf)

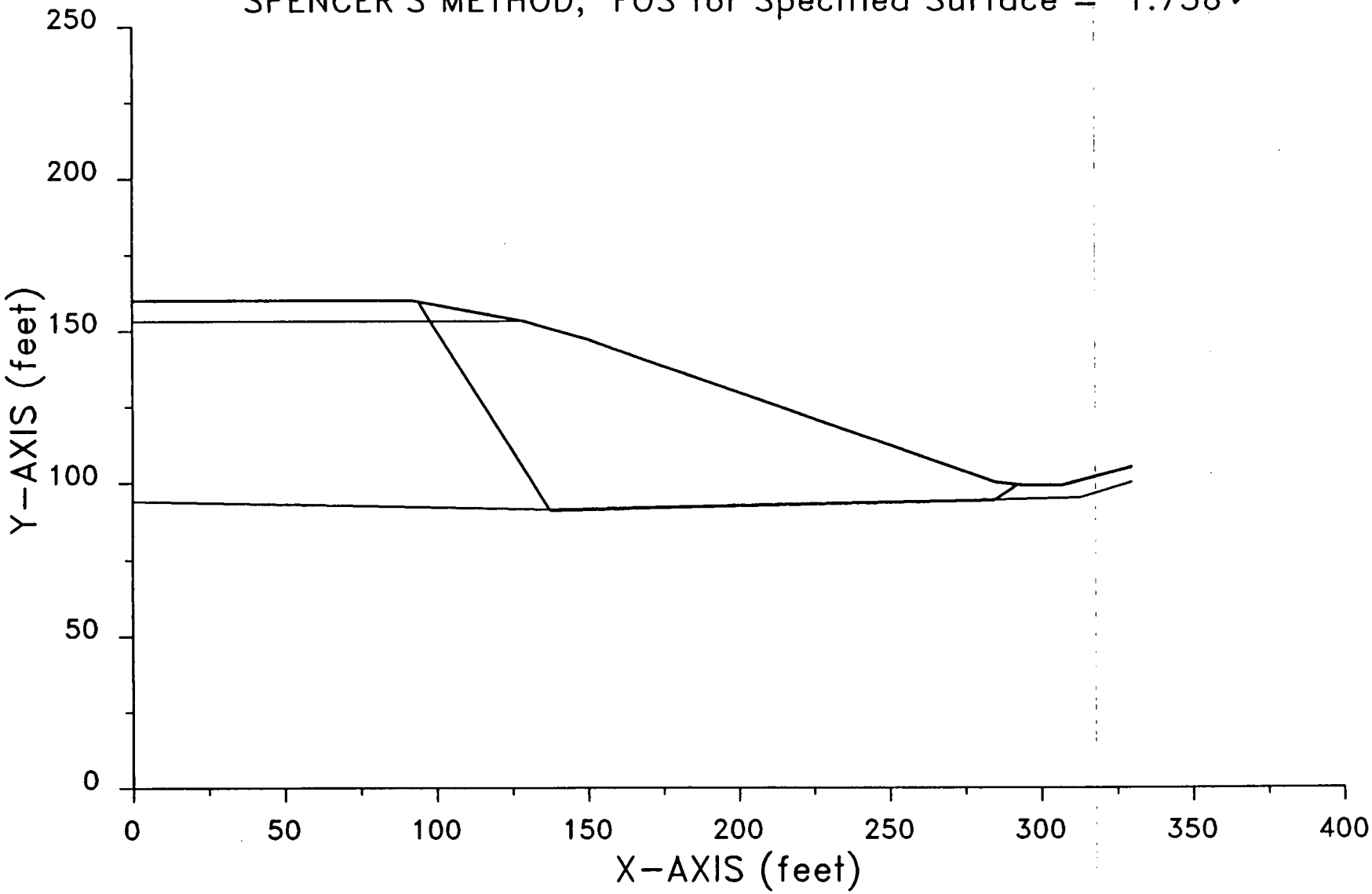
Total Length of failure surface = 217.42 feet

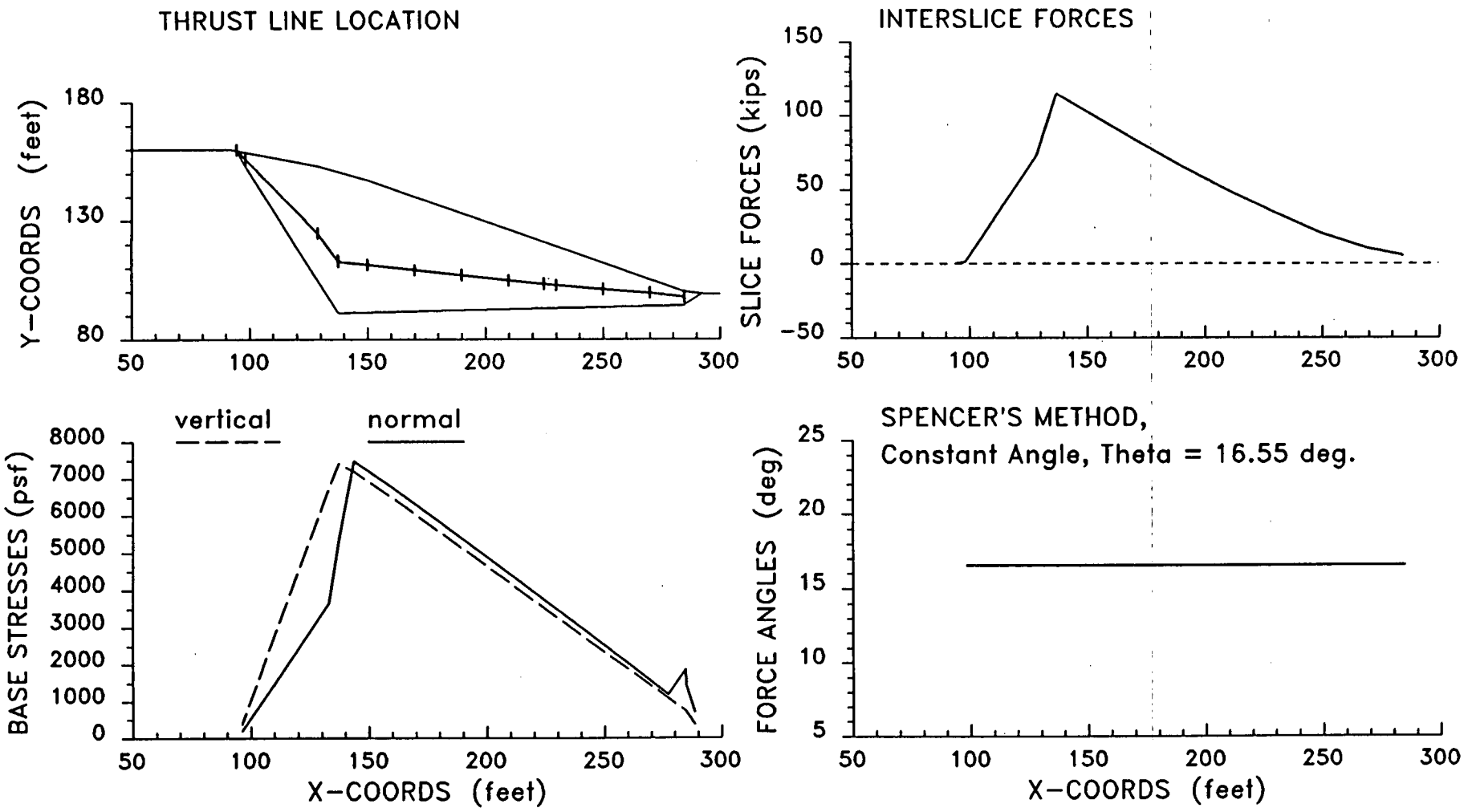
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.938 ✓

Total shear strength available along specified failure surface = 249.66E+03 lb

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 1.756





OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 1.756 ✓

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	331.2
4	2880.0	1065.6
5	6480.0	1332.0
6	10080.0	1332.0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	292.36	99.18
2	284.85	94.40
3	284.65	94.19
4	224.80	93.00
5	137.68	91.18
6	137.43	91.42
7	98.20	153.00
8	94.43	159.54

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.68	96.84	2.75	7.36	-32.49	6.34	2532.
2	284.92	94.45	5.58	.15	-32.49	19.12	107.
3	284.75	94.29	5.79	.20	-46.40	19.12	143.
4	277.33	94.04	8.62	14.65	-1.14	19.12	15779.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37500.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55869.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.20	19.29	56730.
9	200.00	92.48	37.12	20.00	-1.20	19.29	92795.
10	180.00	92.06	44.49	20.00	-1.20	19.03	111215.
11	160.00	91.65	51.85	20.00	-1.20	19.29	129634.
12	143.84	91.31	57.45	12.32	-1.20	15.95	88475.
13	137.55	91.30	59.26	.25	43.83	15.95	1852.
14	133.21	98.04	53.76	8.43	57.50	15.95	56649.
15	113.60	128.83	27.09	30.80	57.50	10.71	104286.
16	96.32	156.27	2.91	3.77	60.04	10.71	1373.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.5205	1.7642	1.7741
3	16.5358	1.7646	1.7642

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.5511	1.7563	1.7560

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.5511	1.7563	1.7560

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	683.0	.0	30.00	0.	0.	0.	.00
2	1428.3	200.0	25.00	0.	0.	0.	.00
3	1850.4	86.4	18.78	0.	0.	0.	.00
4	1171.5	86.4	18.78	0.	0.	0.	.00
5	2027.0	86.4	18.78	0.	0.	0.	.00
6	3005.3	852.5	4.23	0.	0.	0.	.00
7	3592.9	852.5	4.23	0.	0.	0.	.00
8	4067.2	852.5	4.23	0.	0.	0.	.00
9	4890.0	852.5	4.23	0.	0.	0.	.00
10	5829.4	852.5	4.23	0.	0.	0.	.00
11	6764.9	1332.0	.00	0.	0.	0.	.00
12	7469.0	1332.0	.00	0.	0.	0.	.00
13	5395.3	852.5	4.23	0.	0.	0.	.00
14	3644.0	200.0	25.00	0.	0.	0.	.00
15	1796.2	200.0	25.00	0.	0.	0.	.00
16	183.2	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.68	683.0	344.0	.0	224.5
2	284.92	1428.3	697.5	.0	493.1
3	284.75	1850.4	724.2	.0	407.4
4	277.33	1171.5	1077.0	.0	276.0
5	260.00	2027.0	1875.0	.0	441.6
6	240.00	3005.3	2793.5	.0	612.0
7	227.40	3592.9	3369.8	.0	636.8
8	217.40	4067.2	3833.1	.0	656.7
9	200.00	4890.0	4639.8	.0	691.4
10	180.00	5829.4	5560.7	.0	731.0
11	160.00	6764.9	6481.7	.0	758.4
12	143.84	7469.0	7181.4	.0	758.4
13	137.55	5395.3	7407.0	.0	712.7
14	133.21	3644.0	6719.9	.0	1081.4
15	113.60	1796.2	3385.9	.0	590.8
16	96.32	183.2	364.2	.0	60.2

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	16.55	5063.	3.44	5.50	.624
2	284.85	16.55	5287.	3.43	5.65	.607
3	284.65	16.55	5770.	3.40	5.93	.573
4	270.00	16.55	10344.	5.51	11.30	.488
5	250.00	16.55	20398.	7.57	18.70	.405
6	230.00	16.55	34414.	9.54	26.00	.367

7	224.80	16.55	38256.	10.15	27.92	.363
8	210.00	16.55	49708.	11.97	33.41	.358
9	190.00	16.55	66265.	14.55	40.83	.356
10	170.00	16.55	84058.	17.16	48.14	.356
11	150.00	16.55	102830.	19.81	55.56	.356
12	137.68	16.55	114583.	21.49	59.34	.362
13	137.43	16.55	113418.	21.55	59.17	.364
14	129.00	16.55	72624.	19.91	48.35	.412
15	98.20	16.55	1012.	2.71	5.83	.465
16	94.43	.00	-2.	.15	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3410.62 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 610.80 (psf)

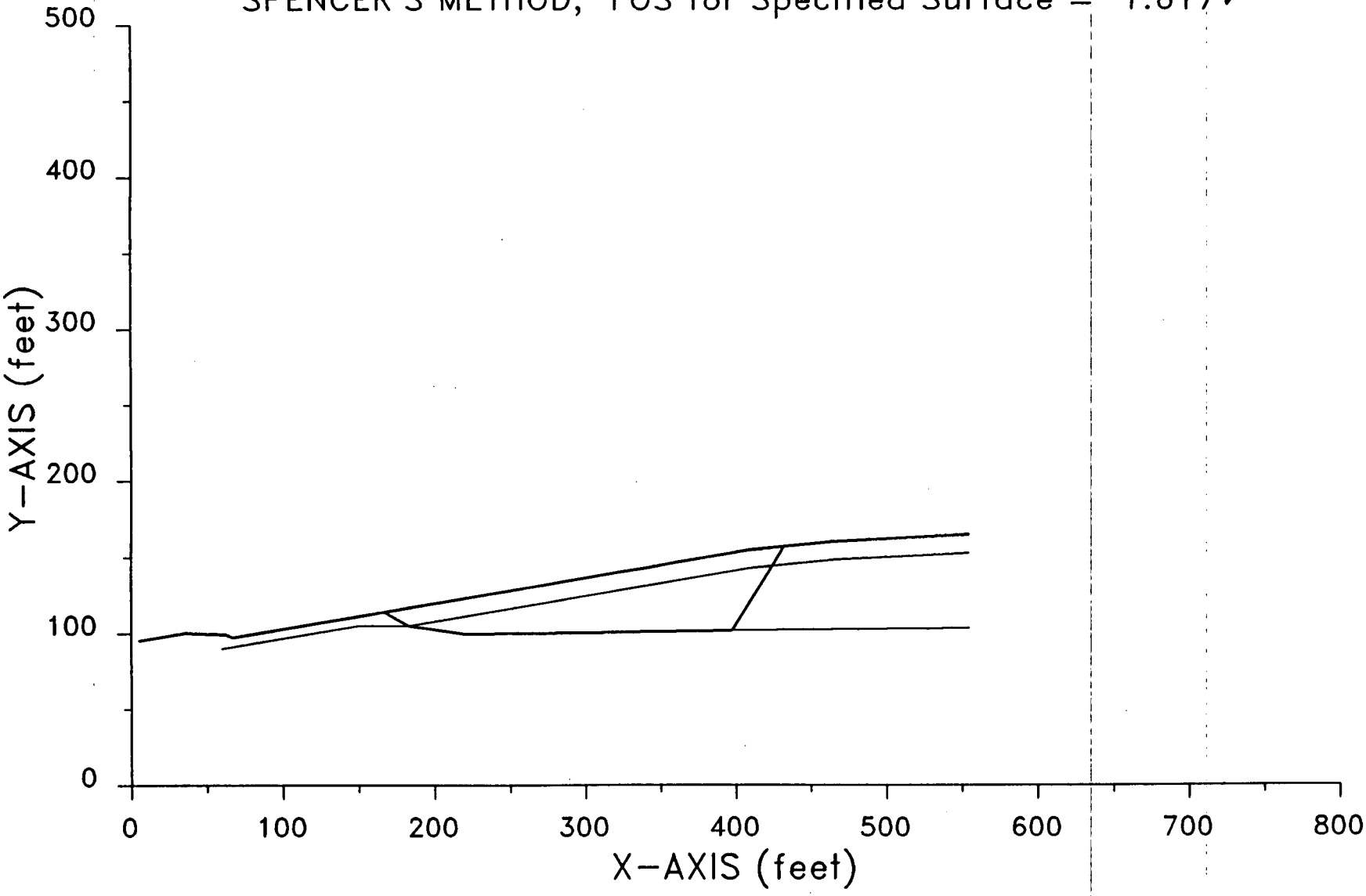
Total Length of failure surface = 237.10 feet

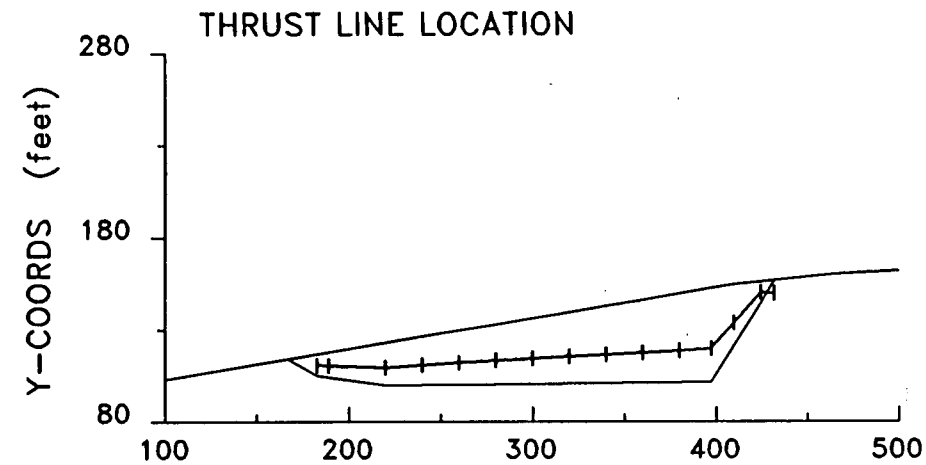
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

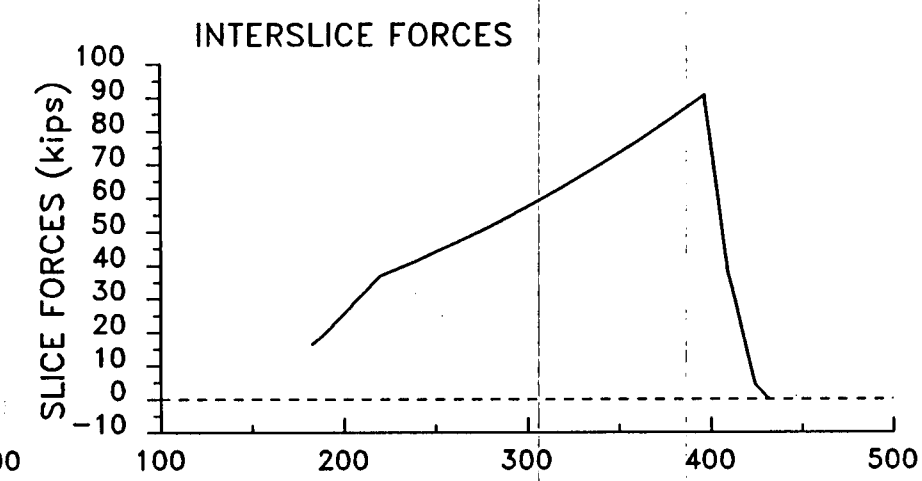
FACTOR OF SAFETY = 1.756

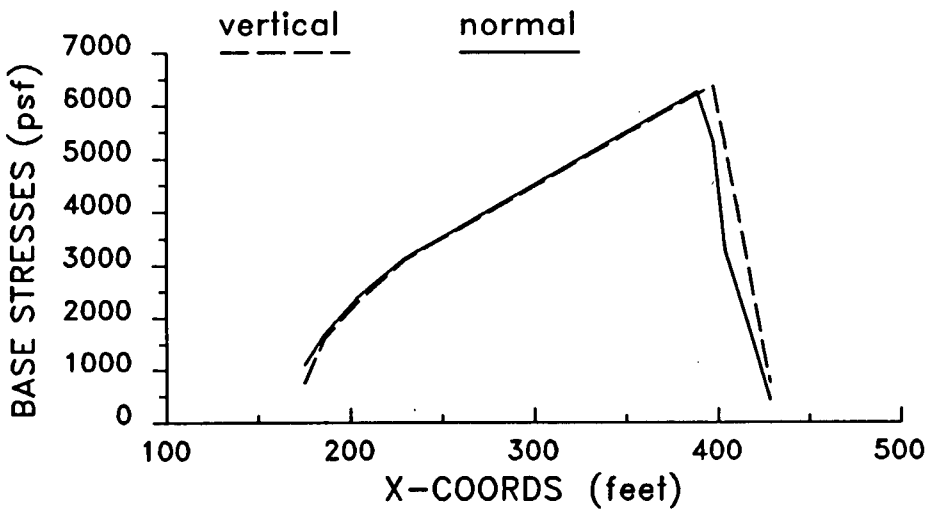
Total shear strength available along specified failure surface = 254.36E+03 lb

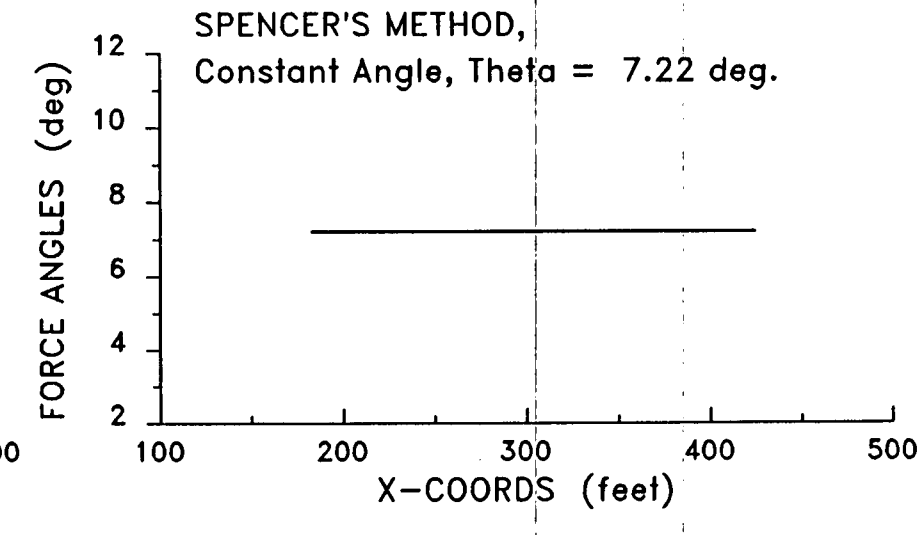
OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.617✓











OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.617 ✓

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	302.4
4	2880.0	388.8
5	6480.0	741.6
6	10080.0	741.6

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	397.52	101.62
6	397.76	101.87
7	424.78	144.28
8	432.07	156.91

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.70	37.35	20.00	.60	9.37	93364.
9	330.00	100.91	40.44	20.00	.60	9.37	101091.
10	350.00	101.12	43.58	20.00	.60	9.65	108943.
11	370.00	101.33	46.72	20.00	.60	9.37	116795.
12	388.76	101.53	49.63	17.52	.60	9.46	108693.
13	397.64	101.75	50.89	.24	46.17	9.46	1527.
14	403.88	111.48	42.20	12.24	57.50	9.46	64572.
15	417.39	132.68	22.76	14.78	57.50	5.71	42046.
16	428.42	150.59	5.95	7.29	60.00	5.71	5421.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.1277	1.6152	1.6625
3	7.2211	1.6173	1.6152
4	7.2190	1.6173	1.6173

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.2190	1.6173	1.6173

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1095.0	.0	30.00	0.	0.	0.	.00

2	1680.6	273.6	2.29	0.	0.	0.	.00
3	2408.8	273.6	2.29	0.	0.	0.	.00
4	3125.8	106.6	5.60	0.	0.	0.	.00
5	3521.9	106.6	5.60	0.	0.	0.	.00
6	3911.6	106.6	5.60	0.	0.	0.	.00
7	4307.7	106.6	5.60	0.	0.	0.	.00
8	4702.7	106.6	5.60	0.	0.	0.	.00
9	5091.3	106.6	5.60	0.	0.	0.	.00
10	5486.1	106.6	5.60	0.	0.	0.	.00
11	5881.0	106.6	5.60	0.	0.	0.	.00
12	6247.3	106.6	5.60	0.	0.	0.	.00
13	5307.2	106.6	5.60	0.	0.	0.	.00
14	3266.9	.0	25.00	0.	0.	0.	.00
15	1761.6	.0	25.00	0.	0.	0.	.00
16	414.9	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1095.0	739.6	.0	390.9
2	186.00	1680.6	1594.4	.0	210.7
3	204.50	2408.8	2304.8	.0	228.7
4	230.00	3125.8	3100.0	.0	255.3
5	250.00	3521.9	3493.8	.0	279.3
6	270.00	3911.6	3881.3	.0	302.9
7	290.00	4307.7	4275.0	.0	326.9
8	310.00	4702.7	4668.2	.0	350.9
9	330.00	5091.3	5054.5	.0	374.4
10	350.00	5486.1	5447.1	.0	398.3
11	370.00	5881.0	5839.7	.0	422.3
12	388.76	6247.3	6204.0	.0	444.4
13	397.64	5307.2	6361.9	.0	387.5
14	403.88	3266.9	5275.5	.0	941.9
15	417.39	1761.6	2844.8	.0	507.9
16	428.42	414.9	743.6	.0	148.1

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.22	16401.	5.60	11.83	.473
2	189.00	7.22	19104.	6.30	13.68	.460
3	220.00	7.22	36830.	9.55	23.20	.412
4	240.00	7.22	41347.	10.72	26.40	.406
5	260.00	7.22	46267.	11.79	29.50	.399
6	280.00	7.22	51585.	12.78	32.60	.392
7	300.00	7.22	57307.	13.72	35.80	.383
8	320.00	7.22	63389.	14.62	38.89	.376
9	340.00	7.22	69863.	15.48	41.98	.369

10	360.00	7.22	76737.	16.31	45.17	.361
11	380.00	7.22	84009.	17.12	48.26	.355
12	397.52	7.22	90704.	17.82	51.00	.349
13	397.76	7.22	89460.	17.85	50.79	.351
14	410.00	7.22	37818.	12.49	33.62	.372
15	424.78	7.22	4192.	5.85	11.90	.492
16	432.07	.00	0.	-7.23	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3573.31 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 386.41 (psf)

Total Length of failure surface = 298.47 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.617

Total shear strength available along specified failure surface = 186.52E+03 lb

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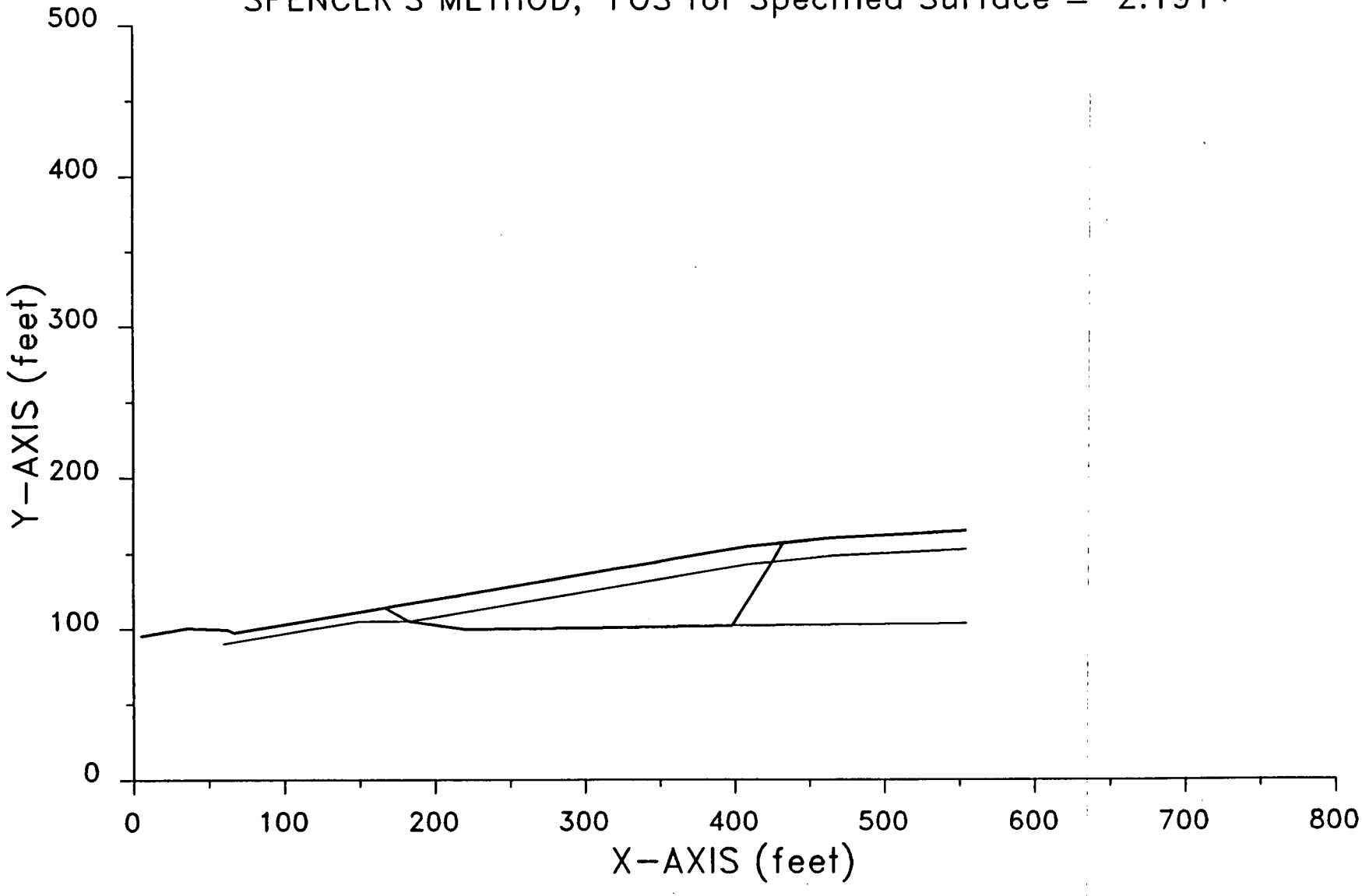
OSDF Final Long Term – Large Displ.

SPENCER'S METHOD, FOS for Specified Surface = 2.191 ✓



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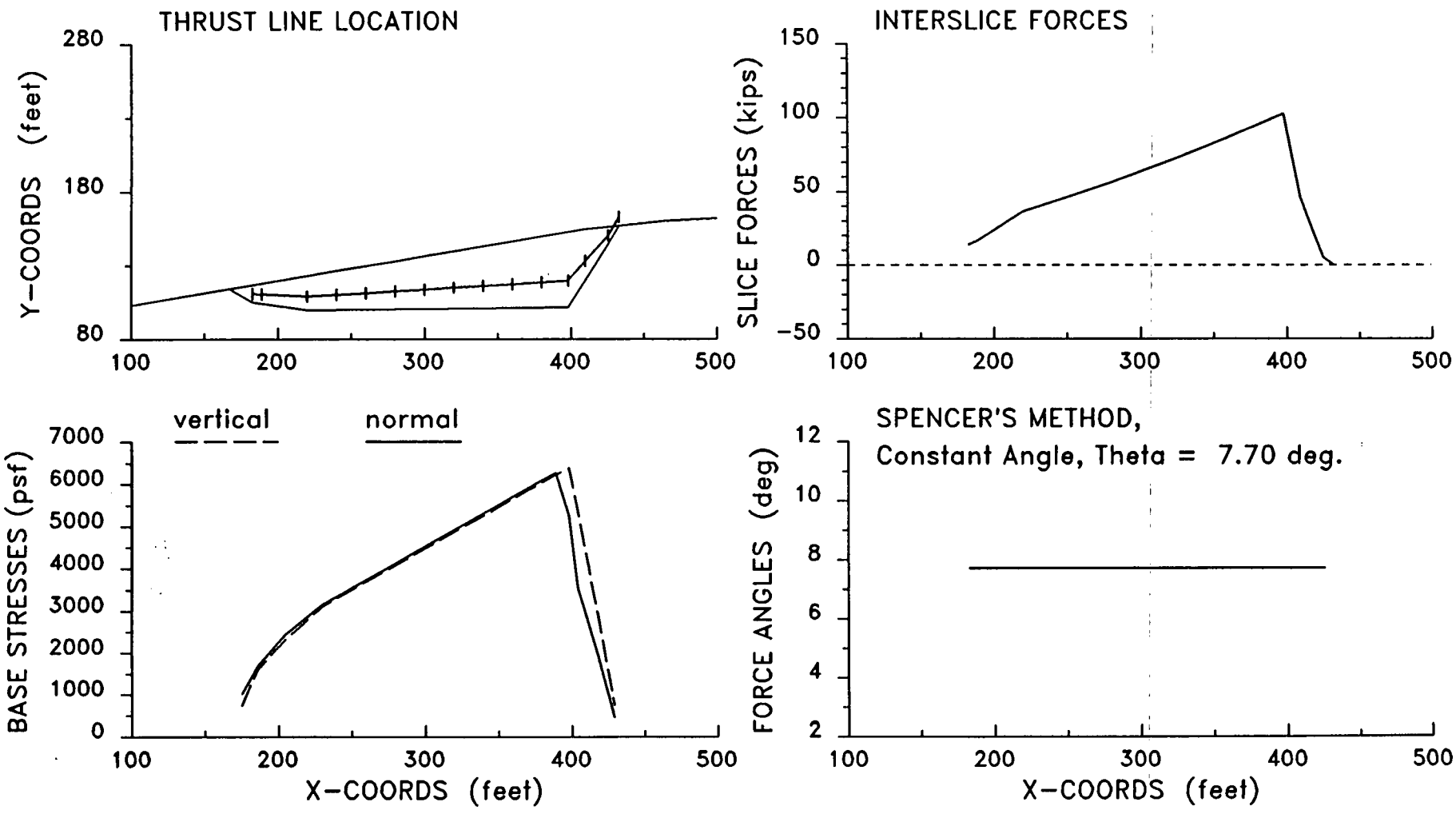

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.191

1269

000254

XSTABL File: NLD10B2S 10-27-97 10:54

```
*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*           Method of Slices            *
*                                       *
*         Copyright (C) 1992 - 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.201                 96 - 1202 *
*****************************************
```

Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	259.2
4	2880.0	734.4
5	6480.0	1094.4
6	10080.0	1094.4

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	398.30	101.62
6	398.55	101.88
7	425.62	144.36
8	432.91	156.99

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.70	37.35	20.00	.59	9.37	93366.
9	330.00	100.91	40.44	20.00	.59	9.37	101097.
10	350.00	101.12	43.58	20.00	.59	9.65	108953.
11	370.00	101.33	46.72	20.00	.59	9.37	116809.
12	389.15	101.53	49.70	18.30	.59	9.46	113689.
13	398.42	101.75	51.02	.25	46.12	9.46	1594.
14	404.27	110.86	42.88	11.45	57.49	9.46	61375.
15	417.81	132.11	23.38	15.62	57.49	5.71	45646.
16	429.27	150.68	5.95	7.29	60.01	5.71	5421.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.6391	2.1889	2.2415
3	7.7034	2.1911	2.1889
4	7.7020	2.1910	2.1911

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.7020	2.1910	2.1911

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1007.5	.0	30.00	0.	0.	0.	.00

2	1685.8	100.8	12.41	0.	0.	0.	.00
3	2431.0	100.8	12.41	0.	0.	0.	.00
4	3139.2	446.4	5.71	0.	0.	0.	.00
5	3534.7	446.4	5.71	0.	0.	0.	.00
6	3923.9	446.4	5.71	0.	0.	0.	.00
7	4319.4	446.4	5.71	0.	0.	0.	.00
8	4714.0	446.4	5.71	0.	0.	0.	.00
9	5102.2	446.4	5.71	0.	0.	0.	.00
10	5496.7	446.4	5.71	0.	0.	0.	.00
11	5891.2	446.4	5.71	0.	0.	0.	.00
12	6264.8	446.4	5.71	0.	0.	0.	.00
13	5239.9	446.4	5.71	0.	0.	0.	.00
14	3532.4	.0	25.00	0.	0.	0.	.00
15	1925.6	.0	25.00	0.	0.	0.	.00
16	449.3	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1007.5	739.6	.0	265.5
2	186.00	1685.8	1594.4	.0	215.3
3	204.50	2431.0	2304.8	.0	290.1
4	230.00	3139.2	3100.0	.0	347.0
5	250.00	3534.7	3493.8	.0	365.1
6	270.00	3923.9	3881.3	.0	382.8
7	290.00	4319.4	4275.0	.0	400.9
8	310.00	4714.0	4668.3	.0	418.9
9	330.00	5102.2	5054.8	.0	436.6
10	350.00	5496.7	5447.6	.0	454.6
11	370.00	5891.2	5840.5	.0	472.6
12	389.15	6264.8	6212.5	.0	489.7
13	398.42	5239.9	6377.6	.0	442.9
14	404.27	3532.4	5360.2	.0	751.8
15	417.81	1925.6	2922.0	.0	409.8
16	429.27	449.3	743.7	.0	118.4

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.70	13596.	5.67	11.83	.479
2	189.00	7.70	16334.	6.23	13.68	.456
3	220.00	7.70	36097.	9.03	23.20	.389
4	240.00	7.70	42467.	9.99	26.40	.378
5	260.00	7.70	49121.	10.97	29.50	.372
6	280.00	7.70	56056.	11.96	32.60	.367
7	300.00	7.70	63274.	12.96	35.80	.362
8	320.00	7.70	70741.	13.96	38.89	.359
9	340.00	7.70	78484.	14.95	41.98	.356

10	360.00	7.70	86508.	15.95	45.18	.353
11	380.00	7.70	94813.	16.94	48.27	.351
12	398.30	7.70	102655.	17.84	51.13	.349
13	398.55	7.70	101392.	17.84	50.91	.350
14	410.00	7.70	46029.	13.00	34.85	.373
15	425.62	7.70	4855.	5.82	11.90	.489
16	432.91	.00	0.	5.86	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3613.19 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 399.57 (psf)

Total Length of failure surface = 299.35 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.191 ✓

Total shear strength available along specified failure surface = 262.07E+03 lb

GCL 11 – Not Approved for Phase I. Pending Approval for Phase II

GCL 12

COMPUTATION COVER SHEET

1269

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 12 - Compliance Package

Computations By:
(Cognizant Engineer)

Signature [illegible] Date 17 OCT 97

Printed Name and Title M. CATALINA OROZCO
STAFF ENGINEER

Assumptions and Procedures Checked By:
(Checker)

Signature Robert A. Morgan - III Date 17 OCT 97

Printed Name and Title ROBERT A. MORGAN III
SR. STAFF ENGINEER

Computations Checked by:

Signature Robert A. Morgan - III Date 17 OCT 97

Printed Name and Title ROBERT A. MORGAN III
SR. STAFF ENGINEER

Computations Backchecked by:
(Cognizant Engineer)

Signature [illegible] Date 17 OCT 97

Printed Name and Title M. CATALINA OROZCO
STAFF ENGINEER

Approved by:
(PDP)

Signature [illegible] Date 17 Oct 97

Printed Name and Title Gary R. Schmertmann
Sr. Project Engineer

Approved by:
(DTL and TETL)

Signature [illegible] Date 19 Oct 97

Printed Name and Title Kenneth W Cargill
Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

Written By: MCO Date: 10/17/97 Reviewed by: RAM Date: 10/17/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 12 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 12 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample No.	Case	Test Type	Measured Shear Strengths		
			5 psi *	20 psi	45 psi
12	Peak	GCL Internal	-	7.9 psi ✓	16.6 psi ✓
		GCL/GMB Interface	-	7.1 ✓	12.9 ✓
12	Large-displacement	GCL Internal	-	2.6 ✓	5.4 ✓
		GCL/GMB Interface	-	4.5 ✓	5.7 ✓

* NOTE: Measured shear strength at 5 psi normal stress are assumed to be equal to zero. This is a conservative assumption in the context of RCI no. 1702-006R.

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix B.

QA Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
12	GCL Internal	NPK12AS ✓	2.2 ✓	YES ✓
	GCL/GMB Interface	NPK12BS ✓	1.9 ✓	YES ✓
Baseline	Large-displacement	NA	1.6	NA
12	GCL Internal	NLD12AS ✓	1.6 ✓	YES ✓
	GCL/GMB Interface	NLD12BS ✓	1.9 ✓	YES ✓

XMCD 10/17/97
RAM 10/17/97

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 12I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-12). GCL's initial moisture content was 8.7%. GCL's final moisture content ranged from 70% to 78% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20 and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 12G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

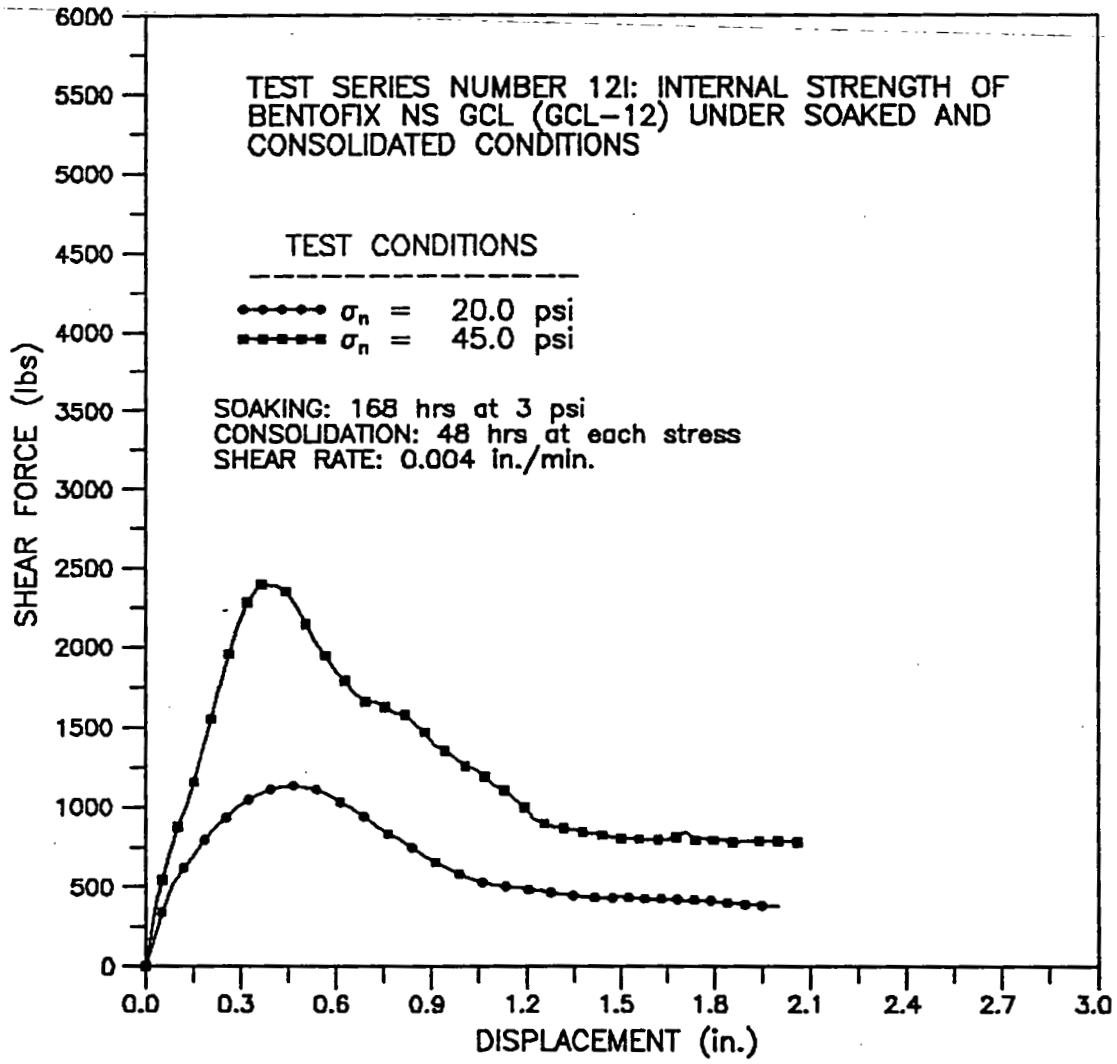
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-12) with woven geotextile against geomembrane. GCL's initial moisture content was 9.0%. GCL's final moisture content ranged from 54 to 95% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-10); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20 and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.

(2) For each test, sliding (i.e., internal shear failure) was observed to occur within the GCL.

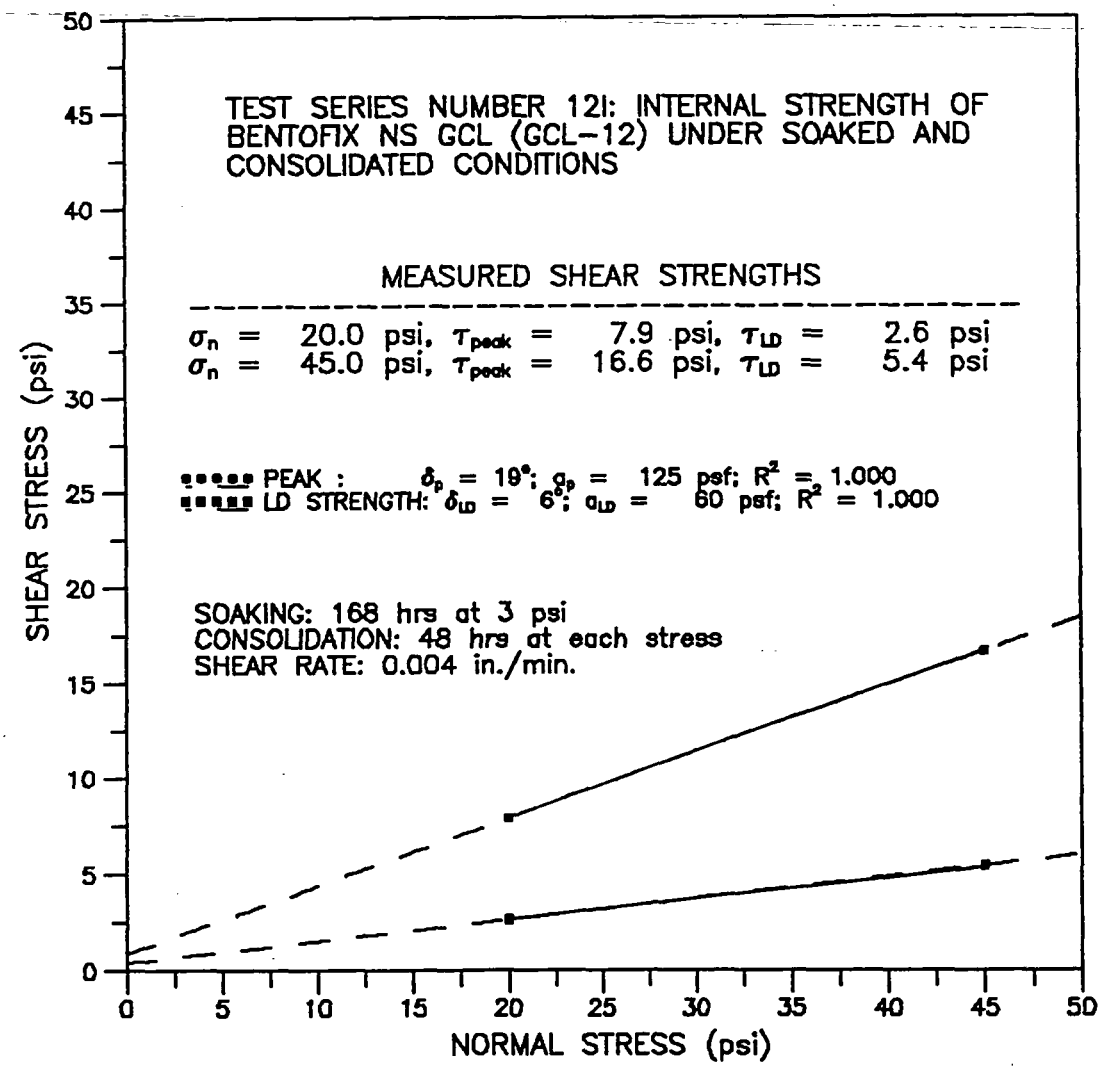
DATE TESTED: 1 TO 10 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730095
FILE NO.	

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



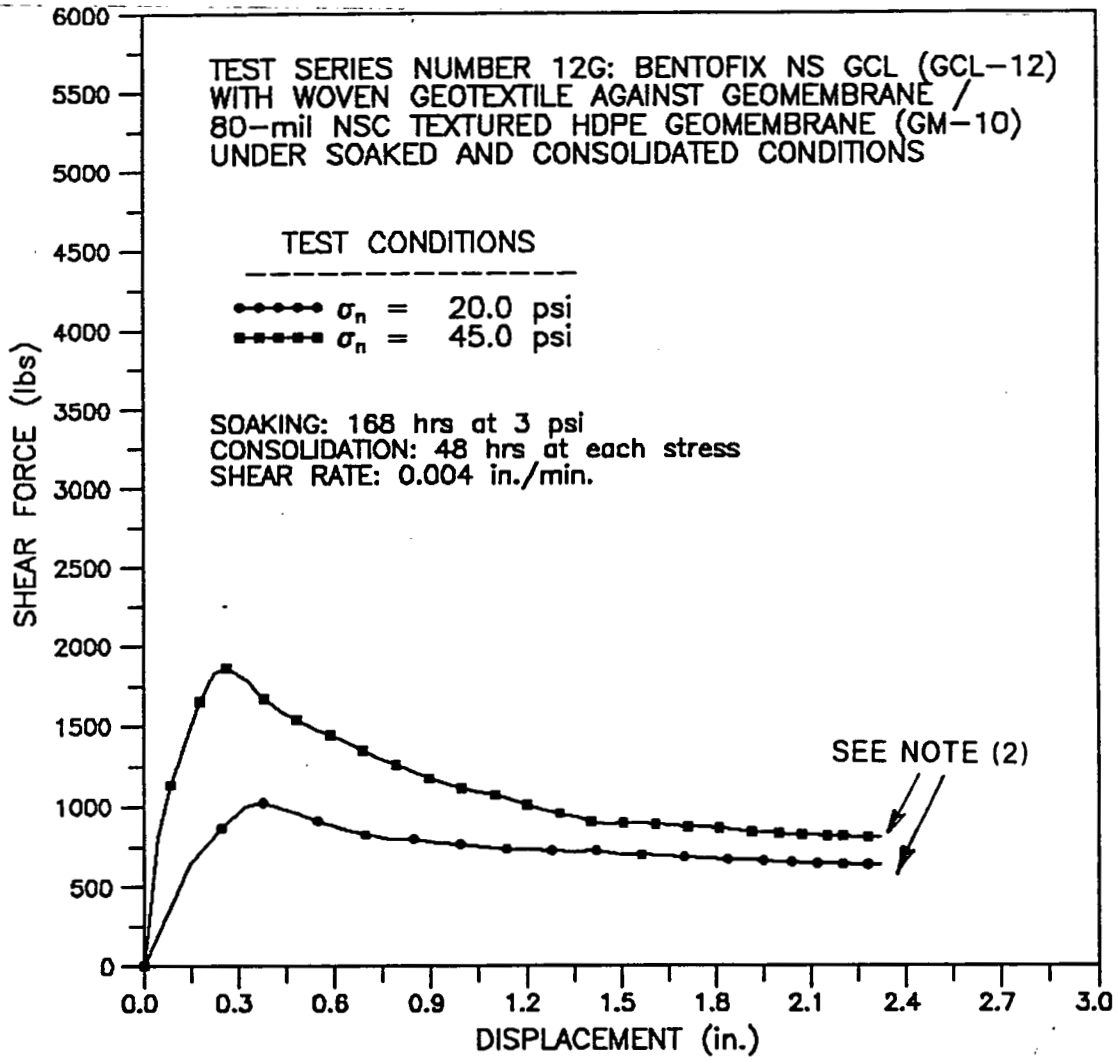
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) For each test, sliding (i.e, internal shear failure) was observed to occur within the GCL

DATE TESTED: 1 TO 10 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730095
FILE NO.	000268

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

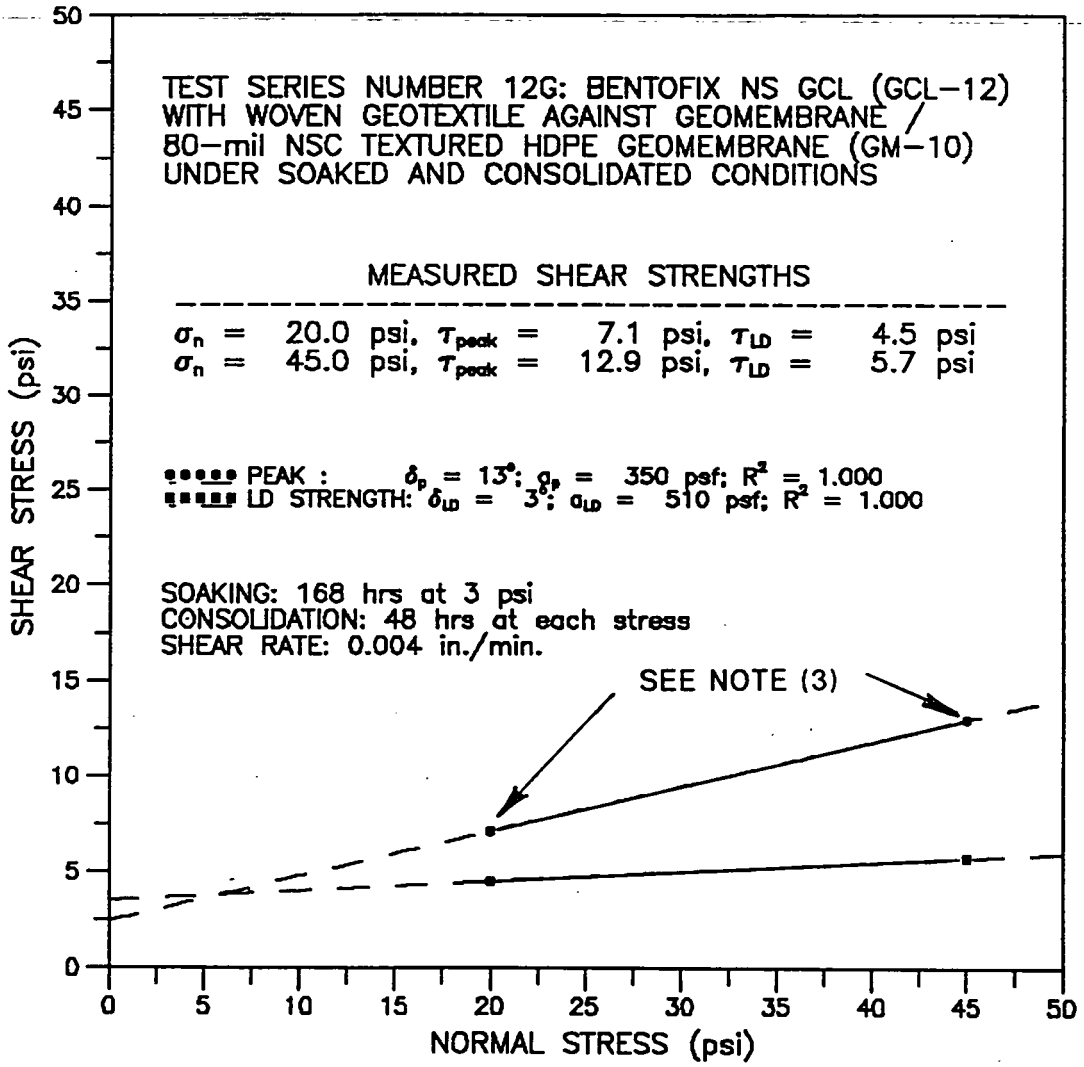
(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 1 TO 10 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730095
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 1 TO 10 OCTOBER 1997

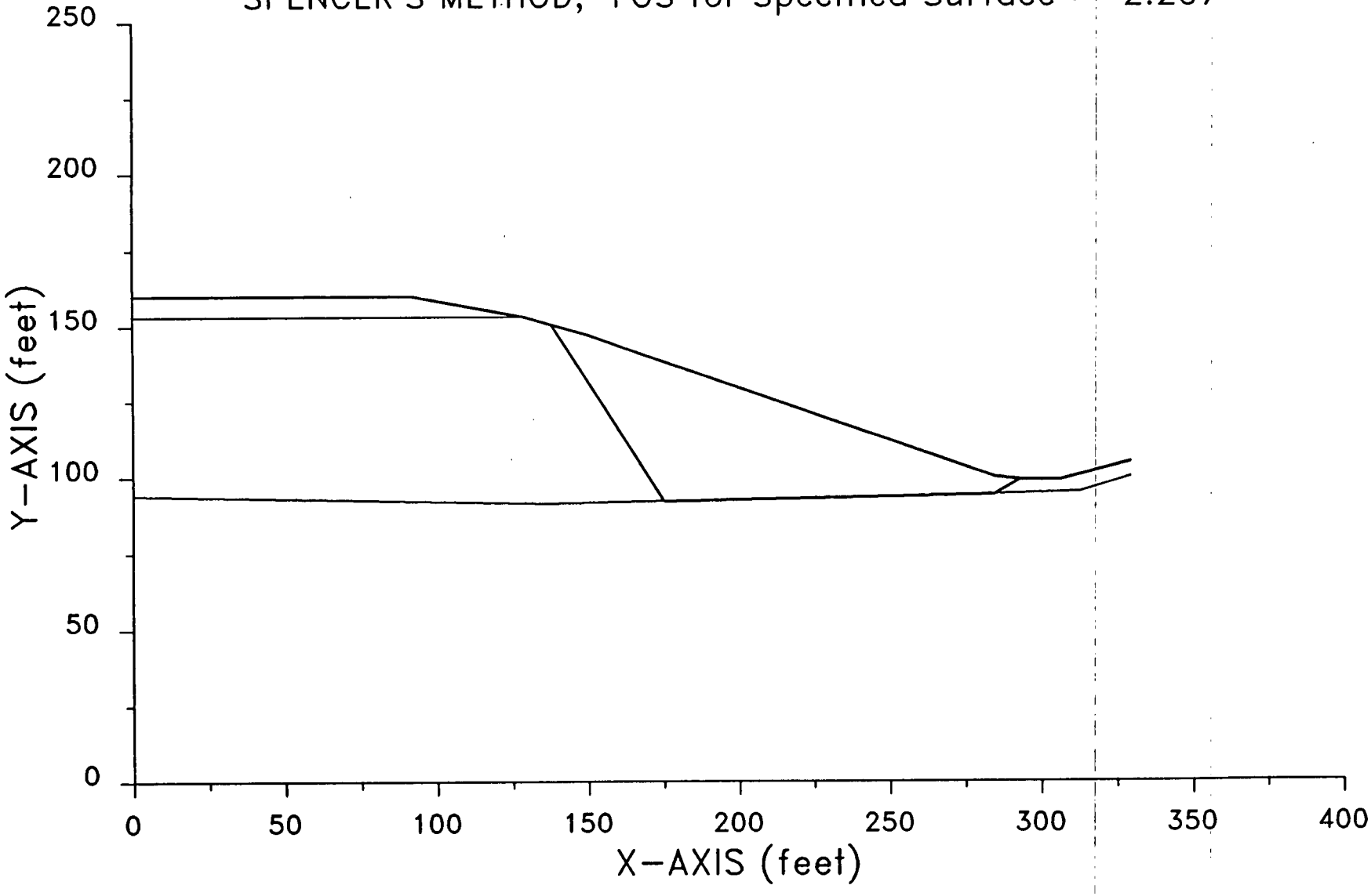
GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

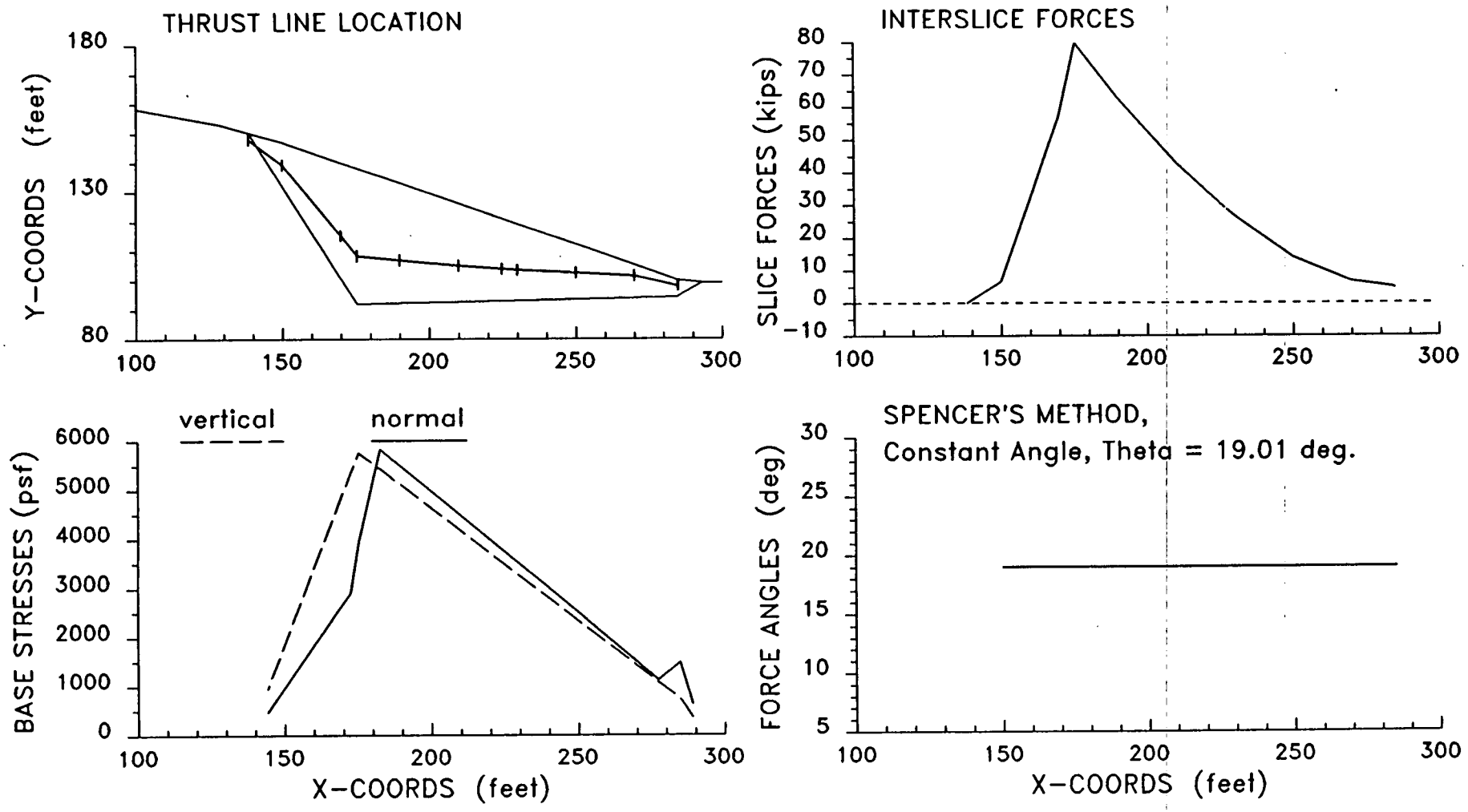
FIGURE NO.	A-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730095
FILE NO.	

MCO 10/17/97
RAM 10/17/97

APPENDIX B

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.207





OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.207 ✓

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*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	1137.6 ✓
5	6480.0	2390.4
6	10080.0	2390.4

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 7 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	293.27	99.08
2	285.17	94.40
3	284.97	94.20
4	224.80	93.00
5	175.56	92.03
6	175.40	92.19
7	138.37	150.32

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	289.22	96.74	2.79	8.10	-30.02	6.34	2825.
2	285.09	94.31	5.68	.17	-45.00	6.34	121.
3	284.98	94.21	5.79	.03	-45.00	19.12	22.
4	277.48	94.05	8.55	14.97	-1.14	19.12	16008.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37495.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55867.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.13	19.29	56713.
9	200.00	92.51	37.09	20.00	-1.13	19.29	92721.
10	182.78	92.17	43.42	14.44	-1.13	19.03	78371.
11	175.48	92.11	46.00	.16	45.00	19.03	931.
12	172.70	96.43	42.64	5.40	57.50	19.03	28771.
13	160.00	116.37	27.13	20.00	57.50	19.29	67834.
14	144.18	141.19	7.47	11.63	57.50	15.95	10856.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	19.0519	2.2116	2.1867
3	19.0375	2.2111	2.2116

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	19.0104	2.2071	2.2079

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	19.0104	2.2071	2.2079

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	623.4	.0	30.00	0.	0.	0.	.00

2	1429.7	-379.2	27.77	0.	0.	0.	.00
3	1472.5	-379.2	27.77	0.	0.	0.	.00
4	1110.9	-379.2	27.77	0.	0.	0.	.00
5	1999.8	-379.2	27.77	0.	0.	0.	.00
6	3009.3	135.4	19.19	0.	0.	0.	.00
7	3625.4	135.4	19.19	0.	0.	0.	.00
8	4118.8	135.4	19.19	0.	0.	0.	.00
9	4978.1	135.4	19.19	0.	0.	0.	.00
10	5823.7	135.4	19.19	0.	0.	0.	.00
11	3943.5	135.4	19.19	0.	0.	0.	.00
12	2899.7	200.0	25.00	0.	0.	0.	.00
13	1822.8	200.0	25.00	0.	0.	0.	.00
14	457.0	200.0	25.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	289.22	623.4	348.8	.0	163.1
2	285.09	1429.7	709.4	.0	169.4
3	284.98	1472.5	723.8	.0	179.6
4	277.48	1110.9	1069.3	.0	93.3
5	260.00	1999.8	1874.7	.0	305.4
6	240.00	3009.3	2793.4	.0	535.8
7	227.40	3625.4	3369.8	.0	633.0
8	217.40	4118.8	3832.0	.0	710.8
9	200.00	4978.1	4636.1	.0	846.3
10	182.78	5823.7	5427.3	.0	979.6
11	175.48	3943.5	5749.8	.0	683.1
12	172.70	2899.7	5329.8	.0	703.3
13	160.00	1822.8	3391.7	.0	475.7
14	144.18	457.0	933.4	.0	187.2

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.17	19.01	4483.	3.74	5.58	.669
2	285.00	19.01	4771.	3.73	5.77	.647
3	284.97	19.01	4823.	3.73	5.81	.642
4	270.00	19.01	6651.	7.41	11.30	.656
5	250.00	19.01	13955.	8.92	18.70	.477
6	230.00	19.01	26560.	10.25	26.00	.394
7	224.80	19.01	30439.	10.72	27.92	.384
8	210.00	19.01	42835.	12.23	33.39	.366
9	190.00	19.01	62811.	14.46	40.79	.355
10	175.56	19.01	79524.	16.13	46.05	.350
11	175.40	19.01	78966.	16.14	45.95	.351
12	170.00	19.01	56990.	14.47	39.33	.368
13	150.00	19.01	6520.	7.13	14.93	.477

16/37

14	138.37	.00	-2.	-2.47	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 2626.61 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 497.68 (psf)

Total Length of failure surface = 188.22 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.207 ✓

Total shear strength available along specified failure surface = 206.74E+03 lb

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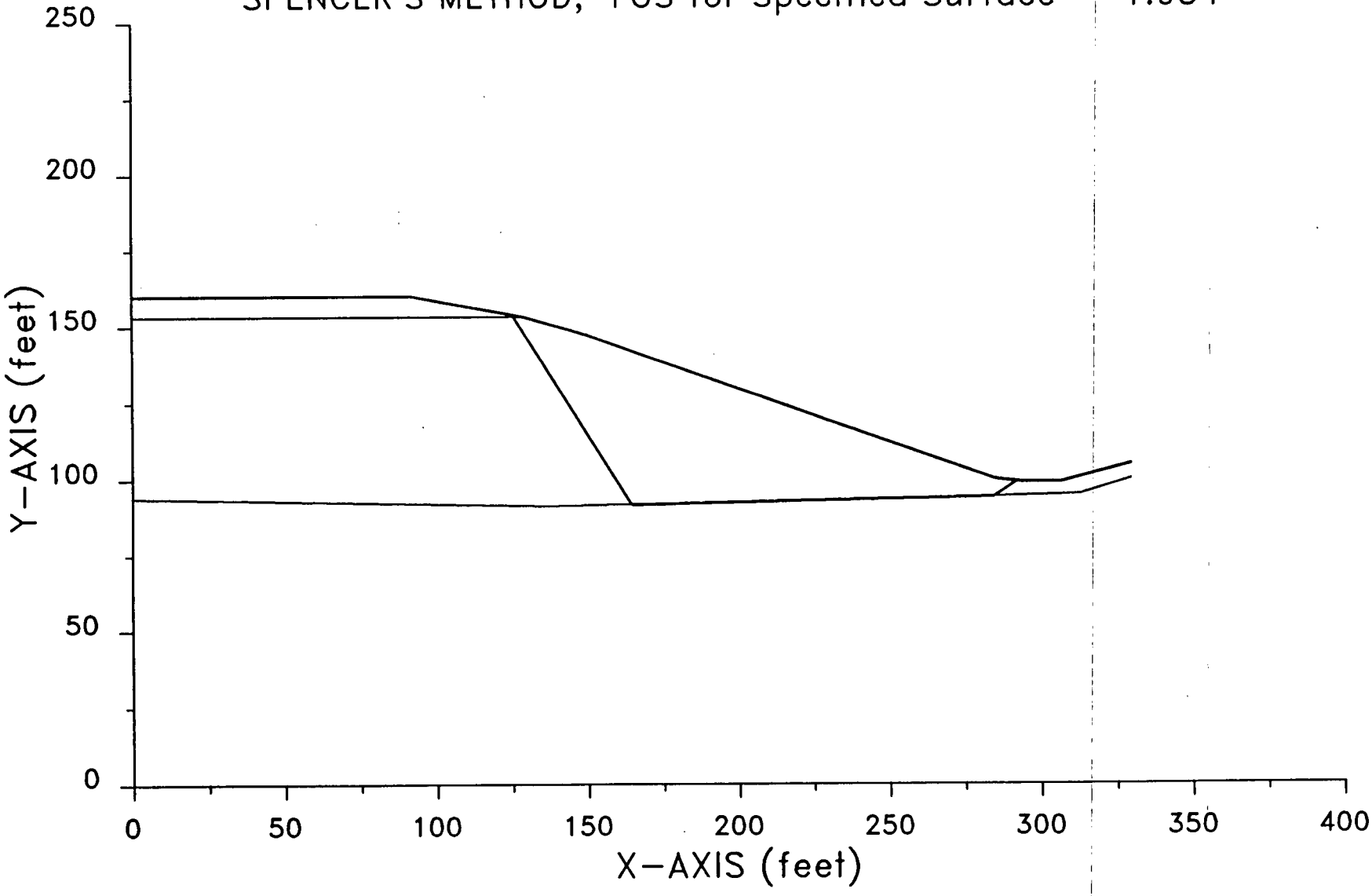
OSDF Interim Closure/Short-Term,Peak

SPENCER'S METHOD, FOS for Specified Surface = 1.934 ✓



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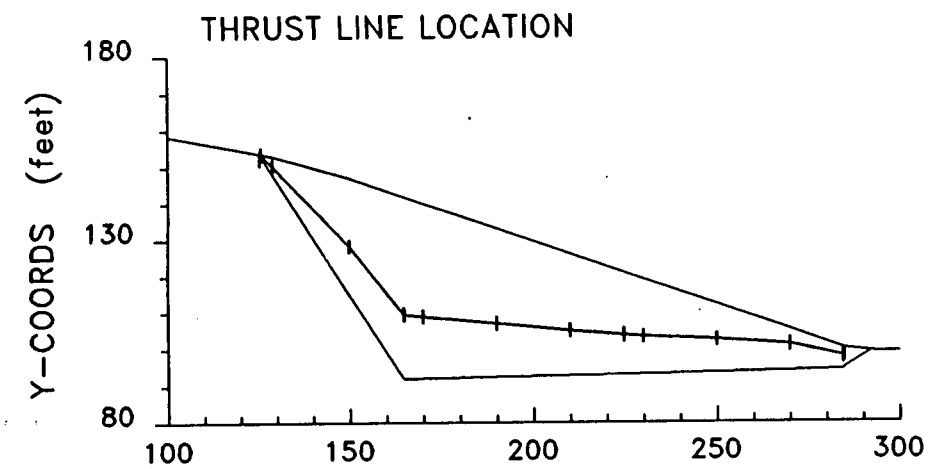

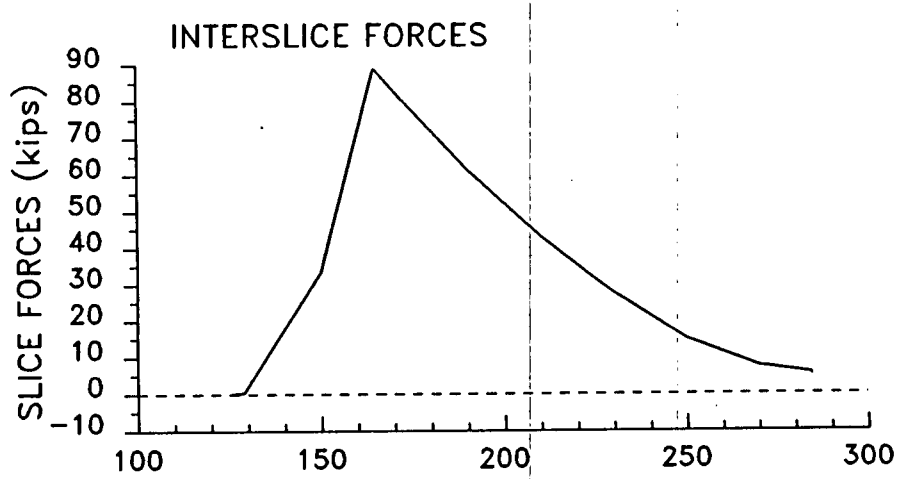

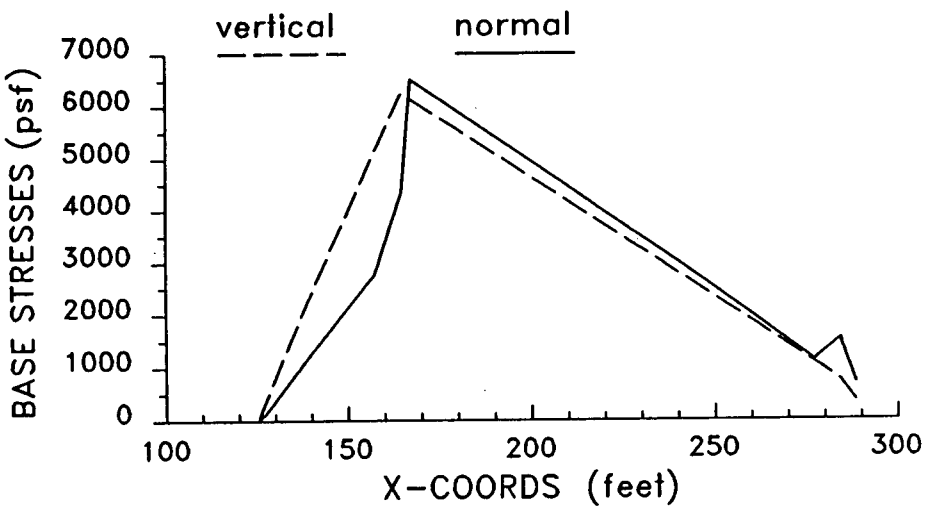

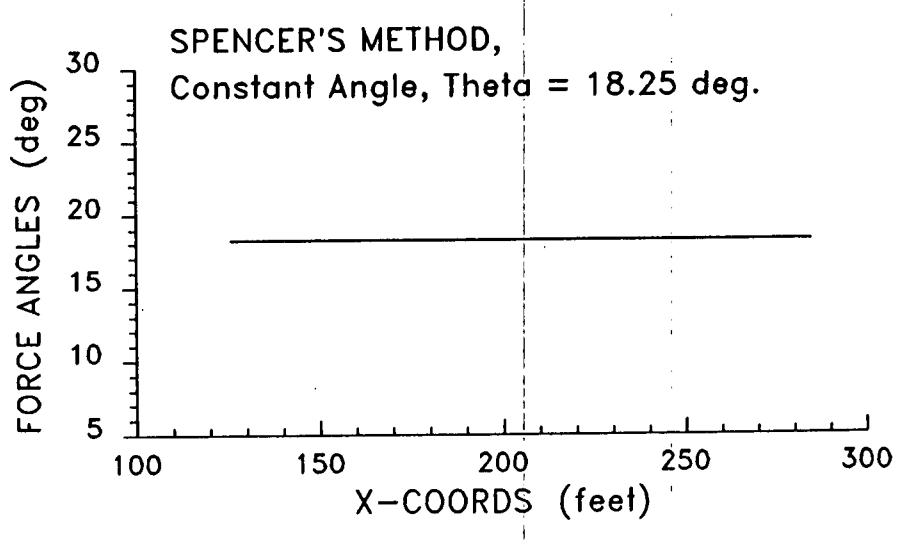

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 1.934 ✓

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
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*           Method of Slices            *
*                                       *
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```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	1022.4
5	6480.0	1857.6
6	10080.0	1857.6

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	292.31	99.19
2	284.78	94.40
3	284.58	94.19
4	224.80	93.00
5	164.88	91.78
6	164.69	91.97
7	125.81	153.00
8	125.42	153.68

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.65	96.86	2.73	7.31	-32.45	6.34	2495.
2	284.89	94.47	5.57	.22	-32.45	19.12	156.
3	284.68	94.29	5.82	.20	-46.40	19.12	142.
4	277.29	94.04	8.63	14.58	-1.14	19.12	15724.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37498.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55869.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.17	19.29	56722.
9	200.00	92.50	37.10	20.00	-1.17	19.29	92762.
10	180.00	92.09	44.46	20.00	-1.17	19.03	111155.
11	167.44	91.83	49.06	5.12	-1.17	19.29	31401.
12	164.78	91.88	49.95	.19	45.00	19.29	1205.
13	157.34	103.50	40.93	14.69	57.50	19.29	75139.
14	139.50	131.51	18.49	21.00	57.50	15.95	48534.
15	127.40	150.50	2.81	3.19	57.50	10.71	1119.
16	125.61	153.34	.30	.39	60.07	10.71	15.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.2621	1.9386	1.9337
3	18.2543	1.9384	1.9386

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.2492	1.9344	1.9345

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	18.2492	1.9344	1.9345

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	679.6	.0	30.00	0.	0.	0.	.00
2	1427.8	200.0	25.00	0.	0.	0.	.00
3	1531.6	-340.8	25.33	0.	0.	0.	.00
4	1120.1	-340.8	25.33	0.	0.	0.	.00
5	1997.3	-340.8	25.33	0.	0.	0.	.00
6	3003.1	354.2	13.06	0.	0.	0.	.00
7	3608.8	354.2	13.06	0.	0.	0.	.00
8	4096.2	354.2	13.06	0.	0.	0.	.00
9	4943.0	354.2	13.06	0.	0.	0.	.00
10	5909.7	354.2	13.06	0.	0.	0.	.00
11	6512.9	1857.6	.00	0.	0.	0.	.00
12	4340.7	354.2	13.06	0.	0.	0.	.00
13	2745.8	200.0	25.00	0.	0.	0.	.00
14	1201.7	200.0	25.00	0.	0.	0.	.00
15	122.5	200.0	25.00	0.	0.	0.	.00
16	19.2	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.65	679.6	341.3	.0	202.8
2	284.89	1427.8	696.3	.0	447.6
3	284.68	1531.6	727.4	.0	198.6
4	277.29	1120.1	1078.5	.0	97.9
5	260.00	1997.3	1874.9	.0	312.5
6	240.00	3003.1	2793.4	.0	543.3
7	227.40	3608.8	3369.8	.0	616.0
8	217.40	4096.2	3832.6	.0	674.4
9	200.00	4943.0	4638.1	.0	776.0
10	180.00	5909.7	5557.8	.0	891.9
11	167.44	6512.9	6133.0	.0	960.3
12	164.78	4340.7	6243.7	.0	703.7
13	157.34	2745.8	5116.0	.0	765.3
14	139.50	1201.7	2311.2	.0	393.1
15	127.40	122.5	350.7	.0	132.9
16	125.61	19.2	37.7	.0	5.7

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	18.25	4887.	3.53	5.46	.646
2	284.78	18.25	5207.	3.52	5.68	.620
3	284.58	18.25	5580.	3.55	5.96	.596
4	270.00	18.25	7425.	7.13	11.30	.631
5	250.00	18.25	14844.	8.81	18.70	.471
6	230.00	18.25	27545.	10.13	26.00	.390

7	224.80	18.25	31310.	10.62	27.92	.380
8	210.00	18.25	43120.	12.18	33.40	.365
9	190.00	18.25	61580.	14.48	40.81	.355
10	170.00	18.25	82897.	16.86	48.12	.350
11	164.88	18.25	88789.	17.48	50.01	.349
12	164.69	18.25	88050.	17.49	49.89	.351
13	150.00	18.25	33230.	13.12	31.97	.410
14	129.00	18.25	210.	2.10	5.01	.419
15	125.81	18.25	11.	.27	.60	.446
16	125.42	.00	-1.	-1.60	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 2850.90 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 539.75 (psf)

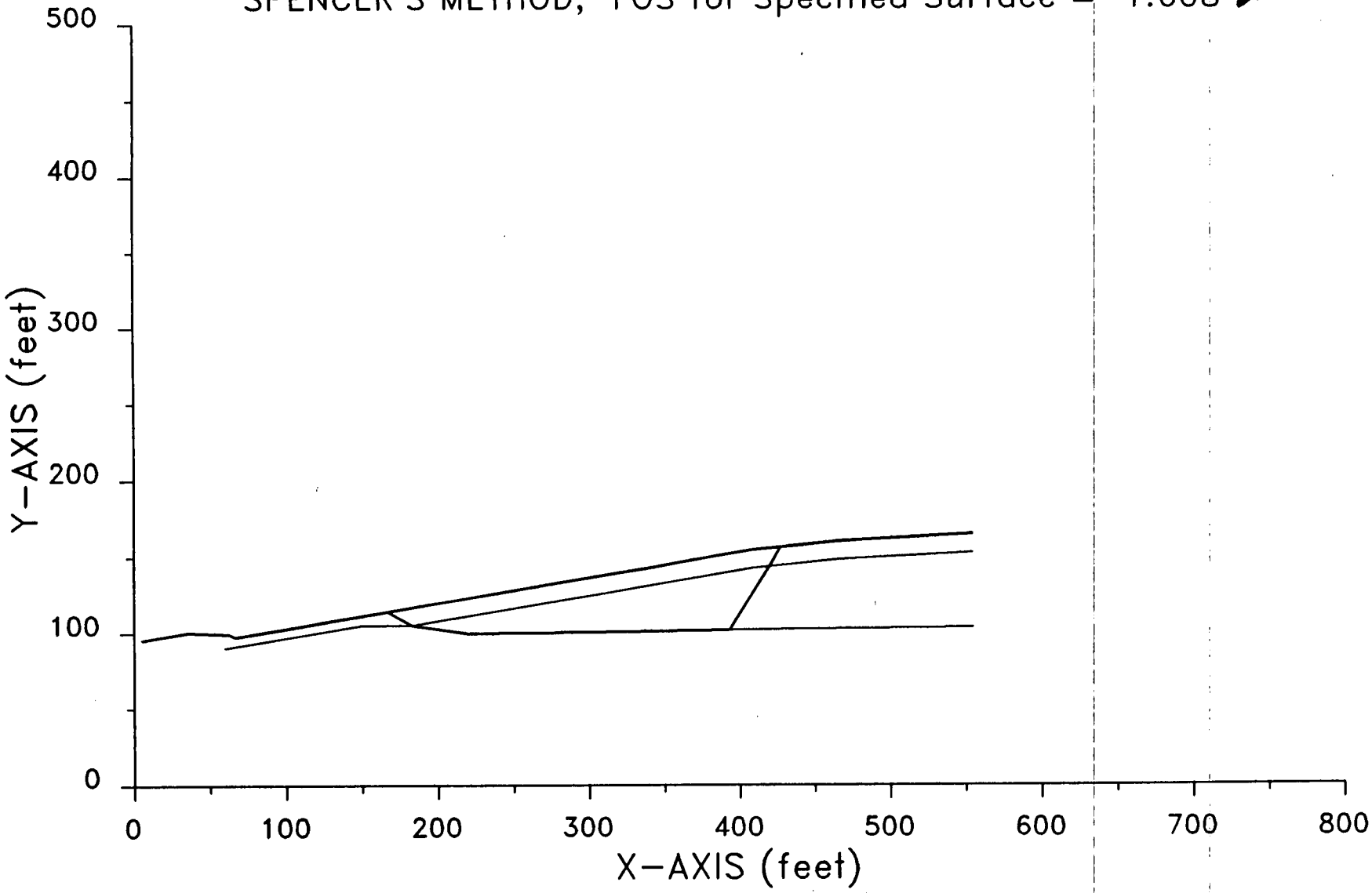
Total Length of failure surface = 202.35 feet

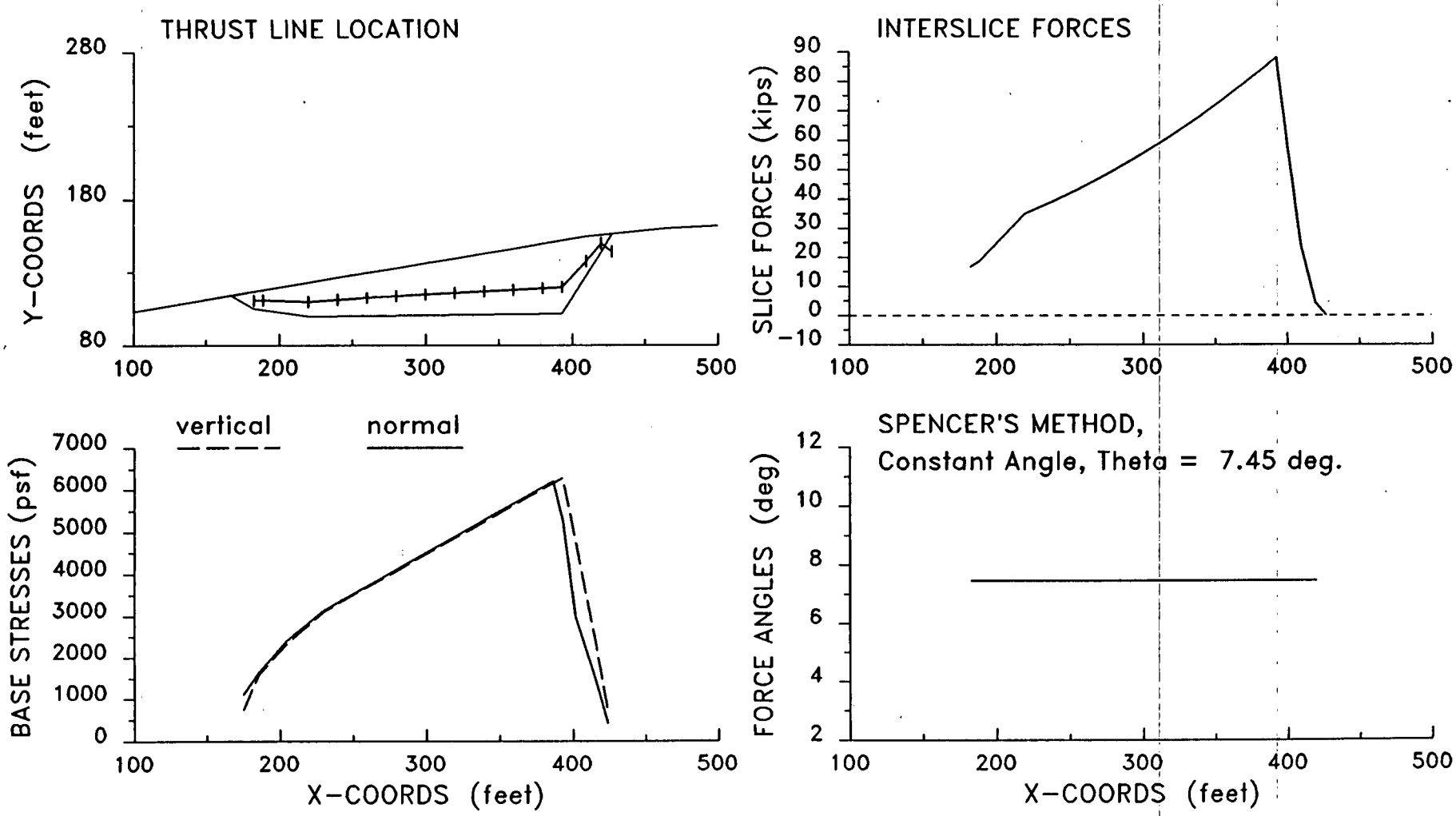
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.934

Total shear strength available along specified failure surface = 211.27E+03 lb

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.608





OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.608 ✓

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*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	374.4
5	6480.0	777.6
6	10080.0	777.6

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	393.30	101.66
6	393.46	101.82
7	420.21	143.82
8	427.51	156.45

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.65	9.37	93341.
9	330.00	100.94	40.41	20.00	.65	9.37	101023.
10	350.00	101.17	43.53	20.00	.65	9.65	108830.
11	370.00	101.40	46.65	20.00	.65	9.37	116637.
12	386.65	101.58	49.22	13.30	.65	9.46	81835.
13	393.38	101.74	50.19	.16	45.00	9.46	1004.
14	401.73	114.80	38.52	16.54	57.51	9.46	79634.
15	415.11	135.81	19.41	10.21	57.51	5.71	24768.
16	423.86	150.14	5.95	7.30	59.97	5.71	5429.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.3601	1.6061	1.6500
3	7.4560	-----	1.6061
3	7.4081	1.6072	-----
4	7.4536	1.6082	1.6072
5	7.4525	1.6082	1.6082

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.4525	1.6082	1.6082

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta

1	1103.6	.0	30.00	0.	0.	0.	.00
2	1652.0	-124.8	9.83	0.	0.	0.	.00
3	2397.9	-124.8	9.83	0.	0.	0.	.00
4	3126.1	51.8	6.39	0.	0.	0.	.00
5	3522.7	51.8	6.39	0.	0.	0.	.00
6	3912.9	51.8	6.39	0.	0.	0.	.00
7	4309.5	51.8	6.39	0.	0.	0.	.00
8	4703.0	51.8	6.39	0.	0.	0.	.00
9	5089.8	51.8	6.39	0.	0.	0.	.00
10	5482.8	51.8	6.39	0.	0.	0.	.00
11	5875.8	51.8	6.39	0.	0.	0.	.00
12	6199.2	51.8	6.39	0.	0.	0.	.00
13	5242.6	51.8	6.39	0.	0.	0.	.00
14	2967.0	.0	25.00	0.	0.	0.	.00
15	1494.8	.0	25.00	0.	0.	0.	.00
16	413.1	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1103.6	739.6	.0	396.2
2	186.00	1652.0	1594.4	.0	100.5
3	204.50	2397.9	2304.8	.0	180.9
4	230.00	3126.1	3100.0	.0	249.9
5	250.00	3522.7	3493.8	.0	277.6
6	270.00	3912.9	3881.3	.0	304.7
7	290.00	4309.5	4275.0	.0	332.4
8	310.00	4703.0	4667.0	.0	359.8
9	330.00	5089.8	5051.1	.0	386.7
10	350.00	5482.8	5441.5	.0	414.1
11	370.00	5875.8	5831.8	.0	441.4
12	386.65	6199.2	6153.0	.0	464.0
13	393.38	5242.6	6273.7	.0	397.4
14	401.73	2967.0	4814.6	.0	860.3
15	415.11	1494.8	2425.7	.0	433.4
16	423.86	413.1	743.7	.0	148.3

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.45	16575.	5.63	11.83	.476
2	189.00	7.45	18588.	6.56	13.68	.480
3	220.00	7.45	34778.	9.96	23.20	.429
4	240.00	7.45	39189.	11.12	26.40	.421
5	260.00	7.45	44077.	12.17	29.50	.412
6	280.00	7.45	49435.	13.13	32.60	.403
7	300.00	7.45	55269.	14.04	35.80	.392

8	320.00	7.45	61448.	14.89	38.87	.383
9	340.00	7.45	68082.	15.71	41.95	.375
10	360.00	7.45	75178.	16.51	45.12	.366
11	380.00	7.45	82735.	17.28	48.19	.359
12	393.30	7.45	88014.	17.78	50.26	.354
13	393.46	7.45	87232.	17.80	50.12	.355
14	410.00	7.45	23875.	9.65	26.91	.359
15	420.21	7.45	4170.	5.84	11.90	.491
16	427.51	.00	0.	-12.32	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3525.57 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 381.52 (psf)

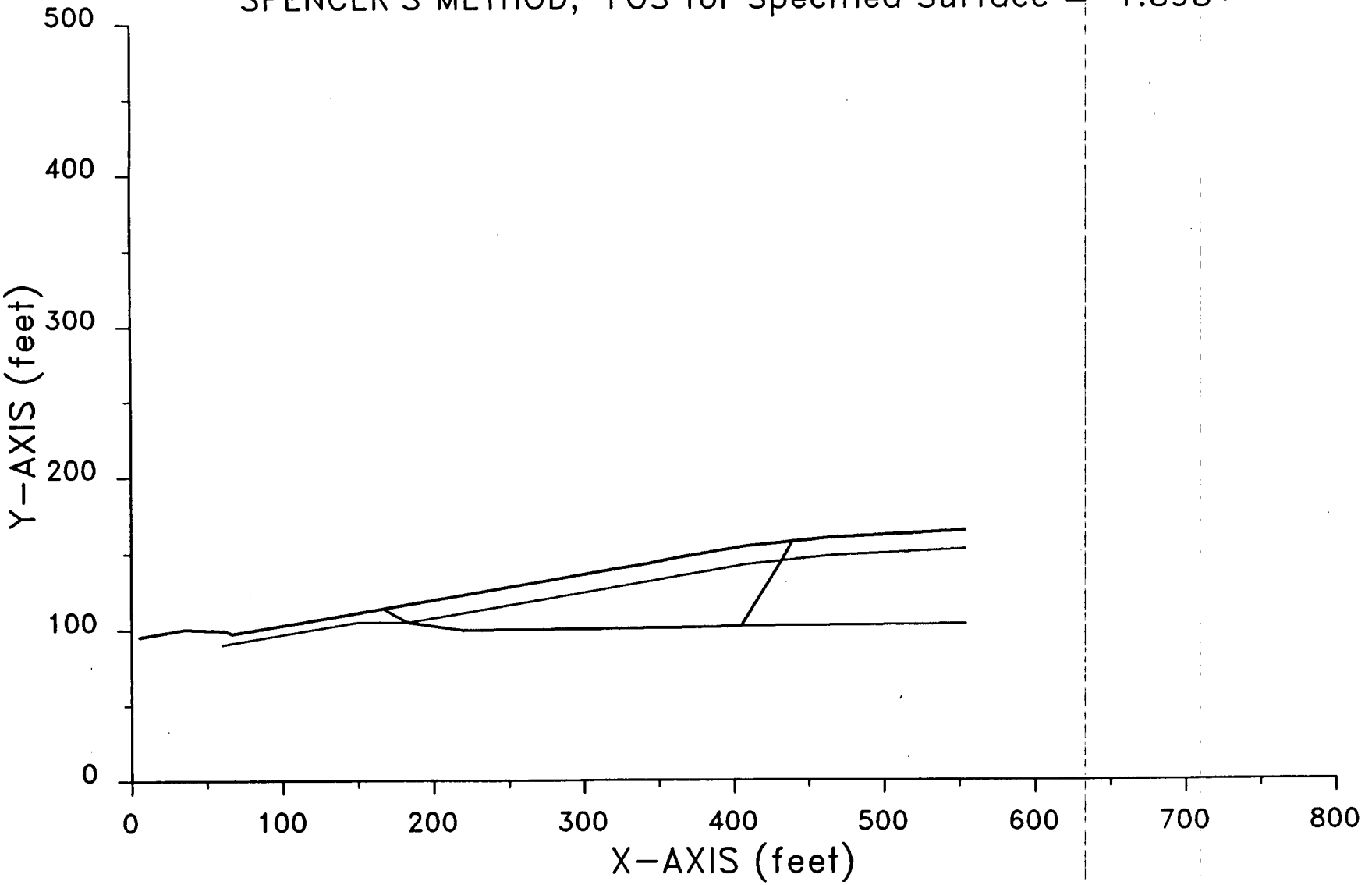
Total Length of failure surface = 293.65 feet

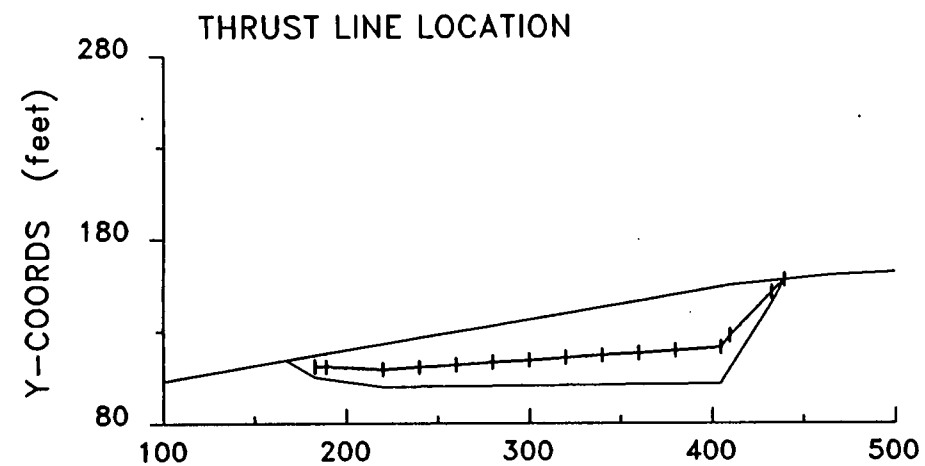
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

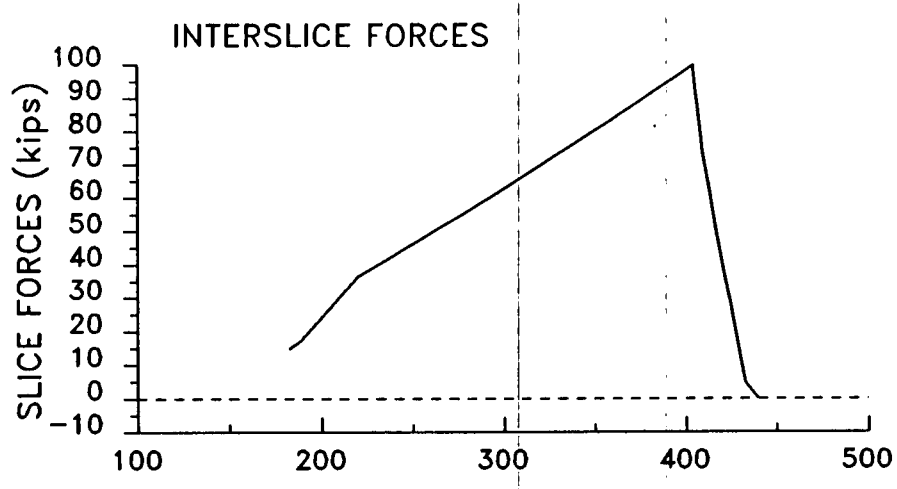
FACTOR OF SAFETY = 1.608 ✓

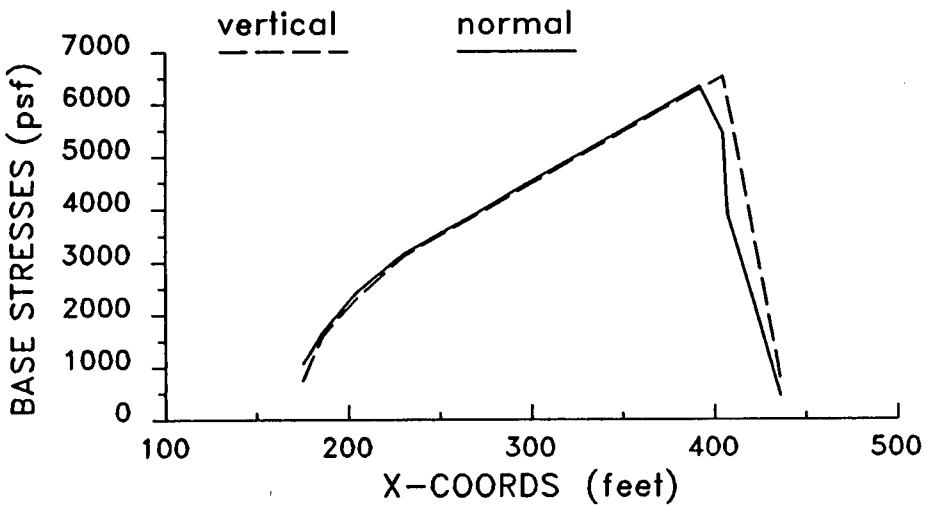
Total shear strength available along specified failure surface = 180.17E+03 lb

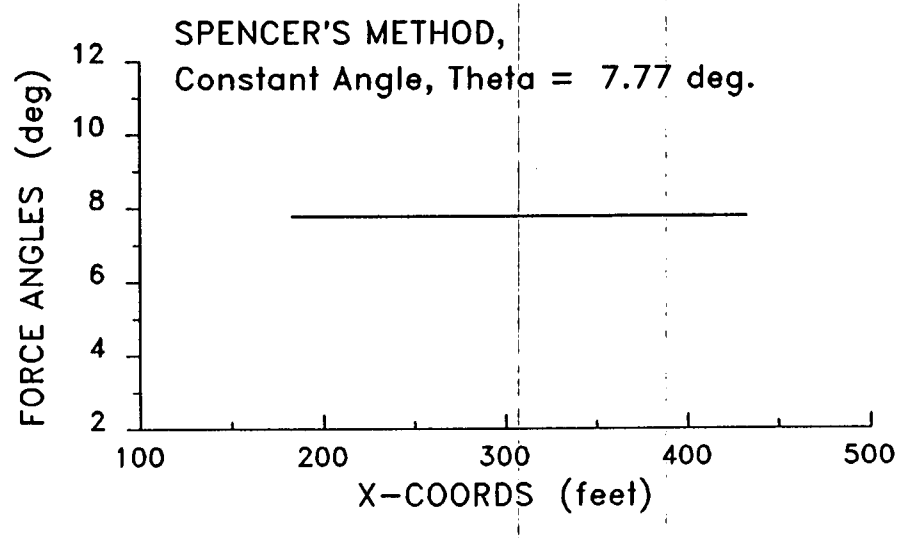
OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.898 ✓











OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.898 ✓

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```

Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	648.0
5	6480.0	820.8
6	10080.0	820.8

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	404.92	101.70
6	405.17	101.95
7	432.64	145.06
8	439.93	157.69

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.70	37.35	20.00	.60	9.37	93363.
9	330.00	100.91	40.44	20.00	.60	9.37	101089.
10	350.00	101.12	43.58	20.00	.60	9.65	108939.
11	370.00	101.33	46.72	20.00	.60	9.37	116790.
12	392.46	101.57	50.21	24.92	.60	9.46	156396.
13	405.05	101.82	52.05	.25	45.00	9.46	1627.
14	407.59	105.74	48.56	4.83	57.49	9.46	29317.
15	421.32	127.30	28.54	22.64	57.49	5.71	80764.
16	436.29	151.38	5.95	7.29	60.01	5.71	5420.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.7091	1.8964	1.9349
3	7.7694	1.8981	1.8964
4	7.7681	1.8981	1.8981

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.7681	1.8981	1.8981

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1050.5	.0	30.00	0.	0.	0.	.00

2	1667.8	-216.0	16.70	0.	0.	0.	.00
3	2426.0	-216.0	16.70	0.	0.	0.	.00
4	3139.7	509.8	2.75	0.	0.	0.	.00
5	3534.2	509.8	2.75	0.	0.	0.	.00
6	3922.4	509.8	2.75	0.	0.	0.	.00
7	4316.9	509.8	2.75	0.	0.	0.	.00
8	4710.2	509.8	2.75	0.	0.	0.	.00
9	5097.2	509.8	2.75	0.	0.	0.	.00
10	5490.4	509.8	2.75	0.	0.	0.	.00
11	5883.7	509.8	2.75	0.	0.	0.	.00
12	6320.8	509.8	2.75	0.	0.	0.	.00
13	5417.0	509.8	2.75	0.	0.	0.	.00
14	3875.6	.0	25.00	0.	0.	0.	.00
15	2277.5	.0	25.00	0.	0.	0.	.00
16	431.9	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1050.5	739.6	.0	319.5
2	186.00	1667.8	1594.4	.0	149.8
3	204.50	2426.0	2304.8	.0	269.6
4	230.00	3139.7	3100.0	.0	348.0
5	250.00	3534.2	3493.8	.0	357.9
6	270.00	3922.4	3881.3	.0	367.8
7	290.00	4316.9	4275.0	.0	377.7
8	310.00	4710.2	4668.1	.0	387.7
9	330.00	5097.2	5054.4	.0	397.5
10	350.00	5490.4	5447.0	.0	407.4
11	370.00	5883.7	5839.5	.0	417.4
12	392.46	6320.8	6275.9	.0	428.4
13	405.05	5417.0	6506.1	.0	405.6
14	407.59	3875.6	6069.7	.0	952.1
15	421.32	2277.5	3566.9	.0	559.5
16	436.29	431.9	743.7	.0	131.4

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.77	14864.	5.68	11.83	.480
2	189.00	7.77	17191.	6.46	13.68	.472
3	220.00	7.77	36294.	9.38	23.20	.404
4	240.00	7.77	42684.	10.32	26.40	.391
5	260.00	7.77	49196.	11.31	29.50	.383
6	280.00	7.77	55828.	12.35	32.60	.379
7	300.00	7.77	62581.	13.41	35.80	.374
8	320.00	7.77	69410.	14.48	38.89	.372
9	340.00	7.77	76354.	15.57	41.98	.371

10	360.00	7.77	83416.	16.66	45.17	.369
11	380.00	7.77	90595.	17.76	48.26	.368
12	404.92	7.77	99704.	19.13	52.15	.367
13	405.17	7.77	98439.	19.16	51.94	.369
14	410.00	7.77	73432.	17.59	45.17	.389
15	432.64	7.77	4538.	5.82	11.90	.489
16	439.93	.00	0.	-.28	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3664.04 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 395.54 (psf)

Total Length of failure surface = 306.71 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.898

Total shear strength available along specified failure surface = 230.26E+03 lb

GCL 13

COMPUTATION COVER SHEET

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 13 - Compliance Package

Computations By: (Cognizant Engineer)
Signature Robert A. Morgan III — Date 13 OCT 1997
Printed Name ROBERT A. MORGAN III
and Title SR. STAFF ENGINEER

Assumptions and Procedures Checked By: (Checker)
Signature [illegible] — Date 14 Oct 97
Printed Name Gary R. Schmertmann
and Title Sr. Project Engr.

Computations Checked by:
Signature [illegible] — Date 14 Oct 97
Printed Name Gary R. Schmertmann
and Title Sr. Project Engr.

Computations Backchecked by: (Cognizant Engineer)
Signature Robert A. Morgan III — Date 15 OCT 1997
Printed Name ROBERT A. MORGAN III
and Title SR STAFF ENGINEER

Approved by: (PDP)
Signature [illegible] — Date 15 Oct 97
Printed Name Gary R. Schmertmann
and Title Sr. Project Engr.

Approved by: (DTL and TETL)
Signature [illegible] — Date 15 Oct 97
Printed Name Kenneth W Cargill
and Title

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

Written By: RAM Date: 10 / 13 / 97 Reviewed by: GRS Date: 10 / 14 / 97

Client: FDF Project: OSDF Project/Proposal No.: GQ 0166 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 13 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 13 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample No.	Case	Test Type	Measured Shear Strengths		
			5 psi	20 psi	45 psi
13	Peak	GCL Internal	6.1 psi	10.8 psi	17.2 psi
		GCL/GMB Interface	2.4	9.7	13.2
13	Large-displacement	GCL Internal	3.3	3.0	5.4
		GCL/GMB Interface	1.6	2.6	6.2

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix B.

QA Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
13	GCL Internal	NPK13AS	2.5	YES
	GCL/GMB Interface	NPK13BS	2.1	YES
Baseline	Large-displacement	NA	1.6	NA
13	GCL Internal	NLD13AS	1.7	YES
	GCL/GMB Interface	NLD13BS	1.7	YES

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GRS 10/14/97

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 13I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-13). GCL's initial moisture content was 8.3%. GCL's final moisture content ranged from 65% to 90% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 13G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

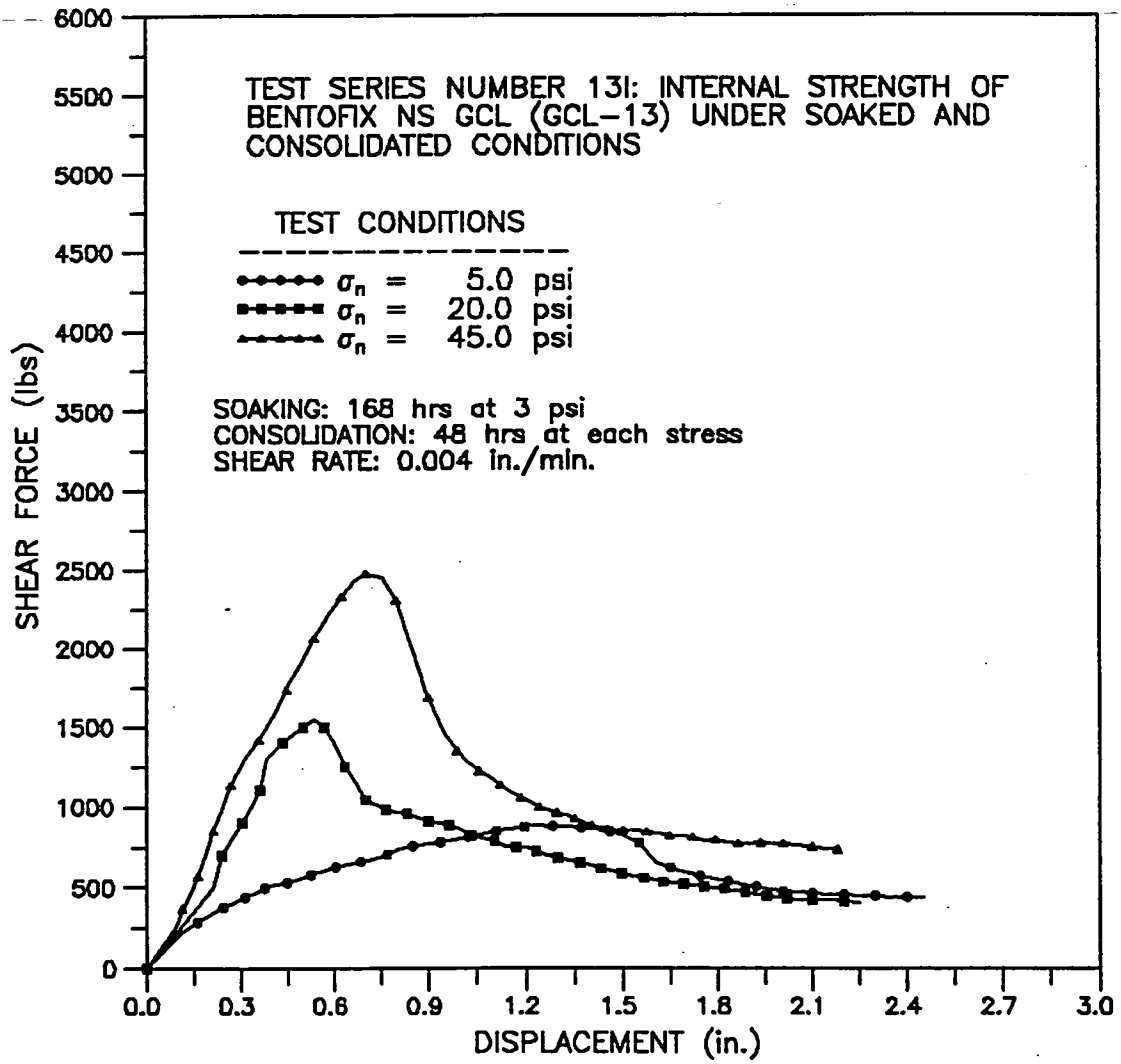
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-13) with woven geotextile against geomembrane. GCL's initial moisture content was 8.6%. GCL's final moisture content ranged from 79 to 97% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-14); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.

(2) For each test, sliding (i.e., internal shear failure) was observed to occur within the GCL.

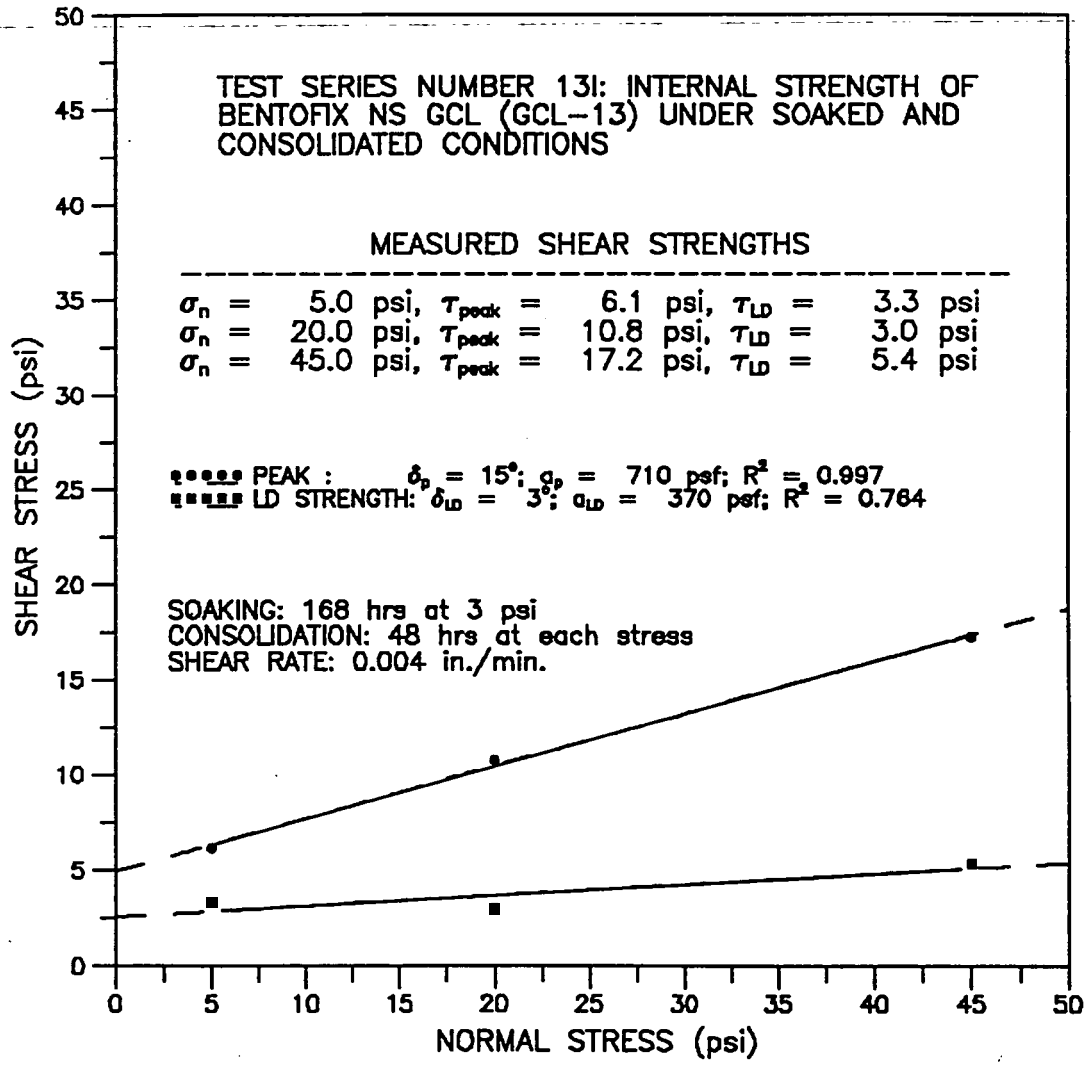
DATE TESTED: 20 TO 29 SEPTEMBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730090
FILE NO.	000306

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



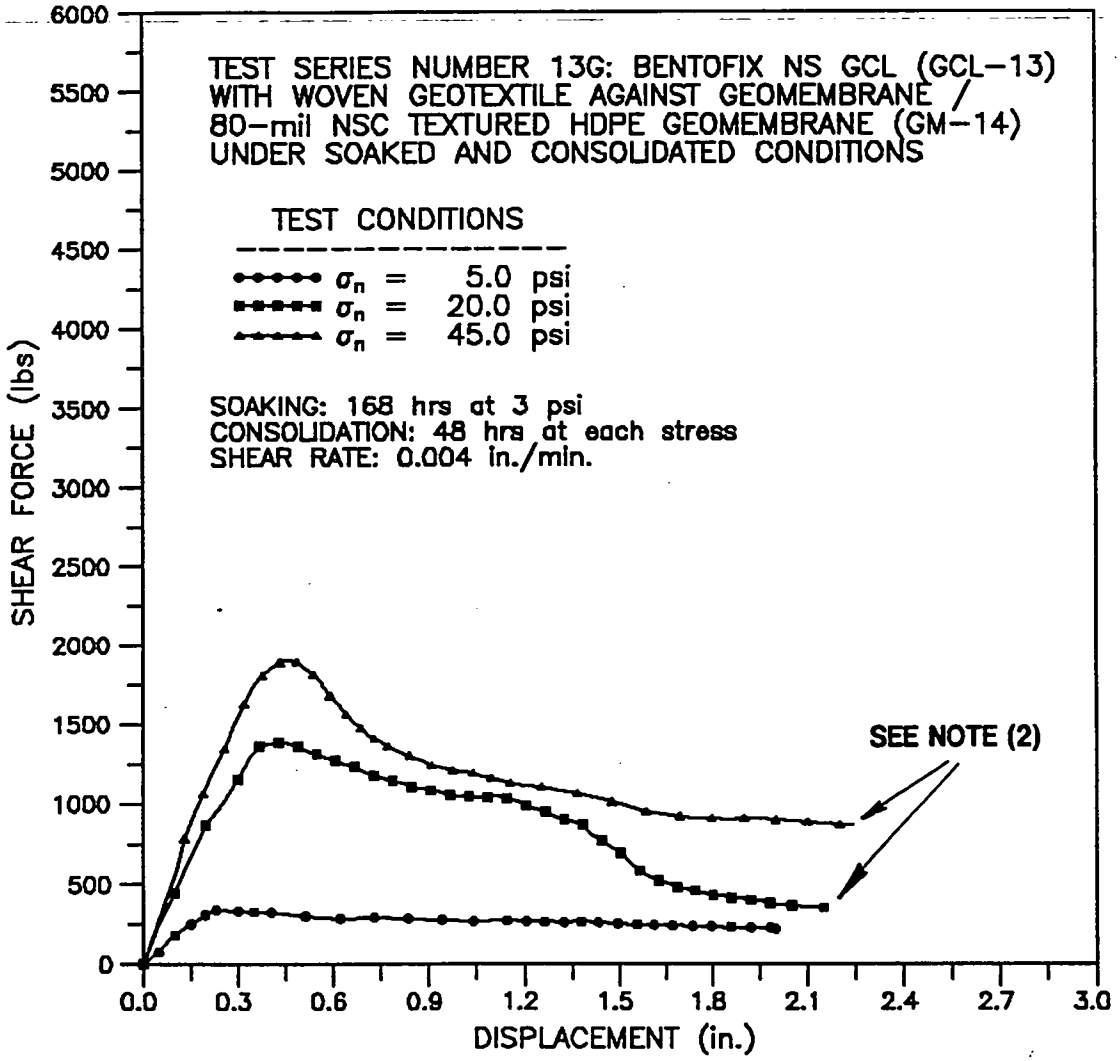
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) For each test, sliding (i.e, internal shear failure) was observed to occur within the GCL.

DATE TESTED: 27 AUGUST TO 5 SEPTEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730090
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

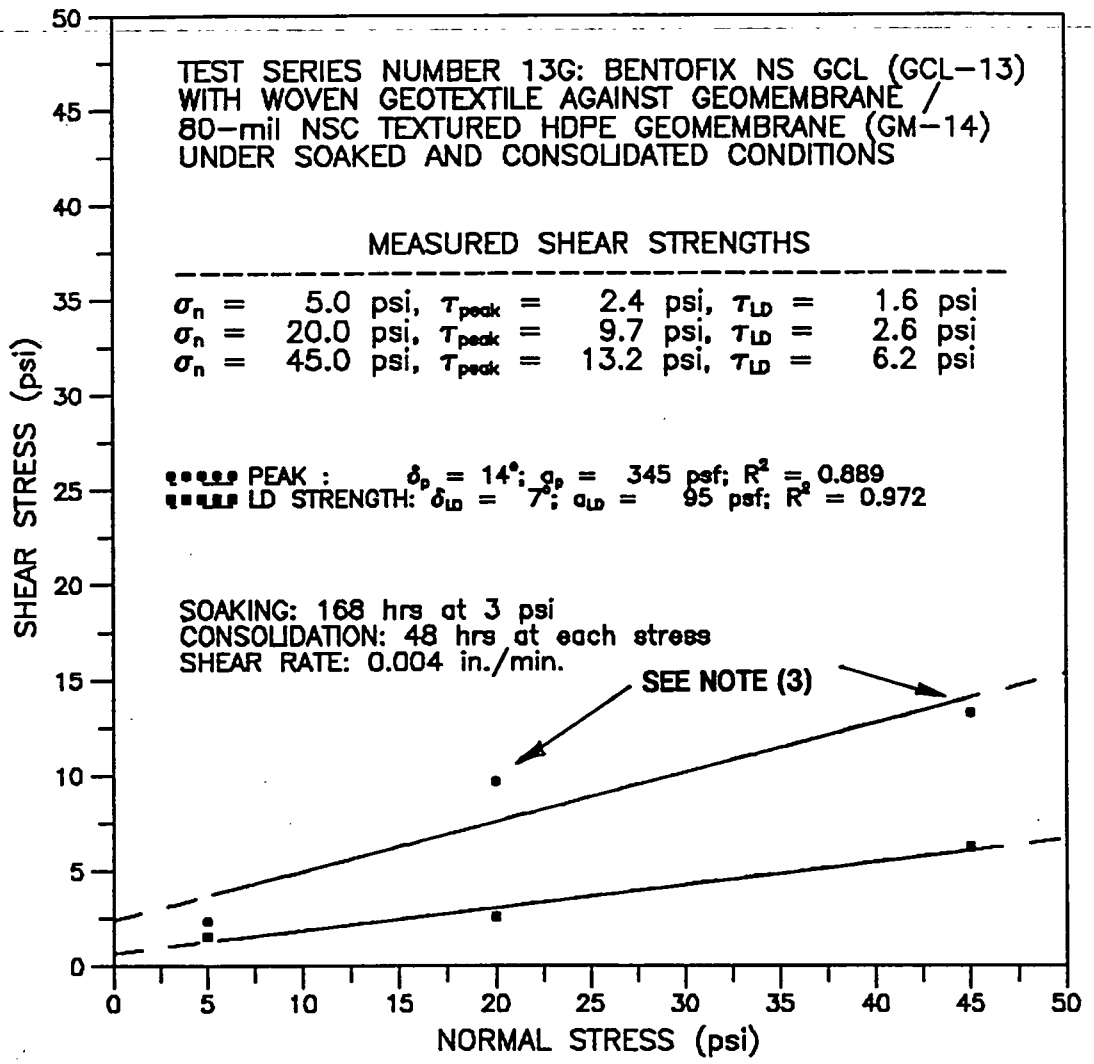
(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 22 SEPTEMBER TO 1 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730090
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 22 SEPTEMBER TO 1 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730090
FILE NO.	

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APPENDIX B

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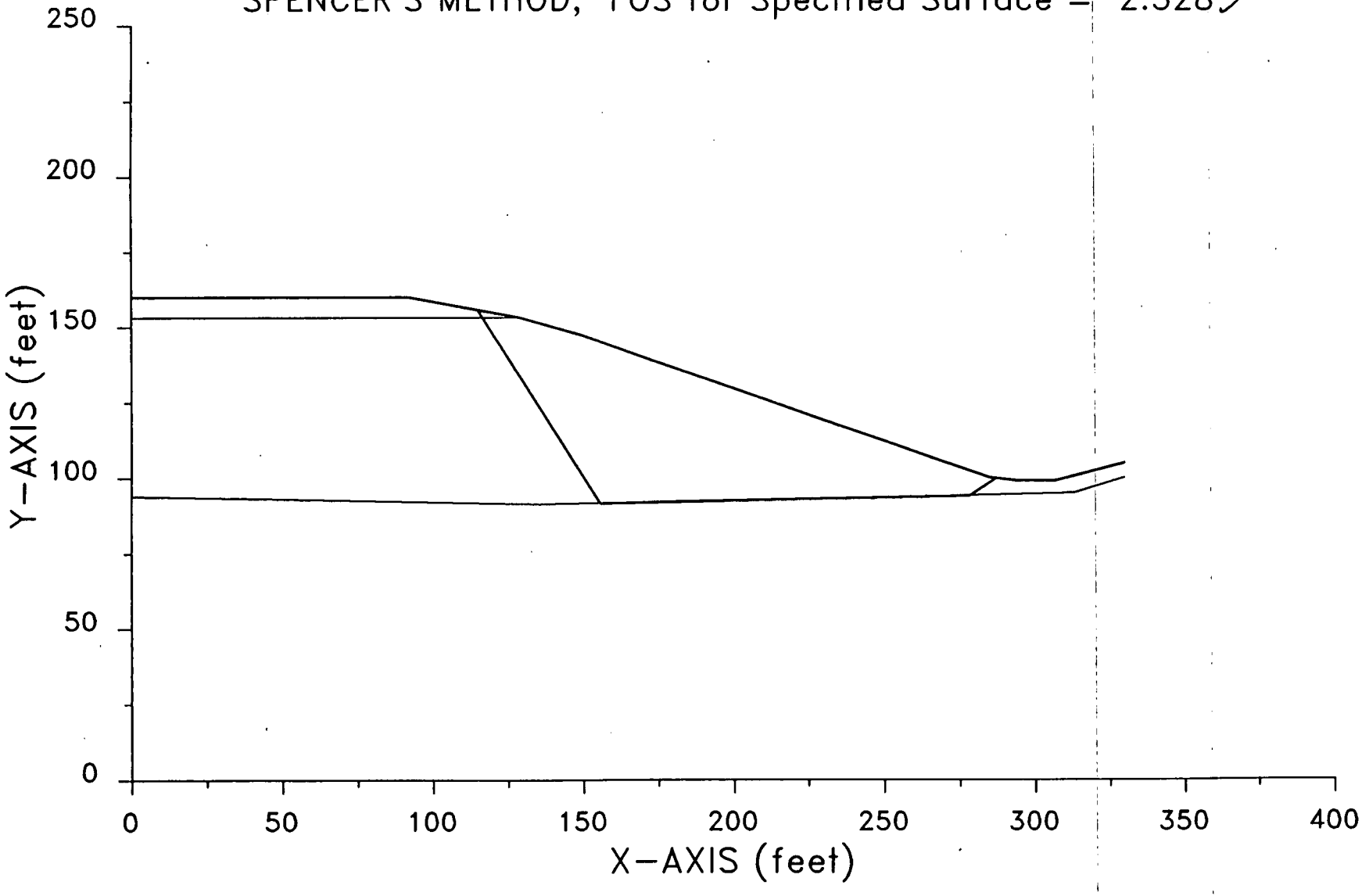
OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.528



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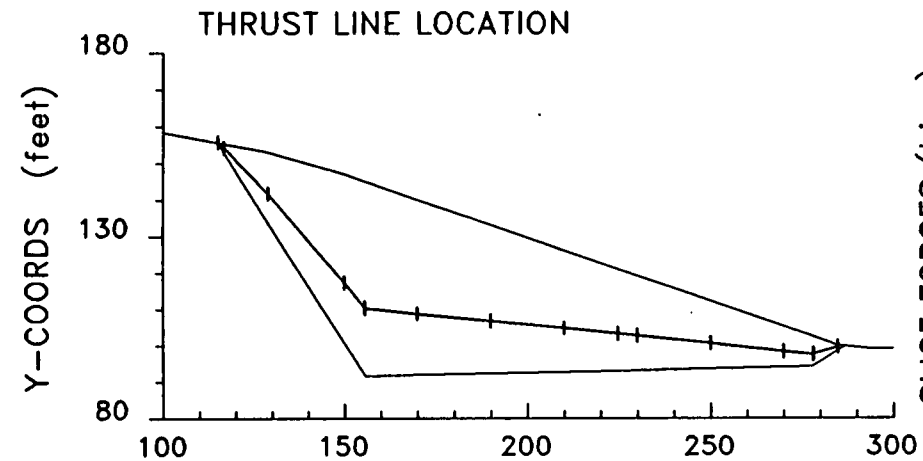

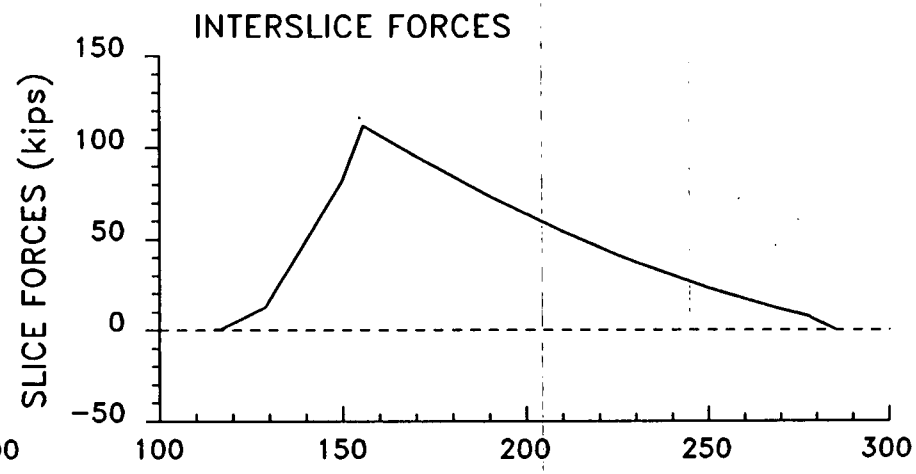

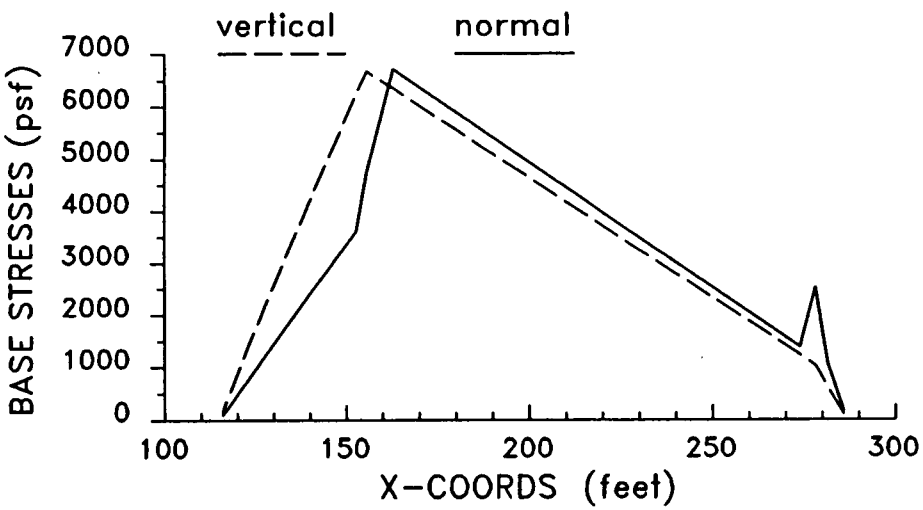

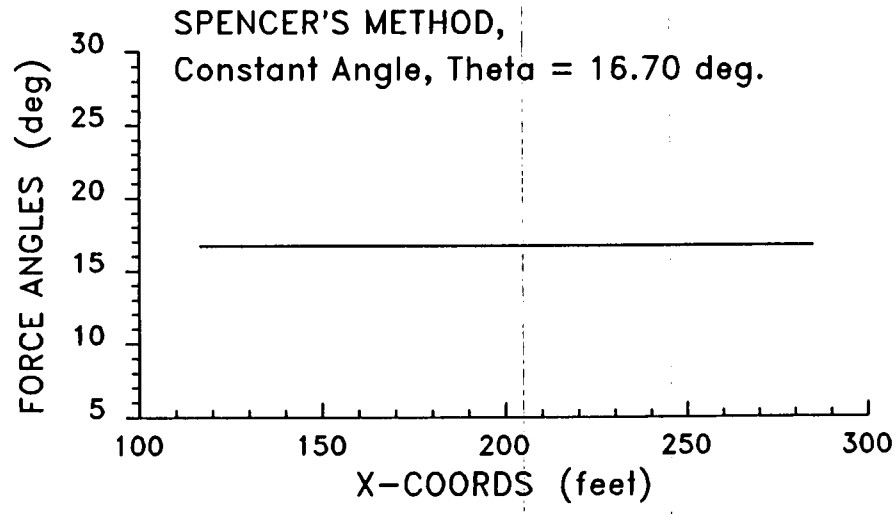

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.528 ✓

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XSTABL File: NPK13AS 10-09-97 17:21

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.201                 96 á 1202 *
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```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	878.4
4	2880.0	1555.2
5	6480.0	2476.8
6	36000.0	2476.8

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	287.00	99.78
2	278.35	94.27
3	278.14	94.06
4	224.80	93.00
5	155.88	91.57
6	155.65	91.79
7	116.66	153.00
8	115.15	155.62

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	286.00	99.14	.75	2.00	-32.49	6.34	187.
2	281.67	96.39	4.77	6.65	-32.49	19.12	3964.
3	278.24	94.16	8.18	.21	-45.00	19.12	212.
4	274.07	93.98	9.81	8.14	-1.14	19.12	9982.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37501.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55870.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.19	19.29	56728.
9	200.00	92.49	37.11	20.00	-1.19	19.29	92786.
10	180.00	92.07	44.48	20.00	-1.19	19.03	111199.
11	162.94	91.72	50.75	14.12	-1.19	19.29	89582.
12	155.76	91.68	53.30	.23	43.73	19.29	1534.
13	152.82	96.23	49.79	5.65	57.50	19.29	35160.
14	139.50	117.14	32.86	21.00	57.50	15.95	86248.
15	122.83	143.31	10.85	12.34	57.50	10.71	16742.
16	115.90	154.31	1.17	1.51	60.05	10.71	220.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.1696	2.5645	2.6663
3	16.3875	-----	2.5645
3	16.2786	2.5700	-----
4	16.3770	2.5751	2.5700
5	16.3721	2.5748	2.5751

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.6784	2.5320	2.5202
3	16.6740	2.5319	2.5320

Nonlinear M-C Iteration Number - 3

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.7031	2.5285	2.5274
3	16.7027	2.5285	2.5285

Nonlinear M-C Iteration Number - 4

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.7027	2.5284	2.5285

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.7027	2.5284	2.5285

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	157.1	.0	30.00	0.	0.	0.	.00
2	1053.1	200.0	25.00	0.	0.	0.	.00
3	2520.4	652.8✓	17.40✓	0.	0.	0.	.00
4	1371.4	652.8	17.40	0.	0.	0.	.00
5	2051.2	652.8	17.40	0.	0.	0.	.00
6	3012.5	817.9✓	14.36✓	0.	0.	0.	.00
7	3611.8	817.9	14.36	0.	0.	0.	.00
8	4095.2	817.9	14.36	0.	0.	0.	.00
9	4934.1	817.9	14.36	0.	0.	0.	.00
10	5891.8	817.9	14.36	0.	0.	0.	.00
11	6700.3	2476.8✓	.00✓	0.	0.	0.	.00
12	4765.8	817.9✓	14.36✓	0.	0.	0.	.00
13	3590.5	200.0	25.00	0.	0.	0.	.00
14	2349.5	200.0	25.00	0.	0.	0.	.00
15	736.7	200.0	25.00	0.	0.	0.	.00
16	79.0	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf) ✓	Shear Stress (psf)
1	286.00	157.1	93.5	.0	35.9
2	281.67	1053.1	595.8	.0	273.3
3	278.24	2520.4	1022.3	.0	570.5
4	274.07	1371.4	1226.2	.0	428.1
5	260.00	2051.2	1875.1	.0	512.4

6	240.00	3012.5	2793.5	.0	628.5
7	227.40	3611.8	3369.8	.0	689.2
8	217.40	4095.2	3832.9	.0	738.1
9	200.00	4934.1	4639.3	.0	823.1
10	180.00	5891.8	5559.9	.0	920.0
11	162.94	6700.3	6344.3	.0	979.6
12	155.76	4765.8	6662.8	.0	806.0
13	152.82	3590.5	6223.3	.0	741.3
14	139.50	2349.5	4107.0	.0	512.4
15	122.83	736.7	1356.7	.0	215.0
16	115.90	79.0	145.9	.0	18.0

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	16.70	284.	.94	1.50	.626
2	278.35	16.70	6840.	3.28	8.04	.409
3	278.14	16.70	7509.	3.25	8.32	.390
4	270.00	16.70	11379.	4.30	11.30	.381
5	250.00	16.70	22929.	6.92	18.70	.370
6	230.00	16.70	37304.	9.42	26.00	.362
7	224.80	16.70	41435.	10.06	27.92	.360
8	210.00	16.70	54154.	11.89	33.41	.356
9	190.00	16.70	73478.	14.34	40.82	.351
10	170.00	16.70	95242.	16.74	48.14	.348
11	155.88	16.70	111733.	18.47	53.37	.346
12	155.65	16.70	110831.	18.47	53.23	.347
13	150.00	16.70	81954.	16.54	46.34	.357
14	129.00	16.70	12318.	7.97	19.37	.411
15	116.66	16.70	187.	1.08	2.33	.464
16	115.15	.00	0.	-.07	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3165.26 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 598.83 (psf)

Total Length of failure surface = 208.75 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.528 ✓

Total shear strength available along specified failure surface = 316.07E+03 lb

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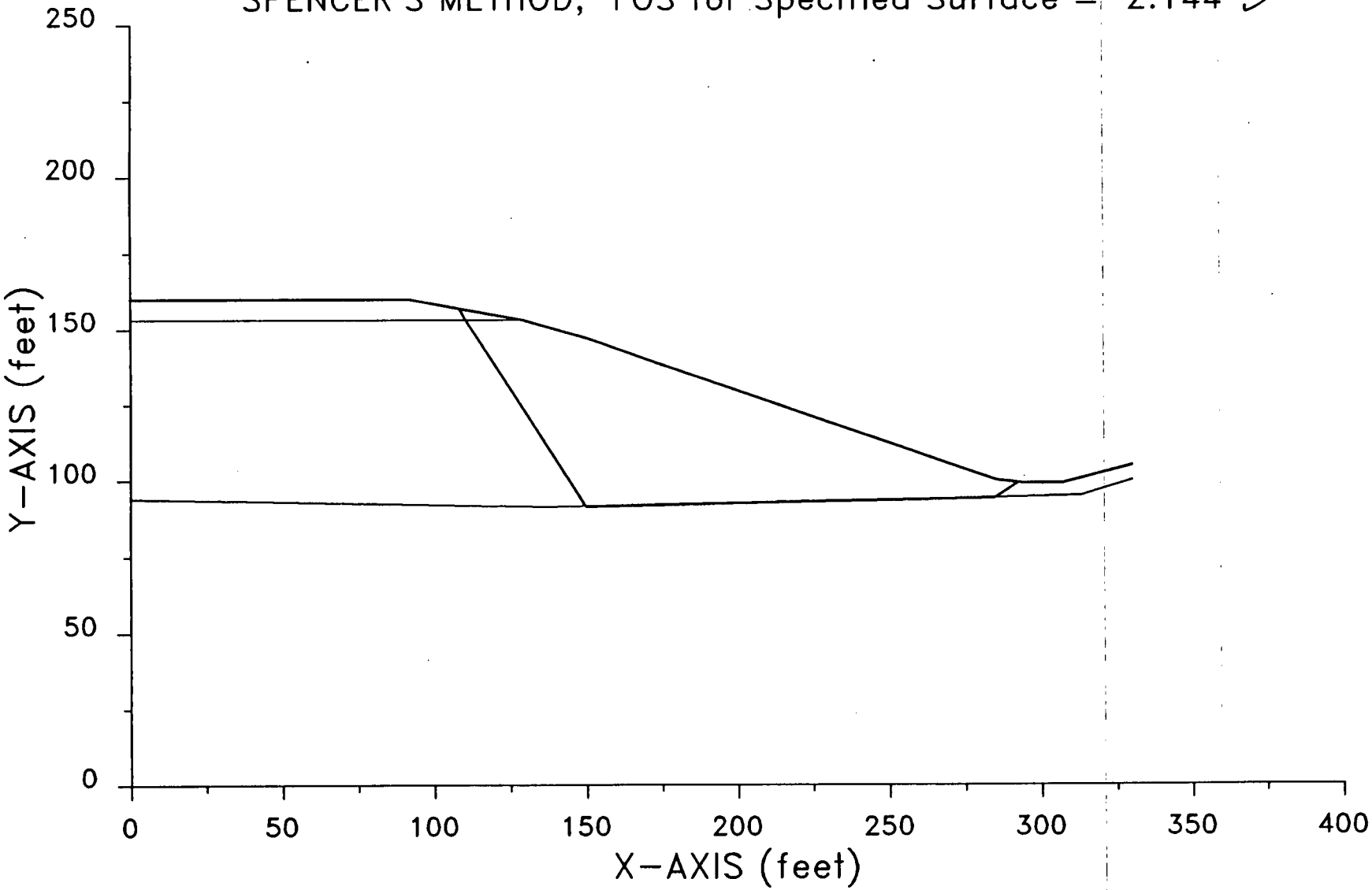
OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.144



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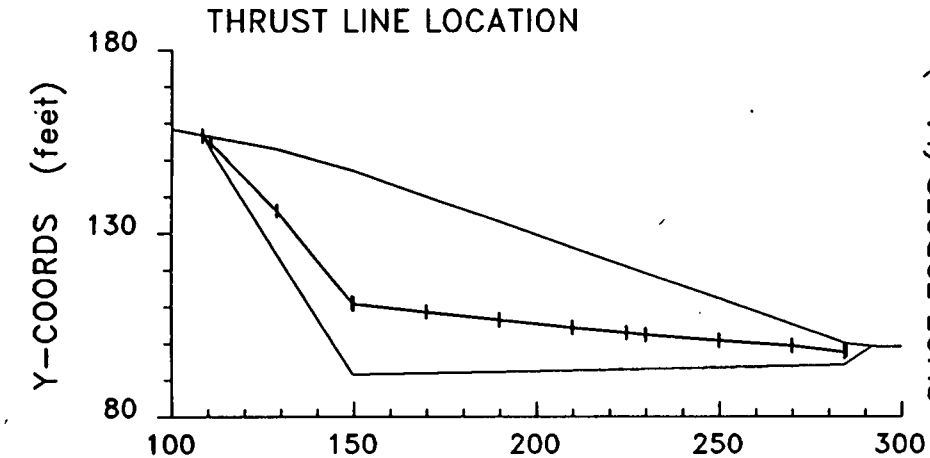

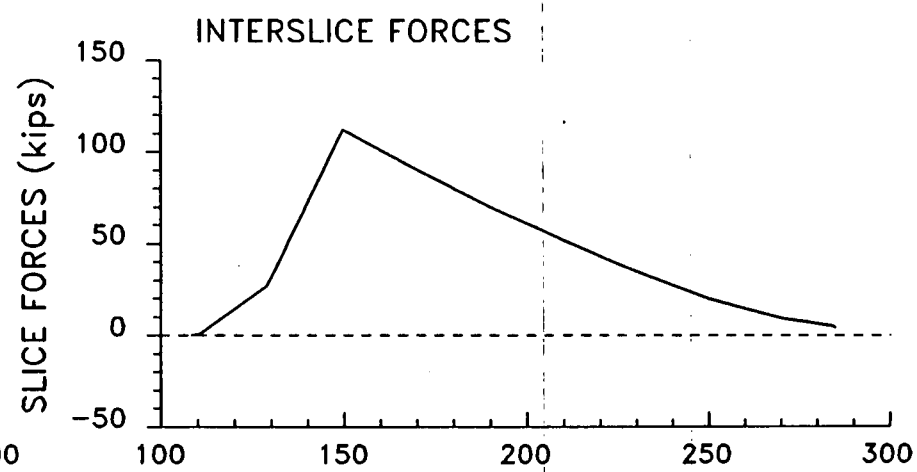

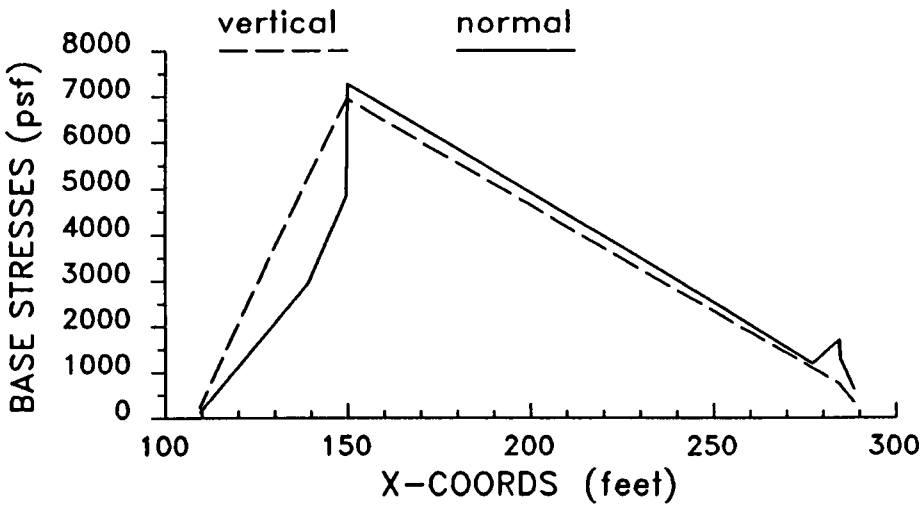

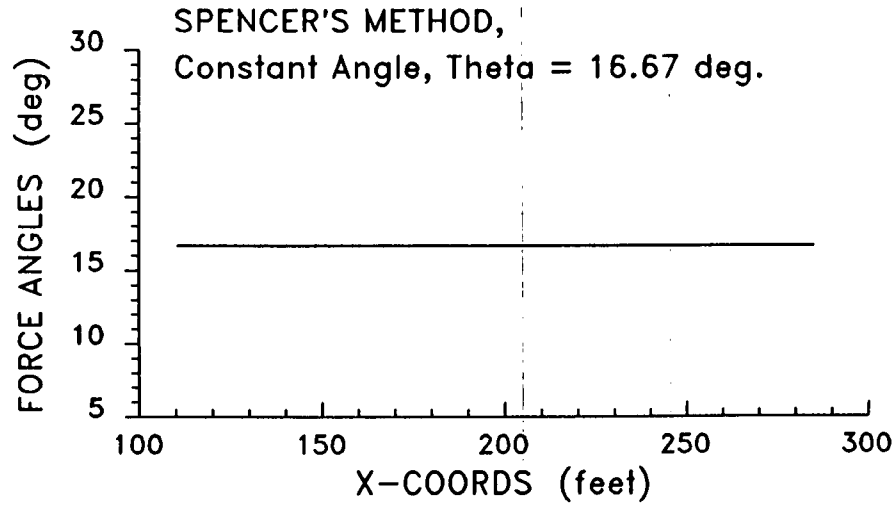

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.144

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*              X S T A B L              *
*                                       *
*       Slope Stability Analysis        *
*              using the                *
*           Method of Slices            *
*                                       *
*        Copyright (C) 1992 á 96        *
*   Interactive Software Designs, Inc.  *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	345.6
4	2880.0	1396.8
5	6480.0	1900.8
6	10080.0	1900.8

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	292.24	99.20
2	284.70	94.39
3	284.49	94.19
4	224.80	93.00
5	149.87	91.47
6	149.68	91.67
7	110.61	153.00
8	108.35	156.91

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.62	96.89	2.71	7.24	-32.51	6.34	2452.
2	284.85	94.49	5.57	.30	-32.51	19.12	209.
3	284.60	94.29	5.85	.21	-43.60	19.12	154.
4	277.24	94.05	8.64	14.49	-1.14	19.12	15654.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37496.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55867.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.17	19.29	56723.
9	200.00	92.49	37.11	20.00	-1.17	19.29	92766.
10	180.00	92.09	44.46	20.00	-1.17	19.03	111162.
11	160.00	91.68	51.82	20.00	-1.17	19.29	129558.
12	149.93	91.47	55.55	.13	-1.17	15.95	903.
13	149.77	91.57	55.49	.19	46.47	15.95	1318.
14	139.34	107.90	42.14	20.68	57.50	15.95	108944.
15	119.80	138.57	16.17	18.39	57.50	10.71	37179.
16	109.48	154.95	1.74	2.26	59.95	10.71	491.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.6698	2.1576	2.1809
3	16.6806	2.1579	2.1576

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.6738	2.1436	2.1438

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.6738	2.1436	2.1438

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	608.3	.0	30.00	0.	0.	0.	.00
2	1293.9	200.0	25.00	0.	0.	0.	.00
3	1691.9	-4.8	25.95	0.	0.	0.	.00
4	1171.6	-4.8	25.95	0.	0.	0.	.00
5	2033.7	-4.8	25.95	0.	0.	0.	.00
6	3022.6	993.6	7.97	0.	0.	0.	.00
7	3614.8	993.6	7.97	0.	0.	0.	.00
8	4091.4	993.6	7.97	0.	0.	0.	.00
9	4919.5	993.6	7.97	0.	0.	0.	.00
10	5864.8	993.6	7.97	0.	0.	0.	.00
11	6803.2	1900.8	.00	0.	0.	0.	.00
12	7271.6	1900.8	.00	0.	0.	0.	.00
13	4828.1	993.6	7.97	0.	0.	0.	.00
14	2948.5	200.0	25.00	0.	0.	0.	.00
15	1089.7	200.0	25.00	0.	0.	0.	.00
16	114.3	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.62	608.3	338.7	.0	163.8
2	284.85	1293.9	695.8	.0	374.8
3	284.60	1691.9	731.3	.0	381.9
4	277.24	1171.6	1080.4	.0	263.8
5	260.00	2033.7	1874.8	.0	459.5
6	240.00	3022.6	2793.4	.0	660.9
7	227.40	3614.8	3369.8	.0	699.6
8	217.40	4091.4	3832.6	.0	730.7
9	200.00	4919.5	4638.3	.0	784.8
10	180.00	5864.8	5558.1	.0	846.6
11	160.00	6803.2	6477.9	.0	886.7
12	149.93	7271.6	6943.4	.0	886.7
13	149.77	4828.1	6936.8	.0	778.8
14	139.34	2948.5	5268.1	.0	734.7
15	119.80	1089.7	2021.7	.0	330.4
16	109.48	114.3	217.4	.0	30.8

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	16.67	4168.	3.39	5.42	.626
2	284.70	16.67	4544.	3.38	5.71	.592
3	284.49	16.67	4981.	3.34	5.99	.557
4	270.00	16.67	9324.	5.33	11.30	.472
5	250.00	16.67	19763.	7.22	18.70	.386
6	230.00	16.67	34820.	9.10	26.00	.350

7	224.80	16.67	39009.	9.70	27.92	.347
8	210.00	16.67	51589.	11.49	33.40	.344
9	190.00	16.67	70071.	14.02	40.81	.343
10	170.00	16.67	90246.	16.57	48.12	.344
11	150.00	16.67	111659.	19.17	55.53	.345
12	149.87	16.67	111799.	19.19	55.57	.345
13	149.68	16.67	110946.	19.20	55.42	.346
14	129.00	16.67	26889.	11.87	28.87	.411
15	110.61	16.67	393.	1.62	3.48	.464
16	108.35	.00	-1.	-.40	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3202.87 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 599.72 (psf)

Total Length of failure surface = 221.39 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.144

Total shear strength available along specified failure surface = 284.60E+03 lb

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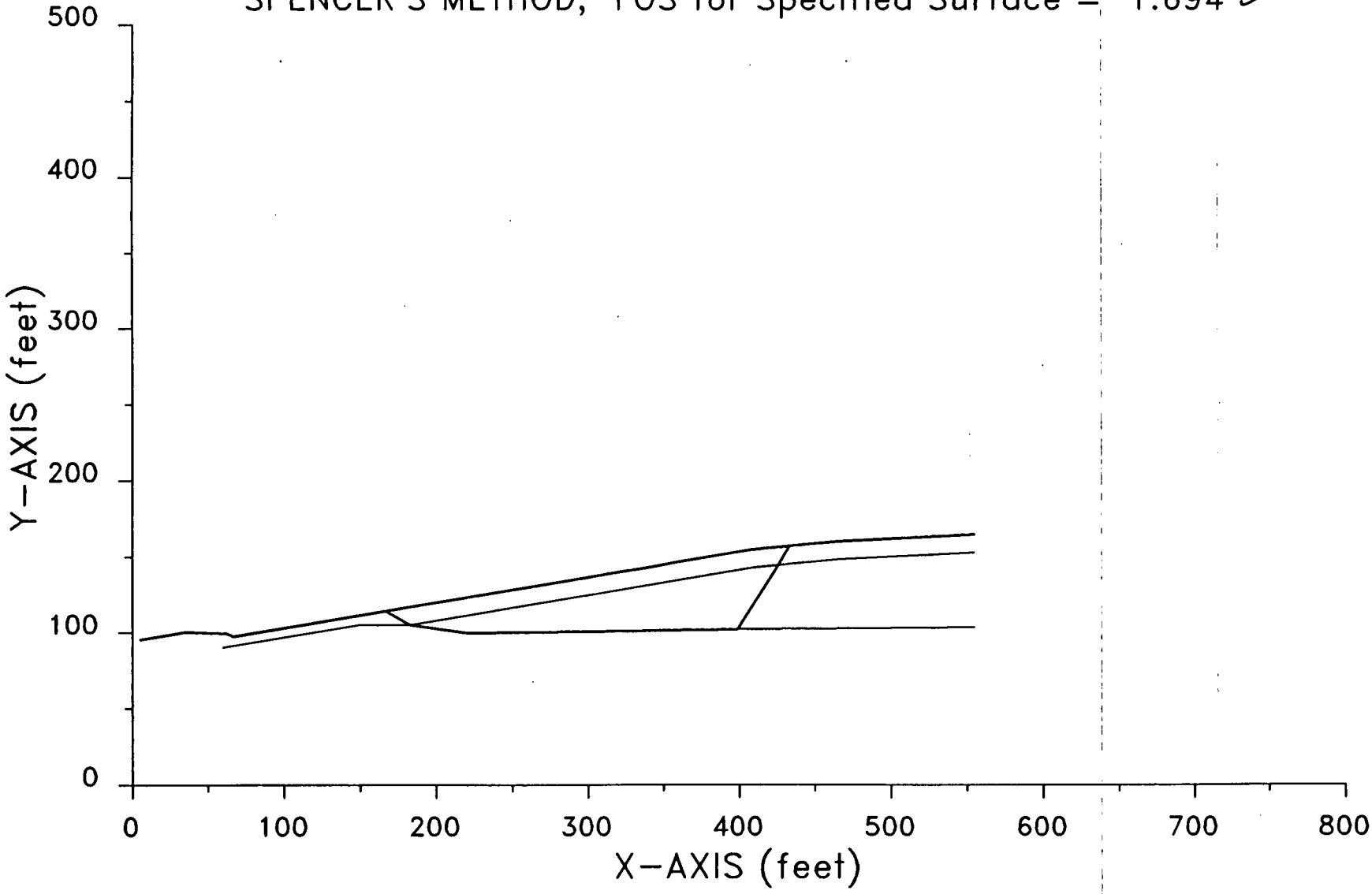
OSDF Final Long Term – Large Displ.

SPENCER'S METHOD, FOS for Specified Surface = 1.694



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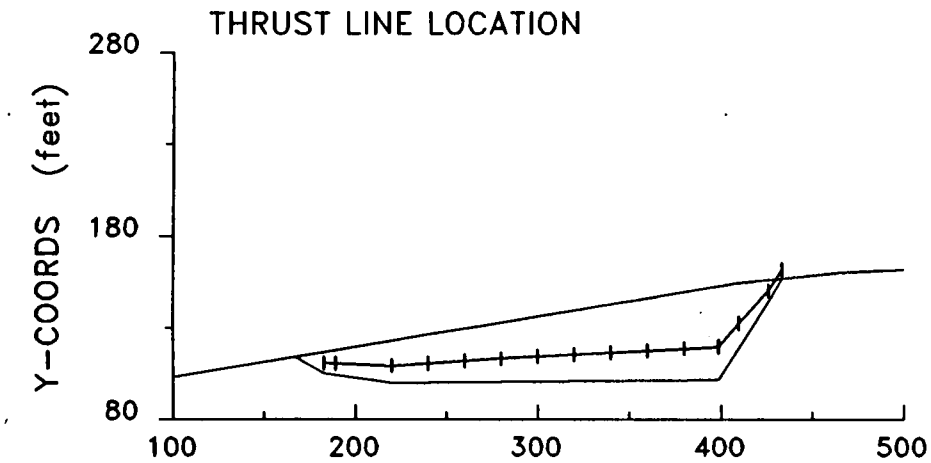

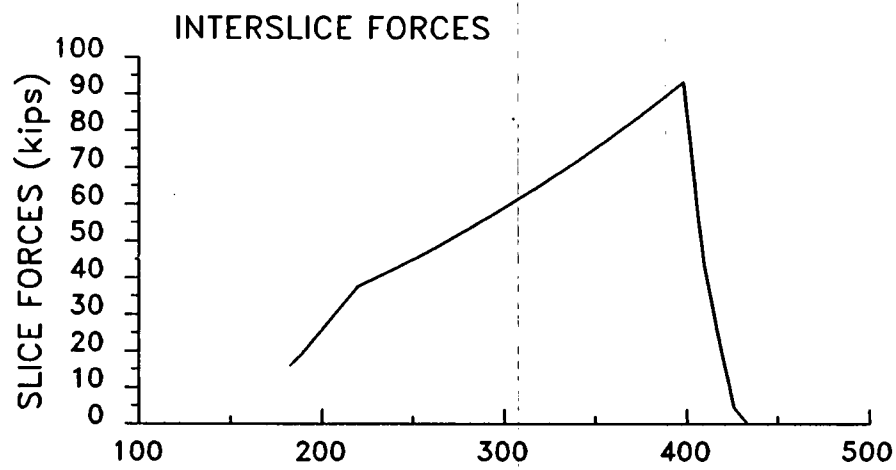

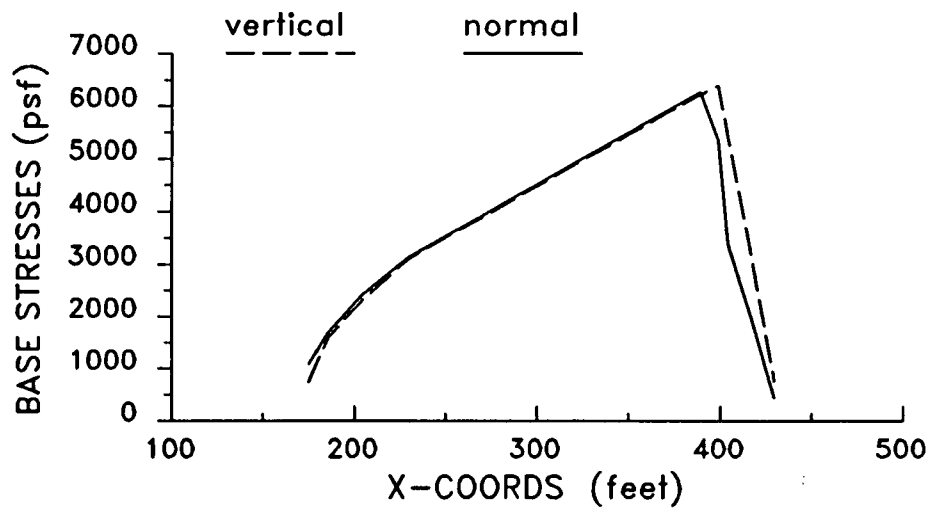

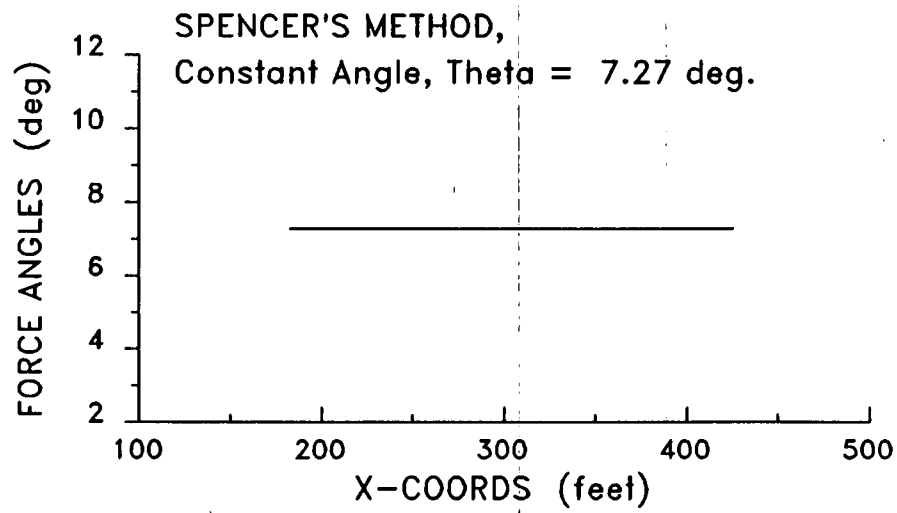

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.694

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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0 ✓	.0 ✓
2	.0 ✓	.0 ✓
3	720.0 ✓	432.0 ✓
4	2880.0 ✓	432.0 ✓
5	6480.0 ✓	777.6
6	10080.0 ✓	777.6

Value less than actual test value of 3.3 psi = 475 psf because envelope must be defined with continually increasing strengths. This is conservative. ✓

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

RAM 10/14/97

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	398.78	101.64
6	399.02	101.88
7	426.12	144.41
8	433.41	157.04

✓

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.60	9.37	93362.
9	330.00	100.92	40.43	20.00	.60	9.37	101085.
10	350.00	101.13	43.57	20.00	.60	9.65	108934.
11	370.00	101.34	46.71	20.00	.60	9.37	116782.
12	389.39	101.54	49.72	18.78	.60	9.46	116727.
13	398.90	101.76	51.09	.24	45.00	9.46	1534.
14	404.51	110.50	43.29	10.98	57.49	9.46	59413.
15	418.06	131.76	23.74	16.12	57.49	5.71	47849.
16	429.77	150.73	5.95	7.29	60.01	5.71	5421.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.1901	1.6923	1.7400
3	7.2757	-----	1.6923
3	7.2329	1.6933	-----
4	7.2738	1.6943	1.6933

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.2738	1.6943	1.6933

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta

1	1078.2	.0	30.00	0.	0.	0.	.00
2	1693.1	432.0	.00	0.	0.	0.	.00
3	2416.5	432.0	.00	0.	0.	0.	.00
4	3127.7	155.5	5.48	0.	0.	0.	.00
5	3523.5	155.5	5.48	0.	0.	0.	.00
6	3913.1	155.5	5.48	0.	0.	0.	.00
7	4309.0	155.5	5.48	0.	0.	0.	.00
8	4703.7	155.5	5.48	0.	0.	0.	.00
9	5092.0	155.5	5.48	0.	0.	0.	.00
10	5486.5	155.5	5.48	0.	0.	0.	.00
11	5881.0	155.5	5.48	0.	0.	0.	.00
12	6259.4	155.5	5.48	0.	0.	0.	.00
13	5357.5	155.5	5.48	0.	0.	0.	.00
14	3388.1	.0	25.00	0.	0.	0.	.00
15	1858.4	.0	25.00	0.	0.	0.	.00
16	420.6	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1078.2	739.6	.0	367.4
2	186.00	1693.1	1594.4	.0	255.0
3	204.50	2416.5	2304.8	.0	255.0
4	230.00	3127.7	3100.0	.0	269.0
5	250.00	3523.5	3493.8	.0	291.4
6	270.00	3913.1	3881.3	.0	313.5
7	290.00	4309.0	4275.0	.0	335.9
8	310.00	4703.7	4668.1	.0	358.3
9	330.00	5092.0	5054.3	.0	380.3
10	350.00	5486.5	5446.7	.0	402.7
11	370.00	5881.0	5839.1	.0	425.0
12	389.39	6259.4	6215.5	.0	446.5
13	398.90	5357.5	6386.2	.0	395.4
14	404.51	3388.1	5411.1	.0	932.5
15	418.06	1858.4	2968.0	.0	511.5
16	429.77	420.6	743.7	.0	143.3

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.27	15871.	5.61	11.83	.474
2	189.00	7.27	18852.	6.20	13.68	.453
3	220.00	7.27	37434.	9.37	23.20	.404
4	240.00	7.27	42227.	10.53	26.40	.399
5	260.00	7.27	47393.	11.60	29.50	.393
6	280.00	7.27	52925.	12.62	32.60	.387
7	300.00	7.27	58830.	13.59	35.80	.380
8	320.00	7.27	65056.	14.52	38.89	.373

9	340.00	7.27	71643.	15.41	41.98	.367
10	360.00	7.27	78597.	16.29	45.17	.361
11	380.00	7.27	85918.	17.14	48.26	.355
12	398.78	7.27	93123.	17.93	51.19	.350
13	399.02	7.27	91922.	17.95	50.99	.352
14	410.00	7.27	43388.	13.35	35.59	.375
15	426.12	7.27	4302.	5.85	11.90	.492
16	433.41	.00	0.	4.54	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3591.45 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 389.53 (psf)

Total Length of failure surface = 299.87 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.694

Total shear strength available along specified failure surface = 197.90E+03 lb

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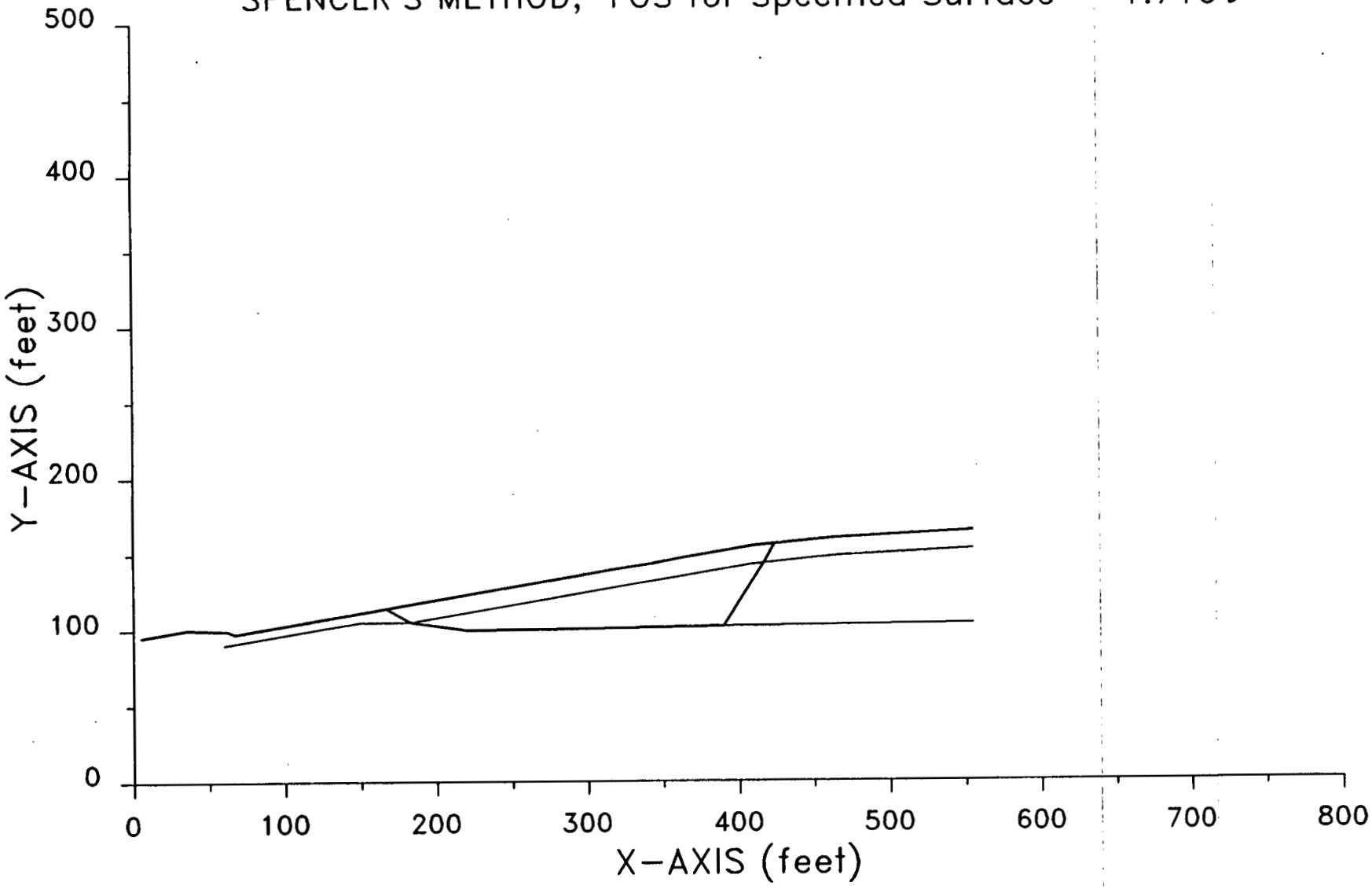
OSDF Final Long Term – Large Displ.

SPENCER'S METHOD, FOS for Specified Surface = 1.716



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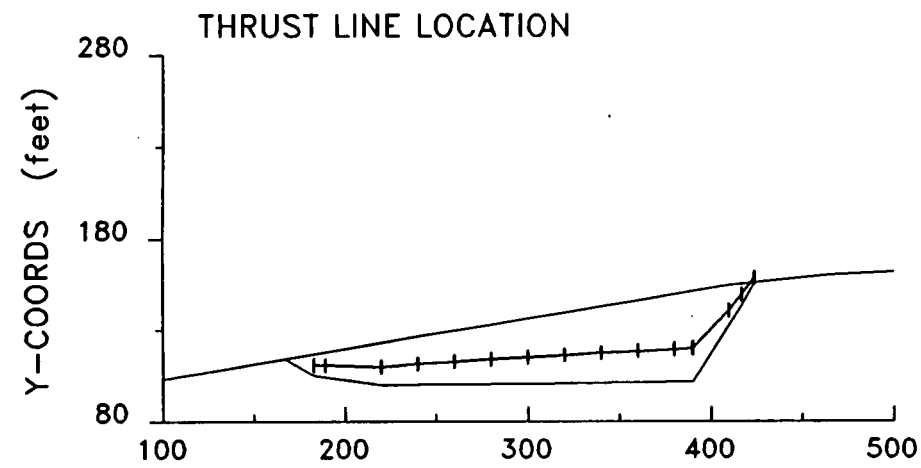

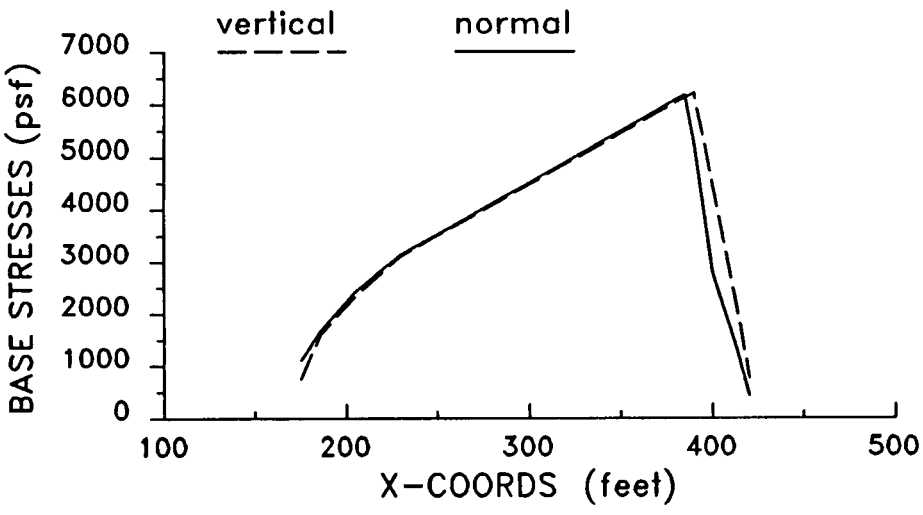

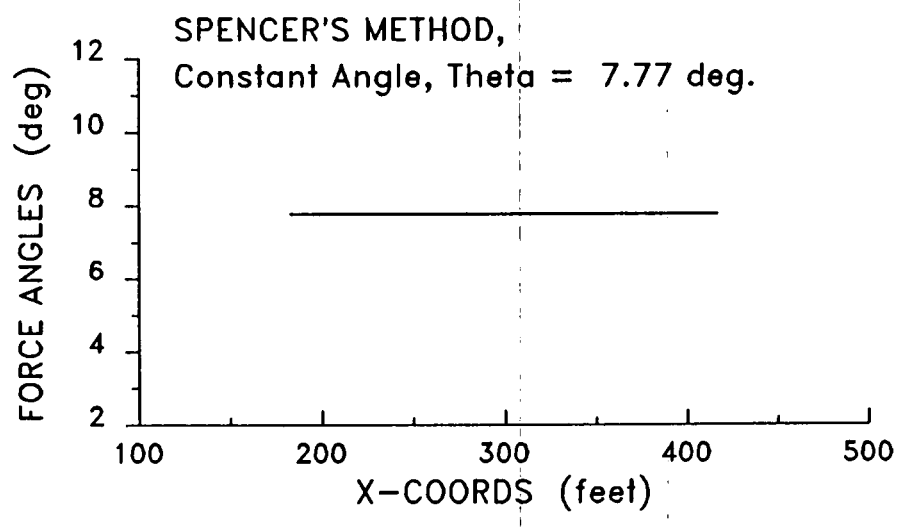

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.716

1269

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000333

XSTABL File: NLD13BS 10-10-97 14:30

```
*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
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*                                       *
*  Ver. 5.201                 96 á 1202 *
*****************************************
```

Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	230.4
4	2880.0	374.4
5	6480.0	892.8
6	10080.0	892.8

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	390.11	101.63
6	390.27	101.78
7	416.83	143.48
8	424.12	156.11

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.65	9.37	93339.
9	330.00	100.94	40.41	20.00	.65	9.37	101018.
10	350.00	101.17	43.53	20.00	.65	9.65	108821.
11	370.00	101.40	46.65	20.00	.65	9.37	116625.
12	385.05	101.57	48.97	10.11	.65	9.46	61886.
13	390.19	101.71	49.69	.16	43.15	9.46	1013.
14	400.14	117.27	35.79	19.73	57.51	9.46	88242.
15	413.42	138.12	16.92	6.83	57.51	5.71	14451.
16	420.48	149.80	5.95	7.29	60.01	5.71	5420.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.7278	1.7146	1.7541
3	7.7673	1.7156	1.7146

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.7673	1.7156	1.7146

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1086.1	.0	30.00	0.	0.	0.	.00
2	1673.9	182.4	3.81	0.	0.	0.	.00

3	2406.3	182.4	3.81	0.	0.	0.	.00
4	3125.9	-40.3	8.19	0.	0.	0.	.00
5	3523.4	-40.3	8.19	0.	0.	0.	.00
6	3914.5	-40.3	8.19	0.	0.	0.	.00
7	4311.9	-40.3	8.19	0.	0.	0.	.00
8	4706.1	-40.3	8.19	0.	0.	0.	.00
9	5093.4	-40.3	8.19	0.	0.	0.	.00
10	5487.1	-40.3	8.19	0.	0.	0.	.00
11	5880.8	-40.3	8.19	0.	0.	0.	.00
12	6173.5	-40.3	8.19	0.	0.	0.	.00
13	5213.2	-40.3	8.19	0.	0.	0.	.00
14	2789.1	.0	25.00	0.	0.	0.	.00
15	1318.9	.0	25.00	0.	0.	0.	.00
16	419.3	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1086.1	739.6	.0	365.5
2	186.00	1673.9	1594.4	.0	171.4
3	204.50	2406.3	2304.8	.0	199.8
4	230.00	3125.9	3100.0	.0	238.9
5	250.00	3523.4	3493.8	.0	272.2
6	270.00	3914.5	3881.3	.0	305.1
7	290.00	4311.9	4275.0	.0	338.4
8	310.00	4706.1	4667.0	.0	371.5
9	330.00	5093.4	5050.9	.0	404.0
10	350.00	5487.1	5441.1	.0	437.1
11	370.00	5880.8	5831.2	.0	470.1
12	385.05	6173.5	6121.3	.0	494.7
13	390.19	5213.2	6211.5	.0	414.1
14	400.14	2789.1	4473.2	.0	758.1
15	413.42	1318.9	2115.2	.0	358.5
16	420.48	419.3	743.7	.0	141.1

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.77	15932.	5.68	11.83	.480
2	189.00	7.77	18394.	6.47	13.68	.473
3	220.00	7.77	35227.	9.93	23.20	.428
4	240.00	7.77	39417.	11.28	26.40	.427
5	260.00	7.77	44201.	12.46	29.50	.422
6	280.00	7.77	49569.	13.52	32.60	.415
7	300.00	7.77	55529.	14.47	35.80	.404
8	320.00	7.77	61942.	15.36	38.87	.395
9	340.00	7.77	68922.	16.19	41.94	.386
10	360.00	7.77	76479.	16.98	45.11	.376

11	380.00	7.77	84611.	17.74	48.19	.368
12	390.11	7.77	88938.	18.11	49.75	.364
13	390.27	7.77	88202.	18.13	49.63	.365
14	410.00	7.77	16113.	7.76	21.94	.354
15	416.83	7.77	4307.	5.81	11.90	.489
16	424.12	.00	0.	2.35	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3499.64 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 380.24 (psf)

Total Length of failure surface = 290.09 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.716 ✓

Total shear strength available along specified failure surface = 189.23E+03 lb

GCL 14

COMPUTATION COVER SHEET

1269

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 14 - Compliance Package

Computations By:
(Cognizant Engineer)

Signature Robert A. Morgan III — Date 13 OCT 1997

Printed Name and Title ROBERT A. MORGAN III, SR. STAFF ENGINEER

Assumptions and Procedures Checked By:
(Checker)

Signature [illegible] — Date 14 Oct 97

Printed Name and Title Gary R. Schmertmann, Sr. Project Engr.

Computations Checked by:

Signature [illegible] — Date 14 Oct 97

Printed Name and Title Gary R. Schmertmann, Sr. Project Engr.

Computations Backchecked by:
(Cognizant Engineer)

Signature Robert A. Morgan III — Date 15 OCT 1997

Printed Name and Title ROBERT A. MORGAN III, SR. STAFF ENGINEER

Approved by:
(PDP)

Signature [illegible] — Date 15 Oct 97

Printed Name and Title Gary R. Schmertmann, Sr. Project Engr.

Approved by:
(DTL and TETL)

Signature [illegible] — Date 15 Oct 97

Printed Name and Title Kenneth W. Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

Written By: RAM Date: 10/13/97 Reviewed by: GES Date: 10/14/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 14 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 14 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample No.	Case	Test Type	Measured Shear Strengths		
			5 psi	20 psi	45 psi
14	Peak	GCL Internal	6.0 psi	12.9 psi	15.3 psi
		GCL/GMB Interface	2.7	9.5	11.0
14	Large-displacement	GCL Internal	3.9	3.8	6.0
		GCL/GMB Interface	1.7	4.9	6.8

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix B.

QA Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
14	GCL Internal	NPK14AS	2.5	YES
	GCL/GMB Interface	NPK14BS	2.0	YES
Baseline	Large-displacement	NA	1.6	NA
14	GCL Internal	NLD14AS	1.9	YES
	GCL/GMB Interface	NLD14BS	2.1	YES

RAM 10/13/97
GRS 10/14/97

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 14I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-14). GCL's initial moisture content was 9.7%. GCL's final moisture content ranged from 62% to 84% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 14G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

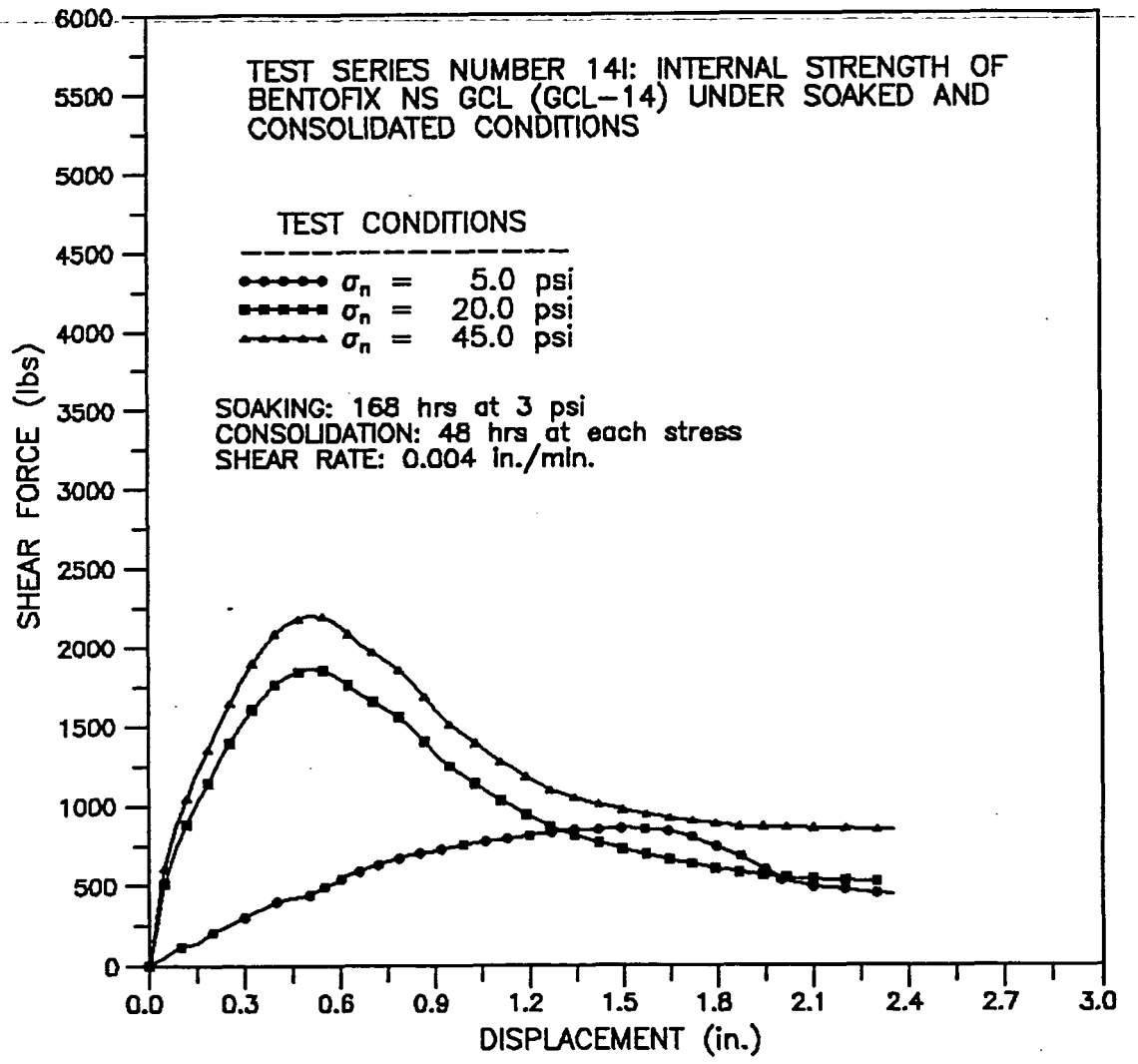
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-14) with woven geotextile against geomembrane. GCL's initial moisture content was 8.5%. GCL's final moisture content ranged from 64 to 107% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-16); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.

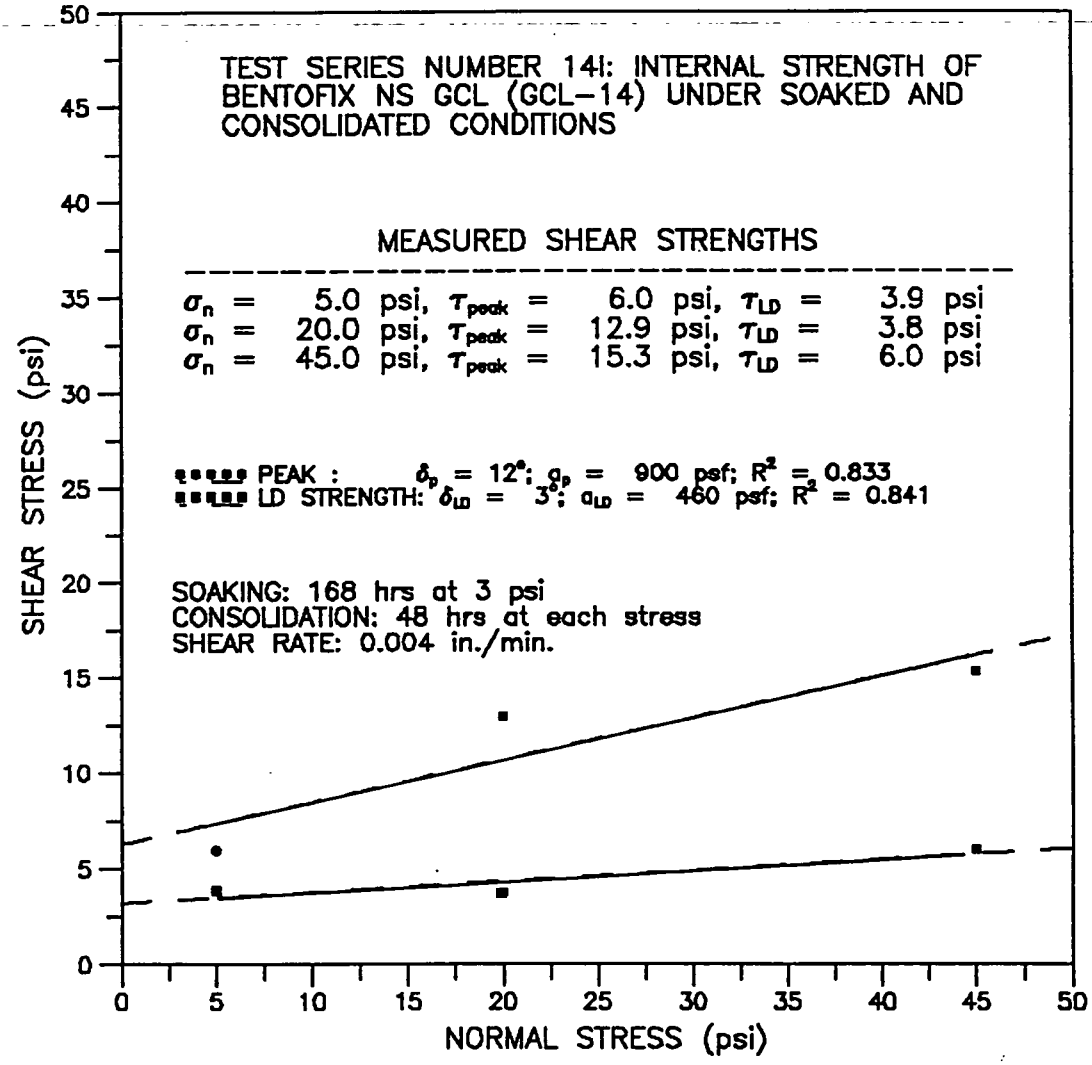
(2) For each test, sliding (i.e., internal shear failure) was observed to occur within the GCL.

DATE TESTED: 22 SEPTEMBER TO 3 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	G00166-04.1
DOCUMENT NO.	F9730091
FILE NO.	000343

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



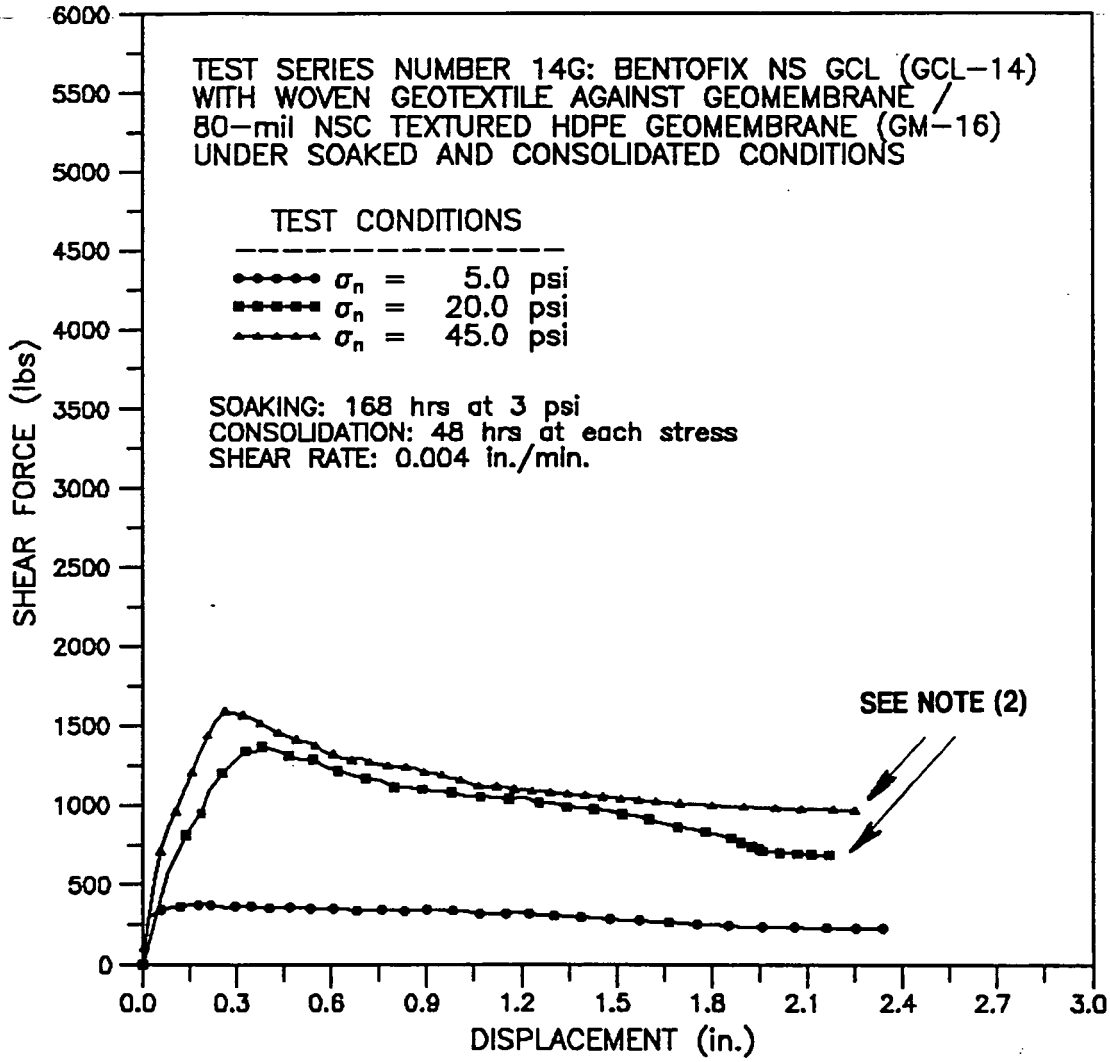
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) For each test, sliding (i.e, internal shear failure) was observed to occur within the GCL.

DATE TESTED: 22 SEPTEMBER TO 3 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730091
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

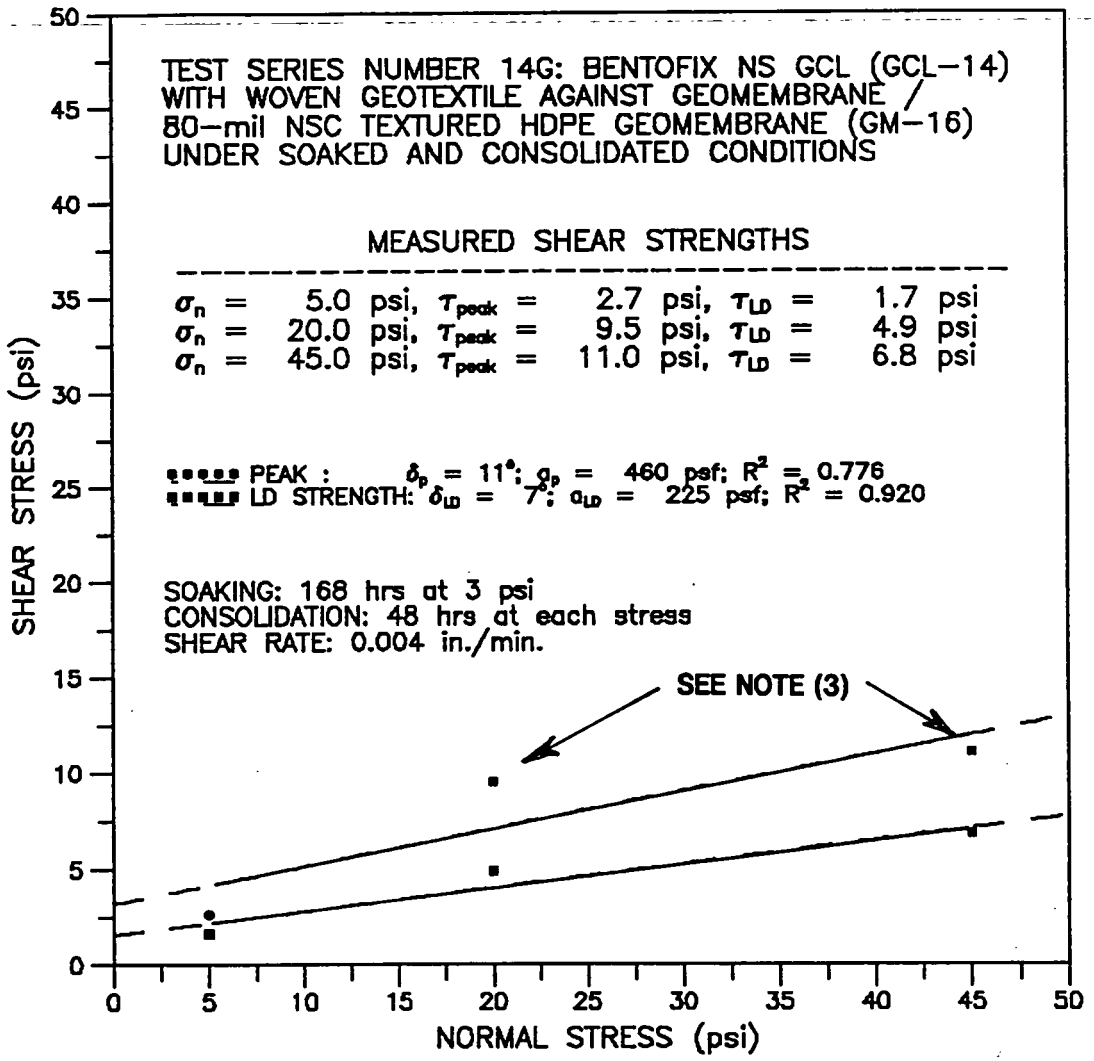
DATE TESTED: 24 SEPTEMBER TO 3 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	G00166-04.1
DOCUMENT NO.	00973091
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 24 SEPTEMBER TO 3 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	0F973091
FILE NO.	

RAM 10/13/97

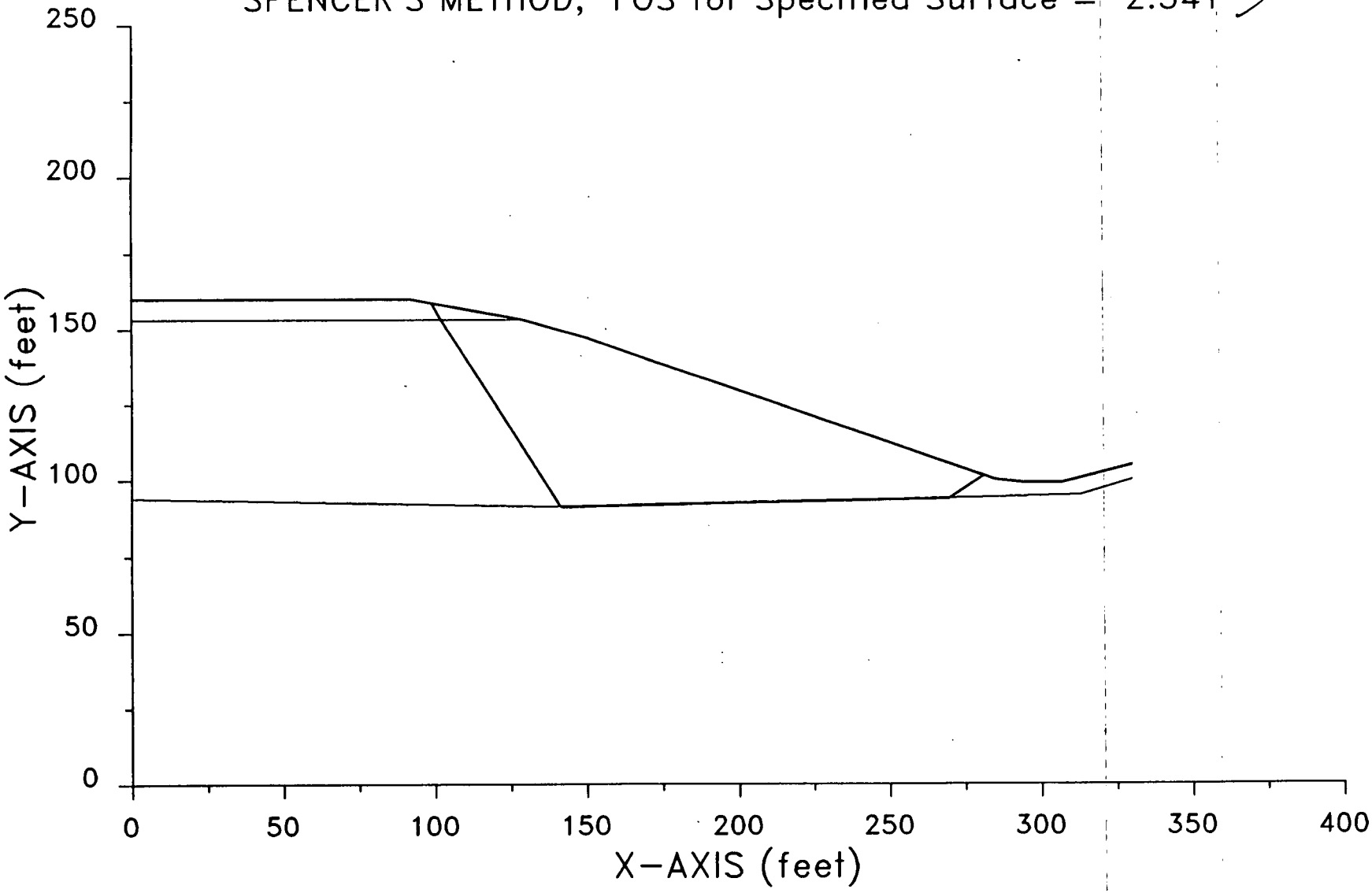
GRS 10/14/97

APPENDIX B

NPK14AS 10-09-97 17:27

OSDF Interim Closure/Short-Term,Peak

SPENCER'S METHOD, FOS for Specified Surface = 2.541



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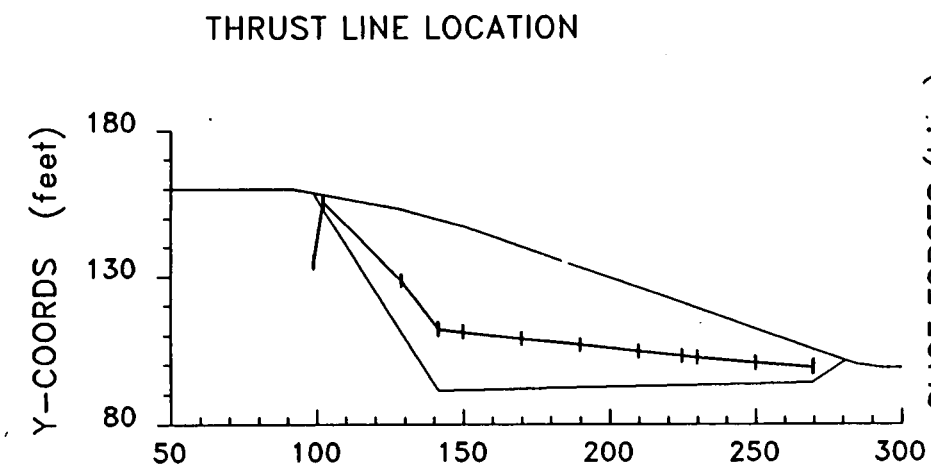

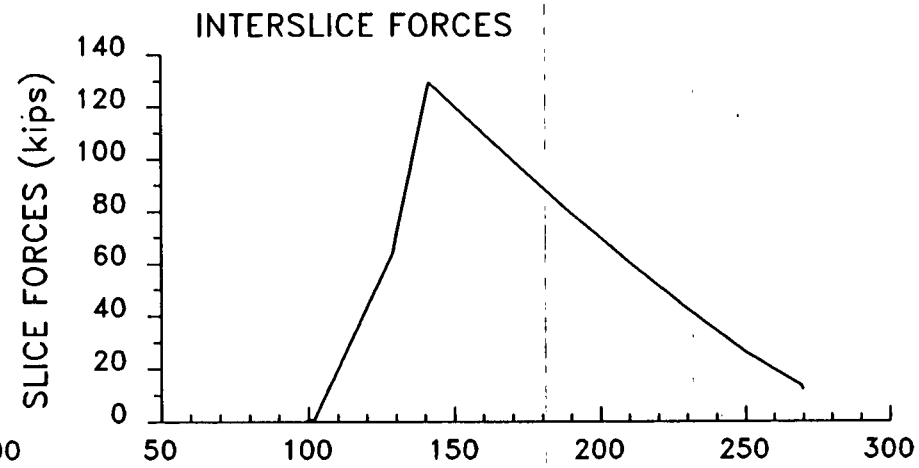

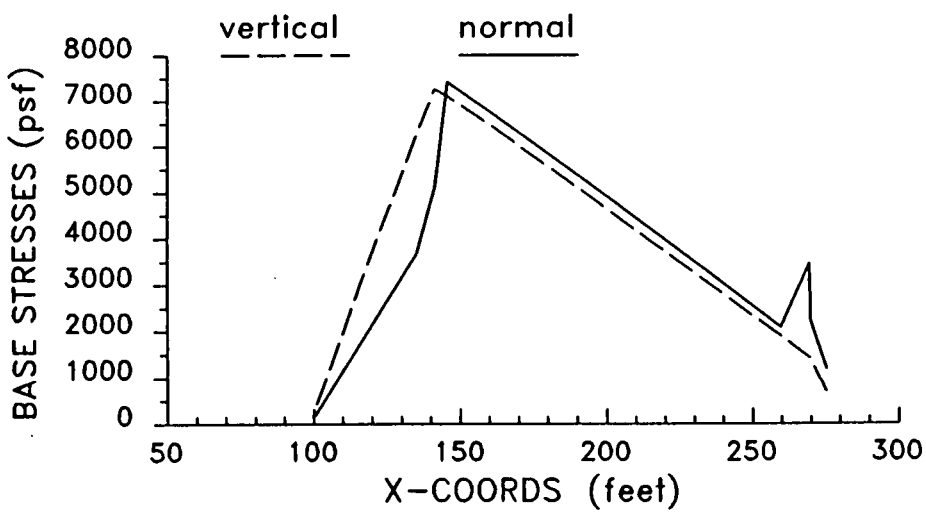

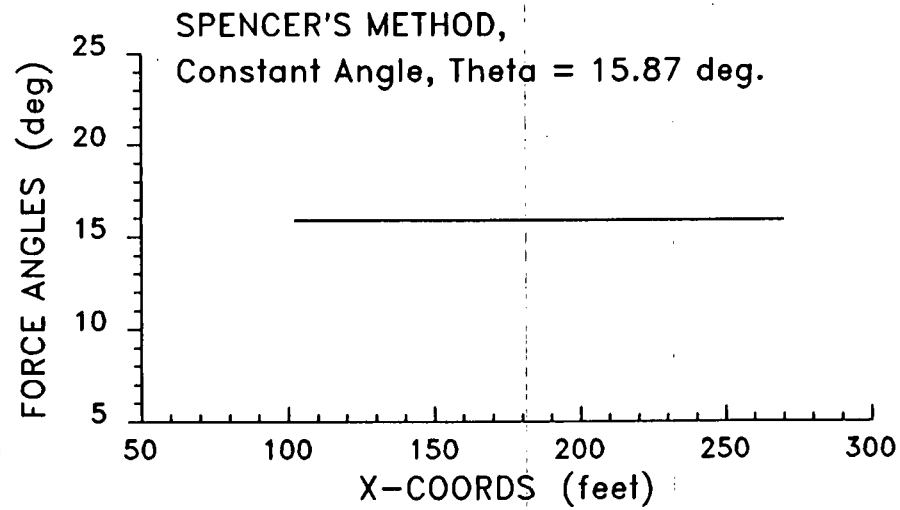

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.541 ✓

1269

11/37

0003351

XSTABL File: NPK14AS 10-09-97 17:27

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	864.0
4	2880.0	1857.6
5	6480.0	2203.2
6	36000.0	2203.2

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	281.11	101.35
2	269.73	94.10
3	269.53	93.89
4	224.80	93.00
5	141.66	91.27
6	141.44	91.50
7	102.26	153.00
8	98.98	158.68

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	275.55	97.81	5.46	11.11	-32.50	19.12	7588.
2	269.86	94.18	11.06	.27	-32.50	19.29	379.
3	269.63	93.99	11.34	.20	-46.40	19.29	277.
4	259.77	93.70	15.09	19.53	-1.14	19.29	36830.
5	240.00	93.30	22.35	20.00	-1.14	19.03	55869.
6	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
7	217.40	92.85	30.66	14.80	-1.19	19.29	56728.
8	200.00	92.48	37.12	20.00	-1.19	19.29	92790.
9	180.00	92.07	44.48	20.00	-1.19	19.03	111206.
10	160.00	91.65	51.85	20.00	-1.19	19.29	129621.
11	145.83	91.36	56.83	8.34	-1.19	15.95	59250.
12	141.55	91.39	58.03	.22	46.27	15.95	1599.
13	135.22	101.26	49.96	12.44	57.50	15.95	77684.
14	115.63	132.01	23.52	26.74	57.50	10.71	78602.
15	100.62	155.84	2.53	3.28	59.99	10.71	1037.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	15.3164	2.5884	2.7192
3	15.5763	-----	2.5884
3	15.4464	2.5954	-----
4	15.5633	2.6018	2.5954
5	15.5573	2.6015	2.6018

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	15.8810	2.5429	2.5299
3	15.8744	2.5426	2.5429

Nonlinear M-C Iteration Number - 3

ITERATIONS FOR SPENCER'S METHOD

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Iter #	Theta	FOS_force	FOS_moment
2	15.8746	2.5415	2.5415

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	15.8746	2.5415	2.5415

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1162.6	200.0	25.00	0.	0.	0.	.00
2	2239.7	200.0	25.00	0.	0.	0.	.00
3	3451.9	1581.1	5.48	0.	0.	0.	.00
4	2075.7	532.8	24.70	0.	0.	0.	.00
5	3034.8	1581.1	5.48	0.	0.	0.	.00
6	3621.2	1581.1	5.48	0.	0.	0.	.00
7	4094.3	1581.1	5.48	0.	0.	0.	.00
8	4915.1	1581.1	5.48	0.	0.	0.	.00
9	5852.2	1581.1	5.48	0.	0.	0.	.00
10	6785.8	2203.2	.00	0.	0.	0.	.00
11	7412.8	2203.2	.00	0.	0.	0.	.00
12	5113.0	1581.1	5.48	0.	0.	0.	.00
13	3652.2	200.0	25.00	0.	0.	0.	.00
14	1687.3	200.0	25.00	0.	0.	0.	.00
15	173.6	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	275.55	1162.6	683.0	.0	292.0
2	269.86	2239.7	1382.9	.0	489.6
3	269.63	3451.9	1417.2	.0	752.5
4	259.77	2075.7	1885.8	.0	585.3
5	240.00	3034.8	2793.4	.0	736.8
6	227.40	3621.2	3369.8	.0	758.9
7	217.40	4094.3	3833.0	.0	776.8
8	200.00	4915.1	4639.5	.0	807.8
9	180.00	5852.2	5560.3	.0	843.2
10	160.00	6785.8	6481.0	.0	866.9
11	145.83	7412.8	7104.3	.0	866.9
12	141.55	5113.0	7253.6	.0	815.3
13	135.22	3652.2	6244.9	.0	748.8
14	115.63	1687.3	2939.5	.0	388.3
15	100.62	173.6	316.2	.0	39.4

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	270.00	15.87	11927.	5.12	10.93	.468
2	269.73	15.87	12473.	5.14	11.20	.459
3	269.53	15.87	13364.	5.05	11.47	.440
4	250.00	15.87	26087.	7.08	18.70	.379
5	230.00	15.87	42662.	9.23	26.00	.355
6	224.80	15.87	47154.	9.86	27.92	.353
7	210.00	15.87	60418.	11.72	33.41	.351
8	190.00	15.87	79340.	14.30	40.82	.350
9	170.00	15.87	99405.	16.90	48.14	.351
10	150.00	15.87	120366.	19.53	55.56	.352
11	141.66	15.87	129220.	20.65	58.11	.355
12	141.44	15.87	128182.	20.65	57.95	.356
13	129.00	15.87	63725.	17.46	41.97	.416
14	102.26	15.87	891.	2.37	5.06	.469
15	98.98	.00	0.	-23.95	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3530.83 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 634.90 (psf)

Total Length of failure surface = 221.47 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.541 ✓

Total shear strength available along specified failure surface = 357.37E+03 lb

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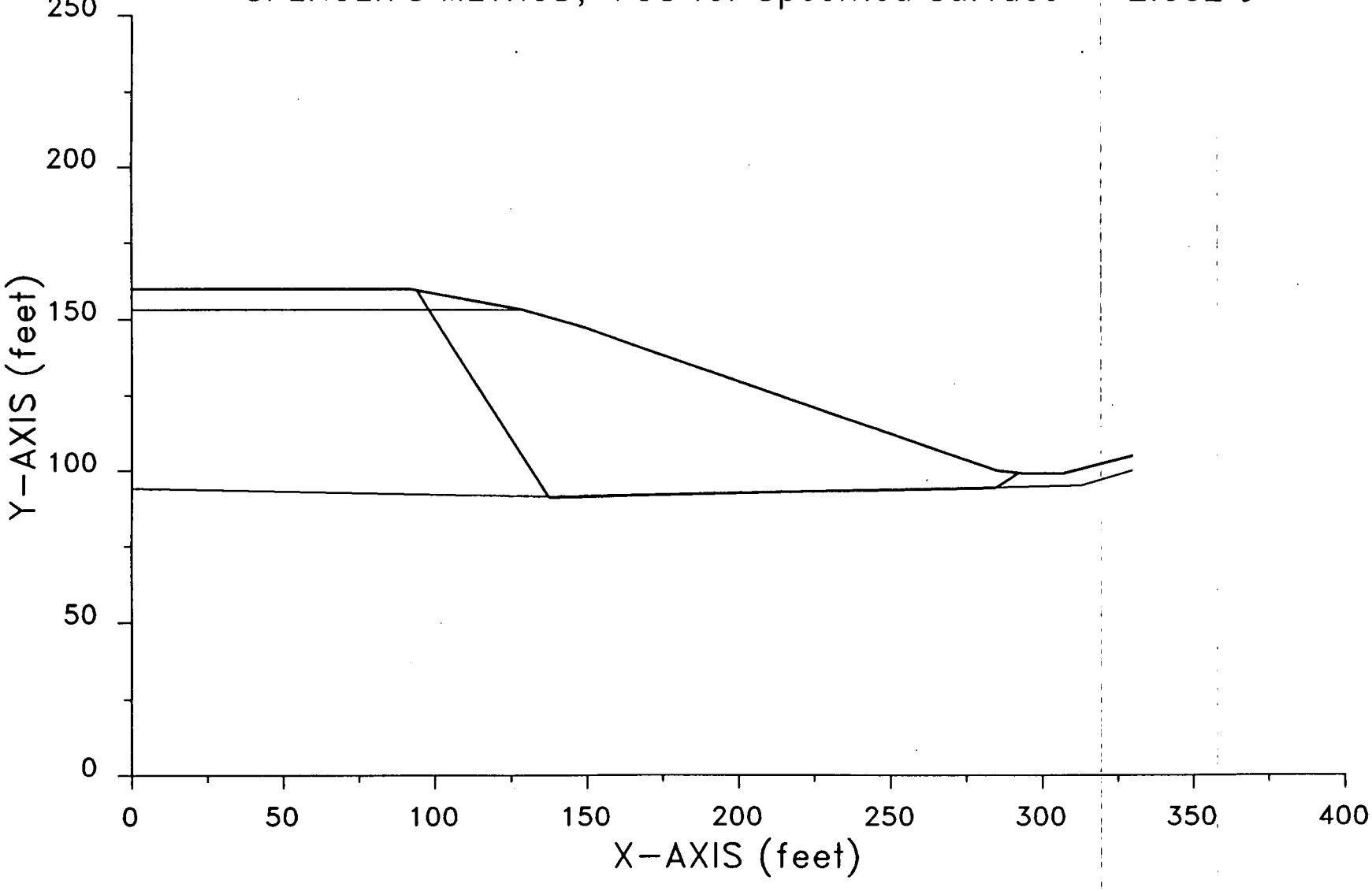
OSDF Interim Closure/Short-Term,Peak

SPENCER'S METHOD, FOS for Specified Surface = 2.002



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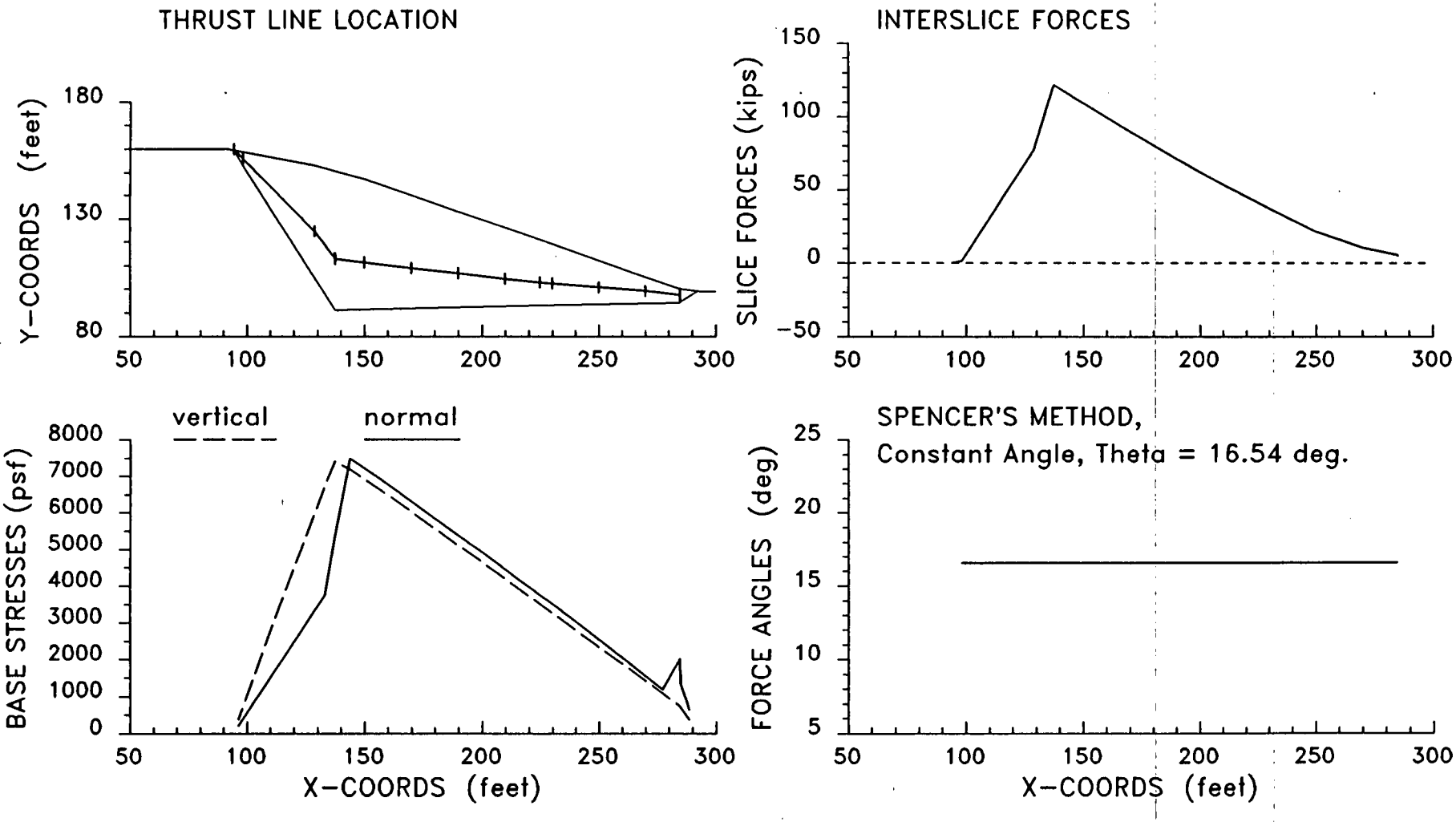

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.002

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	388.8
4	2880.0	1368.0
5	6480.0	1584.0
6	10080.0	1584.0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	292.36	99.18
2	284.85	94.40
3	284.65	94.19
4	224.80	93.00
5	137.68	91.18
6	137.43	91.42
7	98.20	153.00
8	94.43	159.54

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.68	96.84	2.75	7.36	-32.49	6.34	2532.
2	284.92	94.45	5.58	.15	-32.49	19.12	107.
3	284.75	94.29	5.79	.20	-46.40	19.12	143.
4	277.33	94.04	8.62	14.65	-1.14	19.12	15779.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37500.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55869.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.20	19.29	56730.
9	200.00	92.48	37.12	20.00	-1.20	19.29	92795.
10	180.00	92.06	44.49	20.00	-1.20	19.03	111215.
11	160.00	91.65	51.85	20.00	-1.20	19.29	129634.
12	143.84	91.31	57.45	12.32	-1.20	15.95	88475.
13	137.55	91.30	59.26	.25	43.83	15.95	1852.
14	133.21	98.04	53.76	8.43	57.50	15.95	56649.
15	113.60	128.83	27.09	30.80	57.50	10.71	104286.
16	96.32	156.27	2.91	3.77	60.04	10.71	1373.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.5001	2.0124	2.0250
3	16.5142	2.0128	2.0124

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.5431	2.0021	2.0013

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.5431	2.0021	2.0013

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb) 22/37	
1	635.2	.0	30.00	0.	0.	0.	.00
2	1332.6	200.0	25.00	0.	0.	0.	.00
3	1999.7	62.4	24.39	0.	0.	0.	.00
4	1178.4	62.4	24.39	0.	0.	0.	.00
5	2043.6	62.4	24.39	0.	0.	0.	.00
6	3029.3	1195.2	3.43	0.	0.	0.	.00
7	3614.7	1195.2	3.43	0.	0.	0.	.00
8	4087.2	1195.2	3.43	0.	0.	0.	.00
9	4906.7	1195.2	3.43	0.	0.	0.	.00
10	5842.4	1195.2	3.43	0.	0.	0.	.00
11	6775.3	1584.0	.00	0.	0.	0.	.00
12	7479.4	1584.0	.00	0.	0.	0.	.00
13	5372.5	1195.2	3.43	0.	0.	0.	.00
14	3740.2	200.0	25.00	0.	0.	0.	.00
15	1848.8	200.0	25.00	0.	0.	0.	.00
16	188.8	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.68	635.2	344.0	.0	183.2
2	284.92	1332.6	697.5	.0	410.3
3	284.75	1999.7	724.2	.0	484.0
4	277.33	1178.4	1077.0	.0	298.0
5	260.00	2043.6	1875.0	.0	493.9
6	240.00	3029.3	2793.5	.0	687.8
7	227.40	3614.7	3369.8	.0	705.3
8	217.40	4087.2	3833.1	.0	719.5
9	200.00	4906.7	4639.8	.0	744.0
10	180.00	5842.4	5560.7	.0	772.1
11	160.00	6775.3	6481.7	.0	791.2
12	143.84	7479.4	7181.4	.0	791.2
13	137.55	5372.5	7407.0	.0	758.0
14	133.21	3740.2	6719.9	.0	971.0
15	113.60	1848.8	3385.9	.0	530.5
16	96.32	188.8	364.2	.0	54.5

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	16.54	4512.	3.44	5.50	.624
2	284.85	16.54	4713.	3.43	5.65	.607
3	284.65	16.54	5244.	3.33	5.93	.562
4	270.00	16.54	10156.	5.24	11.30	.464
5	250.00	16.54	21309.	7.18	18.70	.384
6	230.00	16.54	36914.	9.14	26.00	.352

7	224.80	16.54	41130.	9.77	27.92	.350
8	210.00	16.54	53556.	11.66	33.41	.349
9	190.00	16.54	71217.	14.34	40.83	.351
10	170.00	16.54	89872.	17.06	48.14	.354
11	150.00	16.54	109331.	19.82	55.56	.357
12	137.68	16.54	121507.	21.55	59.34	.363
13	137.43	16.54	120360.	21.59	59.17	.365
14	129.00	16.54	77269.	19.91	48.35	.412
15	98.20	16.54	1071.	2.71	5.83	.465
16	94.43	.00	-3.	.24	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3437.69 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 617.27 (psf)

Total Length of failure surface = 237.10 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.002 ✓

Total shear strength available along specified failure surface = 293.02E+03 lb

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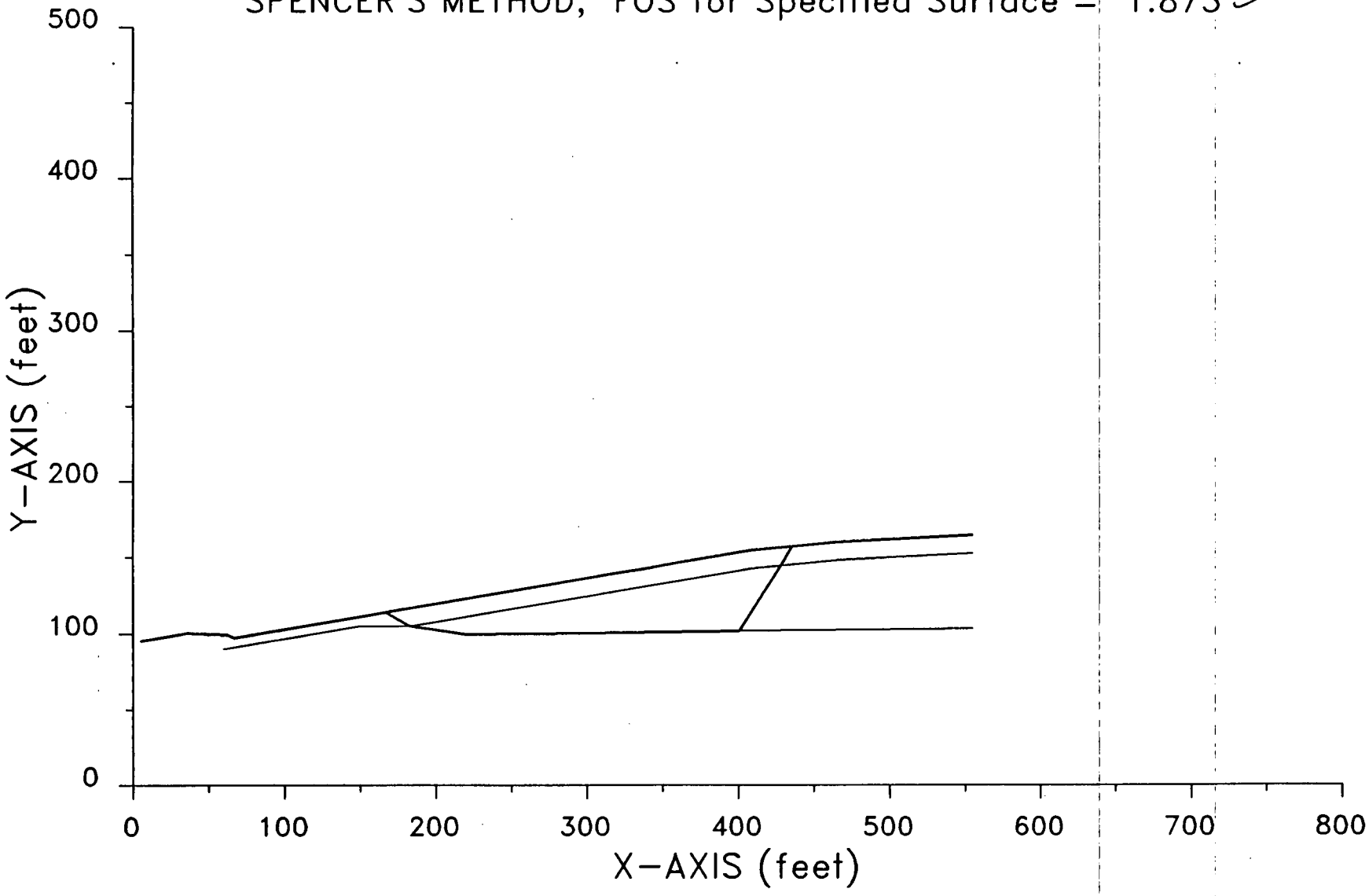
OSDF Final Long Term – Large Displ.

SPENCER'S METHOD, FOS for Specified Surface = 1.873



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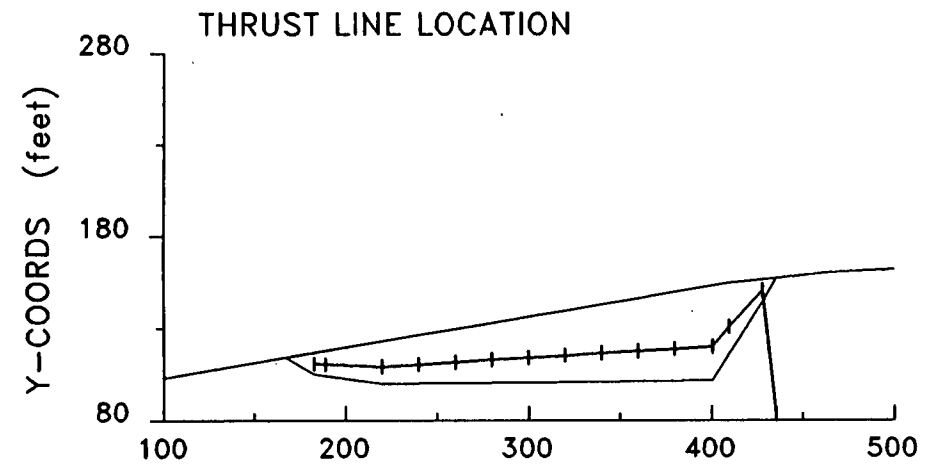

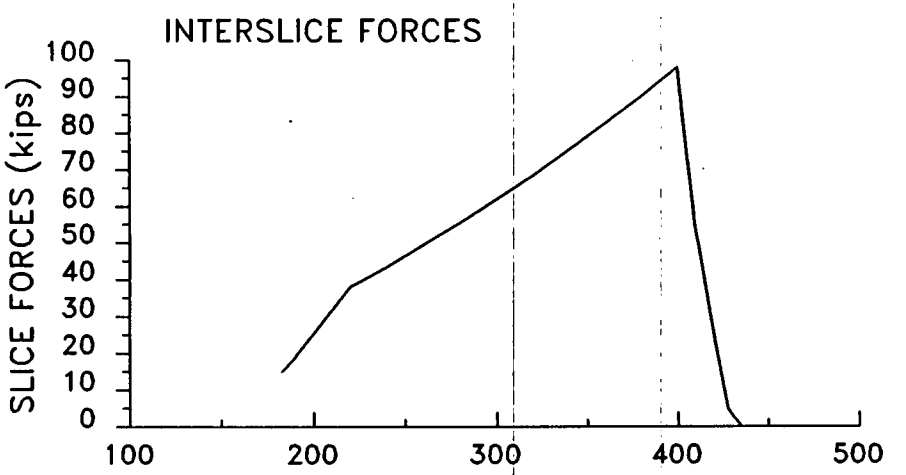

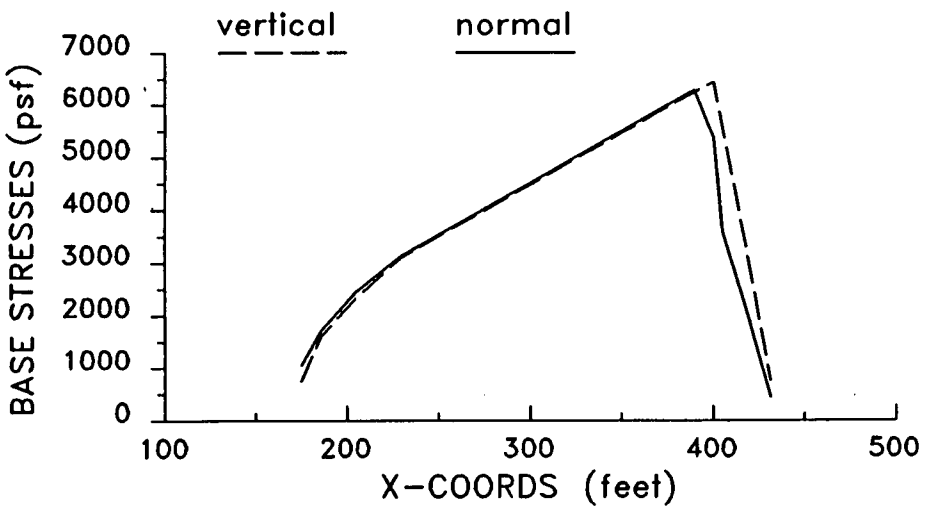

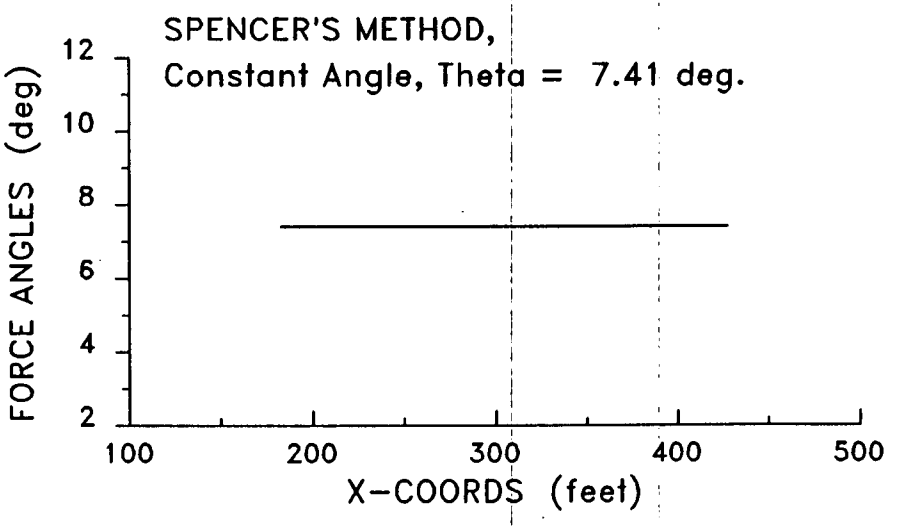

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.873

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*                                       *
*       Slope Stability Analysis        *
*              using the                *
*           Method of Slices            *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0 ✓	.0 ✓
2	.0 ✓	.0 ✓
3	720.0 ✓	547.2 ✓
4	2880.0 ✓	547.2 ✓
5	6480.0 ✓	864.0 ✓
6	10080.0 ✓	864.0 ✓

Value less than actual test value of 3.9 psi = 562 psf. Conservative ✓

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points : ✓

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	400.64	101.66
6	400.88	101.90
7	428.09	144.61
8	435.38	157.24

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.60	9.37	93362.
9	330.00	100.92	40.43	20.00	.60	9.37	101085.
10	350.00	101.13	43.57	20.00	.60	9.65	108933.
11	370.00	101.34	46.71	20.00	.60	9.37	116782.
12	390.32	101.55	49.87	20.64	.60	9.46	128661.
13	400.76	101.78	51.38	.24	45.00	9.46	1543.
14	405.44	109.06	44.88	9.12	57.50	9.46	51164.
15	419.04	130.41	25.19	18.09	57.50	5.71	56965.
16	431.73	150.92	5.95	7.29	60.00	5.71	5422.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.3714	1.8719	1.9202
3	7.4075	1.8729	1.8719

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.4075	1.8729	1.8719

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1046.4	.0	30.00	0.	0.	0.	.00
2	1704.6	547.2	.00	0.	0.	0.	.00

3	2428.2	547.2	.00	0.	0.	0.	.00
4	3132.4	293.8	5.03	0.	0.	0.	.00
5	3527.9	293.8	5.03	0.	0.	0.	.00
6	3917.1	293.8	5.03	0.	0.	0.	.00
7	4312.5	293.8	5.03	0.	0.	0.	.00
8	4706.8	293.8	5.03	0.	0.	0.	.00
9	5094.6	293.8	5.03	0.	0.	0.	.00
10	5488.7	293.8	5.03	0.	0.	0.	.00
11	5882.8	293.8	5.03	0.	0.	0.	.00
12	6279.0	293.8	5.03	0.	0.	0.	.00
13	5368.6	293.8	5.03	0.	0.	0.	.00
14	3590.5	.0	25.00	0.	0.	0.	.00
15	2015.3	.0	25.00	0.	0.	0.	.00
16	432.6	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1046.4	739.6	.0	322.6
2	186.00	1704.6	1594.4	.0	292.2
3	204.50	2428.2	2304.8	.0	292.2
4	230.00	3132.4	3100.0	.0	304.0
5	250.00	3527.9	3493.8	.0	322.6
6	270.00	3917.1	3881.3	.0	340.9
7	290.00	4312.5	4275.0	.0	359.5
8	310.00	4706.8	4668.1	.0	378.0
9	330.00	5094.6	5054.3	.0	396.2
10	350.00	5488.7	5446.7	.0	414.7
11	370.00	5882.8	5839.1	.0	433.3
12	390.32	6279.0	6233.6	.0	451.9
13	400.76	5368.6	6422.5	.0	409.1
14	405.44	3590.5	5610.3	.0	894.0
15	419.04	2015.3	3149.0	.0	501.8
16	431.73	432.6	743.7	.0	133.4

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.41	14863.	5.63	11.83	.476
2	189.00	7.41	18080.	6.11	13.68	.447
3	220.00	7.41	37882.	9.12	23.20	.393
4	240.00	7.41	43382.	10.23	26.40	.387
5	260.00	7.41	49177.	11.29	29.50	.383
6	280.00	7.41	55262.	12.33	32.60	.378
7	300.00	7.41	61643.	13.34	35.80	.373
8	320.00	7.41	68267.	14.33	38.89	.368
9	340.00	7.41	75176.	15.30	41.98	.365
10	360.00	7.41	82375.	16.26	45.17	.360

11	380.00	7.41	89863.	17.21	48.26	.357
12	400.64	7.41	97892.	18.18	51.48	.353
13	400.88	7.41	96690.	18.19	51.28	.355
14	410.00	7.41	53082.	14.62	38.48	.380
15	428.09	7.41	4528.	5.84	11.90	.491
16	435.38	.00	0.	-74.33	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3621.23 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 395.14 (psf)

Total Length of failure surface = 301.94 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.873

Total shear strength available along specified failure surface = 223.44E+03 lb

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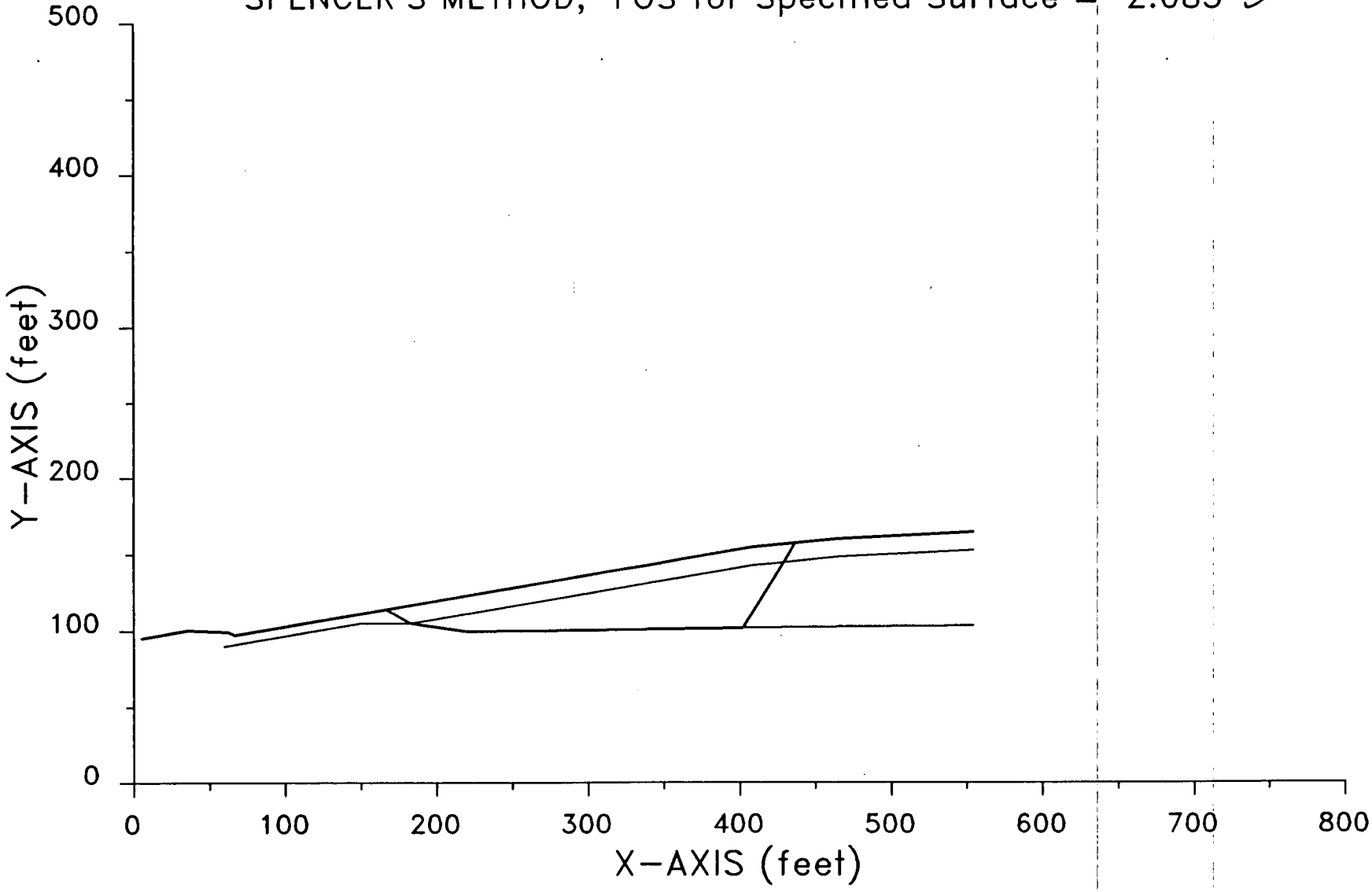
OSDF Final Long Term – Large Displ.

SPENCER'S METHOD, FOS for Specified Surface = 2.083



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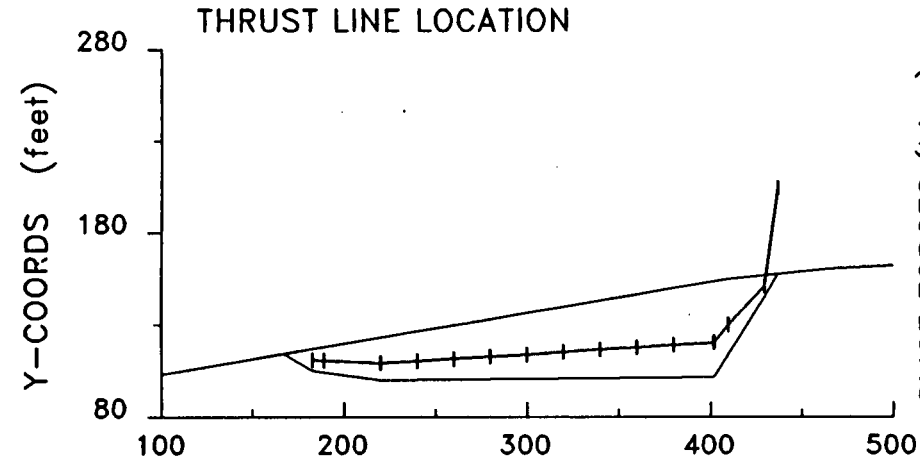

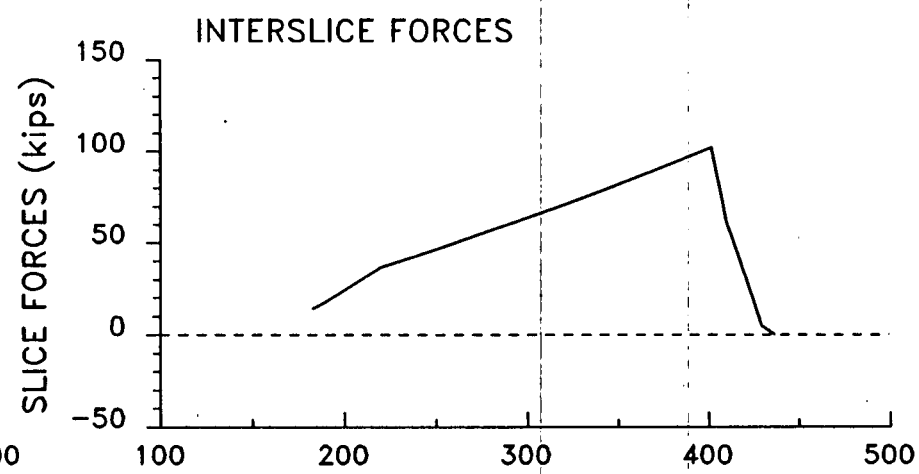

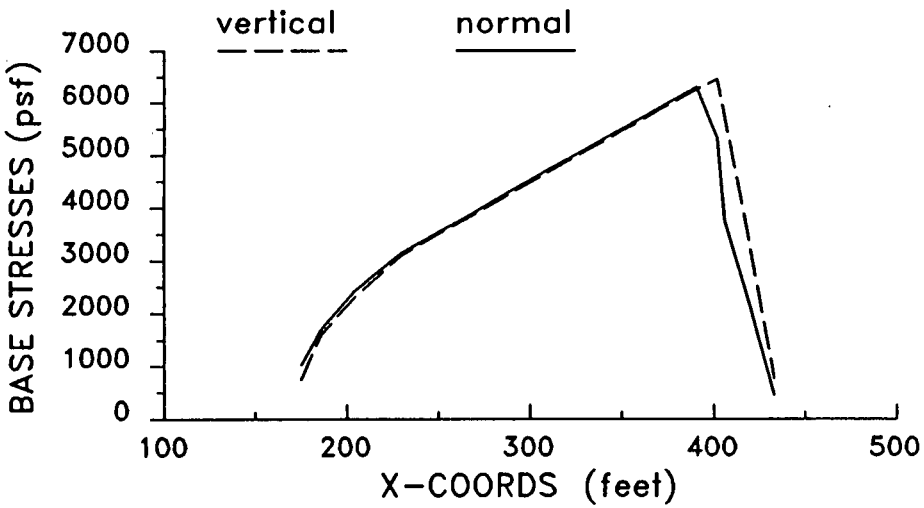

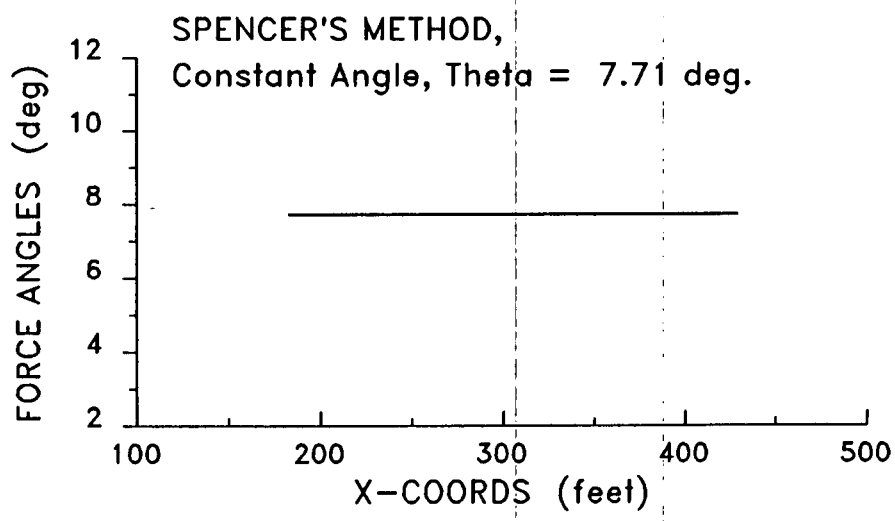

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.083

000372

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*****************************************
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*            Method of Slices           *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

34/37

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	244.8
4	2880.0	705.6
5	6480.0	979.2
6	10080.0	979.2

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	402.06	101.66
6	402.31	101.92
7	429.60	144.76
8	436.89	157.39

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.70	37.35	20.00	.60	9.37	93365.
9	330.00	100.91	40.44	20.00	.60	9.37	101096.
10	350.00	101.12	43.58	20.00	.60	9.65	108952.
11	370.00	101.33	46.72	20.00	.60	9.37	116807.
12	391.03	101.55	49.99	22.06	.60	9.46	137855.
13	402.18	101.79	51.61	.25	46.12	9.46	1613.
14	406.15	107.96	46.10	7.69	57.50	9.46	44317.
15	419.80	129.38	26.30	19.60	57.50	5.71	64445.
16	433.24	151.07	5.95	7.29	60.00	5.71	5422.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.6525	2.0808	2.1274
3	7.7137	2.0827	2.0808
4	7.7124	2.0827	2.0827

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.7124	2.0827	2.0827

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1021.3	.0	30.00	0.	0.	0.	.00

2	1686.2	91.2	12.04	0.	0.	0.	.00
3	2431.9	91.2	12.04	0.	0.	0.	.00
4	3139.4	486.7	4.35	0.	0.	0.	.00
5	3534.5	486.7	4.35	0.	0.	0.	.00
6	3923.2	486.7	4.35	0.	0.	0.	.00
7	4318.2	486.7	4.35	0.	0.	0.	.00
8	4712.4	486.7	4.35	0.	0.	0.	.00
9	5100.1	486.7	4.35	0.	0.	0.	.00
10	5494.1	486.7	4.35	0.	0.	0.	.00
11	5888.2	486.7	4.35	0.	0.	0.	.00
12	6298.2	486.7	4.35	0.	0.	0.	.00
13	5315.5	486.7	4.35	0.	0.	0.	.00
14	3757.4	.0	25.00	0.	0.	0.	.00
15	2143.8	.0	25.00	0.	0.	0.	.00
16	443.4	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1021.3	739.6	.0	283.1
2	186.00	1686.2	1594.4	.0	216.5
3	204.50	2431.9	2304.8	.0	292.9
4	230.00	3139.4	3100.0	.0	348.3
5	250.00	3534.5	3493.8	.0	362.7
6	270.00	3923.2	3881.3	.0	376.9
7	290.00	4318.2	4275.0	.0	391.3
8	310.00	4712.4	4668.3	.0	405.7
9	330.00	5100.1	5054.8	.0	419.8
10	350.00	5494.1	5447.6	.0	434.2
11	370.00	5888.2	5840.4	.0	448.6
12	391.03	6298.2	6249.1	.0	463.5
13	402.18	5315.5	6450.9	.0	427.7
14	406.15	3757.4	5762.9	.0	841.3
15	419.80	2143.8	3288.0	.0	480.0
16	433.24	443.4	743.8	.0	122.9

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.71	14008.	5.67	11.83	.479
2	189.00	7.71	16754.	6.26	13.68	.458
3	220.00	7.71	36608.	9.10	23.20	.392
4	240.00	7.71	43003.	10.07	26.40	.381
5	260.00	7.71	49610.	11.07	29.50	.375
6	280.00	7.71	56424.	12.09	32.60	.371
7	300.00	7.71	63450.	13.12	35.80	.366
8	320.00	7.71	70649.	14.15	38.89	.364
9	340.00	7.71	78053.	15.19	41.98	.362

10	360.00	7.71	85664.	16.23	45.18	.359
11	380.00	7.71	93483.	17.27	48.27	.358
12	402.06	7.71	102346.	18.41	51.72	.356
13	402.31	7.71	101059.	18.42	51.50	.358
14	410.00	7.71	61815.	15.58	40.71	.383
15	429.60	7.71	4747.	5.82	11.90	.489
16	436.89	.00	0.	46.90	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3645.94 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 399.15 (psf)

Total Length of failure surface = 303.53 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.083 ✓

Total shear strength available along specified failure surface = 252.32E+03 lb

GCL 15 – Rejected Based on QC Test Results

GCL 16 – Rejected Due to Small Lot Size (3 Rolls)

GCL 17

COMPUTATION COVER SHEET

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) QA17 and QC07 - Compliance Package

Computations By: (Cognizant Engineer)
Signature [signature] Date 4 NOV 1997
Printed Name and Title M. CATALINA OROZCO STAFF ENGINEER

Assumptions and Procedures Checked By: (Checker)
Signature [signature] Date 4 NOV 1997
Printed Name and Title ROBERT A. MORGAN III SR. STAFF ENGINEER

Computations Checked by:
Signature [signature] Date 4 NOV 1997
Printed Name and Title ROBERT A. MORGAN III SR. STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 4 NOV 1997
Printed Name and Title M. CATALINA OROZCO STAFF ENGINEER

Approved by: (PDP)
Signature [signature] Date 4 Nov 97
Printed Name and Title Gary R. Schmertmann Sr. Project Engineer

Approved by: (DTL and TETL)
Signature [signature] Date 10 Nov 97
Printed Name and Title Kenneth W. Cargill Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

Written By: MCO Date: 11/4/97 Reviewed by: RAM Date: 11/4/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL lot number 97090512 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3). The evaluation is based on the shear test results from GCL QA sample no. 17 and GCL QC sample no. 07.

METHOD

The method for evaluating the GCL samples is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL samples to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 17 and the results of the GCL internal shear tests performed on QC sample no. 07 are shown in the following table. The results of the GCL internal shear tests for QA sample no. 17 were averaged with the results of the GCL internal shear tests for QC sample no. 07. The averaged values for the GCL internal shear tests were used in the stability analyses. The laboratory test results for GCL QA sample no. 17 are presented in Appendix A. The laboratory test results for GCL QC sample no. 07 are presented in Appendix B.

Test Type	Case	Sample No.	Measured Shear Strengths (psi)		
			5 psi	20 psi	45 psi
GCL Internal	Peak	QA 17	0[1]	9.1	14.6
		QC 07	15.6	16.4	18.85
		Average QA17-QC07	**7.8**	**12.75**	**16.725**
	Large-displacement	QA 17	0[1]	3.1	6.7
		QC 07	[2]	[2]	4.51
		Average QA17-QC07	**0**	**3.1**	**5.605**
GCL/GMB Interface	Peak	QA 17	**0[1]**	**6.7**	**14.8**
	Large-displacement	QA 17	**0[1]**	**4.0**	**7.9**

[1] Shear strength values for QA sample 17 at 5 psi normal stress were not available at the time that this calculation package was prepared. These values were assumed to equal zero. This assumption is conservative in the context of RCI 1702-006R.

[2] Large-displacement shear strength values measured for QC sample 07 at 5 and 20 psi normal stress were larger than the value measured at 45 psi normal stress. As this pattern did not conform to normal trends, GeoSyntec requested that the test results be verified. A response from GeoTesting Express dated October 23 1997 indicated that the large-displacement values might be not representative (included in Appendix B). These values were not included in the slope stability analysis performed.

Written By : YMO Date: 11 / 4 /97 Reviewed by: RAM Date: 11 / 4 /97

Client: FMF Project: OSMF Project/Proposal No.: GQ0166 Task No.: 04

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix C.

Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
Average QA17-QC07	GCL Internal	NPPK17AS ✓	2.7 ✓	YES ✓
QA 17	GCL/GMB Interface	NPK17BS ✓	2.0 ✓	YES ✓
Baseline	Large-displacement	NA	1.6	NA
Average QA17-QC07	GCL Internal	NPLD17AS	1.7	YES ✓
QA 17	GCL/GMB Interface	NLD17BS ✓	2.1 ✓	YES ✓

YRCD 4NOV97
RAM 4NOV97

APPENDIX A

4/4

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 171

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-17). GCL's initial moisture content was 10.4%. GCL's final moisture content ranged from 57% to 65% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20 and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 17G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

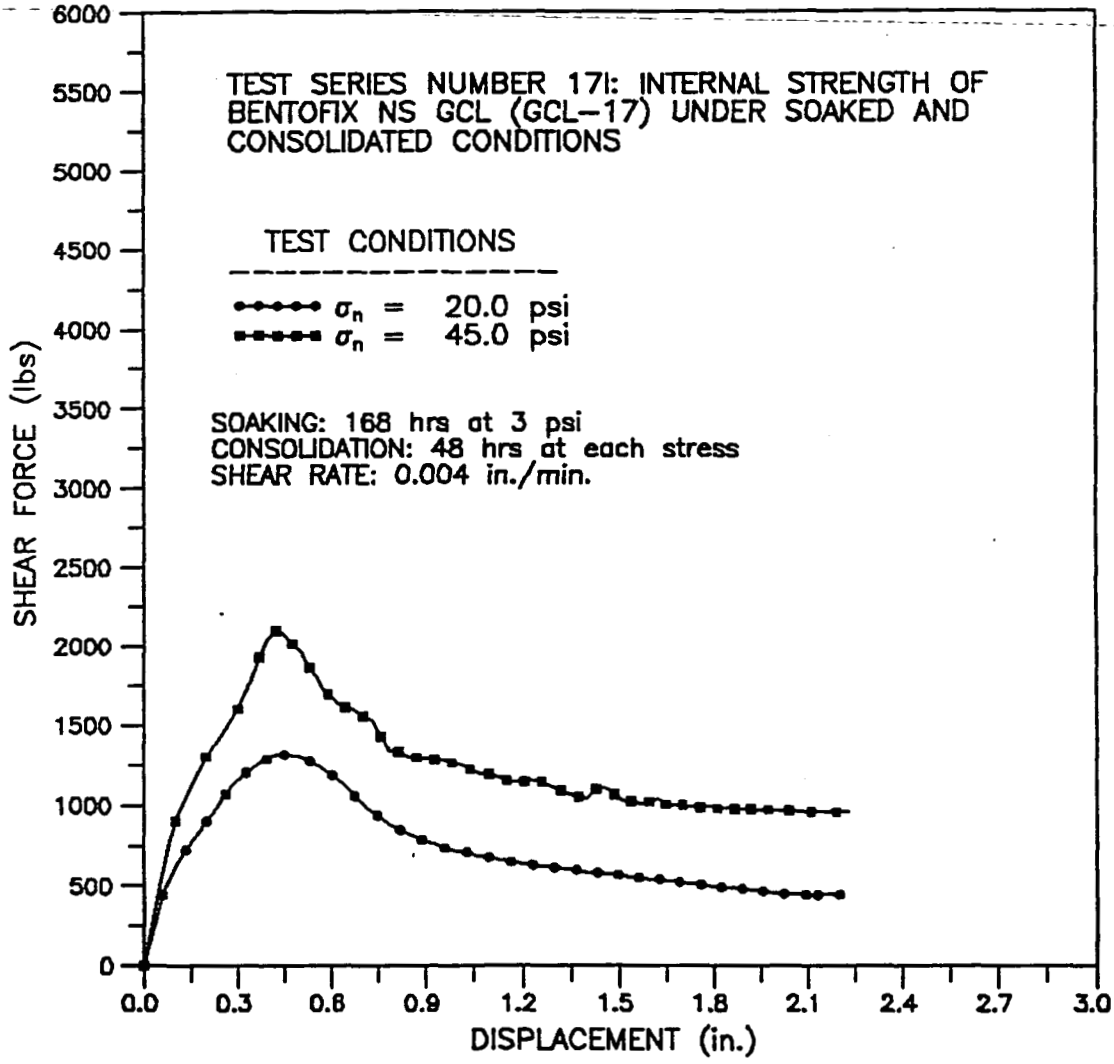
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-17) with woven geotextile against geomembrane. GCL's initial moisture content was 10.2%. GCL's final moisture content ranged from 53 to 74% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-15); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20 and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.

(2) For each test, sliding (i.e., internal shear failure) was observed to occur within the GCL.

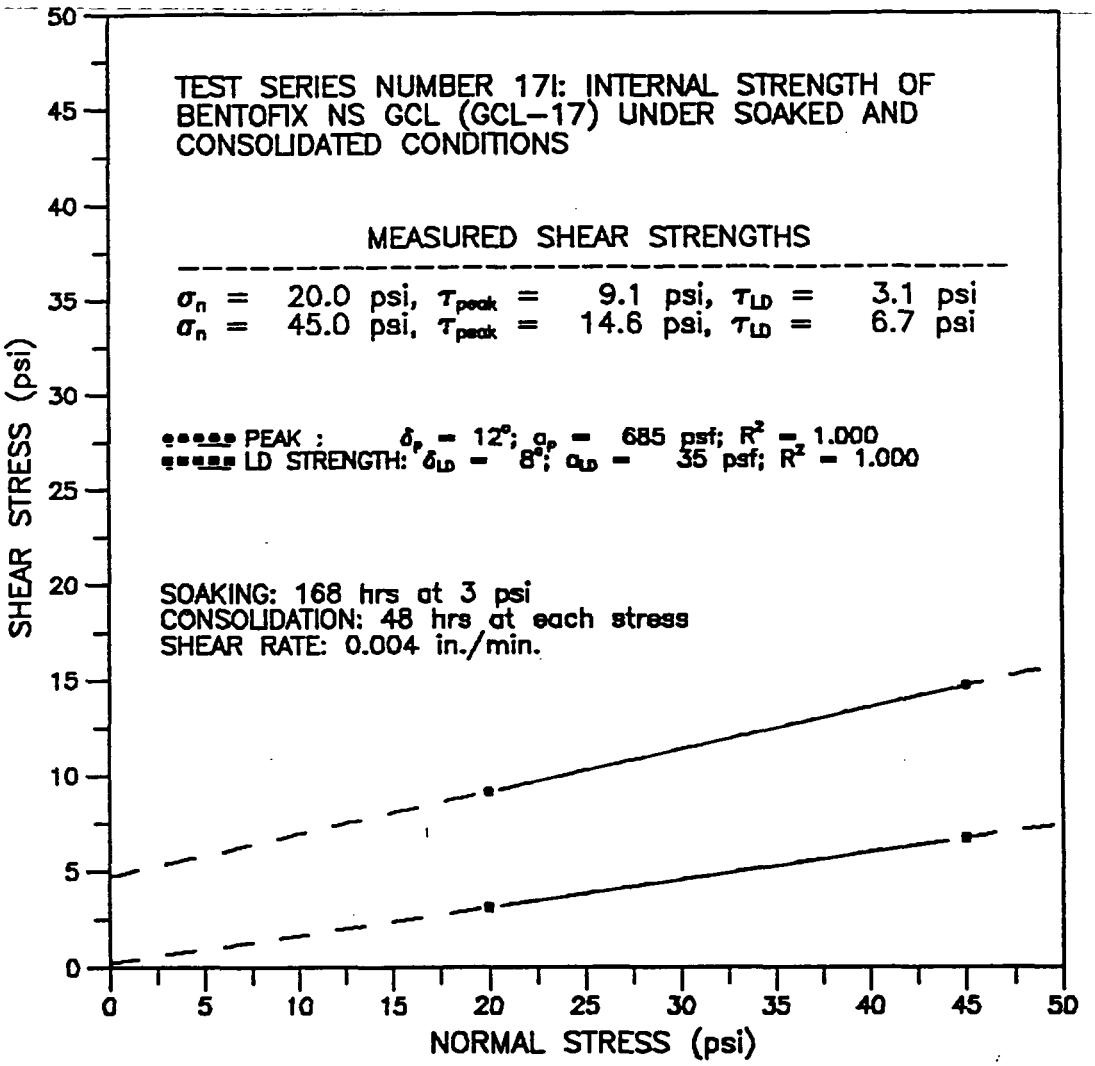
DATE TESTED: 4 TO 13 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730096
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



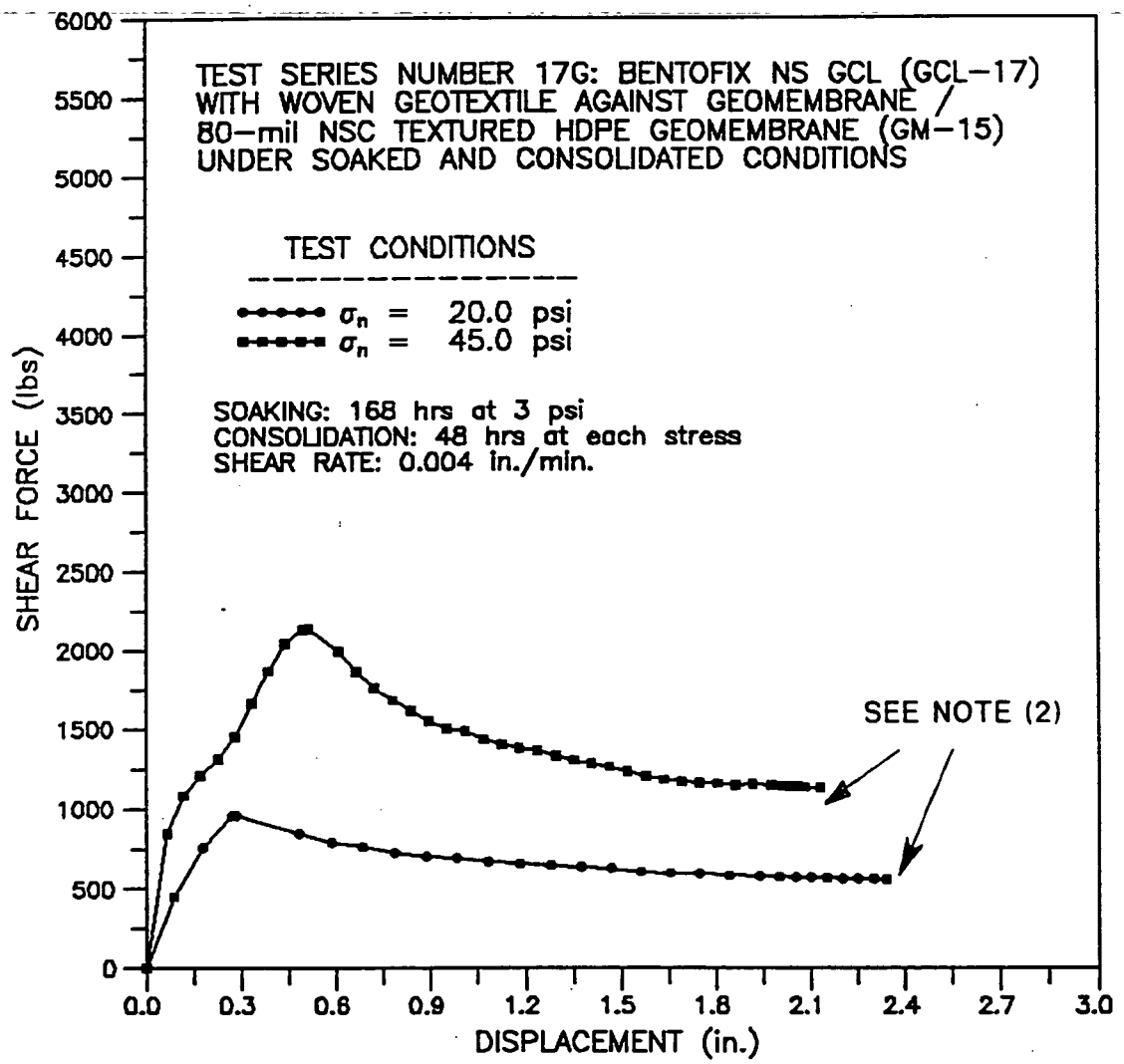
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) For each test, sliding (i.e, internal shear failure) was observed to occur within the GCL.

DATE TESTED: 4 TO 13 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730096
FILE NO.	000388

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 4 TO 13 OCTOBER 1997

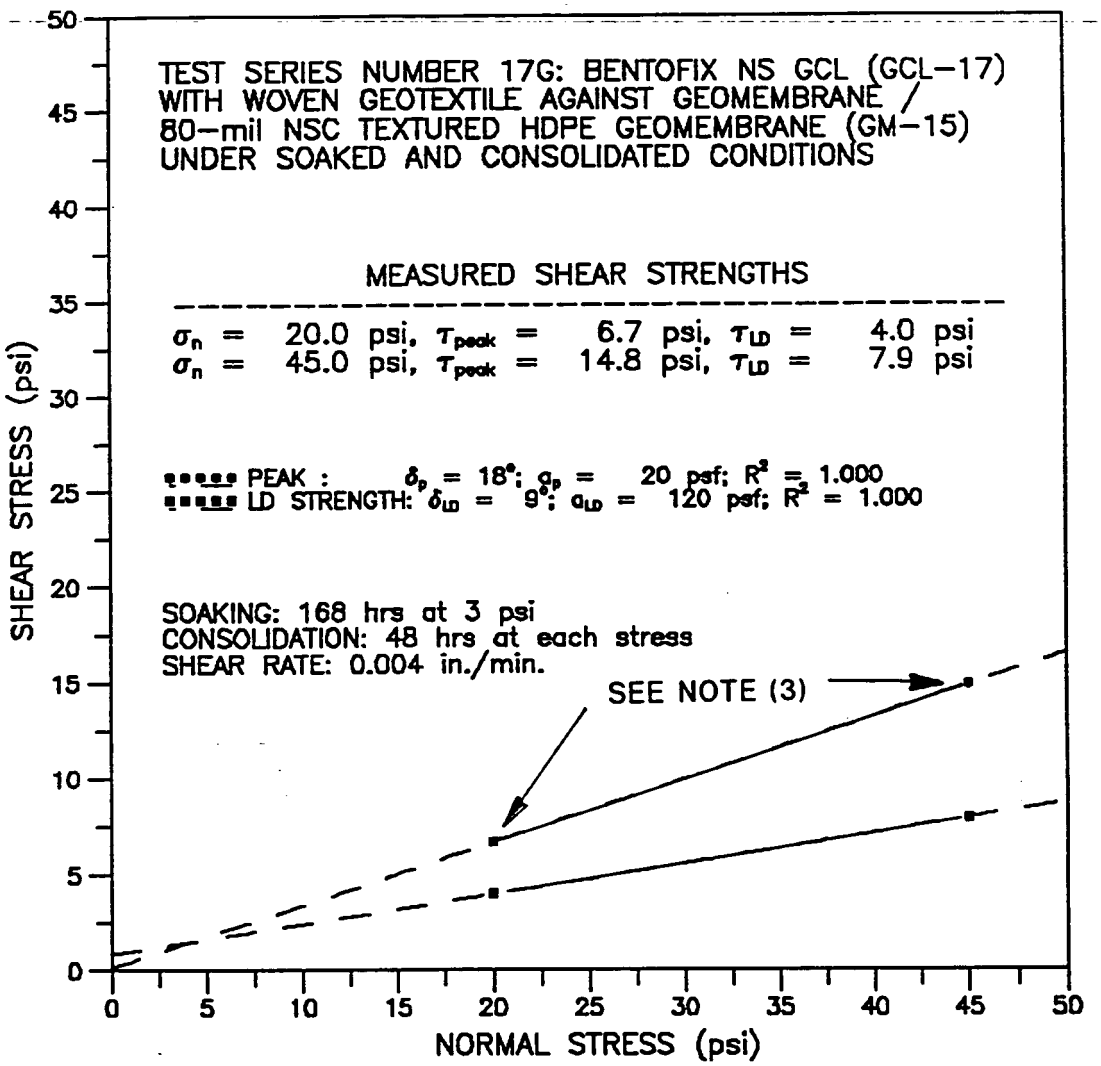
GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	G00166-04.1
DOCUMENT NO.	F9730096
FILE NO.	

9/A

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 4 TO 13 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-4
PROJECT NO.	GO0166-04.1
DOCUMENT NO.	F9730096
FILE NO.	000390

MCD 4 Nov 97

RAM 4 Nov 97

APPENDIX B

Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method by ASTM D 5321

procedure A: Geosynthetic and Geosynthetic Friction

Client: Petro Environmental
Project Name: OSDF Phase 1
Project Location: Fernald, OH

GTX#: 1606
Test Date: 10/10 & 10/13/97
Page: 1 of 2

Test Profile: steel plate with texturing / GCL / steel plate with texturing

Geosynthetic Sample ID & Descriptions: GCL Roll #: 37386

Test Equipment: Top box = 12 in x 12 in; Bottom box = 15 in x 12 in; Load cells and LVDTs connected to data acquisition system for shear force, normal load, and horizontal displacement; Flat plate clamping device; surface area = 144 in²

Test Condition: samples inundated under normal load of 3 psi for seven days, normal load then increased to test conditions for two days prior to shearing

Parameter	Point 1	Point 2	Point 3
Nominal Rate of Horizontal Displacement, in/min	0.004	0.004	—
Normal Compressive Stress, psi	5	20	—
Peak Shear Stress, psi	15.8	16.4	—
Shear Stress @ 2 inches displacement, psi	6.42	5.24	—

Friction Angle: — **degrees**
Cohesion: — **psf**

Comments: Tested By: gpn Checked By: gtt

Shear force vs. displacement plot is presented in Figure 1

Notes: These results apply only to the sample tested for the specific test conditions. The test procedures employed follow accepted industry practice and the indicated test method. GeoTesting Express has no specific knowledge as to conditioning, origin, sampling procedure or intended use of the material.

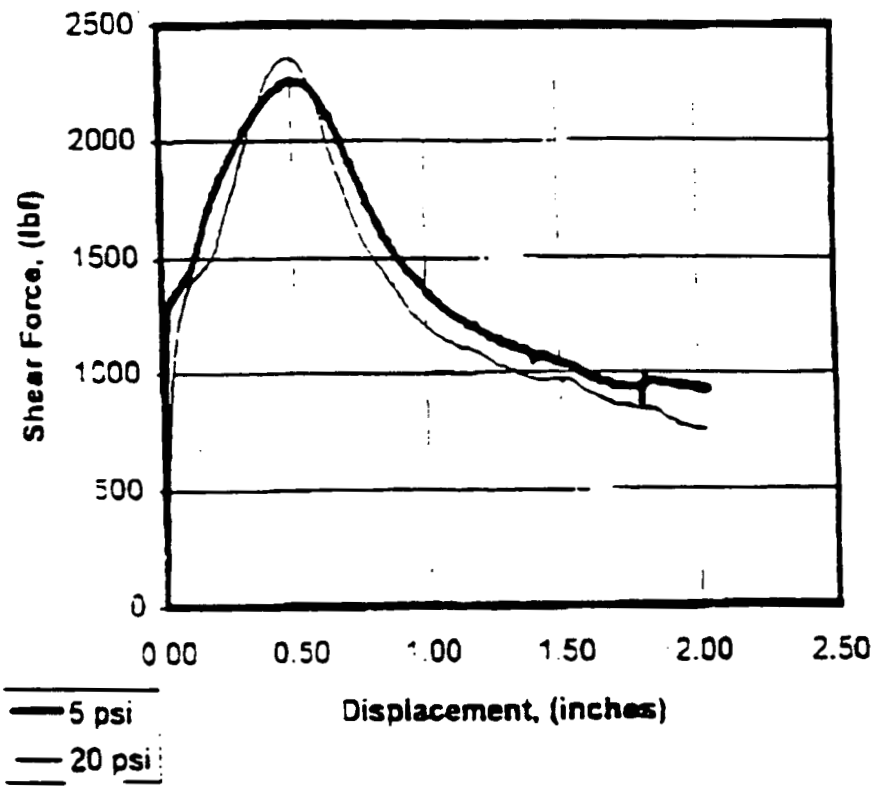
12/94

Direct Shear Test Series by ASTM D 5321

Client: Petro Environmental
Project: OSDF Phase 1
Location: Fernald, OH
Sample ID: GCL Roll # 37386

GTX No: 1606
Test Date: 10/11/97 &10/13/97
Tested by: gpn
Checked by: gtt
Page. 2 of 2

Figure 1. Shear Force vs. Horizontal Displacement



NTH Consultants, Ltd.
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Grand Rapids, MI • (616) 957-1690

JOB Petro-Ferrald Site PROJECT NO 54 7639 SHEET NO. 1
SUBJECT Direct Shear Testing BY KMS DATE 9/29/97
CHK. BY DATE 10/6/97 update

Summary of Test Results

Internal Strength of Hydrated GCL

Peak Strength

Normal Stress (psi)		Measured Shear Strength (psi)	Calculated Secant Angle (°)
Roll #035~~75~~ (571)	.5	3.81	37.3
	.45	17.18	20.9
	.45 (*)	18.06	21.9
# 36844	5 (*)	3.55	35.4
Roll # 36344	20 (*)	9.12	24.5
→ # 37386	45 (*)	18.85	22.7
Roll # 36114	45 (*)	15.76	19.3
Roll # 36344	45 (*)	17.46	21.2
Roll # 036262	45 (*)	14.46	17.8
Roll # 37061	45 (*)	9.20	11.6

Residual Strength @ 2 inches displacement

Normal Stress (psi)		Measured Shear Strength (psi)	Calculated Secant Angle (°)
Roll # 035~~75~~ (571)	5	3.25	33.0
	45	3.10	4.0
	45 (*)	3.98	5.1
# 36844	5 (*)	2.53	26.8
# 36344	20 (*)	2.40	6.9
→ Roll # 37386	45 (*)	4.51	5.7
Roll # 36114	45 (*)	3.35	4.3
Roll # 36344	45 (*)	4.17	5.3
Roll # 036262	45 (*)	3.73	4.7
Roll # 37061	45 (*)	2.92	3.7

(*) Speed for testing = 0.005 inches/minute

other speed = 0.04 inches/minute

PETRO
environmental
technologies

October 24, 1997

Mr. Bill Zebick
Fluor Daniel Fernald
P. O. Box 538704, Mail Stop 64
Cincinnati, Ohio 45253-8704

Letter No. 069

RE: Direct Shear Test Data for
Petro Environmental Samples PET-03 and PET-07
Subcontract No. FSC 597
Petro Environmental Project WC7-024

Dear Mr. Zebick:

Please find attached copies of formal written responses to the shear testing concerns raised in the referenced letter. If beneficial, please do not hesitate to contact, or have GeoSyntec contact either lab. Direct discussions between those well versed in the test procedure may assist in the understanding of the issues.

Lastly, please be aware that Petro Environmental has not sent, and does not intend to send any other samples from this project to either of these labs.

Please do not hesitate to contact me if you should have any question, or require additional information.

Respectfully submitted,

PETRO ENVIRONMENTAL TECHNOLOGIES, INC.

S C Brandstetter

Steven C. Brandstetter
Project Manager

cc: Mike Godber, FDF
Dan Bodine, GeoSyntec
WC7-024 Correspondence

F:\CUR_JOBS\WC7-024\CORRES\FDF-069.DOC

Fernald Site Office PO. Box 538704 • Mail Stop 44 • Cincinnati Ohio 45253-8704 • 513.648.3402 • Fax 648.3407
7851 Palace Drive • Cincinnati Ohio 45249 • 513.489.6789 • Fax 489.7208
8200 Seville Road • Seville, Ohio 44273 • 330.948.1494 • Fax 948.1932

GeoTesting Express
1145 MASSACHUSETTS AVE.
BOXBOROUGH, MA 01719
508-835-0424 (FAX) 508-635-0266

October 23, 1997

Mr. Steve Brandstetter
Petro Environmental Technologies
7851 Palace Drive
Cincinnati, OH 45249

RE: OSDF Phase I (GTX-1606)

Dear Mr Brandstetter:

We have reviewed our test results and confirm that the values reported represent what was measured in the two tests. We agree that the trend of residual strengths for the three normal stresses does not follow the normally expected result of residual strength increasing with normal stress. We think this may be due to problems with the setup of the samples in the large shear box.

Our shear box has a bottom area of 12" x 15" and a top area of 12" x 12". When testing GCLs, we place the GCL over the bottom area. This provides a GCL material for slip to occur on for the full amount of shear box displacement, i.e. 3" As the GCL begins to fail, the top box pulls the upper part of the GCL within the box over the lower part. However the top part of the GCL outside the box does not slip This creates a tendency for the upper part of the GCL outside the moving front of the box to bunch up in front of the box, sometimes called "snow-plowing." We expect that this bunched up GCL material in front of the box adds to the shear force measured at larger displacements. Since this bunched up material lies outside the shear box, the magnitude of the resistive force it contributes is relatively independent of the magnitude of the normal force. This problem should not significantly affect the peak shear stress results.

We have examined the specimens used for the two tests. Both specimens show GCL material bunched up at the front of where the top box was. Both specimens show a distinct shear plane between the bentonite and the bottom geotextile. Additionally, the top geotextile was easily pulled away from the bentonite, indicating that most of the stitching fibers were broken by the shearing process. Based on these observations, we expect that the shear stress we measured at 2 inches of displacement is higher than the residual shear strength of the material.

We don't know what the setup used by the lab for the test at 45 psi was. Based on their results, we expect that their box tested a 12" x 12" sample and did not experience snow-plowing.

We are not clear on the reason for rejection of the material. Usually materials are not rejected because the shear strength is too high. We do not believe that a problem associated with the mechanical aspects of the shear box should necessarily result in a rejection of the material We will do whatever we can to help resolve this issue. We can discuss the matter directly with GeoSyntec if you think it worthwhile.

Respectfully yours,

Gary T. Torosian

Gary T. Torosian
Laboratory Manager

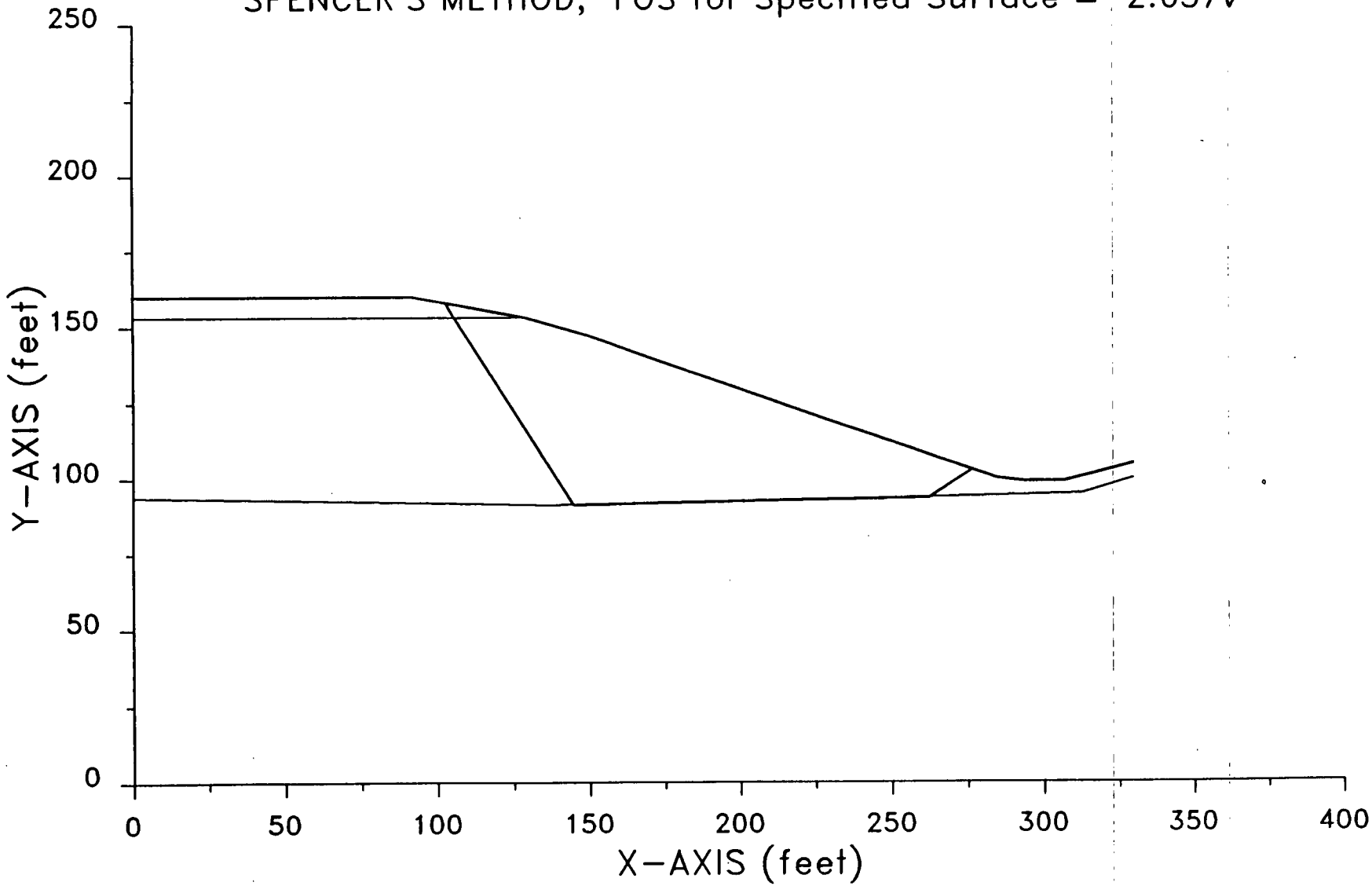
Totally Automated
Geotechnical Testing

MCO 4 NOV 97
RAM 4 NOV 1997

APPENDIX C

NPPK17AS 10-17-97 19:42

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.657✓



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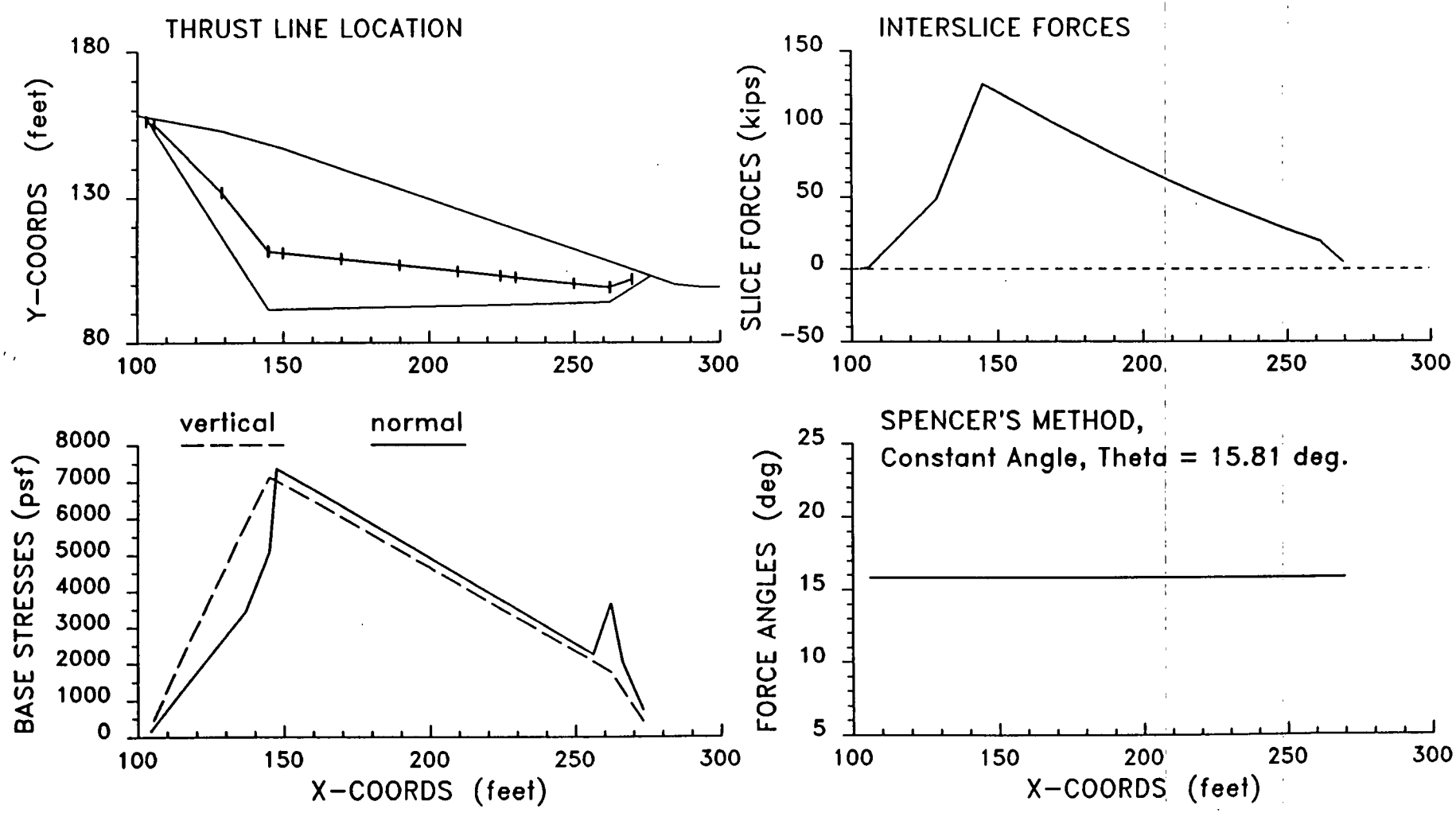

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.657

000399

12669

XSTABL File: NPPK17AS 10-17-97 19:42

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
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*  Ver. 5.201                 96 á 1202 *
*****************************************
```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	1123.2
4	2880.0	1836.0
5	6480.0	2408.4
6	10080.0	2408.4

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	276.60	102.91
2	262.53	93.95
3	262.32	93.75
4	224.80	93.00
5	145.16	91.36
6	144.95	91.57
7	105.81	153.00
8	102.97	157.92

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	273.30	100.81	3.25	6.60	-32.50	19.12	2678.
2	266.27	96.33	10.18	7.47	-32.50	19.29	9504.
3	262.42	93.85	14.00	.21	-43.60	19.29	368.
4	256.16	93.63	16.42	12.32	-1.15	19.29	25282.
5	240.00	93.30	22.35	20.00	-1.15	19.03	55865.
6	227.40	93.05	26.96	5.20	-1.15	19.29	17523.
7	217.40	92.85	30.66	14.80	-1.18	19.29	56725.
8	200.00	92.49	37.11	20.00	-1.18	19.29	92777.
9	180.00	92.08	44.47	20.00	-1.18	19.03	111181.
10	160.00	91.67	51.83	20.00	-1.18	19.29	129586.
11	147.58	91.41	56.28	4.84	-1.18	15.95	34050.
12	145.05	91.47	56.95	.21	45.00	15.95	1505.
13	136.97	104.09	46.63	15.95	57.50	15.95	92968.
14	117.40	134.80	20.39	23.19	57.50	10.71	59111.
15	104.39	155.46	2.19	2.84	60.03	10.71	779.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	15.7319	2.6640	2.7534
3	15.8350	2.6689	2.6640
4	15.8322	2.6687	2.6689

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	15.8108	2.6565	2.6575

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	15.8108	2.6565	2.6575

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	721.8	200.0	25.00	0.	0.	0.	.00
2	2038.5	200.0	25.00	0.	0.	0.	.00
3	3643.1	1378.1	9.03	0.	0.	0.	.00
4	2250.7	885.6	18.26	0.	0.	0.	.00
5	3022.5	1378.1	9.03	0.	0.	0.	.00
6	3613.0	1378.1	9.03	0.	0.	0.	.00
7	4088.6	1378.1	9.03	0.	0.	0.	.00
8	4914.4	1378.1	9.03	0.	0.	0.	.00
9	5857.3	1378.1	9.03	0.	0.	0.	.00
10	6794.3	2408.4	.00	0.	0.	0.	.00
11	7353.5	2408.4	.00	0.	0.	0.	.00
12	5087.7	1378.1	9.03	0.	0.	0.	.00
13	3432.1	200.0	25.00	0.	0.	0.	.00
14	1468.1	200.0	25.00	0.	0.	0.	.00
15	151.9	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	273.30	721.8	405.7	.0	202.0
2	266.27	2038.5	1272.3	.0	433.1
3	262.42	3643.1	1750.2	.0	736.8
4	256.16	2250.7	2052.1	.0	613.0
5	240.00	3022.5	2793.3	.0	699.7
6	227.40	3613.0	3369.8	.0	735.0
7	217.40	4088.6	3832.8	.0	763.5
8	200.00	4914.4	4638.8	.0	812.9
9	180.00	5857.3	5559.1	.0	869.3
10	160.00	6794.3	6479.3	.0	906.6
11	147.58	7353.5	7035.2	.0	906.6
12	145.05	5087.7	7118.4	.0	823.3
13	136.97	3432.1	5829.2	.0	677.7
14	117.40	1468.1	2549.0	.0	333.0
15	104.39	151.9	274.2	.0	33.0

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	270.00	15.81	4539.	3.04	6.49	.468
2	262.53	15.81	17982.	5.07	13.86	.366
3	262.32	15.81	18900.	5.08	14.14	.359
4	250.00	15.81	27325.	6.67	18.70	.357
5	230.00	15.81	43124.	9.18	26.00	.353
6	224.80	15.81	47487.	9.84	27.92	.353
7	210.00	15.81	60525.	11.73	33.40	.351
8	190.00	15.81	79526.	14.28	40.82	.350

9	170.00	15.81	100104.	16.80	48.13	.349
10	150.00	15.81	121857.	19.33	55.54	.348
11	145.16	15.81	127179.	19.96	57.02	.350
12	144.95	15.81	126242.	19.96	56.87	.351
13	129.00	15.81	48189.	15.15	36.40	.416
14	105.81	15.81	678.	2.06	4.39	.470
15	102.97	.00	-2.	-1.90	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3506.83 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 626.36 (psf)

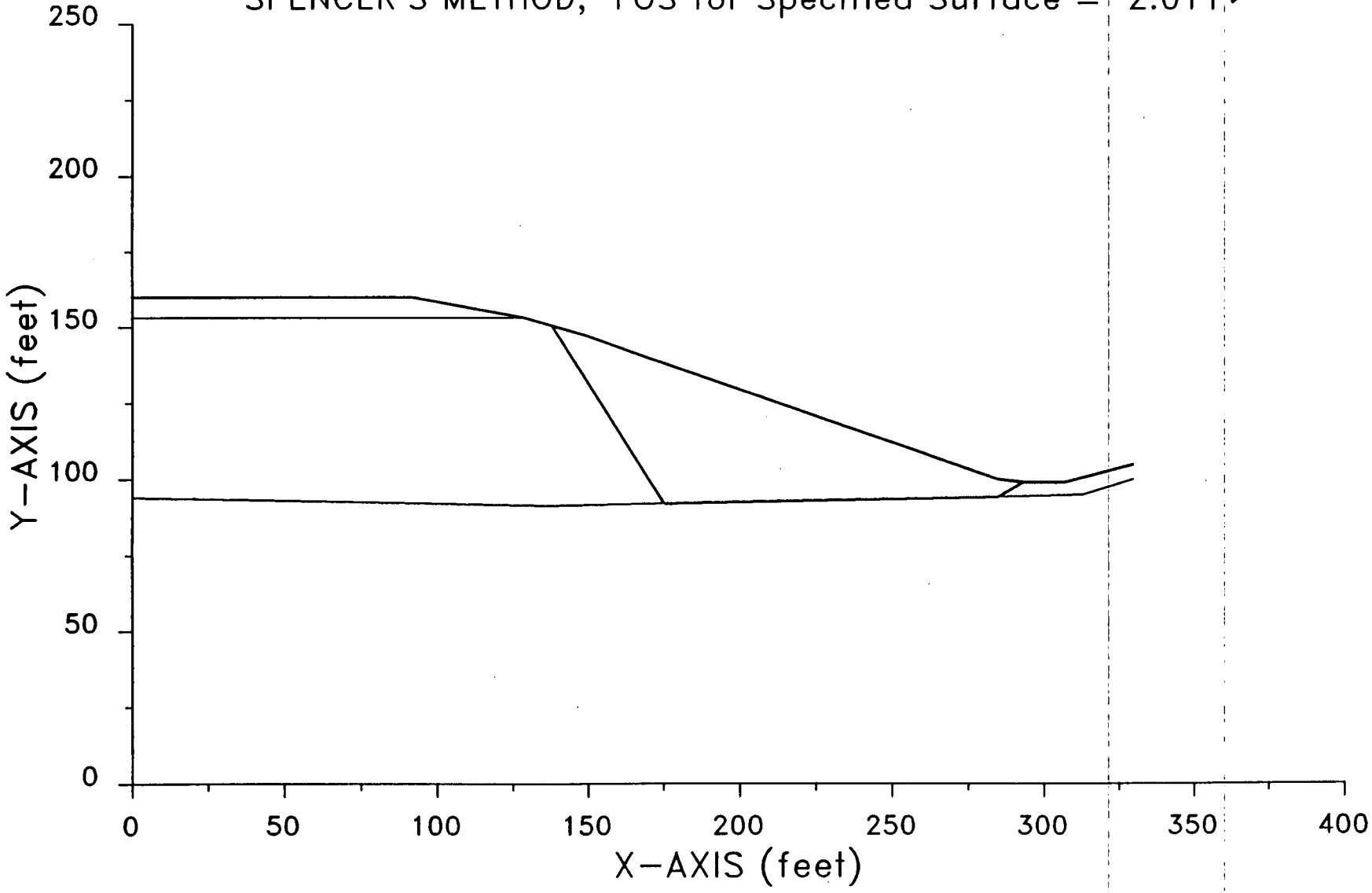
Total Length of failure surface = 212.98 feet

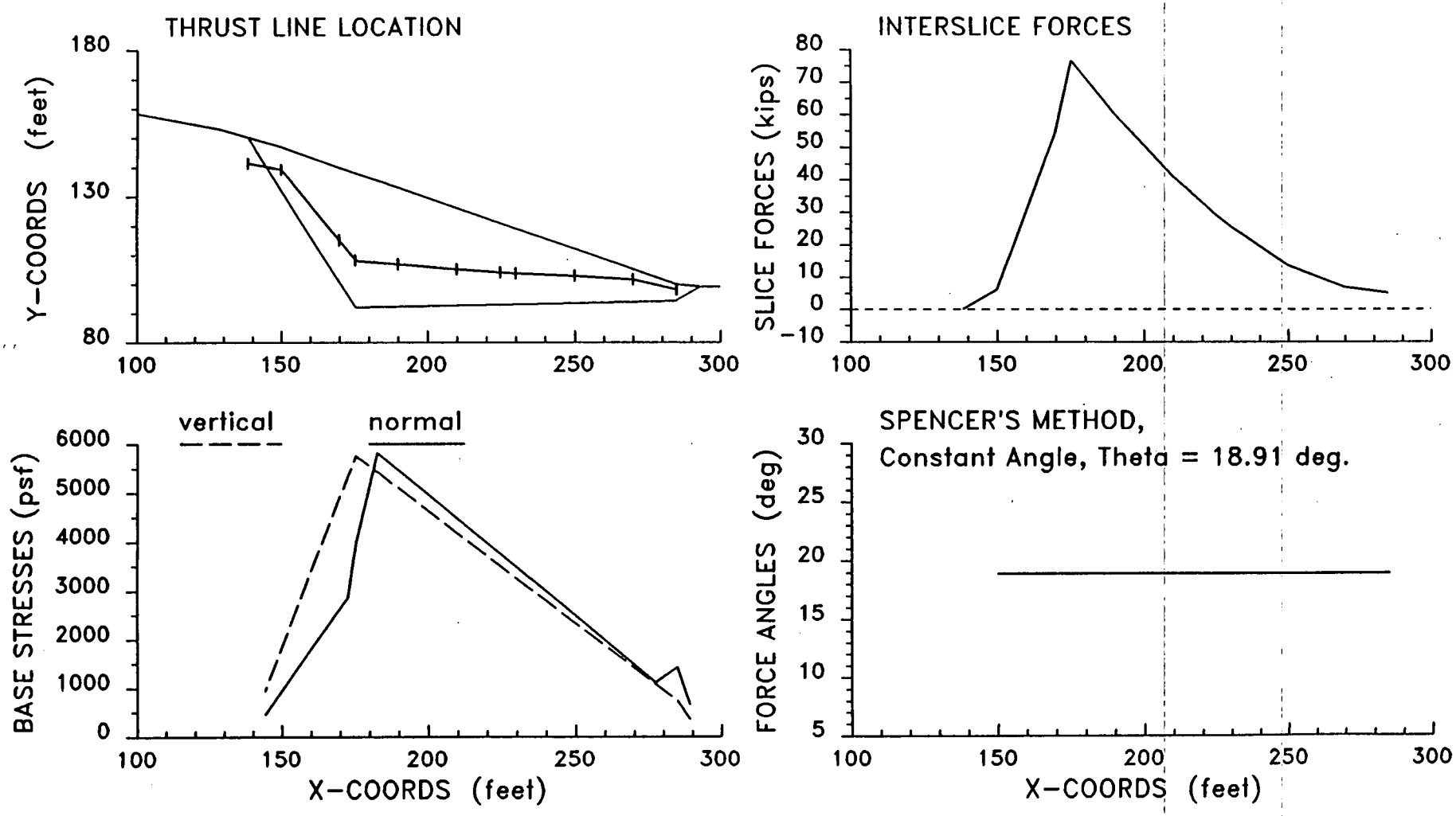
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.657

Total shear strength available along specified failure surface = 354.38E+03 lb

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.011





OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.011

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*                                       *
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*               using the               *
*            Method of Slices           *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	964.8
5	6480.0	2131.2
6	10080.0	2131.2

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 7 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	293.27	99.08
2	285.17	94.40
3	284.97	94.20
4	224.80	93.00
5	175.56	92.03
6	175.40	92.19
7	138.37	150.32

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	289.22	96.74	2.79	8.10	-30.02	6.34	2825.
2	285.09	94.31	5.68	.17	-45.00	6.34	121.
3	284.98	94.21	5.79	.03	-45.00	19.12	22.
4	277.48	94.05	8.55	14.97	-1.14	19.12	16008.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37495.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55867.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.13	19.29	56713.
9	200.00	92.51	37.09	20.00	-1.13	19.29	92721.
10	182.78	92.17	43.42	14.44	-1.13	19.03	78371.
11	175.48	92.11	46.00	.16	45.00	19.03	931.
12	172.70	96.43	42.64	5.40	57.50	19.03	28771.
13	160.00	116.37	27.13	20.00	57.50	19.29	67834.
14	144.18	141.19	7.47	11.63	57.50	15.95	10856.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.9483	2.0138	1.9951
3	18.9348	2.0134	2.0138

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.9063	2.0111	2.0119

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	18.9063	2.0111	2.0119

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	648.6	.0	30.00	0.	0.	0.	.00

2	1376.8	-321.6	24.07	0.	0.	0.	.00
3	1416.7	-321.6	24.07	0.	0.	0.	.00
4	1108.1	-321.6	24.07	0.	0.	0.	.00
5	1990.6	-321.6	24.07	0.	0.	0.	.00
6	2994.4	31.7	17.95	0.	0.	0.	.00
7	3611.0	31.7	17.95	0.	0.	0.	.00
8	4104.9	31.7	17.95	0.	0.	0.	.00
9	4965.0	31.7	17.95	0.	0.	0.	.00
10	5811.4	31.7	17.95	0.	0.	0.	.00
11	3962.6	31.7	17.95	0.	0.	0.	.00
12	2857.8	200.0	25.00	0.	0.	0.	.00
13	1794.3	200.0	25.00	0.	0.	0.	.00
14	445.3	200.0	25.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	289.22	648.6	348.8	.0	186.2
2	285.09	1376.8	709.4	.0	145.9
3	284.98	1416.7	723.8	.0	154.7
4	277.48	1108.1	1069.3	.0	86.2
5	260.00	1990.6	1874.7	.0	282.2
6	240.00	2994.4	2793.4	.0	498.2
7	227.40	3611.0	3369.8	.0	597.5
8	217.40	4104.9	3832.0	.0	677.1
9	200.00	4965.0	4636.1	.0	815.7
10	182.78	5811.4	5427.3	.0	952.0
11	175.48	3962.6	5749.8	.0	654.2
12	172.70	2857.8	5329.8	.0	762.1
13	160.00	1794.3	3391.7	.0	515.5
14	144.18	445.3	933.4	.0	202.7

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.17	18.91	4803.	3.73	5.58	.668
2	285.00	18.91	5077.	3.75	5.77	.650
3	284.97	18.91	5127.	3.75	5.81	.646
4	270.00	18.91	6841.	7.56	11.30	.669
5	250.00	18.91	13646.	9.23	18.70	.494
6	230.00	18.91	25440.	10.52	26.00	.405
7	224.80	18.91	29120.	10.96	27.92	.392
8	210.00	18.91	40978.	12.37	33.39	.371
9	190.00	18.91	60289.	14.49	40.79	.355
10	175.56	18.91	76567.	16.09	46.05	.349
11	175.40	18.91	76001.	16.10	45.95	.350
12	170.00	18.91	54750.	14.44	39.33	.367
13	150.00	18.91	6099.	7.14	14.93	.478

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14	138.37	.00	-3.	-9.02	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 2611.96 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 495.52 (psf)

Total Length of failure surface = 188.22 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.011

Total shear strength available along specified failure surface = 187.57E+03 lb

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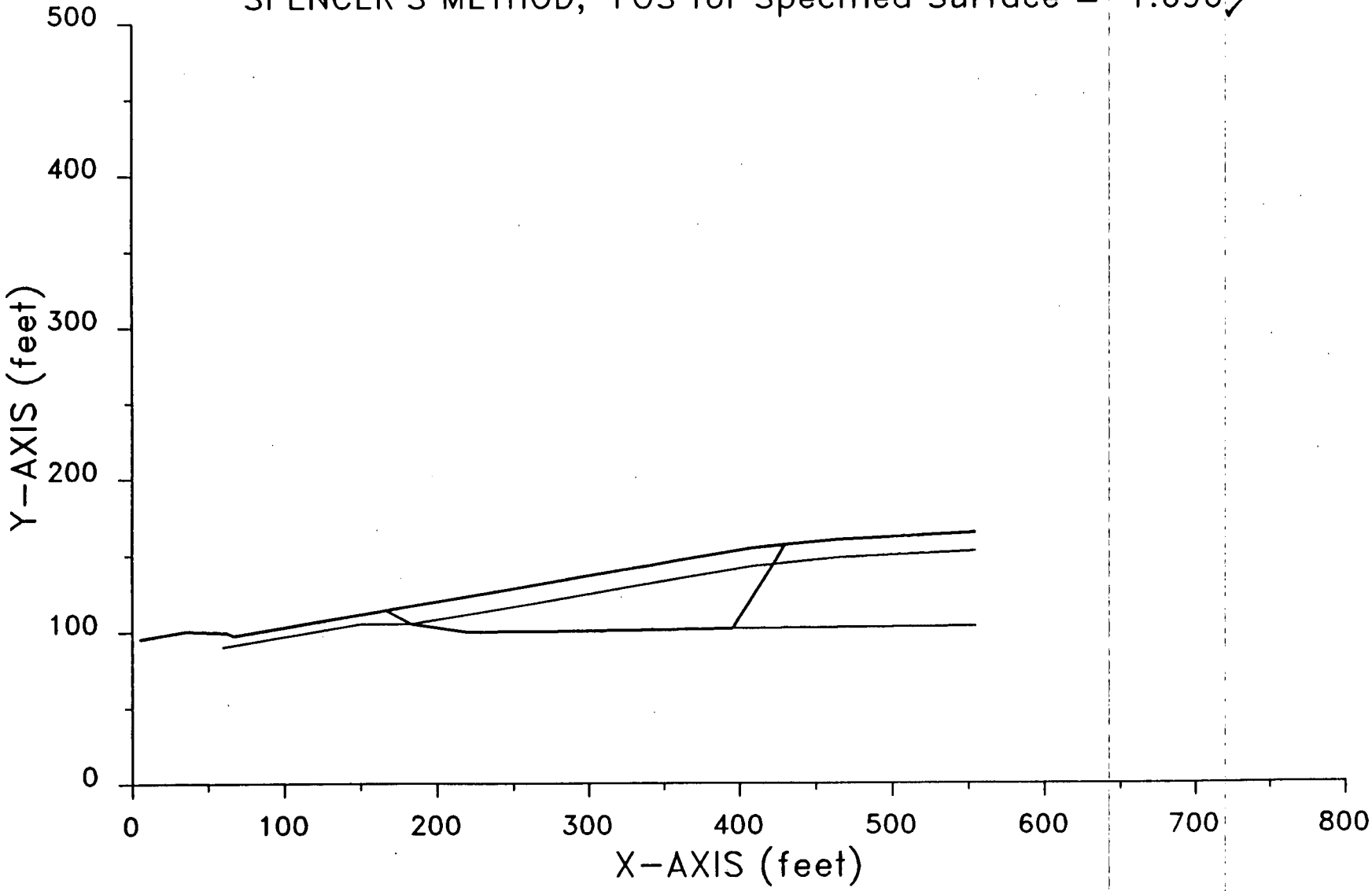
OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.696



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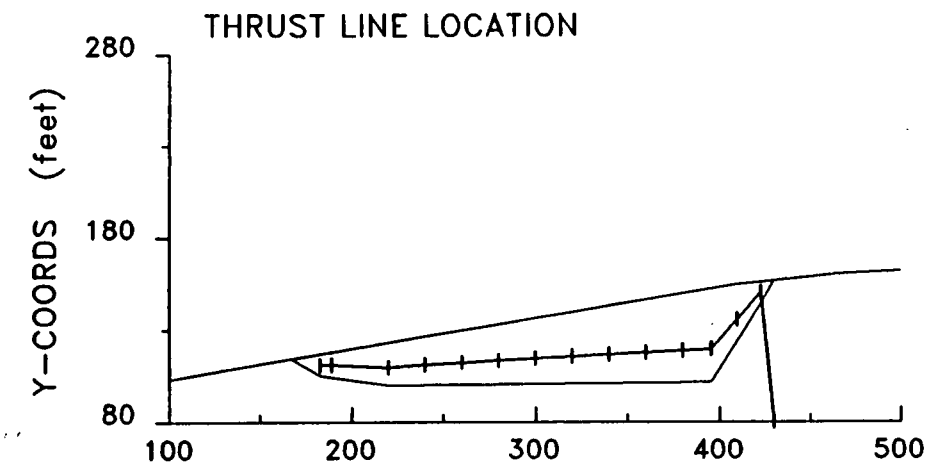

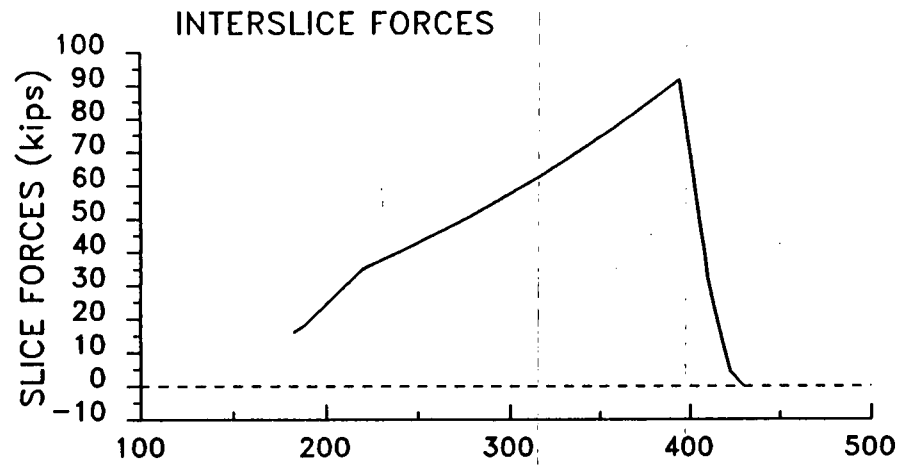

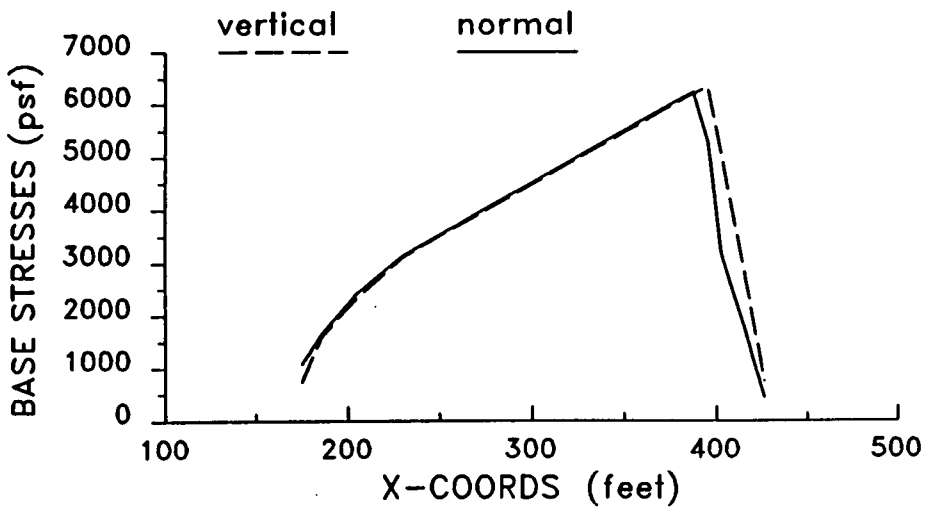

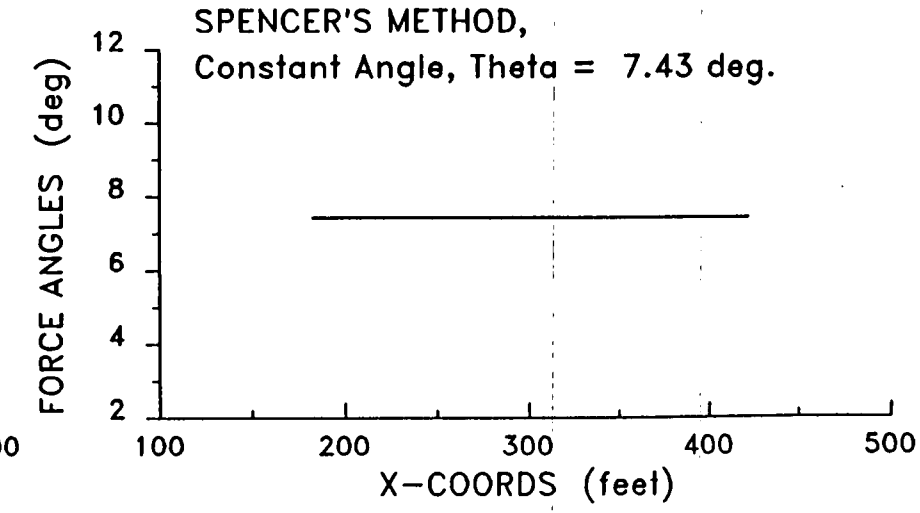

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.696 ✓

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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```

Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters

---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	446.4
5	6480.0	807.1
6	10080.0	807.1

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	395.62	101.61
6	395.86	101.85
7	422.77	144.08
8	430.06	156.71

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.61	9.37	93361.
9	330.00	100.92	40.43	20.00	.61	9.37	101083.
10	350.00	101.13	43.57	20.00	.61	9.65	108930.
11	370.00	101.34	46.71	20.00	.61	9.37	116777.
12	387.81	101.53	49.47	15.62	.61	9.46	96598.
13	395.74	101.73	50.59	.24	45.00	9.46	1518.
14	402.93	112.94	40.58	14.14	57.49	9.46	71719.
15	416.39	134.06	21.28	12.77	57.49	5.71	33966.
16	426.41	150.39	5.95	7.29	60.00	5.71	5421.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.3408	1.6940	1.7404
3	7.4304	1.6962	1.6940
4	7.4283	1.6961	1.6962

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.4283	1.6961	1.6962

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1081.7	.0	30.00	0.	0.	0.	.00

2	1655.6	-148.8	11.68	0.	0.	0.	.00
3	2404.4	-148.8	11.68	0.	0.	0.	.00
4	3129.4	157.8	5.72	0.	0.	0.	.00
5	3525.4	157.8	5.72	0.	0.	0.	.00
6	3915.2	157.8	5.72	0.	0.	0.	.00
7	4311.2	157.8	5.72	0.	0.	0.	.00
8	4706.0	157.8	5.72	0.	0.	0.	.00
9	5094.3	157.8	5.72	0.	0.	0.	.00
10	5488.9	157.8	5.72	0.	0.	0.	.00
11	5883.5	157.8	5.72	0.	0.	0.	.00
12	6230.9	157.8	5.72	0.	0.	0.	.00
13	5283.0	157.8	5.72	0.	0.	0.	.00
14	3169.7	.0	25.00	0.	0.	0.	.00
15	1662.2	.0	25.00	0.	0.	0.	.00
16	419.9	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1081.7	739.6	.0	368.2
2	186.00	1655.6	1594.4	.0	114.0
3	204.50	2404.4	2304.8	.0	205.2
4	230.00	3129.4	3100.0	.0	277.9
5	250.00	3525.4	3493.8	.0	301.3
6	270.00	3915.2	3881.3	.0	324.3
7	290.00	4311.2	4275.0	.0	347.7
8	310.00	4706.0	4668.0	.0	371.1
9	330.00	5094.3	5054.1	.0	394.0
10	350.00	5488.9	5446.5	.0	417.3
11	370.00	5883.5	5838.8	.0	440.6
12	387.81	6230.9	6184.3	.0	461.1
13	395.74	5283.0	6324.2	.0	405.1
14	402.93	3169.7	5072.1	.0	871.4
15	416.39	1662.2	2659.8	.0	457.0
16	426.41	419.9	743.6	.0	142.9

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.43	15922.	5.63	11.83	.476
2	189.00	7.43	18019.	6.50	13.68	.476
3	220.00	7.43	35000.	9.71	23.20	.418
4	240.00	7.43	39974.	10.76	26.40	.407
5	260.00	7.43	45340.	11.75	29.50	.398
6	280.00	7.43	51092.	12.70	32.60	.389
7	300.00	7.43	57236.	13.61	35.80	.380
8	320.00	7.43	63718.	14.50	38.89	.373
9	340.00	7.43	70579.	15.37	41.98	.366

10	360.00	7.43	77826.	16.22	45.17	.359
11	380.00	7.43	85460.	17.06	48.25	.354
12	395.62	7.43	91687.	17.71	50.69	.349
13	395.86	7.43	90506.	17.73	50.49	.351
14	410.00	7.43	32002.	11.20	30.66	.365
15	422.77	7.43	4295.	5.84	11.90	.491
16	430.06	.00	0.	-91.36	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3558.07 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 386.63 (psf)

Total Length of failure surface = 296.35 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

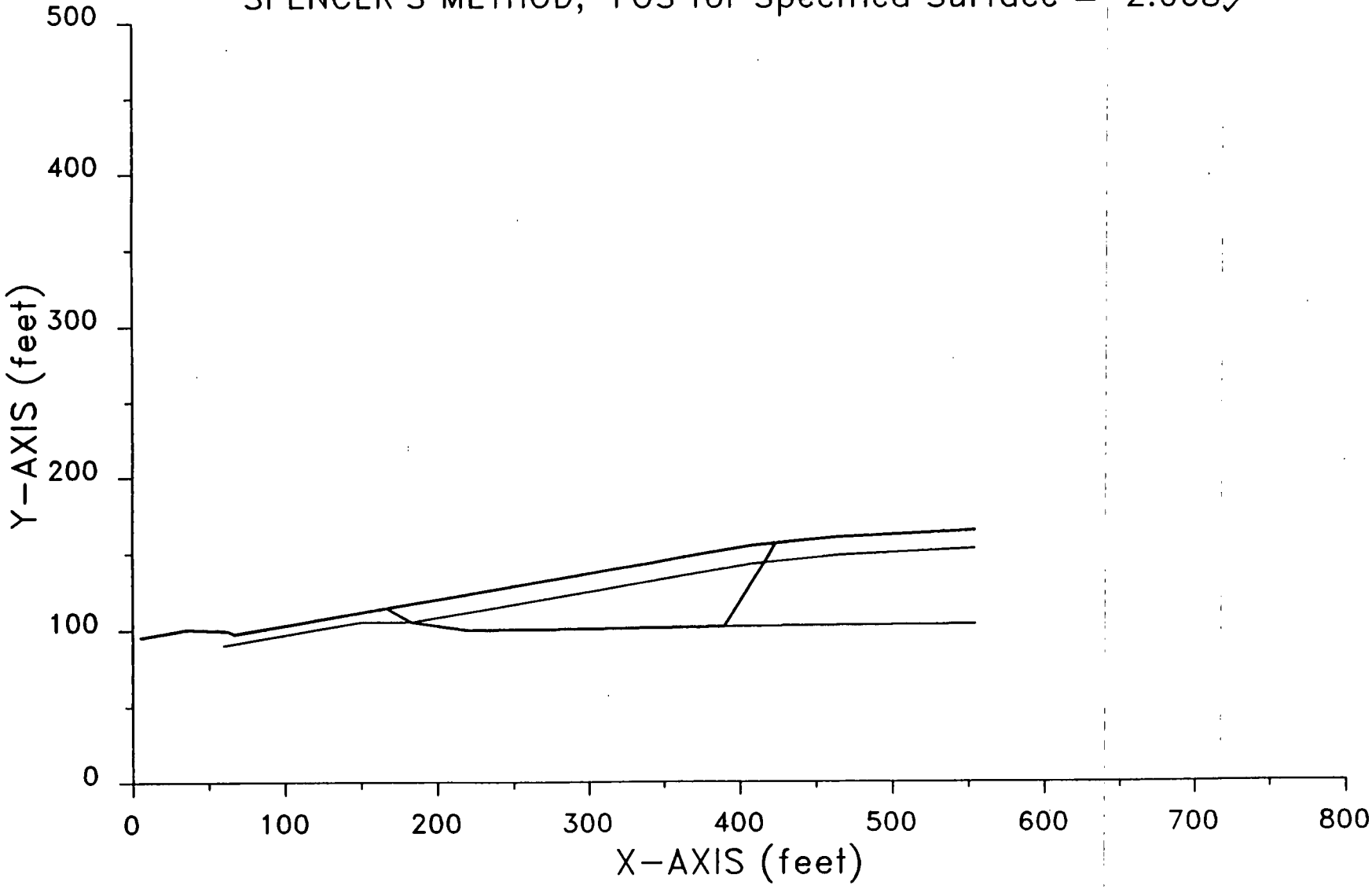
FACTOR OF SAFETY = 1.696 ✓

Total shear strength available along specified failure surface = 194.34E+03 lb

NLDT7BS 10-16-97 11:44

OSDF Final Long Term – Large Displ.

SPENCER'S METHOD, FOS for Specified Surface = 2.068



12669

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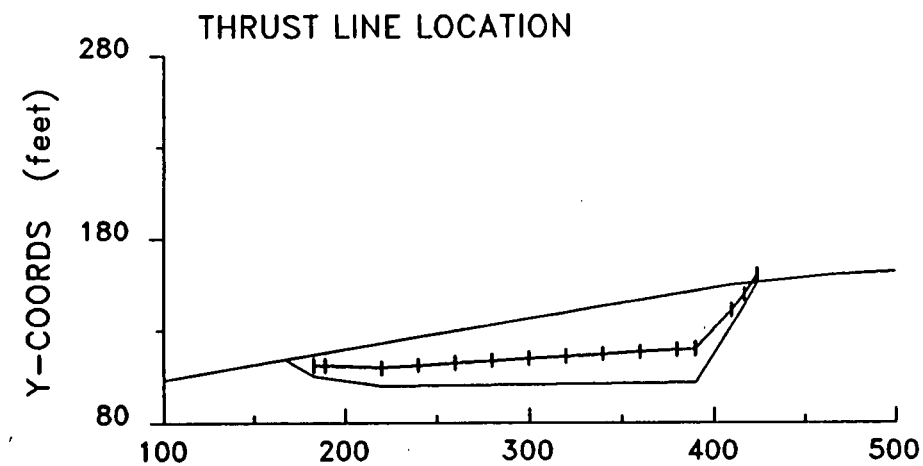

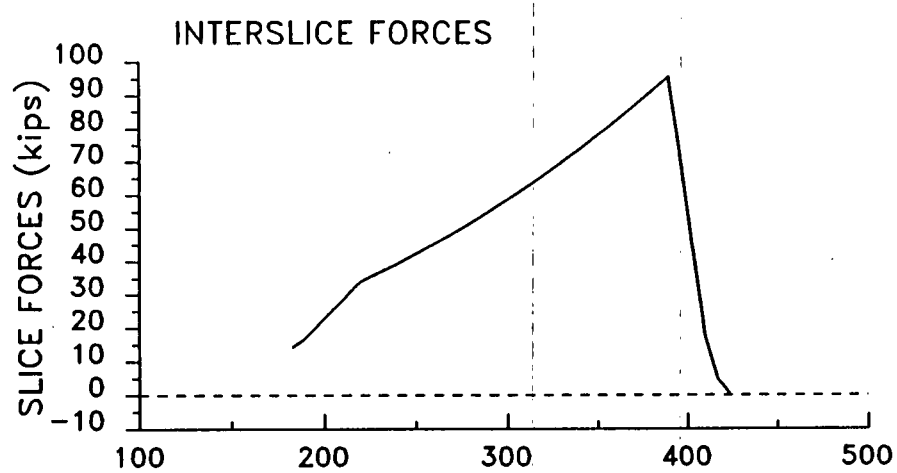

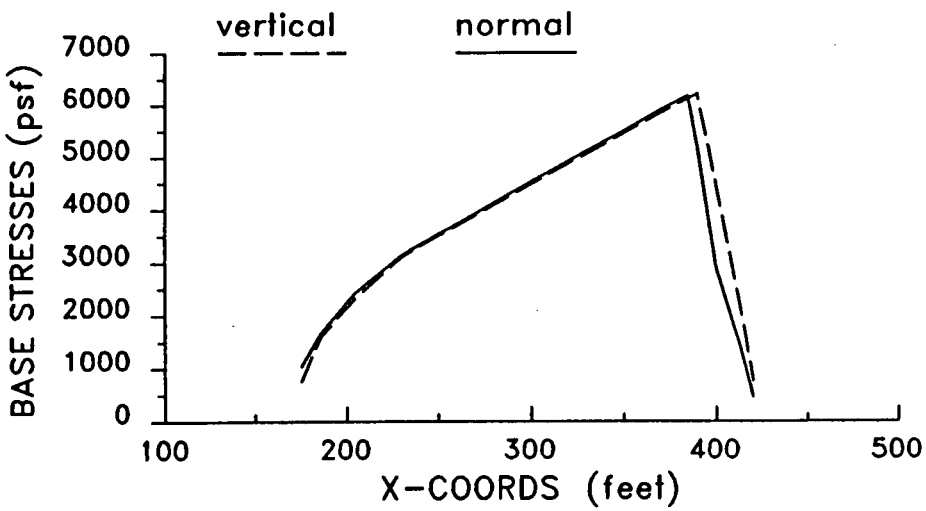

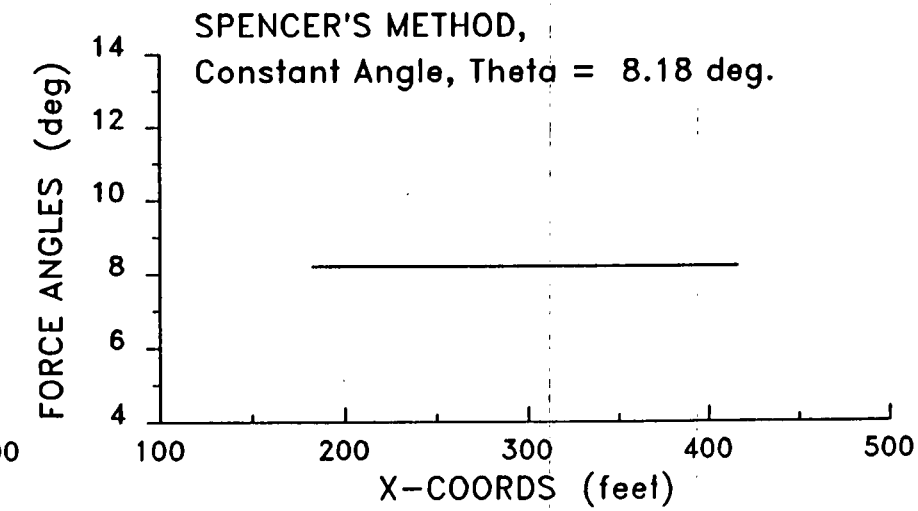

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.068 ✓

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3/4

000420

XSTABL File: NLD17BS 10-16-97 11:44

```
*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
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*                                       *
*  Ver. 5.201                 96 á 1202 *
*****************************************
```

Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters

---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	576.0
5	6480.0	1137.6
6	10080.0	1137.6

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	390.11	101.63
6	390.27	101.78
7	416.83	143.48
8	424.12	156.11

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.65	9.37	93339.
9	330.00	100.94	40.41	20.00	.65	9.37	101018.
10	350.00	101.17	43.53	20.00	.65	9.65	108821.
11	370.00	101.40	46.65	20.00	.65	9.37	116625.
12	385.05	101.57	48.97	10.11	.65	9.46	61886.
13	390.19	101.71	49.69	.16	43.15	9.46	1013.
14	400.14	117.27	35.79	19.73	57.51	9.46	88242.
15	413.42	138.12	16.92	6.83	57.51	5.71	14451.
16	420.48	149.80	5.95	7.29	60.01	5.71	5420.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	8.1291	2.0661	2.1036
3	8.1864	2.0679	2.0661
4	8.1850	2.0679	2.0679

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	8.1850	2.0679	2.0679

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1033.6	.0	30.00	0.	0.	0.	.00

2	1662.5	-192.0	14.93	0.	0.	0.	.00
3	2415.8	-192.0	14.93	0.	0.	0.	.00
4	3135.3	126.7	8.87	0.	0.	0.	.00
5	3532.5	126.7	8.87	0.	0.	0.	.00
6	3923.4	126.7	8.87	0.	0.	0.	.00
7	4320.6	126.7	8.87	0.	0.	0.	.00
8	4714.4	126.7	8.87	0.	0.	0.	.00
9	5101.6	126.7	8.87	0.	0.	0.	.00
10	5495.0	126.7	8.87	0.	0.	0.	.00
11	5888.5	126.7	8.87	0.	0.	0.	.00
12	6181.0	126.7	8.87	0.	0.	0.	.00
13	5158.4	126.7	8.87	0.	0.	0.	.00
14	2890.7	.0	25.00	0.	0.	0.	.00
15	1366.9	.0	25.00	0.	0.	0.	.00
16	439.3	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1033.6	739.6	.0	288.6
2	186.00	1662.5	1594.4	.0	121.5
3	204.50	2415.8	2304.8	.0	218.7
4	230.00	3135.3	3100.0	.0	297.8
5	250.00	3532.5	3493.8	.0	327.8
6	270.00	3923.4	3881.3	.0	357.3
7	290.00	4320.6	4275.0	.0	387.2
8	310.00	4714.4	4667.0	.0	416.9
9	330.00	5101.6	5050.9	.0	446.1
10	350.00	5495.0	5441.1	.0	475.8
11	370.00	5888.5	5831.2	.0	505.5
12	385.05	6181.0	6121.3	.0	527.6
13	390.19	5158.4	6211.5	.0	450.4
14	400.14	2890.7	4473.2	.0	651.9
15	413.42	1366.9	2115.2	.0	308.2
16	420.48	439.3	743.7	.0	122.7

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	8.18	14226.	5.73	11.83	.485
2	189.00	8.18	16379.	6.58	13.68	.481
3	220.00	8.18	33861.	9.72	23.20	.419
4	240.00	8.18	39245.	10.88	26.40	.412
5	260.00	8.18	45155.	11.96	29.50	.405
6	280.00	8.18	51581.	12.98	32.60	.398
7	300.00	8.18	58532.	13.95	35.80	.390
8	320.00	8.18	65867.	14.90	38.87	.383
9	340.00	8.18	73704.	15.82	41.94	.377

10	360.00	8.18	82049.	16.73	45.11	.371
11	380.00	8.18	90903.	17.61	48.19	.366
12	390.11	8.18	95570.	18.06	49.75	.363
13	390.27	8.18	94848.	18.07	49.63	.364
14	410.00	8.18	17387.	7.76	21.94	.353
15	416.83	8.18	4702.	5.79	11.90	.487
16	424.12	.00	0.	3.85	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3518.02 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 386.97 (psf)

Total Length of failure surface = 290.09 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.068

Total shear strength available along specified failure surface = 232.13E+03 lb

GCL 18

COMPUTATION COVER SHEET

1269

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 18 - Compliance Package

Computations By:
(Cognizant Engineer)

Signature [signature] Date DEC 19/1997

Printed Name and Title MARIA CATALINA GROZCO
STAFF ENGINEER

Assumptions and Procedures
Checked By:
(Checker)

Signature [signature] Date 19 DEC 1997

Printed Name and Title ROBERT A. MORGAN III
SR. STAFF ENGINEER

Computations
Checked by:

Signature [signature] Date 19 DEC 1997

Printed Name and Title ROBERT A. MORGAN III
SR. STAFF ENGINEER

Computations Backchecked by:
(Cognizant Engineer)

Signature [signature] Date DEC 19/1997

Printed Name and Title MARIA CATALINA GROZCO
STAFF ENGINEER

Approved by:
(PDP)

Signature [signature] Date 19 Dec 97

Printed Name and Title Gary R. Schmertmann
Sr. Project Engineer

Approved by:
(DTL and TETL)

Signature [signature] Date 20 Dec 97

Printed Name and Title Kenneth W. Cargill
Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

000427

Written By: MCD Date: 12/19/97 Reviewed by: RAM Date: 12/19/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0409 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 18 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 18 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample No.	Case	Test Type	Measured Shear Strengths		
			5 psi	20 psi	45 psi
18	Peak	GCL Internal	0 psi[1]	11.2 psi	14.3 psi
		GCL/GMB Interface	2.0	7.2	11.1
18	Large-displacement	GCL Internal	0[1]	2.5	5.5
		GCL/GMB Interface	1.6	4.6	5.6

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix B.

QA Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
18	GCL Internal	NPK18AS	2.3	YES
	GCL/GMB Interface	NPK18BS	1.9	YES
Baseline	Large-displacement	NA	1.6	NA
18	GCL Internal	NLD18AS	1.6	YES
	GCL/GMB Interface	NLD18BS	1.9	YES

[1] Internal shear strength values for QA sample 18 at 5 psi normal stress were not available at the time that this calculation package was prepared. These values were assumed to equal zero. This assumption is conservative in the context of RCI 1702-006R.

HCO DEC 19 /97
RAM 19 DEC 97

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 181

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-18). GCL's initial moisture content was 9.4%. GCL's final moisture content ranged from 67% to 78% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20 and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 18G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

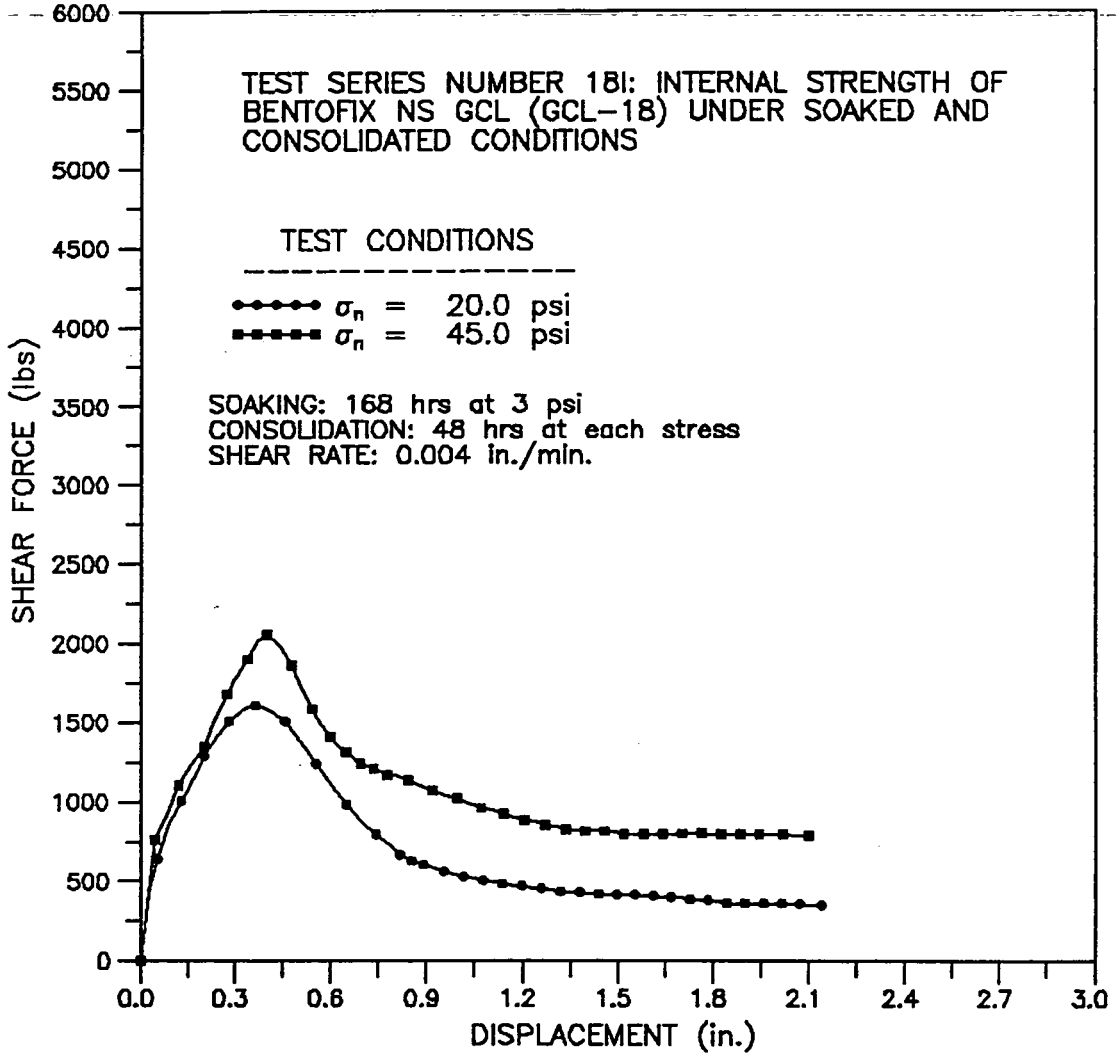
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-18) with woven geotextile against geomembrane. GCL's initial moisture content was 9.3%. GCL's final moisture content ranged from 87 to 108% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-14); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.

(2) For each test, sliding (i.e., internal shear failure) was observed to occur within the GCL.

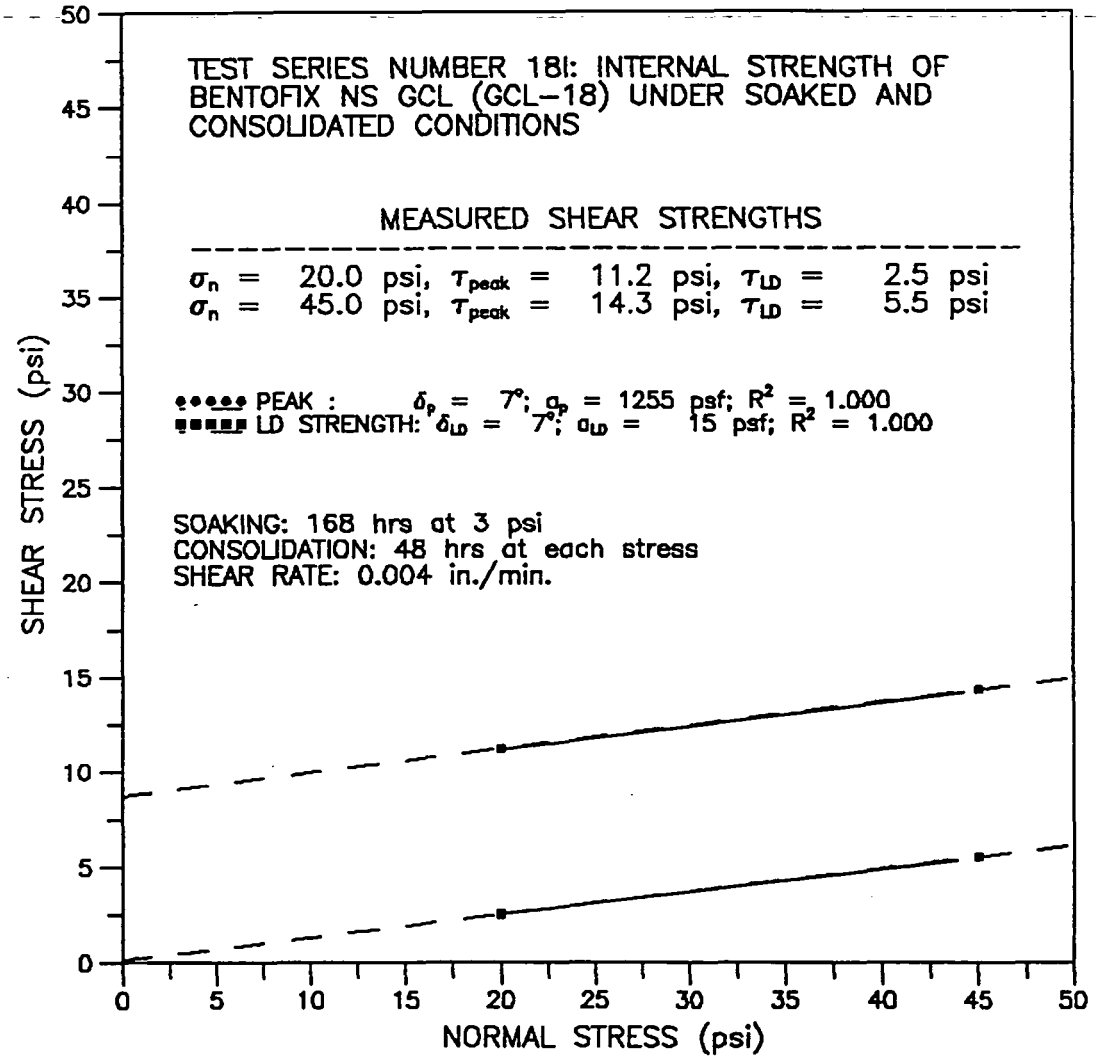
DATE TESTED: 22 TO 31 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730137
FILE NO.	000432

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



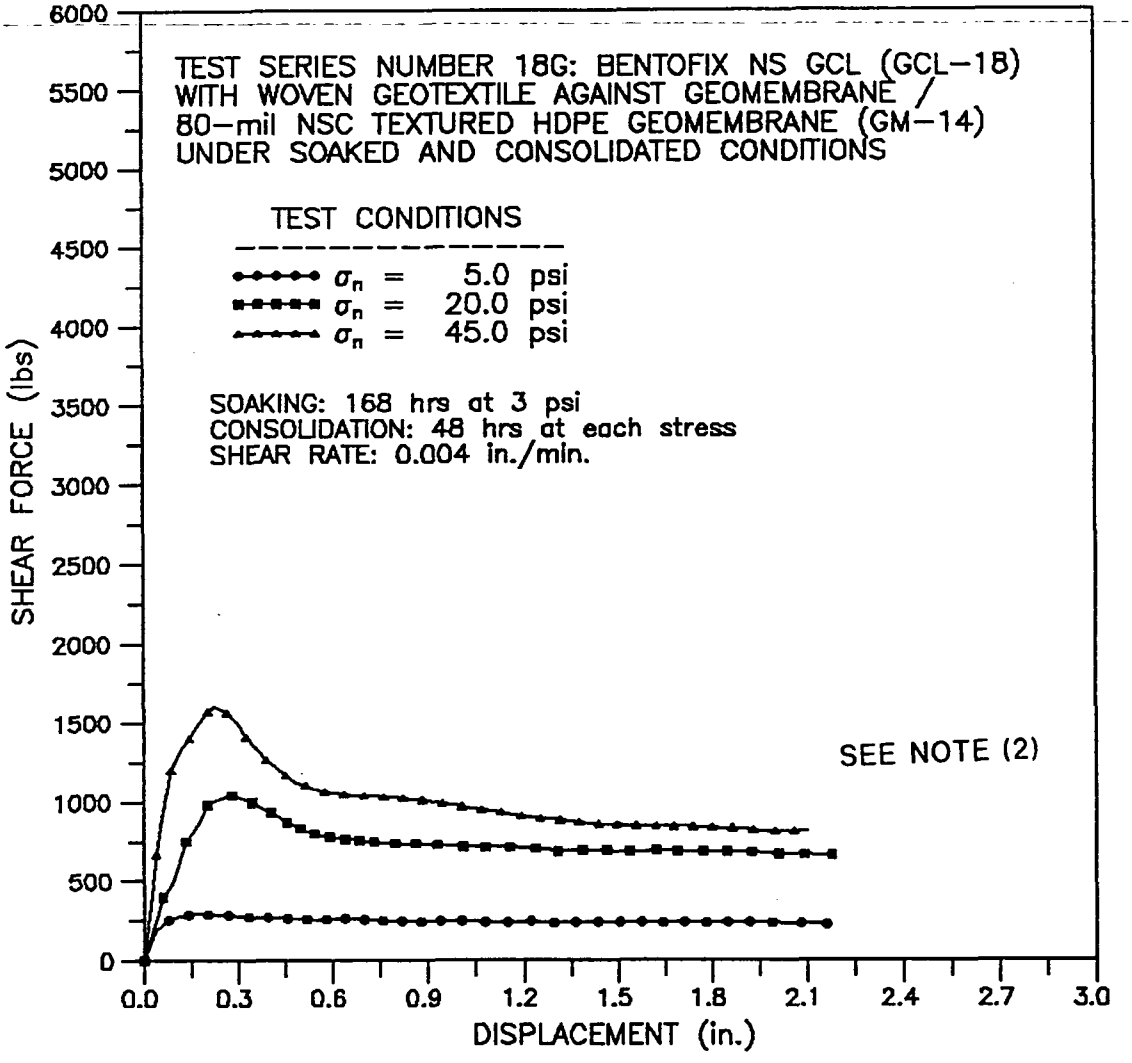
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) For each test, sliding (i.e, internal shear failure) was observed to occur within the GCL.

DATE TESTED: 22 TO 31 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730137
FILE NO.	

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

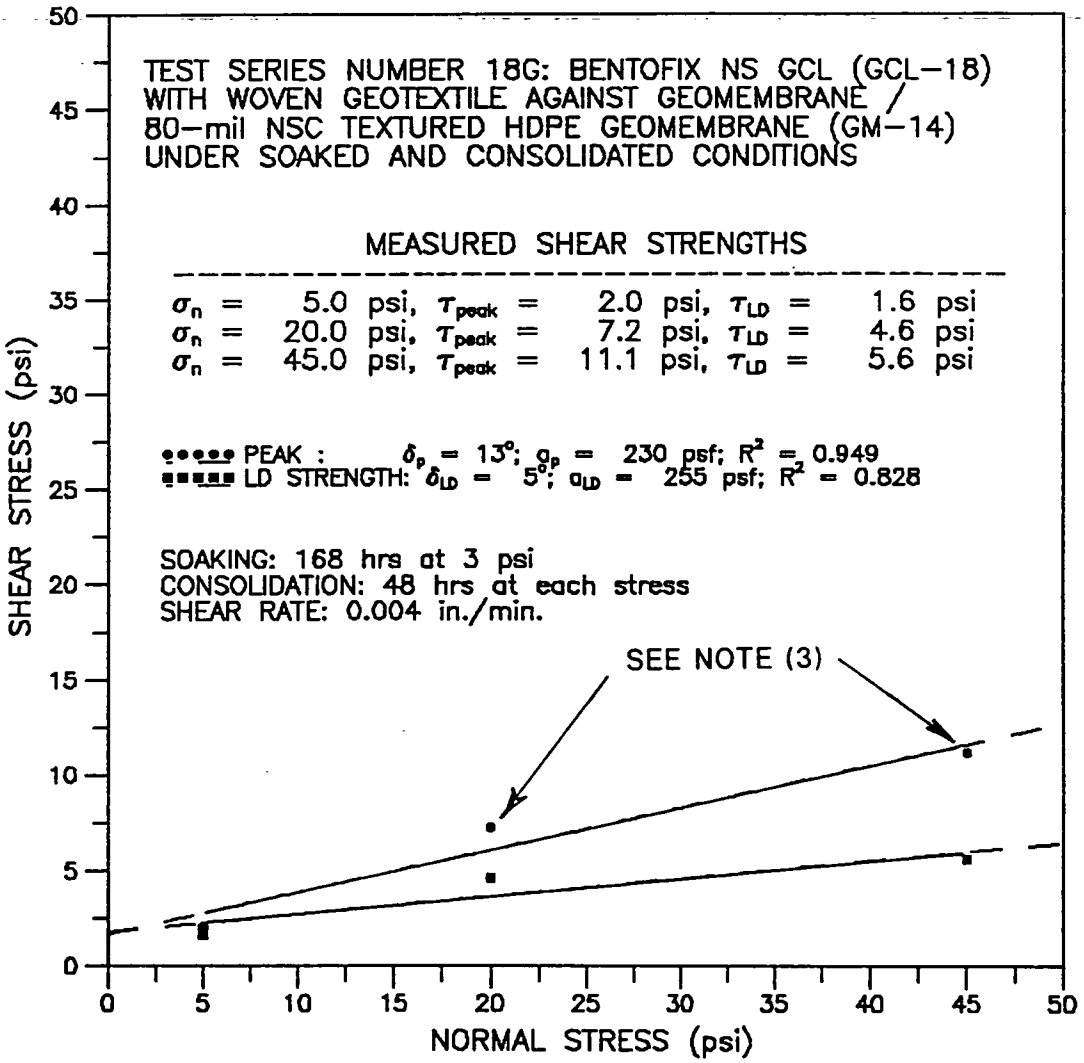
DATE TESTED: 22 OCTOBER TO 14 NOVEMBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730137
FILE NO.	

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 22 OCTOBER TO 14 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730137
FILE NO.	

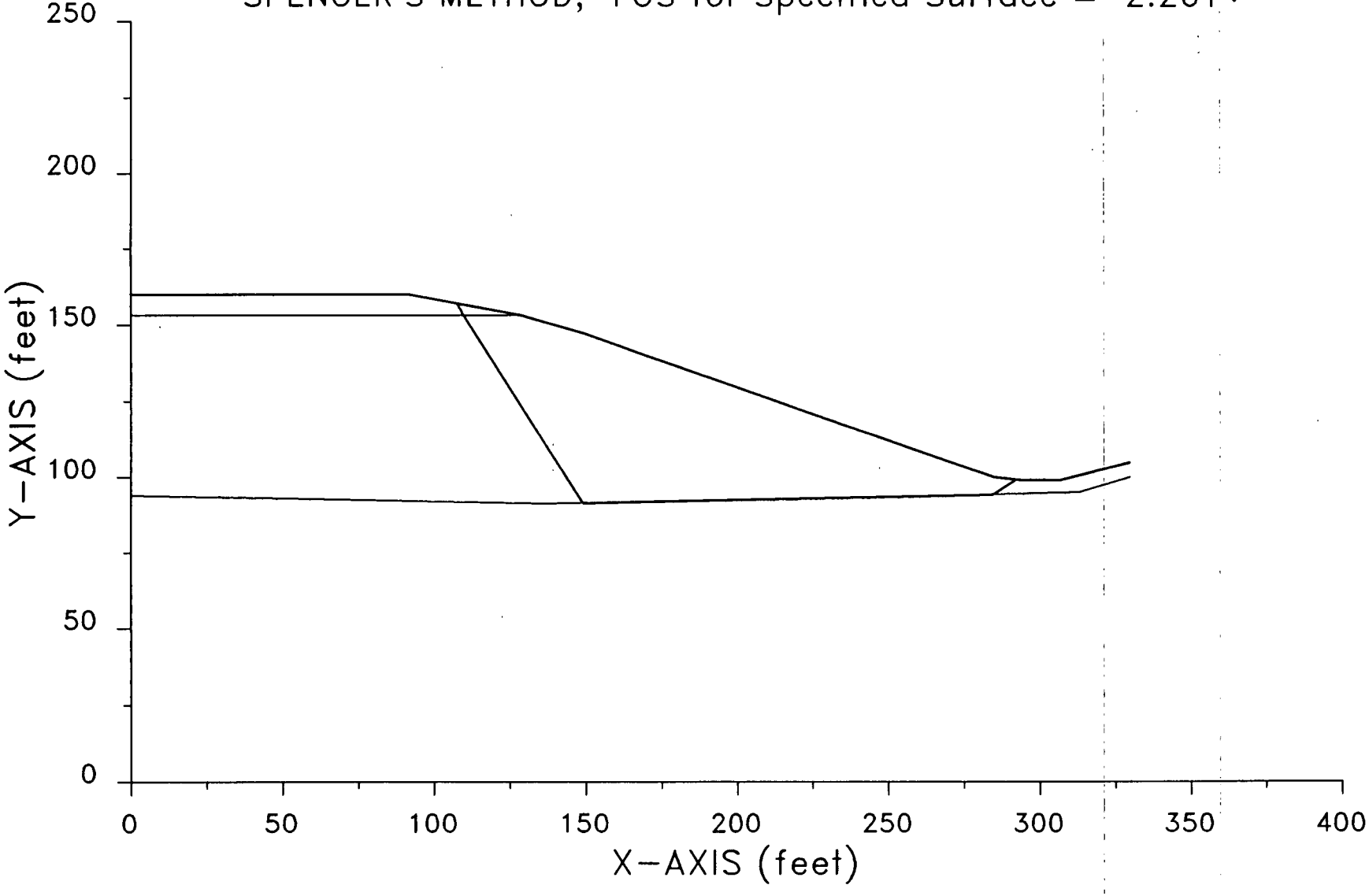
HCD DOC 19/97
RAM 19DEC97

APPENDIX B

NPKT8AS 11-05-97 10:12

OSDF Interim Closure/Short-Term,Peak

SPENCER'S METHOD, FOS for Specified Surface = 2.261 ✓



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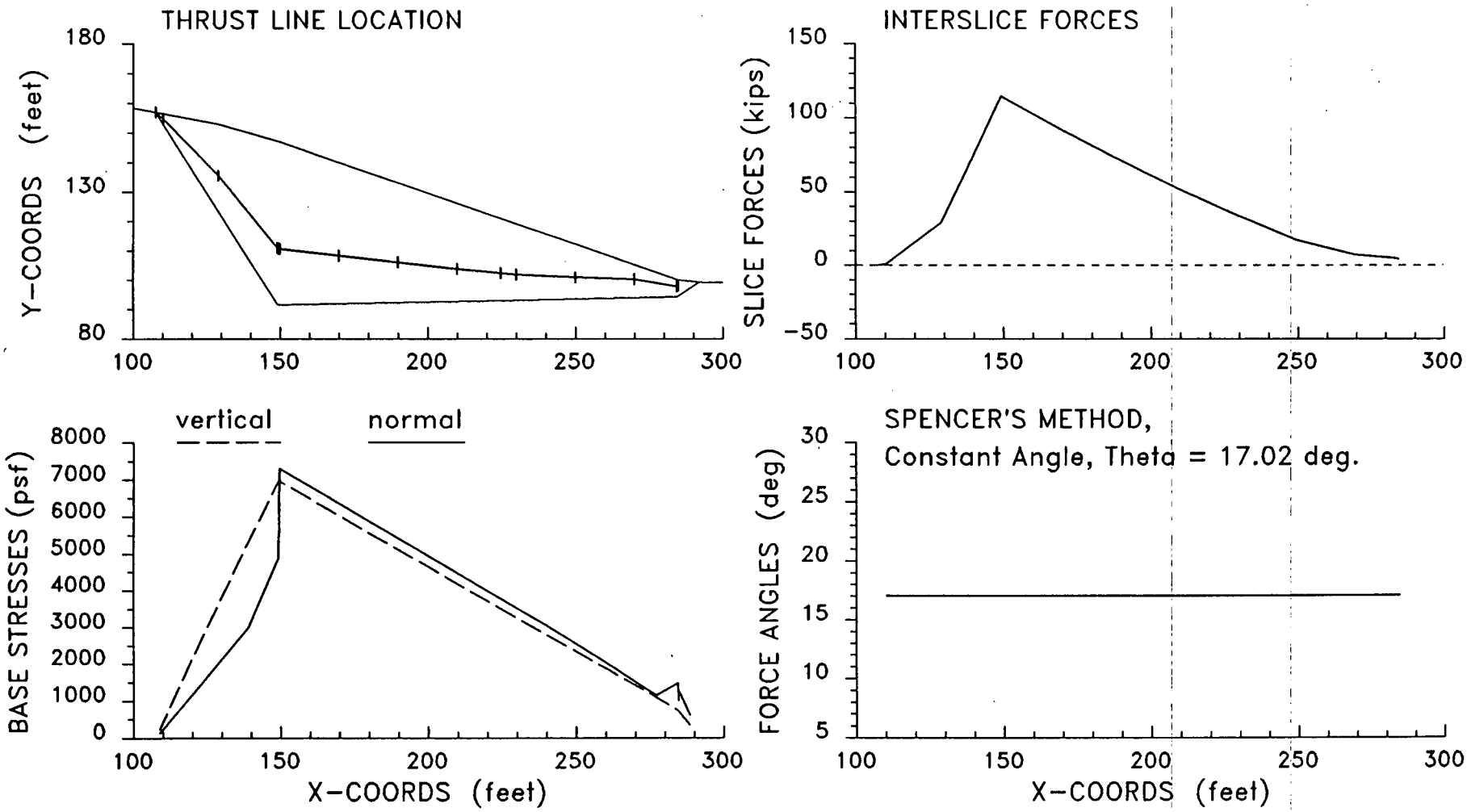

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.261

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*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	1612.8
5	6480.0	2059.2
6	10080.0	2059.2

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	292.25	99.19
2	284.72	94.39
3	284.51	94.19
4	224.80	93.00
5	149.45	91.42
6	149.21	91.66
7	110.13	153.00
8	107.82	157.01

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.63	96.88	2.72	7.25	-32.54	6.34	2461.
2	284.86	94.48	5.57	.27	-32.54	19.12	190.
3	284.72	94.39	5.70	.01	-32.54	19.12	5.
4	284.61	94.29	5.84	.21	-43.60	19.12	153.
5	277.26	94.05	8.64	14.51	-1.14	19.12	15670.
6	260.00	93.70	15.00	20.00	-1.14	19.29	37496.
7	240.00	93.30	22.35	20.00	-1.14	19.03	55868.
8	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
9	217.40	92.84	30.67	14.80	-1.20	19.29	56731.
10	200.00	92.48	37.12	20.00	-1.20	19.29	92800.
11	180.00	92.06	44.49	20.00	-1.20	19.03	111224.
12	160.00	91.64	51.86	20.00	-1.20	19.29	129647.
13	149.73	91.43	55.65	.55	-1.20	15.95	3826.
14	149.33	91.54	55.65	.24	45.00	15.95	1669.
15	139.11	107.52	42.59	20.21	57.50	15.95	107598.
16	119.57	138.19	16.59	18.87	57.50	10.71	39142.
17	108.98	155.00	1.79	2.31	60.04	10.71	515.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.9988	2.2808	2.2945
3	17.0053	2.2810	2.2808

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.0155	2.2610	2.2606

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	17.0155	2.2610	2.2606

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	602.2	.0	30.00	0.	0.	0.	.00
2	1277.3	200.0	25.00	0.	0.	0.	.00
3	990.9	-537.6	36.75	0.	0.	0.	.00
4	1471.9	-537.6	36.75	0.	0.	0.	.00
5	1131.1	-537.6	36.75	0.	0.	0.	.00
6	2028.0	-537.6	36.75	0.	0.	0.	.00
7	3047.5	1255.7	7.07	0.	0.	0.	.00
8	3638.0	1255.7	7.07	0.	0.	0.	.00
9	4115.0	1255.7	7.07	0.	0.	0.	.00
10	4941.9	1255.7	7.07	0.	0.	0.	.00
11	5886.1	1255.7	7.07	0.	0.	0.	.00
12	6823.9	2059.2	.00	0.	0.	0.	.00
13	7301.3	2059.2	.00	0.	0.	0.	.00
14	4888.7	1255.7	7.07	0.	0.	0.	.00
15	2993.9	200.0	25.00	0.	0.	0.	.00
16	1127.3	200.0	25.00	0.	0.	0.	.00
17	117.8	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.63	602.2	339.5	.0	153.8
2	284.86	1277.3	695.7	.0	351.9
3	284.72	990.9	712.9	.0	89.4
4	284.61	1471.9	730.4	.0	248.3
5	277.26	1131.1	1079.9	.0	135.8
6	260.00	2028.0	1874.8	.0	431.9
7	240.00	3047.5	2793.4	.0	722.5
8	227.40	3638.0	3369.8	.0	754.9
9	217.40	4115.0	3833.1	.0	781.0
10	200.00	4941.9	4640.0	.0	826.4
11	180.00	5886.1	5561.2	.0	878.2
12	160.00	6823.9	6482.3	.0	910.8
13	149.73	7301.3	6956.6	.0	910.8
14	149.33	4888.7	6956.4	.0	823.5
15	139.11	2993.9	5324.0	.0	705.9
16	119.57	1127.3	2074.3	.0	320.9
17	108.98	117.8	223.1	.0	30.1

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	17.02	4079.	3.42	5.43	.630
2	284.73	17.02	4412.	3.41	5.70	.599
3	284.72	17.02	4418.	3.41	5.71	.598

4	284.51	17.02	4780.	3.41	5.98	.570
5	270.00	17.02	7182.	6.21	11.30	.549
6	250.00	17.02	17062.	7.24	18.70	.387
7	230.00	17.02	33444.	8.62	26.00	.332
8	224.80	17.02	37943.	9.19	27.92	.329
9	210.00	17.02	51367.	11.00	33.41	.329
10	190.00	17.02	70820.	13.62	40.83	.334
11	170.00	17.02	91769.	16.30	48.15	.339
12	150.00	17.02	113811.	19.05	55.57	.343
13	149.45	17.02	114423.	19.13	55.74	.343
14	149.21	17.02	113402.	19.13	55.57	.344
15	129.00	17.02	29002.	12.12	29.62	.409
16	110.13	17.02	420.	1.65	3.57	.463
17	107.82	.00	-1.	-.13	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3222.18 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 599.63 (psf)

Total Length of failure surface = 222.01 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.261

Total shear strength available along specified failure surface = 300.99E+03 lb

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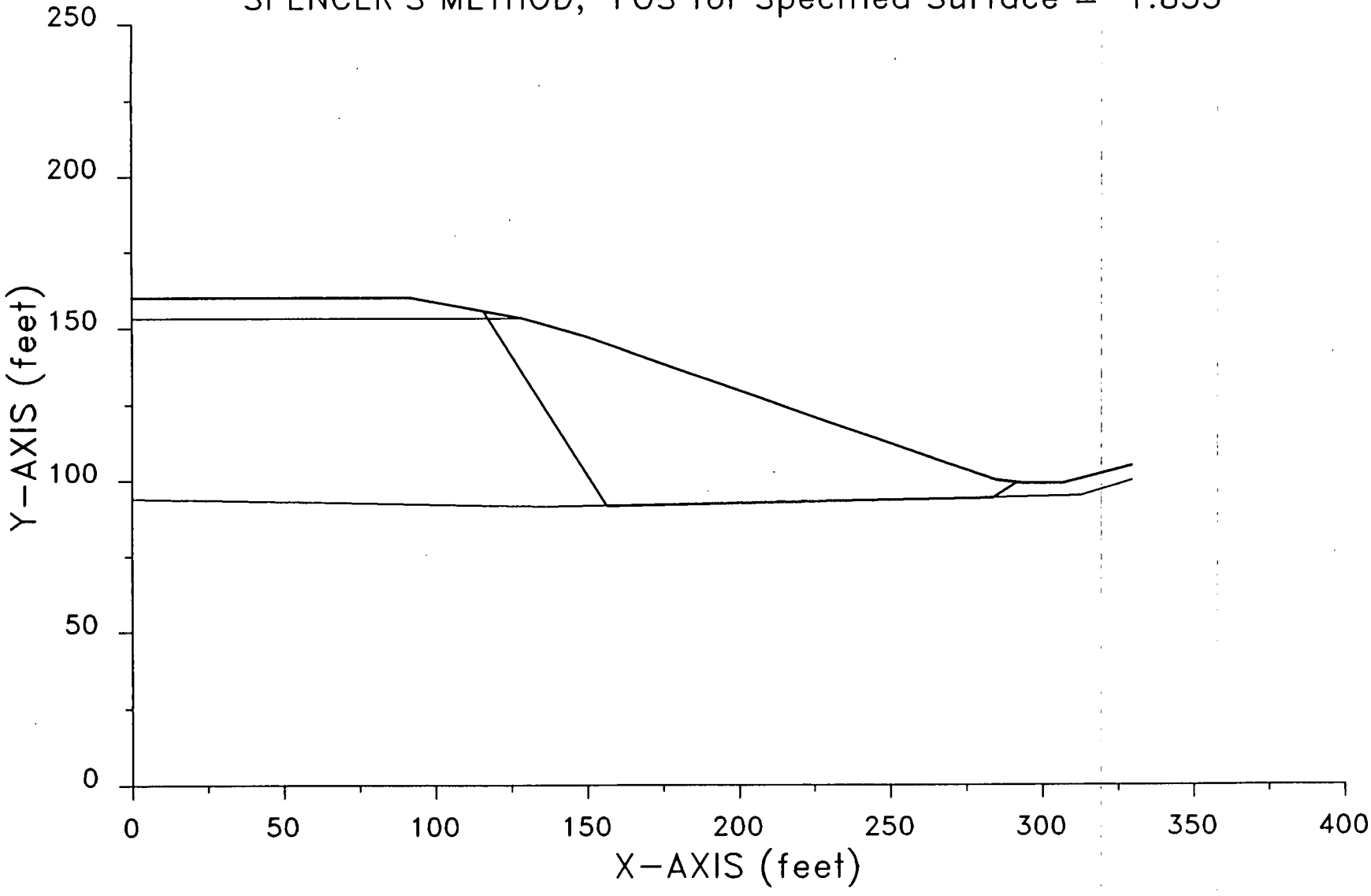
OSDF Interim Closure/Short-Term,Peak

SPENCER'S METHOD, FOS for Specified Surface = 1.853



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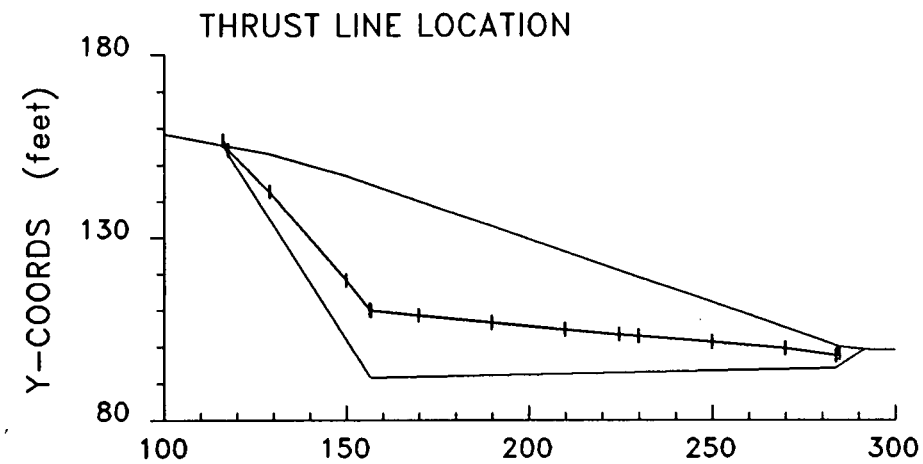

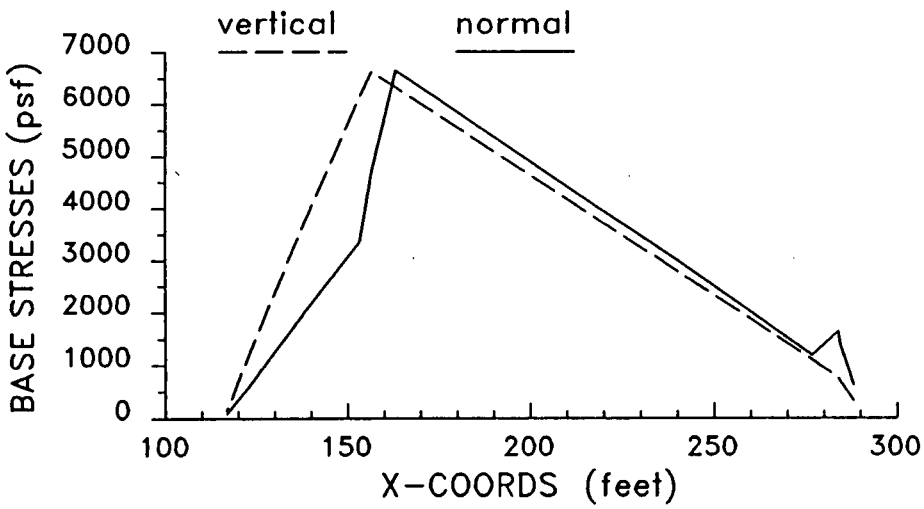

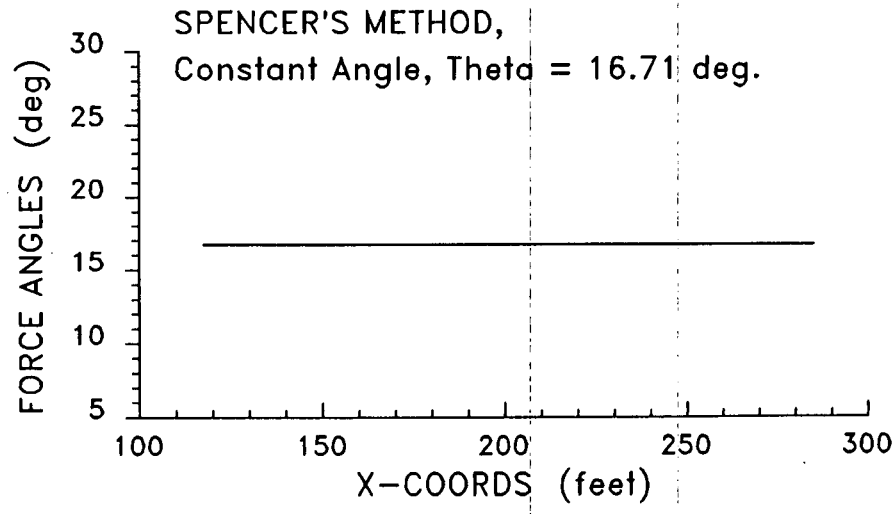

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 1.853

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	288.0
4	2880.0	1036.8
5	6480.0	1598.4
6	10080.0	1598.4

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	291.80	99.24
2	284.17	94.38
3	283.96	94.18
4	224.80	93.00
5	156.82	91.58
6	156.59	91.81
7	117.61	153.00
8	116.21	155.42

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.40	97.08	2.55	6.80	-32.52	6.34	2164.
2	284.59	94.64	5.50	.83	-32.52	19.12	571.
3	284.07	94.28	6.04	.21	-43.60	19.12	159.
4	276.98	94.04	8.74	13.96	-1.14	19.12	15250.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37495.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55867.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.20	19.29	56729.
9	200.00	92.48	37.12	20.00	-1.20	19.29	92795.
10	180.00	92.06	44.49	20.00	-1.20	19.03	111215.
11	163.41	91.72	50.59	13.18	-1.20	19.29	83345.
12	156.71	91.69	52.96	.23	45.00	19.29	1523.
13	153.29	96.98	48.86	6.59	57.50	19.29	40252.
14	139.50	118.64	31.36	21.00	57.50	15.95	82327.
15	123.30	144.06	10.02	11.39	57.50	10.71	14262.
16	116.91	154.21	1.08	1.40	59.95	10.71	189.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.6830	1.8584	1.8851
3	16.7192	1.8593	1.8584

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.7128	1.8526	1.8528

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.7128	1.8526	1.8528

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	616.2	.0	30.00	0.	0.	0.	.00
2	1377.5	200.0	25.00	0.	0.	0.	.00
3	1629.1	38.4	19.12	0.	0.	0.	.00
4	1176.6	38.4	19.12	0.	0.	0.	.00
5	2014.1	38.4	19.12	0.	0.	0.	.00
6	2993.5	587.5	8.87	0.	0.	0.	.00
7	3589.6	587.5	8.87	0.	0.	0.	.00
8	4070.5	587.5	8.87	0.	0.	0.	.00
9	4905.0	587.5	8.87	0.	0.	0.	.00
10	5857.7	587.5	8.87	0.	0.	0.	.00
11	6642.3	1598.4	.00	0.	0.	0.	.00
12	4707.3	587.5	8.87	0.	0.	0.	.00
13	3334.1	200.0	25.00	0.	0.	0.	.00
14	2112.5	200.0	25.00	0.	0.	0.	.00
15	622.7	200.0	25.00	0.	0.	0.	.00
16	68.6	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.40	616.2	318.2	.0	192.0
2	284.59	1377.5	687.4	.0	454.7
3	284.07	1629.1	755.5	.0	325.6
4	276.98	1176.6	1092.4	.0	240.9
5	260.00	2014.1	1874.7	.0	397.6
6	240.00	2993.5	2793.4	.0	569.2
7	227.40	3589.6	3369.8	.0	619.4
8	217.40	4070.5	3833.1	.0	659.9
9	200.00	4905.0	4639.8	.0	730.2
10	180.00	5857.7	5560.7	.0	810.4
11	163.41	6642.3	6323.6	.0	862.8
12	156.71	4707.3	6619.8	.0	713.5
13	153.29	3334.1	6108.0	.0	947.2
14	139.50	2112.5	3920.3	.0	639.7
15	123.30	622.7	1252.2	.0	264.7
16	116.91	68.6	134.7	.0	21.4

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	16.71	4153.	3.19	5.09	.626
2	284.17	16.71	5308.	3.19	5.91	.540
3	283.96	16.71	5720.	3.21	6.18	.520
4	270.00	16.71	9573.	5.49	11.30	.486
5	250.00	16.71	18715.	7.65	18.70	.409
6	230.00	16.71	31848.	9.58	26.00	.368

7	224.80	16.71	35600.	10.15	27.92	.363
8	210.00	16.71	47111.	11.84	33.41	.354
9	190.00	16.71	64497.	14.21	40.83	.348
10	170.00	16.71	83975.	16.59	48.14	.345
11	156.82	16.71	97757.	18.18	53.03	.343
12	156.59	16.71	96798.	18.20	52.88	.344
13	150.00	16.71	67303.	15.98	44.85	.356
14	129.00	16.71	8618.	7.37	17.88	.412
15	117.61	16.71	141.	1.00	2.15	.464
16	116.21	.00	-1.	1.13	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3033.22 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 577.34 (psf)

Total Length of failure surface = 212.18 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.853

Total shear strength available along specified failure surface = 226.94E+03 lb

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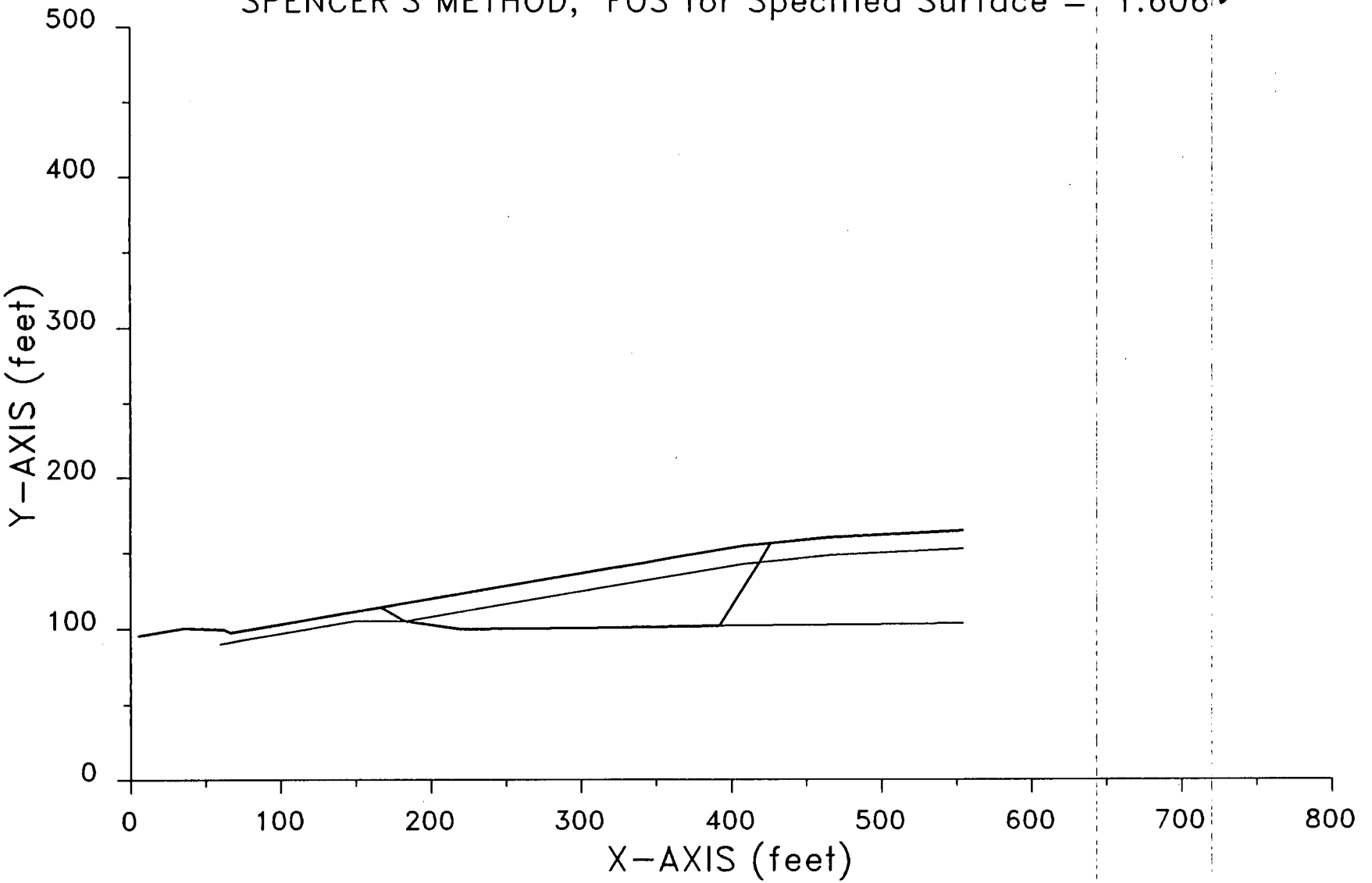
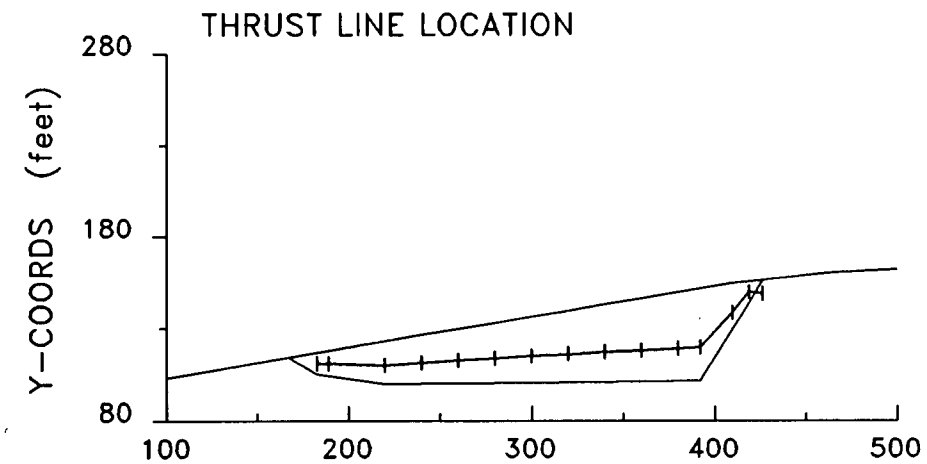
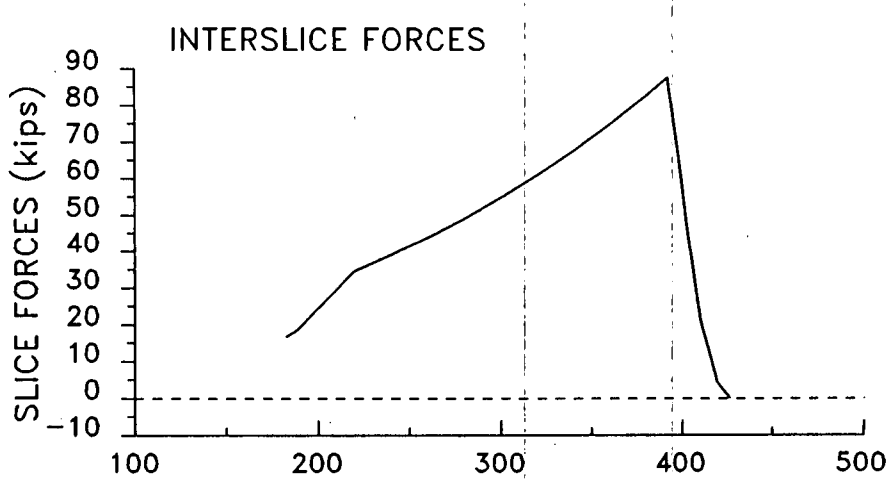
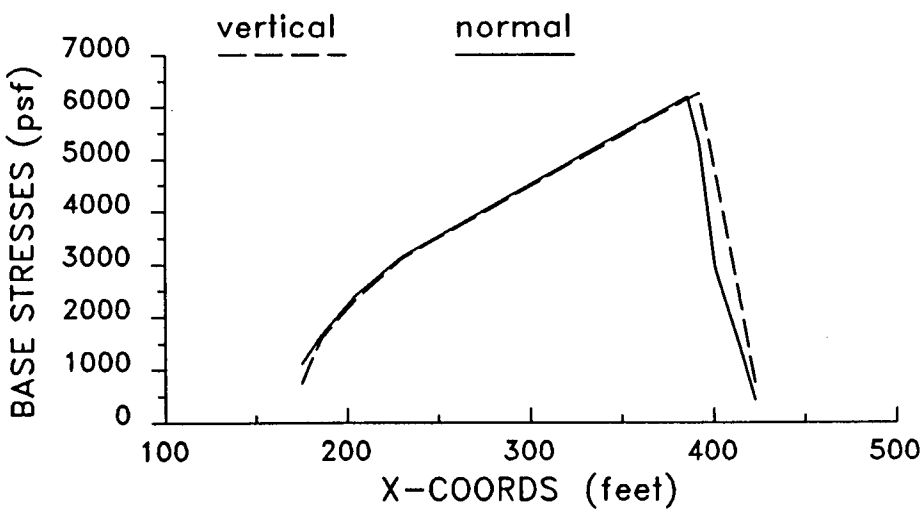
OSDF Final Long Term – Large Displ.

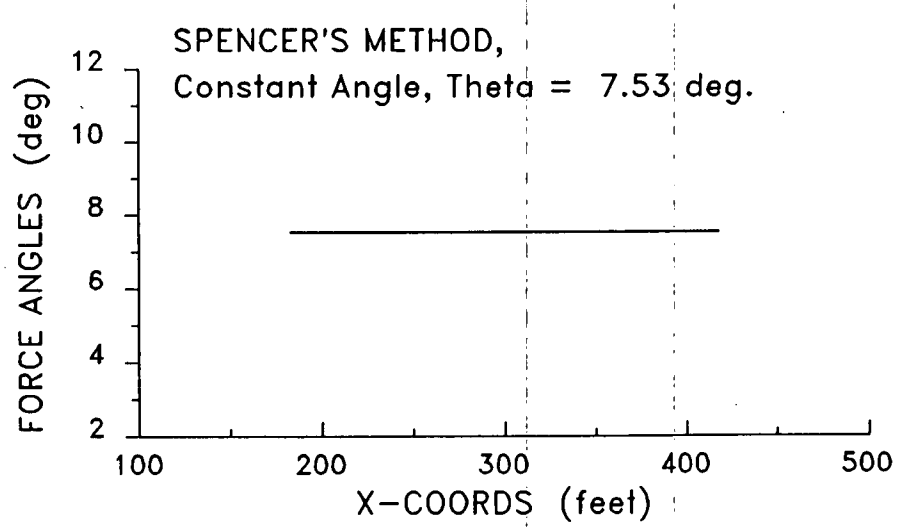
SPENCER'S METHOD, FOS for Specified Surface = 1.606











OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.606

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	360.0
5	6480.0	792.0
6	10080.0	792.0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	392.34	101.66
6	392.50	101.81
7	419.20	143.72
8	426.49	156.35

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.66	9.37	93338.
9	330.00	100.94	40.41	20.00	.66	9.37	101014.
10	350.00	101.17	43.53	20.00	.66	9.65	108815.
11	370.00	101.40	46.65	20.00	.66	9.37	116616.
12	386.17	101.59	49.14	12.34	.66	9.46	75797.
13	392.42	101.73	50.04	.16	43.15	9.46	1001.
14	401.25	115.54	37.70	17.50	57.50	9.46	82462.
15	414.60	136.50	18.66	9.20	57.50	5.71	21460.
16	422.85	150.03	5.95	7.29	60.00	5.71	5422.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.4388	1.6039	1.6463
3	7.5333	-----	1.6039
3	7.4861	1.6049	-----
4	7.5309	1.6060	1.6049
5	7.5297	1.6059	1.6060

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.5297	1.6059	1.6060

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta

1	1106.3	.0	30.00	0.	0.	0.	.00
2	1651.4	-120.0	9.46	0.	0.	0.	.00
3	2396.8	-120.0	9.46	0.	0.	0.	.00
4	3125.5	14.4	6.84	0.	0.	0.	.00
5	3522.3	14.4	6.84	0.	0.	0.	.00
6	3912.9	14.4	6.84	0.	0.	0.	.00
7	4309.7	14.4	6.84	0.	0.	0.	.00
8	4703.3	14.4	6.84	0.	0.	0.	.00
9	5090.0	14.4	6.84	0.	0.	0.	.00
10	5483.0	14.4	6.84	0.	0.	0.	.00
11	5876.0	14.4	6.84	0.	0.	0.	.00
12	6189.9	14.4	6.84	0.	0.	0.	.00
13	5276.0	14.4	6.84	0.	0.	0.	.00
14	2900.0	.0	25.00	0.	0.	0.	.00
15	1435.5	.0	25.00	0.	0.	0.	.00
16	412.2	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1106.3	739.6	.0	397.7
2	186.00	1651.4	1594.4	.0	96.7
3	204.50	2396.8	2304.8	.0	174.0
4	230.00	3125.5	3100.0	.0	242.5
5	250.00	3522.3	3493.8	.0	272.2
6	270.00	3912.9	3881.3	.0	301.3
7	290.00	4309.7	4275.0	.0	331.0
8	310.00	4703.3	4666.9	.0	360.4
9	330.00	5090.0	5050.7	.0	389.3
10	350.00	5483.0	5440.8	.0	418.7
11	370.00	5876.0	5830.8	.0	448.0
12	386.17	6189.9	6142.4	.0	471.5
13	392.42	5276.0	6254.4	.0	403.2
14	401.25	2900.0	4712.1	.0	842.1
15	414.60	1435.5	2332.6	.0	416.8
16	422.85	412.2	743.7	.0	148.2

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.53	16627.	5.64	11.83	.477
2	189.00	7.53	18617.	6.59	13.68	.482
3	220.00	7.53	34591.	10.05	23.20	.433
4	240.00	7.53	38853.	11.25	26.40	.426
5	260.00	7.53	43633.	12.33	29.50	.418
6	280.00	7.53	48923.	13.31	32.60	.408
7	300.00	7.53	54731.	14.21	35.80	.397

8	320.00	7.53	60913.	15.06	38.87	.387
9	340.00	7.53	67588.	15.87	41.94	.378
10	360.00	7.53	74764.	16.64	45.11	.369
11	380.00	7.53	82442.	17.39	48.18	.361
12	392.34	7.53	87426.	17.85	50.10	.356
13	392.50	7.53	86693.	17.87	49.97	.358
14	410.00	7.53	21204.	9.05	25.42	.356
15	419.20	7.53	4161.	5.83	11.90	.490
16	426.49	.00	0.	-7.73	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3515.19 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 380.21 (psf)

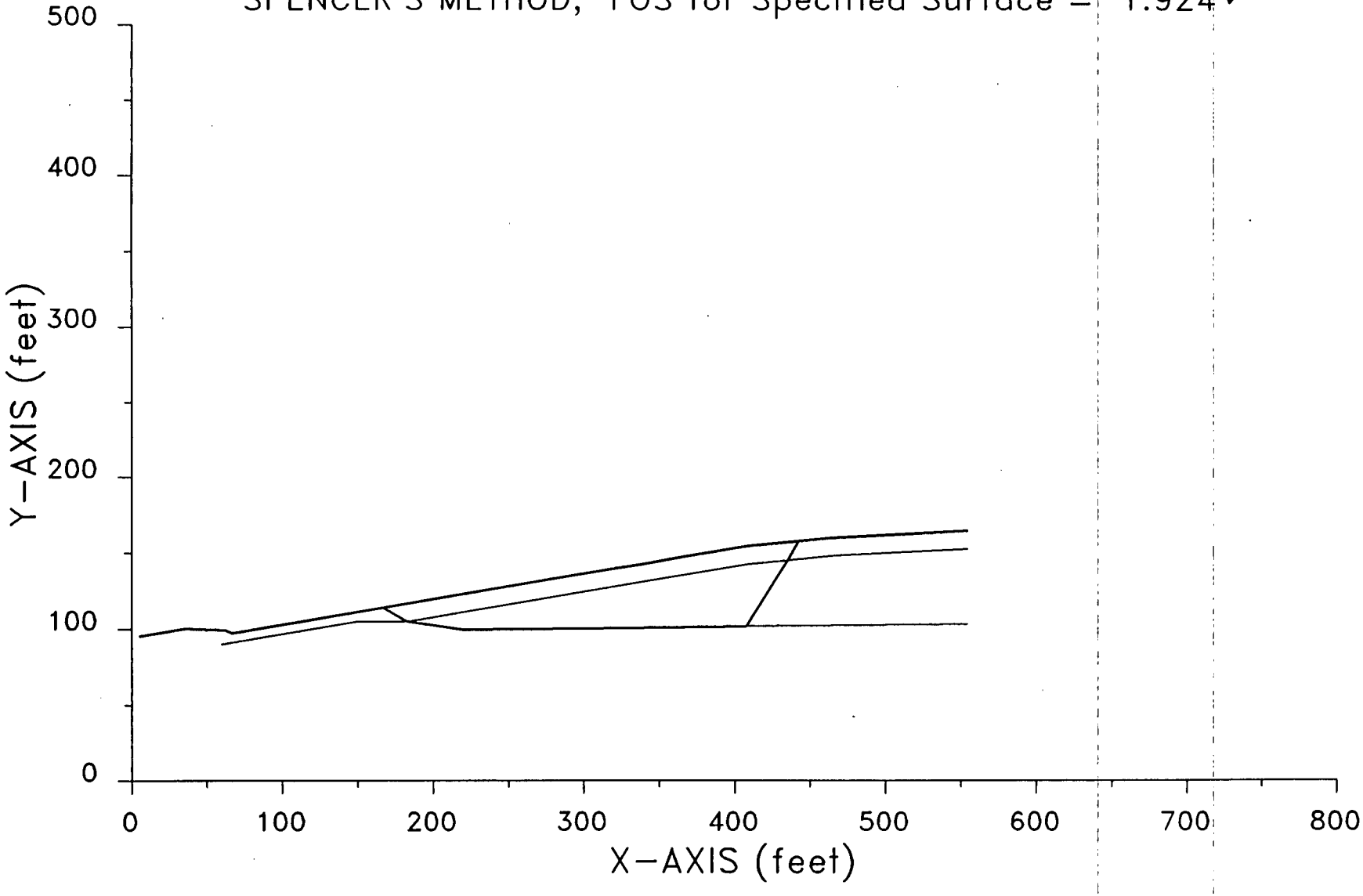
Total Length of failure surface = 292.57 feet

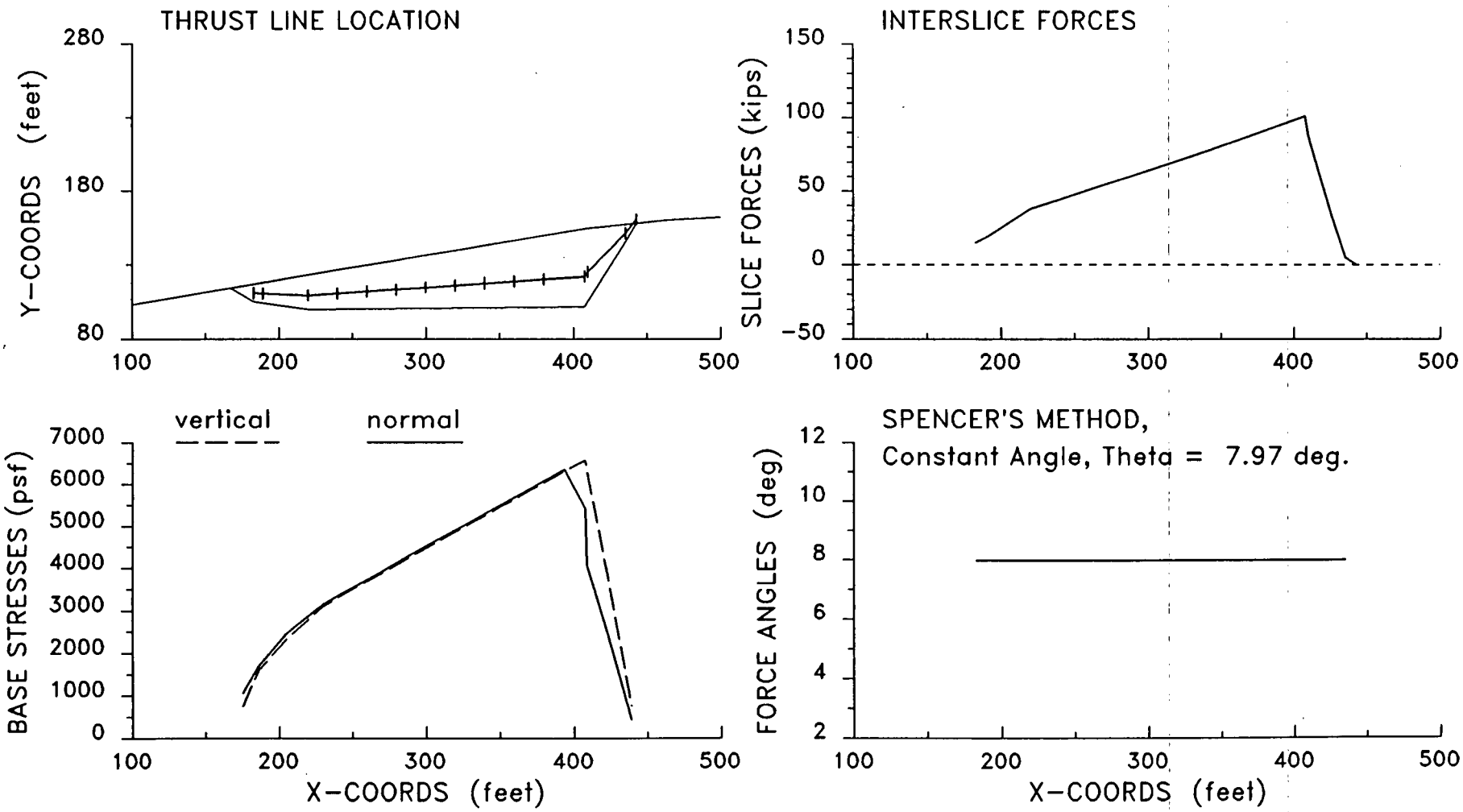
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.606 ✓

Total shear strength available along specified failure surface = 178.64E+03 lb

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.924 ✓





OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.924

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	230.4
4	2880.0	662.4
5	6480.0	806.4
6	10080.0	806.4

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	407.64	101.72
6	407.89	101.98
7	435.53	145.35
8	442.82	157.98

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.70	37.35	20.00	.60	9.37	93365.
9	330.00	100.91	40.44	20.00	.60	9.37	101095.
10	350.00	101.12	43.58	20.00	.60	9.65	108949.
11	370.00	101.33	46.72	20.00	.60	9.37	116804.
12	393.82	101.58	50.43	27.64	.60	9.46	174226.
13	407.77	101.85	52.48	.25	46.12	9.46	1640.
14	408.95	103.64	50.89	2.11	57.49	9.46	13422.
15	422.77	125.32	30.65	25.53	57.49	5.71	97834.
16	439.18	151.67	5.95	7.29	60.01	5.71	5420.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.9226	1.9227	1.9541
3	7.9701	1.9240	1.9227
4	7.9691	1.9240	1.9240

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.9691	1.9240	1.9240

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1050.8	.0	30.00	0.	0.	0.	.00

2	1689.5	86.4	11.31	0.	0.	0.	.00
3	2436.4	86.4	11.31	0.	0.	0.	.00
4	3141.1	547.2	2.29	0.	0.	0.	.00
5	3535.3	547.2	2.29	0.	0.	0.	.00
6	3923.3	547.2	2.29	0.	0.	0.	.00
7	4317.6	547.2	2.29	0.	0.	0.	.00
8	4710.9	547.2	2.29	0.	0.	0.	.00
9	5097.9	547.2	2.29	0.	0.	0.	.00
10	5491.1	547.2	2.29	0.	0.	0.	.00
11	5884.3	547.2	2.29	0.	0.	0.	.00
12	6348.1	547.2	2.29	0.	0.	0.	.00
13	5414.1	547.2	2.29	0.	0.	0.	.00
14	4061.9	.0	25.00	0.	0.	0.	.00
15	2446.8	.0	25.00	0.	0.	0.	.00
16	432.3	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1050.8	739.6	.0	315.3
2	186.00	1689.5	1594.4	.0	220.5
3	204.50	2436.4	2304.8	.0	298.2
4	230.00	3141.1	3100.0	.0	349.7
5	250.00	3535.3	3493.8	.0	357.9
6	270.00	3923.3	3881.3	.0	366.0
7	290.00	4317.6	4275.0	.0	374.2
8	310.00	4710.9	4668.2	.0	382.4
9	330.00	5097.9	5054.7	.0	390.4
10	350.00	5491.1	5447.5	.0	398.6
11	370.00	5884.3	5840.2	.0	406.7
12	393.82	6348.1	6303.4	.0	416.4
13	407.77	5414.1	6559.7	.0	397.0
14	408.95	4061.9	6361.1	.0	984.5
15	422.77	2446.8	3831.8	.0	593.0
16	439.18	432.3	743.7	.0	129.7

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.97	14807.	5.70	11.83	.482
2	189.00	7.97	17581.	6.35	13.68	.465
3	220.00	7.97	37633.	9.35	23.20	.403
4	240.00	7.97	44061.	10.39	26.40	.394
5	260.00	7.97	50575.	11.49	29.50	.389
6	280.00	7.97	57174.	12.61	32.60	.387
7	300.00	7.97	63858.	13.75	35.80	.384
8	320.00	7.97	70590.	14.91	38.89	.383
9	340.00	7.97	77403.	16.08	41.98	.383

10	360.00	7.97	84298.	17.25	45.18	.382
11	380.00	7.97	91276.	18.42	48.27	.382
12	407.64	7.97	101054.	20.05	52.59	.381
13	407.89	7.97	99732.	20.08	52.37	.384
14	410.00	7.97	88251.	19.49	49.41	.394
15	435.53	7.97	4557.	5.80	11.90	.488
16	442.82	.00	0.	2.43	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3692.62 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 395.68 (psf)

Total Length of failure surface = 309.75 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.924

Total shear strength available along specified failure surface = 235.81E+03 lb

GCL 19

COMPUTATION COVER SHEET

1269

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 19 - Compliance Package

Computations By: (Cognizant Engineer)
Signature [signature] Date 28 OCT 1997
Printed Name and Title M. CATALINA OROZCO STAFF ENGINEER

Assumptions and Procedures Checked By: (Checker)
Signature [signature] Date 24 OCT 1997
Printed Name and Title ROBERT A. MORGAN III SR. STAFF ENGINEER

Computations Checked by:
Signature [signature] Date 24 OCT 1997
Printed Name and Title ROBERT A. MORGAN III SR. STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 24 OCT 1997
Printed Name and Title M. CATALINA OROZCO STAFF ENGINEER

Approved by: (PDP)
Signature [signature] Date 24 Oct 97
Printed Name and Title Gary R. Schmertmann Sr. Project Engineer

Approved by: (DTL and TETL)
Signature [signature] Date 27 Oct 97
Printed Name and Title Kenneth W Cargill Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

000466

Written By : MCO Date: 10 / 23 / 97 Reviewed by: RAM Date: 10 / 24 / 97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 19 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 19 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample No.	Case	Test Type	Measured Shear Strengths		
			5 psi	20 psi	45 psi
19	Peak	GCL Internal	0 psi[1]	9.9 psi	12 psi
		GCL/GMB Interface	0[1]	7.0	15.5
19	Large-displacement	GCL Internal	0[1]	3.2	5.7
		GCL/GMB Interface	0[1]	4.1	7.7

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix B.

QA Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
19	GCL Internal	NPK19AS	2.0	YES
	GCL/GMB Interface	NPK19BS	2.1	YES
Baseline	Large-displacement	NA	1.6	NA
19	GCL Internal	NLD19AS	1.7	YES
	GCL/GMB Interface	NLD19BS	2.1	YES

[1] Shear strength values for QA sample 19 at 5 psi normal stress were not available at the time that this calculation package was prepared. These values were assumed to equal zero. This assumption is conservative in the context of RCI 1702-006R.

MCO 10/24/97
RAM 10/24/97

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 19I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-19). GCL's initial moisture content was 9.2%. GCL's final moisture content ranged from 57% to 59% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20 and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 19G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-19) with woven geotextile against geomembrane. GCL's initial moisture content was 9.2%. GCL's final moisture content ranged from 54 to 76% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-14); and
- lower shear box: bedding layer of compacted concrete sand.

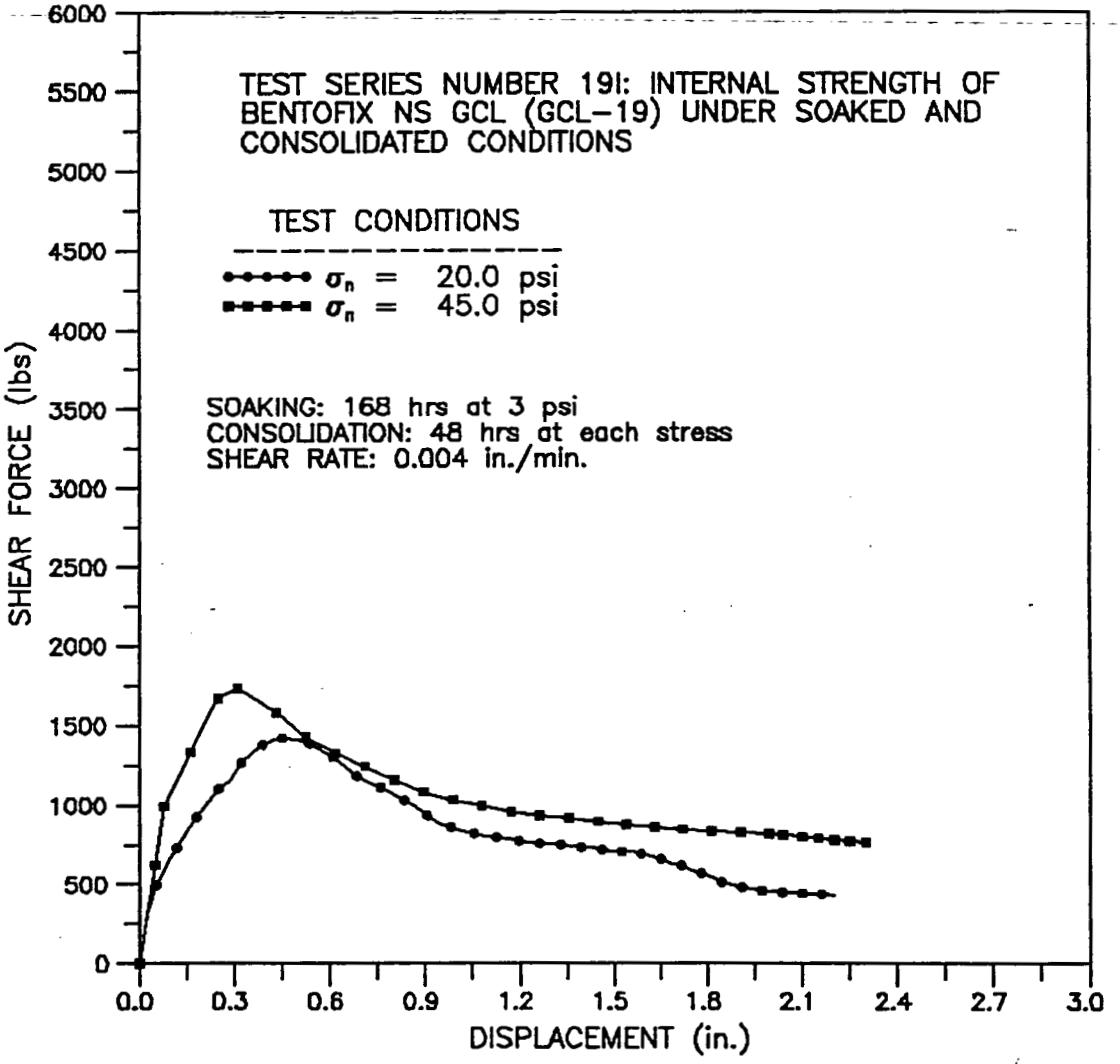
Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20 and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

5/8

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.

(2) For each test, sliding (i.e., internal shear failure) was observed to occur within the GCL.

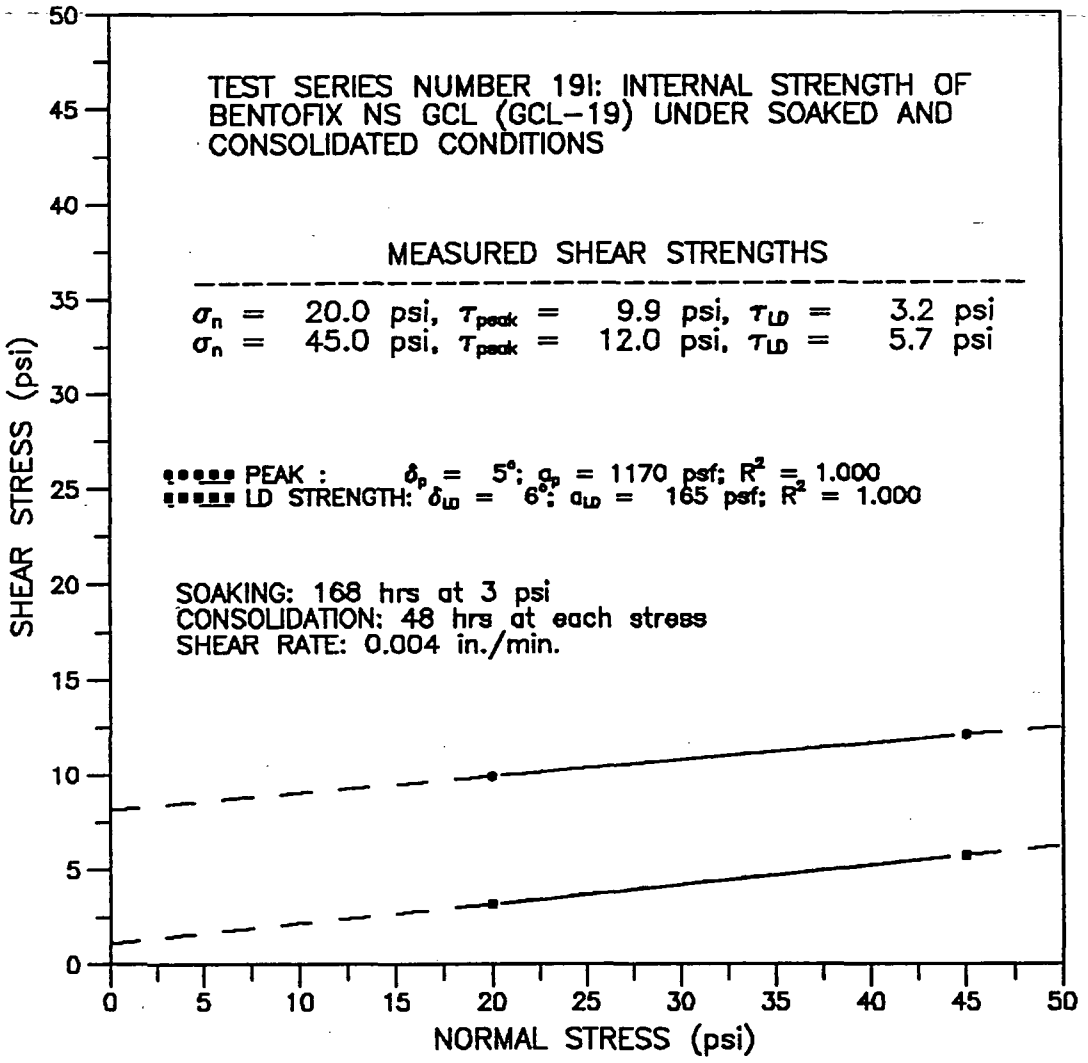
DATE TESTED: 8 TO 17 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730105
FILE NO.	000471

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



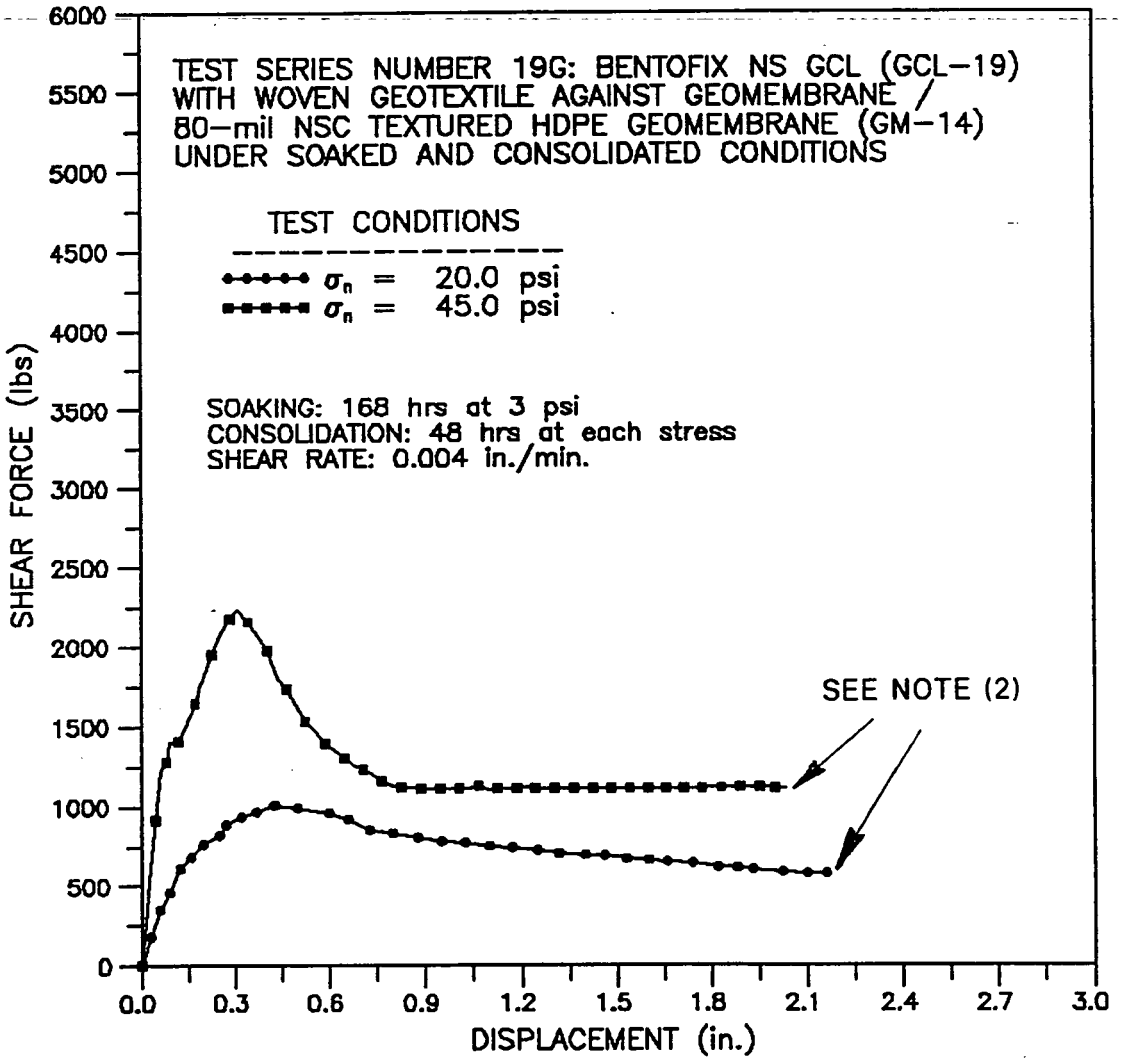
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 8 TO 17 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730105
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

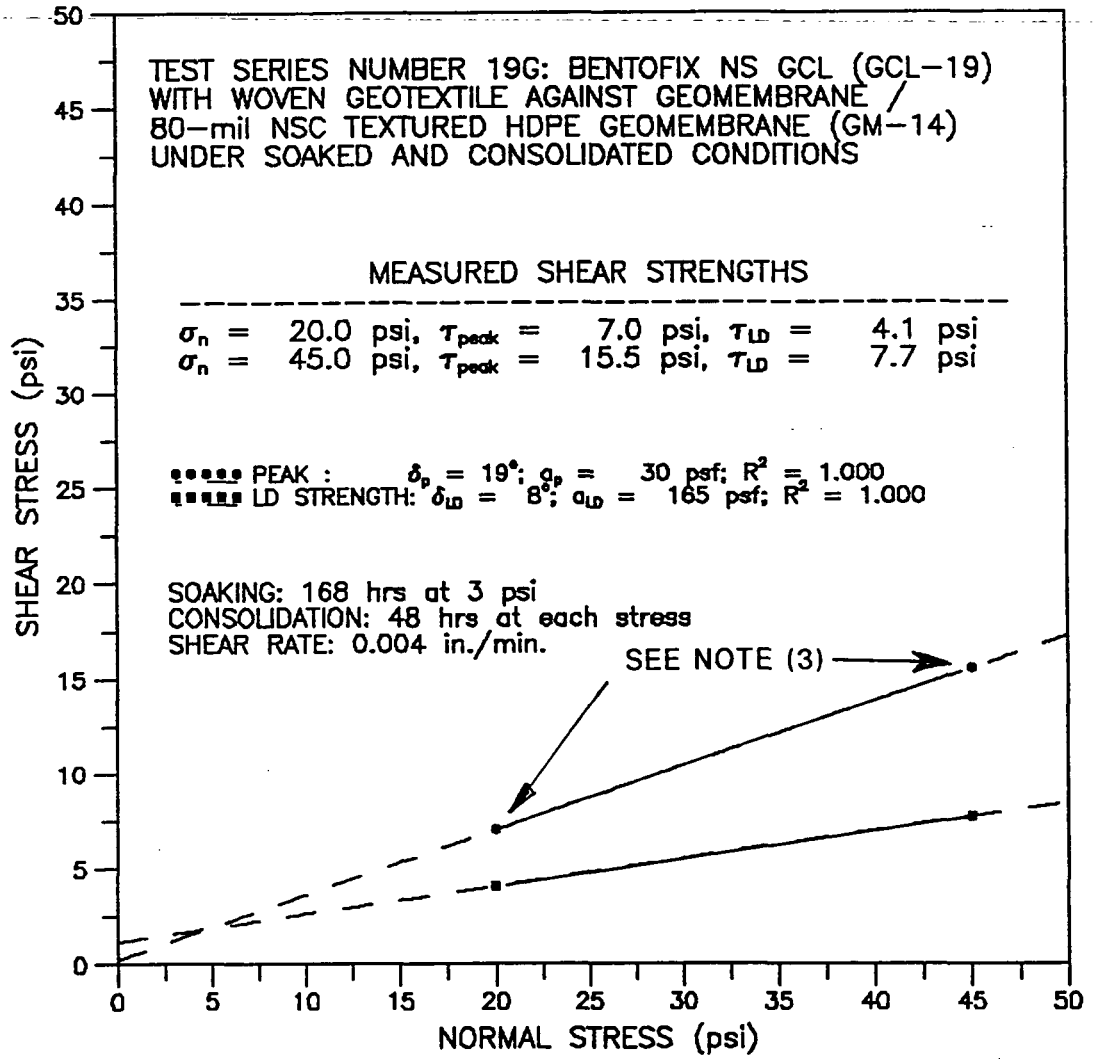
DATE TESTED: 8 TO 17 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	1-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730105
FILE NO.	000473

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 8 TO 17 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

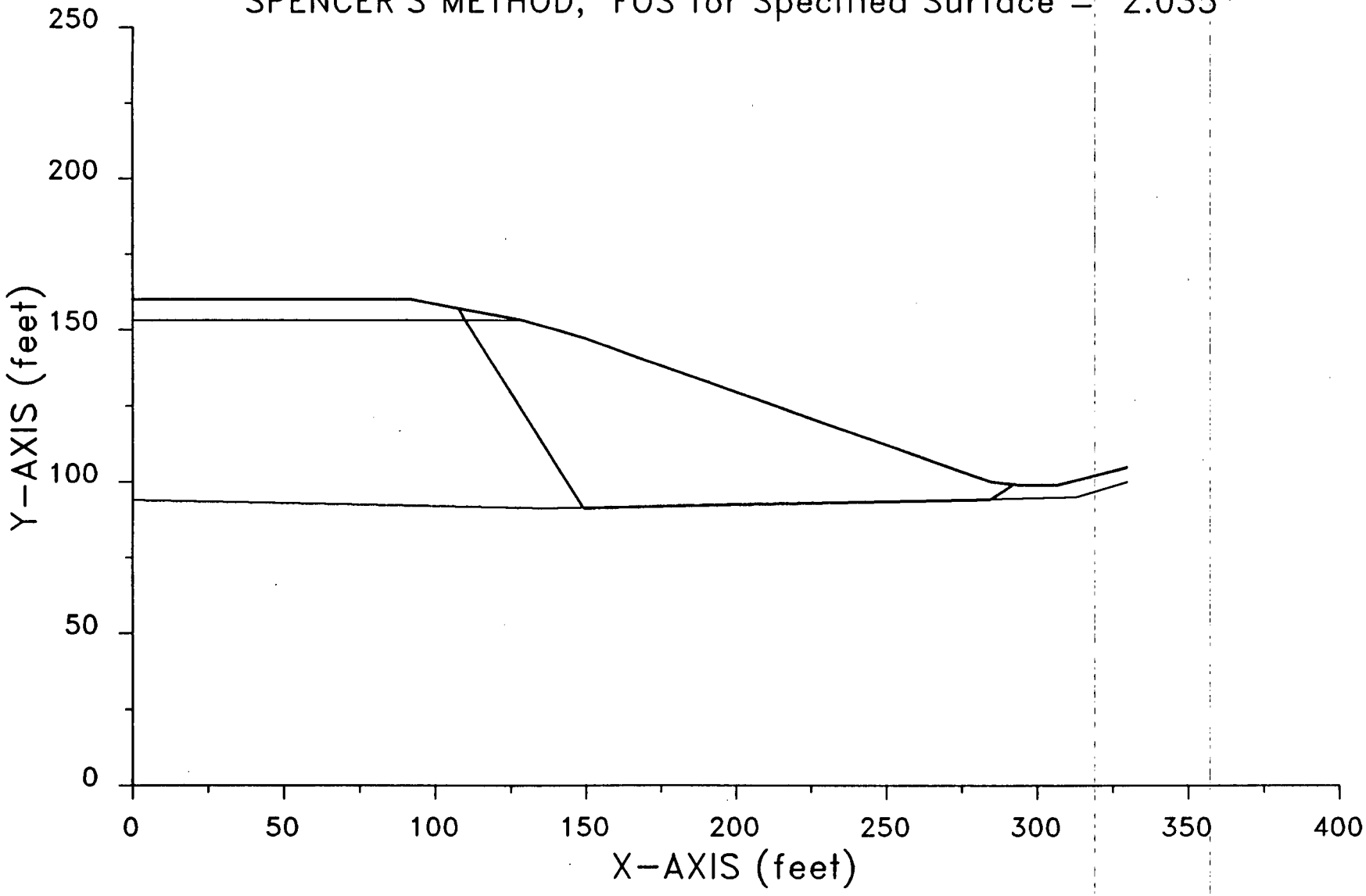
FIGURE NO.	1-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730105
FILE NO.	

MCO 10/23/97
RAM 10/24/97

APPENDIX B

N. AS 10-21-97 19:48

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.035



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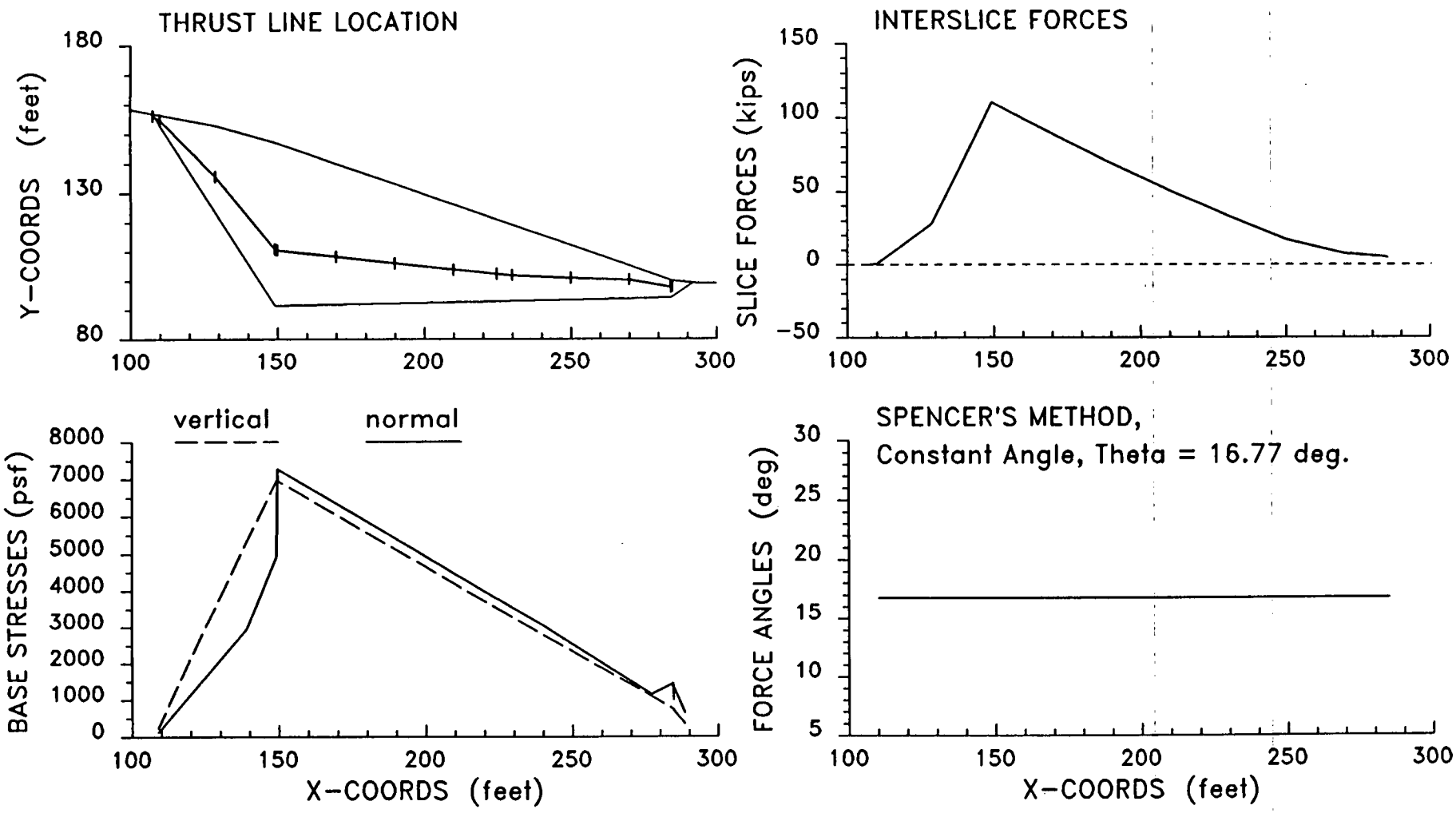
12669



OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.035

XSTABL File: NPK19AS 10-21-97 19:48

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*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 - 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.201                 96 - 1202 *
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```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	1425.6
5	6480.0	1728.0
6	10080.0	1728.0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	292.25	99.19
2	284.72	94.39
3	284.51	94.19
4	224.80	93.00
5	149.45	91.42
6	149.21	91.66
7	110.13	153.00
8	107.82	157.01

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.63	96.88	2.72	7.25	-32.54	6.34	2461.
2	284.86	94.48	5.57	.27	-32.54	19.12	190.
3	284.72	94.39	5.70	.01	-32.54	19.12	5.
4	284.61	94.29	5.84	.21	-43.60	19.12	153.
5	277.26	94.05	8.64	14.51	-1.14	19.12	15670.
6	260.00	93.70	15.00	20.00	-1.14	19.29	37496.
7	240.00	93.30	22.35	20.00	-1.14	19.03	55868.
8	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
9	217.40	92.84	30.67	14.80	-1.20	19.29	56731.
10	200.00	92.48	37.12	20.00	-1.20	19.29	92800.
11	180.00	92.06	44.49	20.00	-1.20	19.03	111224.
12	160.00	91.64	51.86	20.00	-1.20	19.29	129647.
13	149.73	91.43	55.65	.55	-1.20	15.95	3826.
14	149.33	91.54	55.65	.24	45.00	15.95	1669.
15	139.11	107.52	42.59	20.21	57.50	15.95	107598.
16	119.57	138.19	16.59	18.87	57.50	10.71	39142.
17	108.98	155.00	1.79	2.31	60.04	10.71	515.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.7309	2.0506	2.0700
3	16.7536	2.0513	2.0506

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.7658	2.0351	2.0347

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.7658	2.0351	2.0347

SLICE INFORMATION ... continued :

15/37

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	627.1	.0	30.00	0.	0.	0.	.00
2	1329.9	200.0	25.00	0.	0.	0.	.00
3	981.1	-475.2	33.42	0.	0.	0.	.00
4	1428.1	-475.2	33.42	0.	0.	0.	.00
5	1129.4	-475.2	33.42	0.	0.	0.	.00
6	2022.6	-475.2	33.42	0.	0.	0.	.00
7	3038.7	1183.7	4.80	0.	0.	0.	.00
8	3626.4	1183.7	4.80	0.	0.	0.	.00
9	4101.0	1183.7	4.80	0.	0.	0.	.00
10	4924.0	1183.7	4.80	0.	0.	0.	.00
11	5863.6	1183.7	4.80	0.	0.	0.	.00
12	6798.9	1728.0	.00	0.	0.	0.	.00
13	7276.2	1728.0	.00	0.	0.	0.	.00
14	4924.3	1183.7	4.80	0.	0.	0.	.00
15	2948.3	200.0	25.00	0.	0.	0.	.00
16	1105.5	200.0	25.00	0.	0.	0.	.00
17	115.7	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.63	627.1	339.5	.0	177.9
2	284.86	1329.9	695.7	.0	403.0
3	284.72	981.1	712.9	.0	84.7
4	284.61	1428.1	730.4	.0	229.6
5	277.26	1129.4	1079.9	.0	132.8
6	260.00	2022.6	1874.8	.0	422.5
7	240.00	3038.7	2793.4	.0	707.1
8	227.40	3626.4	3369.8	.0	731.3
9	217.40	4101.0	3833.1	.0	750.9
10	200.00	4924.0	4640.0	.0	784.9
11	180.00	5863.6	5561.2	.0	823.7
12	160.00	6798.9	6482.3	.0	849.1
13	149.73	7276.2	6956.6	.0	849.1
14	149.33	4924.3	6956.4	.0	784.9
15	139.11	2948.3	5324.0	.0	773.8
16	119.57	1105.5	2074.3	.0	351.6
17	108.98	115.7	223.1	.0	32.8

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	16.77	4377.	3.40	5.43	.627
2	284.73	16.77	4733.	3.40	5.70	.596
3	284.72	16.77	4739.	3.40	5.71	.595

16/37

4	284.51	16.77	5087.	3.42	5.98	.572
5	270.00	16.77	7440.	6.26	11.30	.554
6	250.00	16.77	17107.	7.33	18.70	.392
7	230.00	16.77	33141.	8.65	26.00	.333
8	224.80	16.77	37505.	9.22	27.92	.330
9	210.00	16.77	50441.	11.01	33.41	.330
10	190.00	16.77	68993.	13.63	40.83	.334
11	170.00	16.77	88766.	16.32	48.15	.339
12	150.00	16.77	109480.	19.07	55.57	.343
13	149.45	16.77	110055.	19.14	55.74	.343
14	149.21	16.77	109017.	19.16	55.57	.345
15	129.00	16.77	27673.	12.17	29.62	.411
16	110.13	16.77	404.	1.66	3.57	.464
17	107.82	.00	-1.	-.84	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3203.48 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 597.61 (psf)

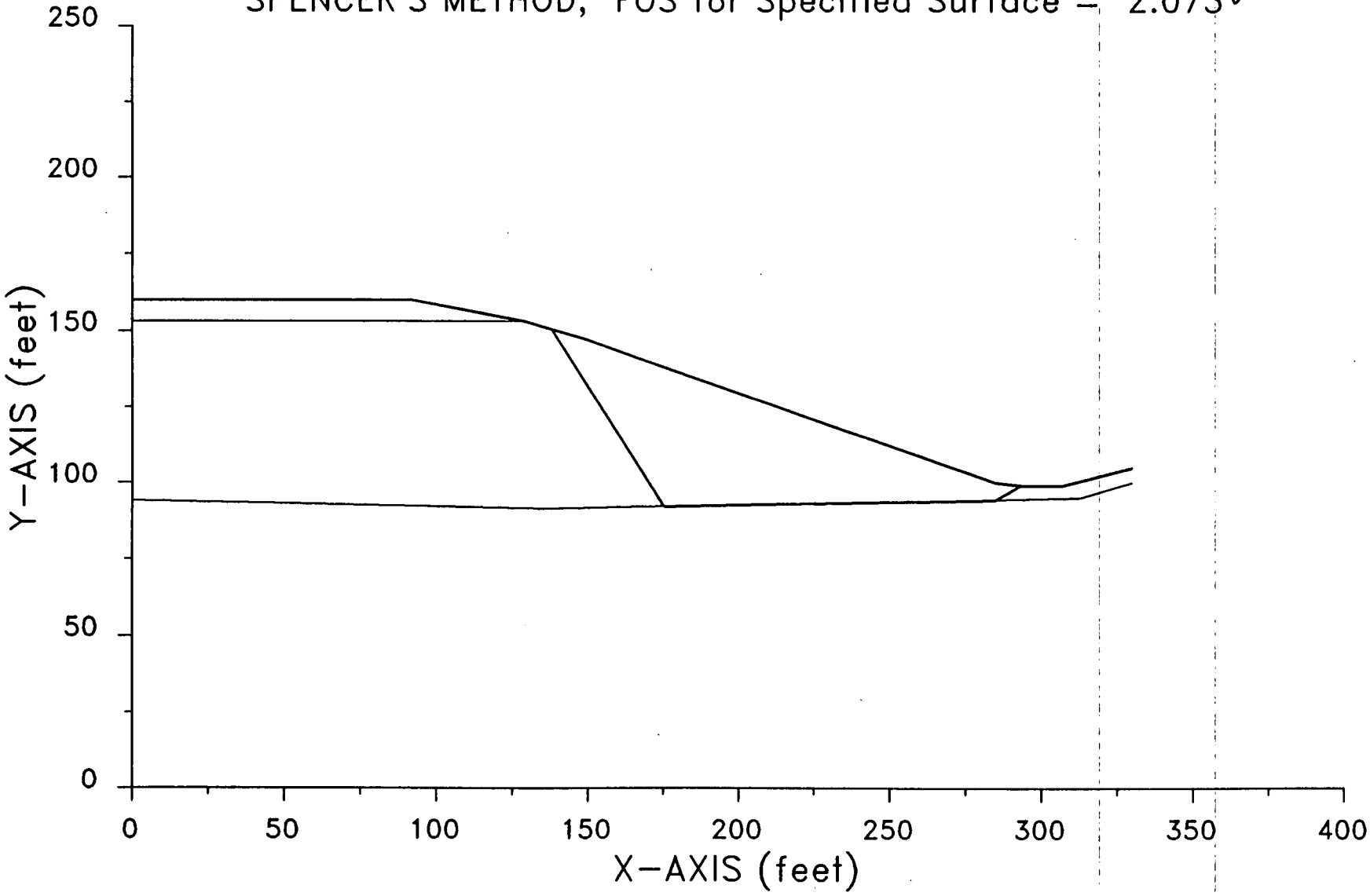
Total Length of failure surface = 222.01 feet

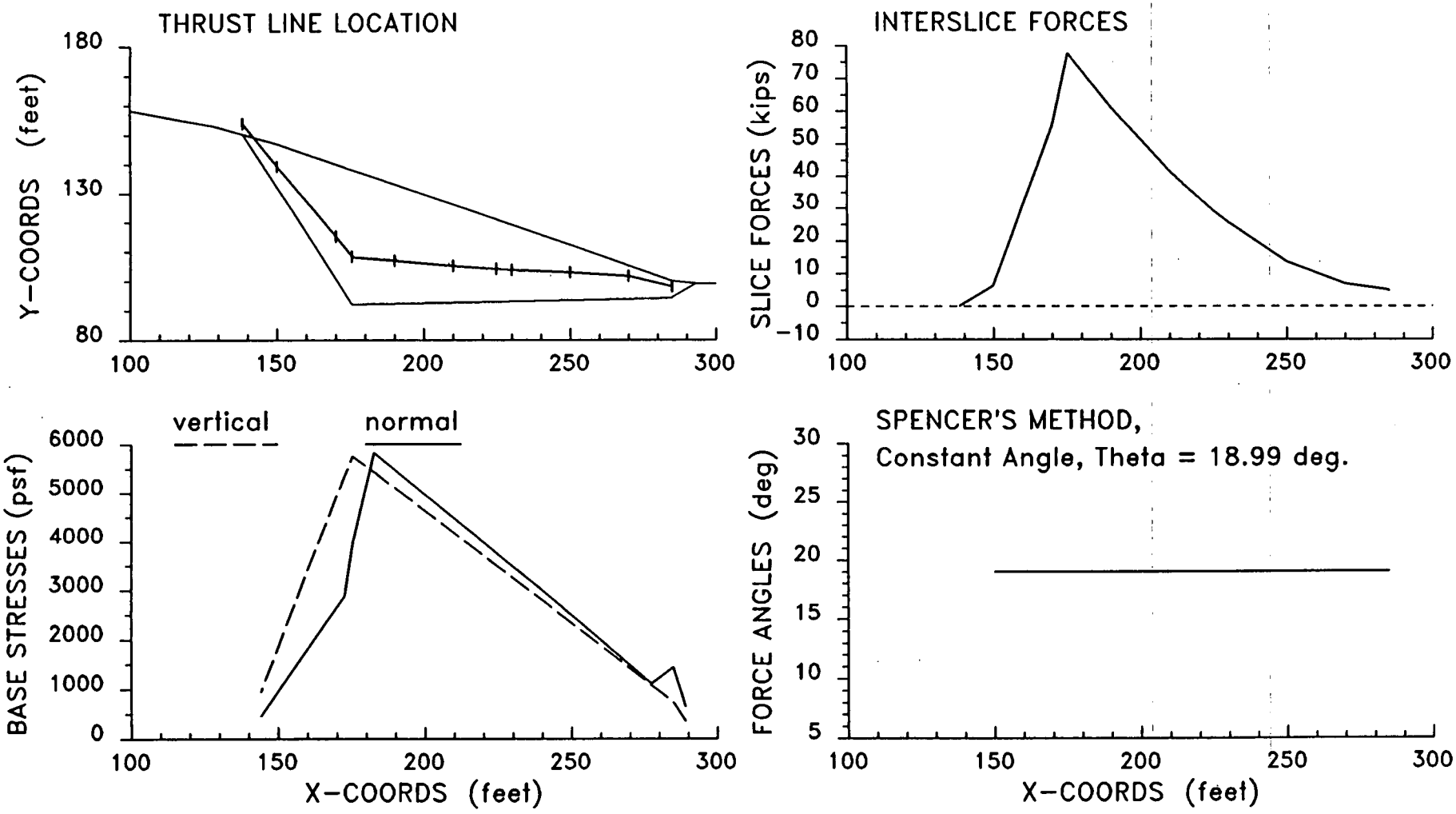
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.035

Total shear strength available along specified failure surface = 270.00E+03 lb

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.073





OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.073

XSTABL File: NPK19BS 10-21-97 19:51

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*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 - 96       *
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*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.201                 96 - 1202 *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	1008.0
5	6480.0	2232.0
6	10080.0	2232.0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 7 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	293.27	99.08
2	285.17	94.40
3	284.97	94.20
4	224.80	93.00
5	175.56	92.03
6	175.40	92.19
7	138.37	150.32

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	289.22	96.74	2.79	8.10	-30.02	6.34	2825.
2	285.09	94.31	5.68	.17	-45.00	6.34	121.
3	284.98	94.21	5.79	.03	-45.00	19.12	22.
4	277.48	94.05	8.55	14.97	-1.14	19.12	16008.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37495.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55867.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.13	19.29	56713.
9	200.00	92.51	37.09	20.00	-1.13	19.29	92721.
10	182.78	92.17	43.42	14.44	-1.13	19.03	78371.
11	175.48	92.11	46.00	.16	45.00	19.03	931.
12	172.70	96.43	42.64	5.40	57.50	19.03	28771.
13	160.00	116.37	27.13	20.00	57.50	19.29	67834.
14	144.18	141.19	7.47	11.63	57.50	15.95	10856.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	19.0353	2.0764	2.0542
3	19.0204	2.0760	2.0764

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.9902	2.0734	2.0743

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	18.9902	2.0734	2.0743

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	640.8	.0	30.00	0.	0.	0.	.00

2	1391.3	-336.0	25.02	0.	0.	0.	.00
3	1431.9	-336.0	25.02	0.	0.	0.	.00
4	1108.8	-336.0	25.02	0.	0.	0.	.00
5	1992.7	-336.0	25.02	0.	0.	0.	.00
6	2998.0	28.8	18.78	0.	0.	0.	.00
7	3615.5	28.8	18.78	0.	0.	0.	.00
8	4110.1	28.8	18.78	0.	0.	0.	.00
9	4971.4	28.8	18.78	0.	0.	0.	.00
10	5819.0	28.8	18.78	0.	0.	0.	.00
11	3954.5	28.8	18.78	0.	0.	0.	.00
12	2869.9	200.0	25.00	0.	0.	0.	.00
13	1802.7	200.0	25.00	0.	0.	0.	.00
14	449.0	200.0	25.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	289.22	640.8	348.8	.0	178.4
2	285.09	1391.3	709.4	.0	151.1
3	284.98	1431.9	723.8	.0	160.2
4	277.48	1108.8	1069.3	.0	87.5
5	260.00	1992.7	1874.7	.0	286.5
6	240.00	2998.0	2793.4	.0	505.5
7	227.40	3615.5	3369.8	.0	606.8
8	217.40	4110.1	3832.0	.0	687.9
9	200.00	4971.4	4636.1	.0	829.1
10	182.78	5819.0	5427.3	.0	968.1
11	175.48	3954.5	5749.8	.0	662.4
12	172.70	2869.9	5329.8	.0	741.9
13	160.00	1802.7	3391.7	.0	501.9
14	144.18	449.0	933.4	.0	197.4

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.17	18.99	4701.	3.73	5.58	.669
2	285.00	18.99	4978.	3.75	5.77	.650
3	284.97	18.99	5028.	3.75	5.81	.645
4	270.00	18.99	6764.	7.54	11.30	.667
5	250.00	18.99	13663.	9.18	18.70	.491
6	230.00	18.99	25620.	10.48	26.00	.403
7	224.80	18.99	29353.	10.92	27.92	.391
8	210.00	18.99	41387.	12.35	33.39	.370
9	190.00	18.99	60995.	14.48	40.79	.355
10	175.56	18.99	77529.	16.09	46.05	.349
11	175.40	18.99	76965.	16.10	45.95	.350
12	170.00	18.99	55480.	14.44	39.33	.367
13	150.00	18.99	6238.	7.13	14.93	.477

14	138.37	.00	-3.	3.49	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 2616.77 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 495.87 (psf)

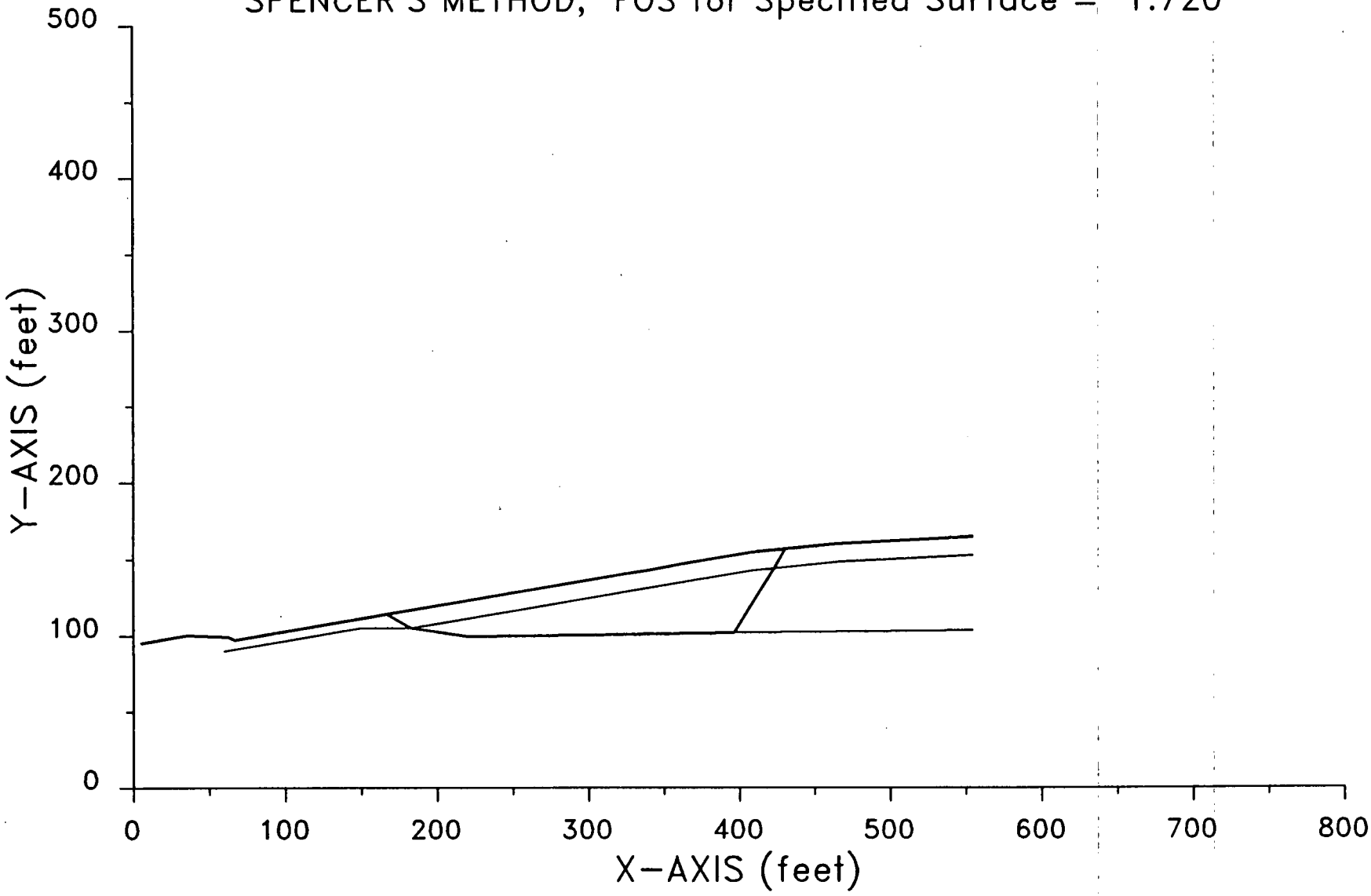
Total Length of failure surface = 188.22 feet

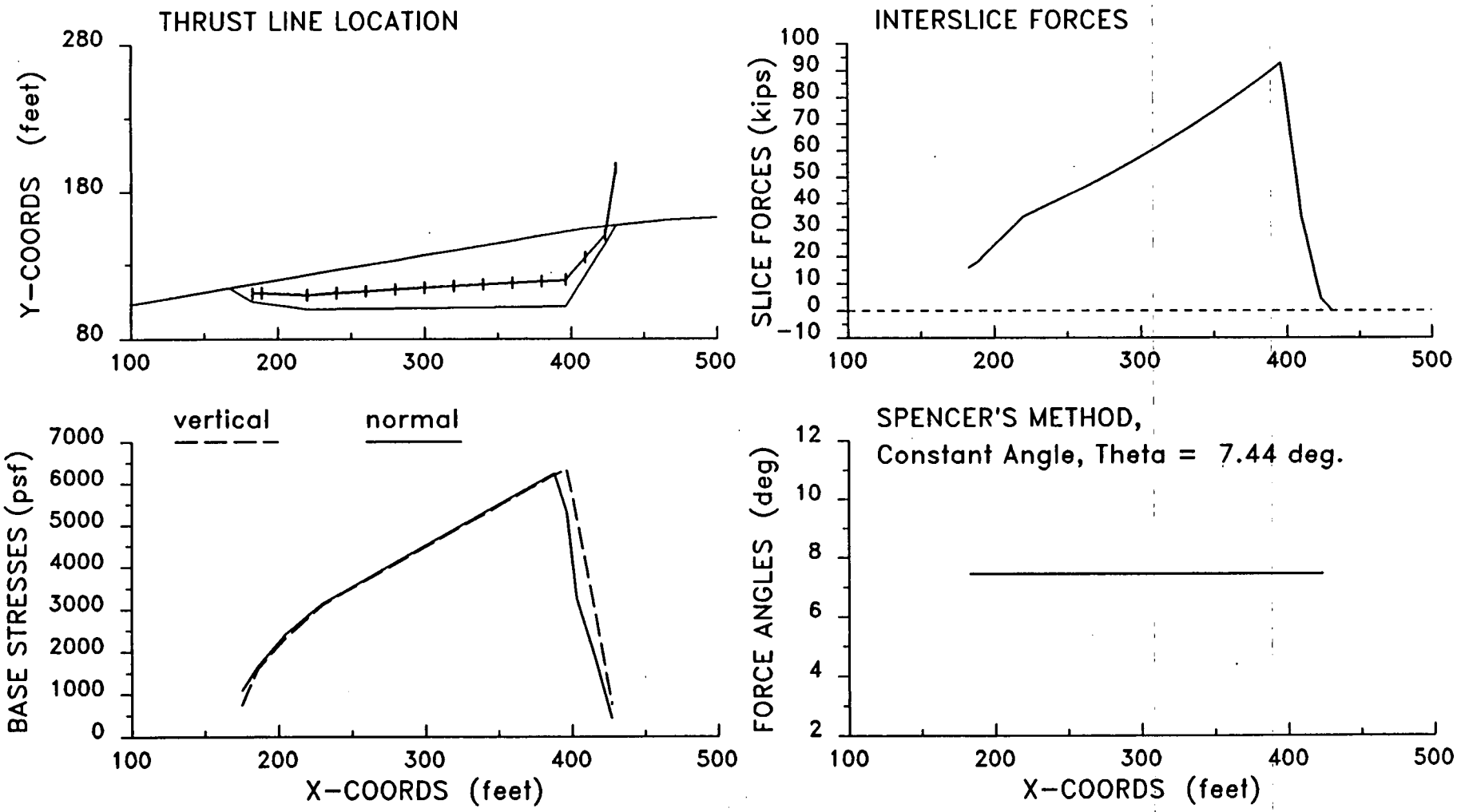
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.073

Total shear strength available along specified failure surface = 193.52E+03 lb

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.720





OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.720 ✓

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*****************************************
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*                                       *
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*               using the               *
*            Method of Slices           *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters

---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	460.8
5	6480.0	820.8
6	10080.0	820.8

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	396.44	101.60
6	396.69	101.85
7	423.64	144.16
8	430.93	156.79

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.70	37.35	20.00	.59	9.37	93366.
9	330.00	100.91	40.44	20.00	.59	9.37	101097.
10	350.00	101.12	43.58	20.00	.59	9.65	108954.
11	370.00	101.33	46.72	20.00	.59	9.37	116810.
12	388.22	101.51	49.56	16.44	.59	9.46	101836.
13	396.57	101.73	50.73	.25	45.00	9.46	1605.
14	403.35	112.30	41.29	13.31	57.50	9.46	68681.
15	416.82	133.45	21.93	13.64	57.50	5.71	37393.
16	427.29	150.48	5.95	7.29	60.01	5.71	5420.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.3578	1.7178	1.7643
3	7.4453	1.7200	1.7178
4	7.4432	1.7199	1.7200

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.4432	1.7199	1.7200

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1076.8	.0	30.00	0.	0.	0.	.00

2	1656.3	-153.6	12.04	0.	0.	0.	.00
3	2405.7	-153.6	12.04	0.	0.	0.	.00
4	3130.0	172.8	5.71	0.	0.	0.	.00
5	3526.0	172.8	5.71	0.	0.	0.	.00
6	3915.7	172.8	5.71	0.	0.	0.	.00
7	4311.7	172.8	5.71	0.	0.	0.	.00
8	4706.9	172.8	5.71	0.	0.	0.	.00
9	5095.7	172.8	5.71	0.	0.	0.	.00
10	5490.7	172.8	5.71	0.	0.	0.	.00
11	5885.8	172.8	5.71	0.	0.	0.	.00
12	6241.7	172.8	5.71	0.	0.	0.	.00
13	5295.1	172.8	5.71	0.	0.	0.	.00
14	3235.3	.0	25.00	0.	0.	0.	.00
15	1718.1	.0	25.00	0.	0.	0.	.00
16	421.6	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1076.8	739.6	.0	361.5
2	186.00	1656.3	1594.4	.0	116.1
3	204.50	2405.7	2304.8	.0	209.1
4	230.00	3130.0	3100.0	.0	282.5
5	250.00	3526.0	3493.8	.0	305.5
6	270.00	3915.7	3881.3	.0	328.1
7	290.00	4311.7	4275.0	.0	351.2
8	310.00	4706.9	4668.3	.0	374.1
9	330.00	5095.7	5054.9	.0	396.7
10	350.00	5490.7	5447.7	.0	419.7
11	370.00	5885.8	5840.5	.0	442.7
12	388.22	6241.7	6194.4	.0	463.4
13	396.57	5295.1	6341.8	.0	408.3
14	403.35	3235.3	5161.3	.0	877.2
15	416.82	1718.1	2740.9	.0	465.8
16	427.29	421.6	743.7	.0	141.5

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.44	15769.	5.63	11.83	.476
2	189.00	7.44	17881.	6.50	13.68	.475
3	220.00	7.44	34987.	9.67	23.20	.417
4	240.00	7.44	40053.	10.71	26.40	.406
5	260.00	7.44	45503.	11.69	29.50	.396
6	280.00	7.44	51332.	12.64	32.60	.388
7	300.00	7.44	57546.	13.56	35.80	.379
8	320.00	7.44	64108.	14.45	38.89	.372
9	340.00	7.44	71044.	15.33	41.99	.365

10	360.00	7.44	78361.	16.19	45.18	.358
11	380.00	7.44	86059.	17.04	48.27	.353
12	396.44	7.44	92669.	17.73	50.84	.349
13	396.69	7.44	91422.	17.75	50.63	.351
14	410.00	7.44	35030.	11.75	31.95	.368
15	423.64	7.44	4329.	5.84	11.90	.491
16	430.93	.00	0.	39.05	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3568.50 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 387.80 (psf)

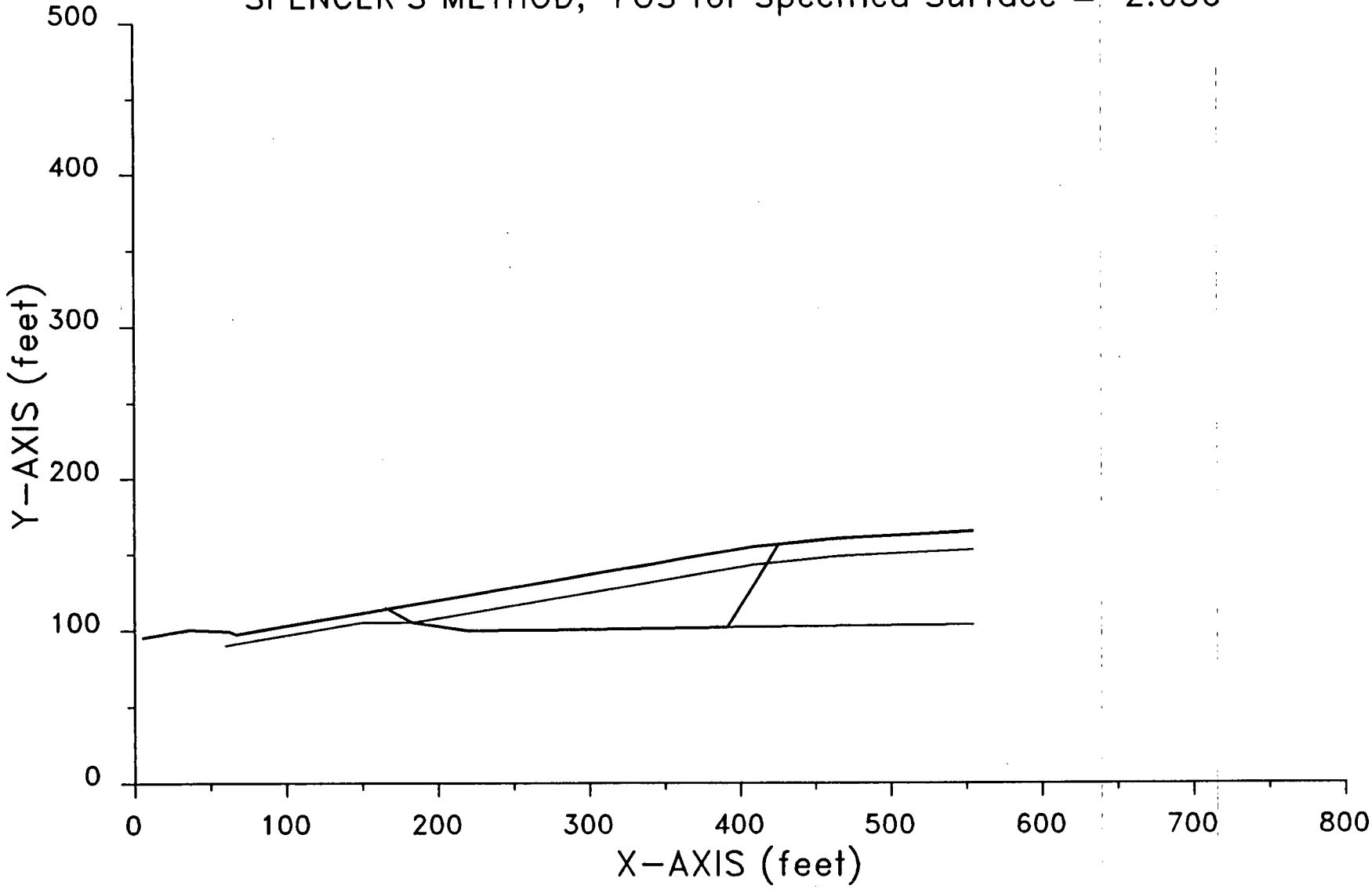
Total Length of failure surface = 297.28 feet

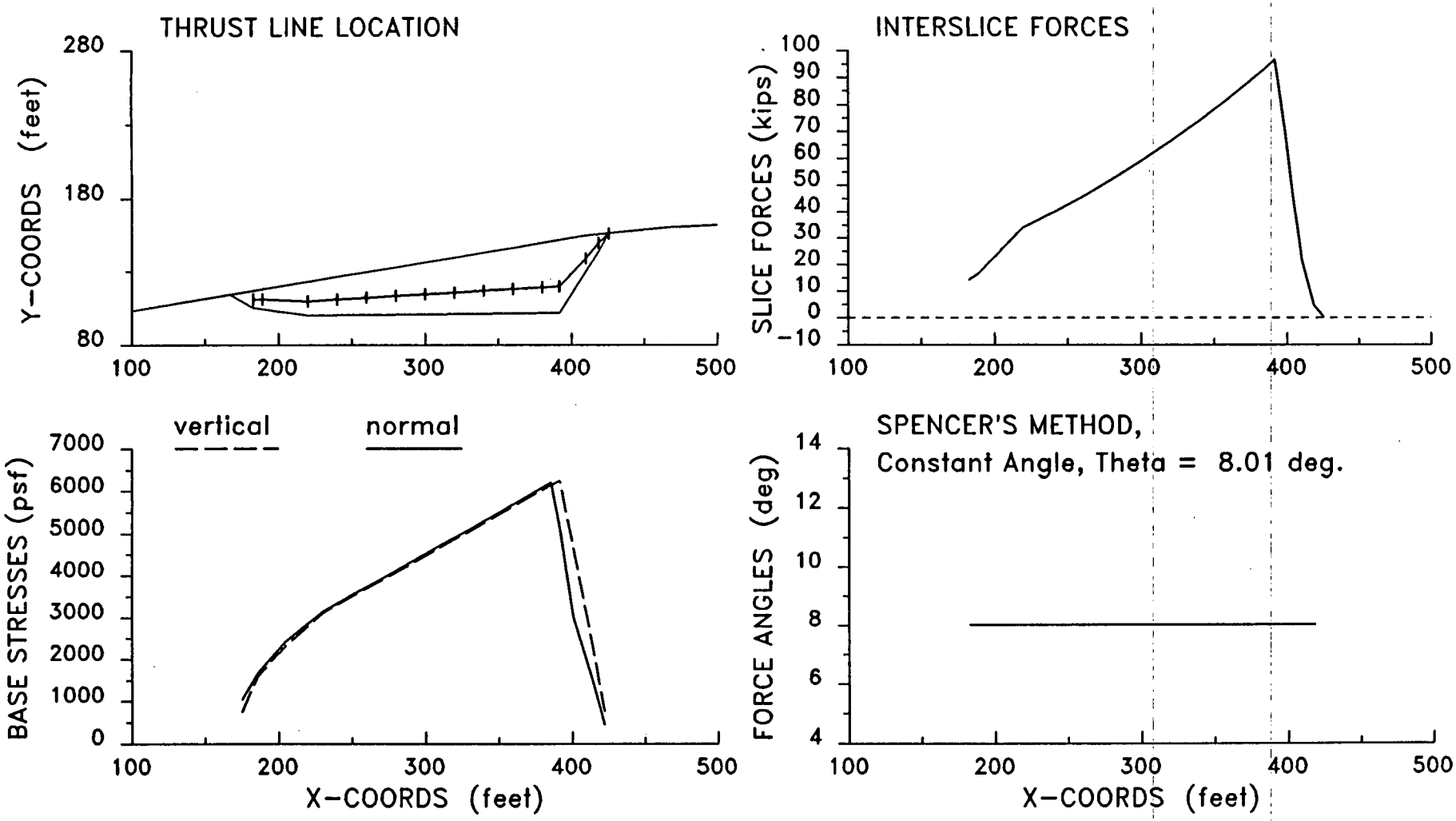
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.720

Total shear strength available along specified failure surface = 198.28E+03 lb

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.056





OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.056

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*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*           Method of Slices            *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
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15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	590.4
5	6480.0	1108.8
6	10080.0	1108.8

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	391.76	101.64
6	391.92	101.80
7	418.59	143.66
8	425.88	156.29

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.65	9.37	93342.
9	330.00	100.94	40.41	20.00	.65	9.37	101025.
10	350.00	101.17	43.53	20.00	.65	9.65	108833.
11	370.00	101.39	46.66	20.00	.65	9.37	116642.
12	385.88	101.57	49.11	11.76	.65	9.46	72187.
13	391.84	101.72	49.95	.16	45.00	9.46	1010.
14	400.96	115.99	37.20	18.08	57.50	9.46	84071.
15	414.29	136.92	18.21	8.59	57.50	5.71	19554.
16	422.23	149.97	5.95	7.29	60.00	5.71	5422.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.9494	2.0542	2.0964
3	8.0127	2.0563	2.0542
4	8.0112	2.0562	2.0563

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	8.0112	2.0562	2.0563

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1031.5	.0	30.00	0.	0.	0.	.00

2	1662.5	-196.8	15.29	0.	0.	0.	.00
3	2416.0	-196.8	15.29	0.	0.	0.	.00
4	3135.5	175.7	8.19	0.	0.	0.	.00
5	3532.3	175.7	8.19	0.	0.	0.	.00
6	3922.8	175.7	8.19	0.	0.	0.	.00
7	4319.6	175.7	8.19	0.	0.	0.	.00
8	4713.3	175.7	8.19	0.	0.	0.	.00
9	5100.4	175.7	8.19	0.	0.	0.	.00
10	5493.7	175.7	8.19	0.	0.	0.	.00
11	5887.1	175.7	8.19	0.	0.	0.	.00
12	6195.7	175.7	8.19	0.	0.	0.	.00
13	5138.3	175.7	8.19	0.	0.	0.	.00
14	3010.1	.0	25.00	0.	0.	0.	.00
15	1473.4	.0	25.00	0.	0.	0.	.00
16	439.9	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1031.5	739.6	.0	289.6
2	186.00	1662.5	1594.4	.0	125.3
3	204.50	2416.0	2304.8	.0	225.4
4	230.00	3135.5	3100.0	.0	305.0
5	250.00	3532.3	3493.8	.0	332.8
6	270.00	3922.8	3881.3	.0	360.2
7	290.00	4319.6	4275.0	.0	387.9
8	310.00	4713.3	4667.1	.0	415.5
9	330.00	5100.4	5051.2	.0	442.6
10	350.00	5493.7	5441.7	.0	470.2
11	370.00	5887.1	5832.1	.0	497.7
12	385.88	6195.7	6138.3	.0	519.3
13	391.84	5138.3	6244.1	.0	445.3
14	400.96	3010.1	4650.4	.0	682.6
15	414.29	1473.4	2276.3	.0	334.1
16	422.23	439.9	743.7	.0	123.5

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	8.01	14216.	5.71	11.83	.483
2	189.00	8.01	16391.	6.53	13.68	.477
3	220.00	8.01	34078.	9.60	23.20	.414
4	240.00	8.01	39605.	10.69	26.40	.405
5	260.00	8.01	45614.	11.72	29.50	.397
6	280.00	8.01	52095.	12.72	32.60	.390
7	300.00	8.01	59058.	13.68	35.80	.382
8	320.00	8.01	66372.	14.62	38.87	.376
9	340.00	8.01	74144.	15.53	41.95	.370

10	360.00	8.01	82382.	16.44	45.12	.364
11	380.00	8.01	91087.	17.33	48.19	.360
12	391.76	8.01	96421.	17.85	50.02	.357
13	391.92	8.01	95654.	17.86	49.89	.358
14	410.00	8.01	21863.	8.70	24.52	.355
15	418.59	8.01	4700.	5.80	11.90	.488
16	425.88	.00	0.	-.65	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3535.25 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 389.46 (psf)

Total Length of failure surface = 291.94 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.056

Total shear strength available along specified failure surface = 233.79E+03 lb

GCL 20 – Rejected Due to Small Lot Size (1 Roll)

GCL 21

COMPUTATION COVER SHEET

1269

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 21 - Compliance Package

Computations By:
(Cognizant Engineer)

Signature [illegible] — Date NOV 6 1997

Printed Name and Title M. CATALINA OROZCO, STAFF ENGINEER

Assumptions and Procedures Checked By:
(Checker)

Signature [illegible] — Date 7 NOV 1997

Printed Name and Title ROBERT A. MORGAN III, SR. STAFF ENGINEER

Computations Checked by:

Signature [illegible] — Date 7 NOV 1997

Printed Name and Title ROBERT A. MORGAN III, SR. STAFF ENGINEER

Computations Backchecked by:
(Cognizant Engineer)

Signature [illegible] — Date NOV 7 1997

Printed Name and Title M. CATALINA OROZCO, STAFF ENGINEER

Approved by:
(PDP)

Signature [illegible] — Date 7 Nov 97

Printed Name and Title Gary R. Schmertmann, Sr. Project Engineer

Approved by:
(DTL and TETL)

Signature [illegible] — Date 10 Nov 97

Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

Written By: MCO Date: 11/6/97 Reviewed by: RAM Date: 11/7/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 21 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 21 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample No.	Case	Test Type	Measured Shear Strengths		
			5 psi	20 psi	45 psi
21	Peak	GCL Internal	0[1] psi	9.4 psi	17.4 psi
		GCL/GMB Interface	0[1]	8.9	14.5
21	Large-displacement	GCL Internal	0[1]	2.6	5.3
		GCL/GMB Interface	0[1]	4.0	6.5

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix B.

QA Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
21	GCL Internal	NPK21AS	2.4	YES
	GCL/GMB Interface	NPK21BS	2.1	YES
Baseline	Large-displacement	NA	1.6	NA
21	GCL Internal	NLD21AS	1.6	YES
	GCL/GMB Interface	NLD21BS	1.9	YES

[1] Shear strength values for QA sample 21 at 5 psi normal stress were not available at the time that this calculation package was prepared. These values were assumed to equal zero. This assumption is conservative in the context of RCI 1702-006R.

YMCO 6 NOV 1997
RAM 7 NOV 1997

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 21I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-21). GCL's initial moisture content was 9.4%. GCL's final moisture content ranged from 67% to 80% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 21G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

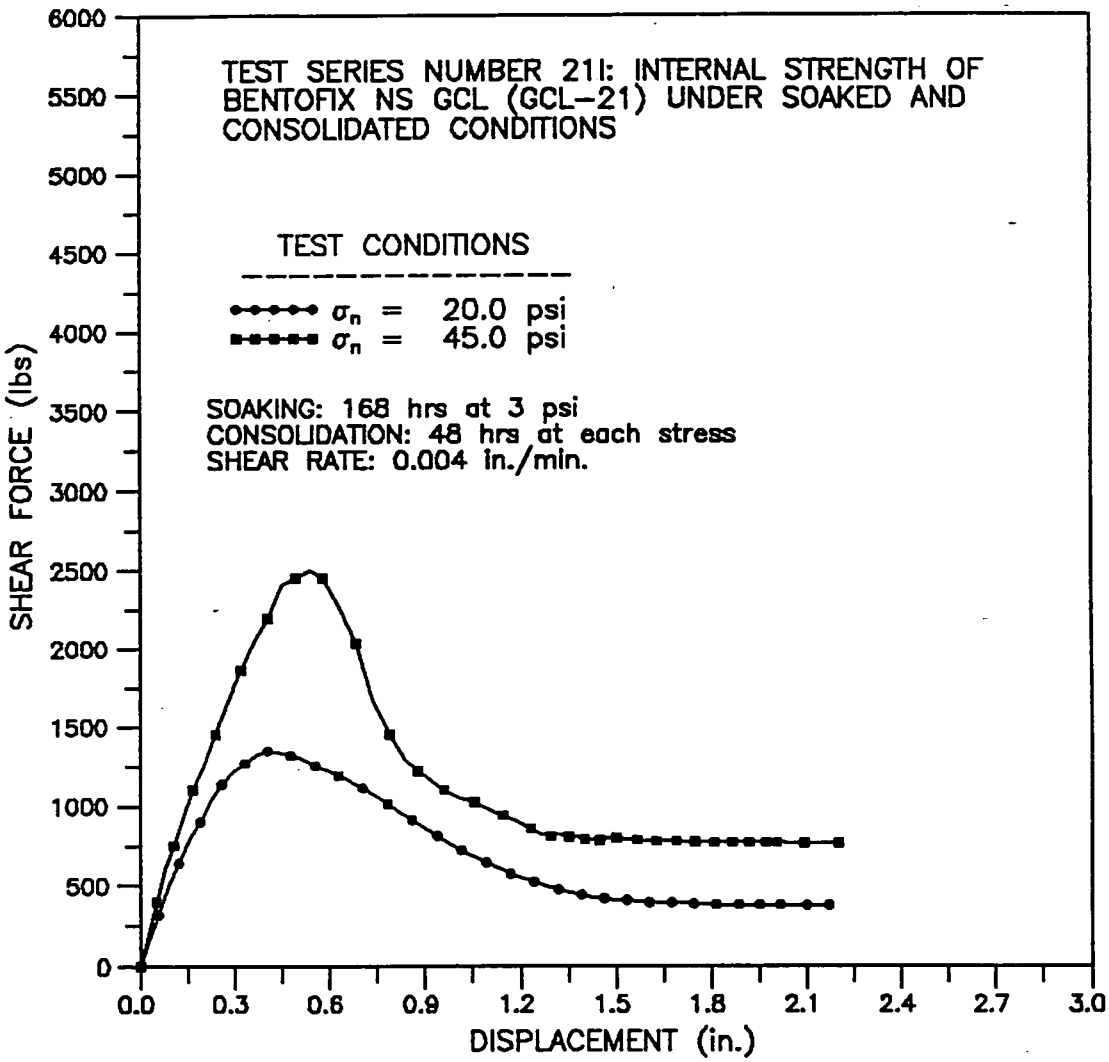
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-21) with woven geotextile against geomembrane. GCL's initial moisture content was 9.1%. GCL's final moisture content ranged from 78 to 110% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-8); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.

(2) For each test, sliding (i.e., internal shear failure) was observed to occur within the GCL.

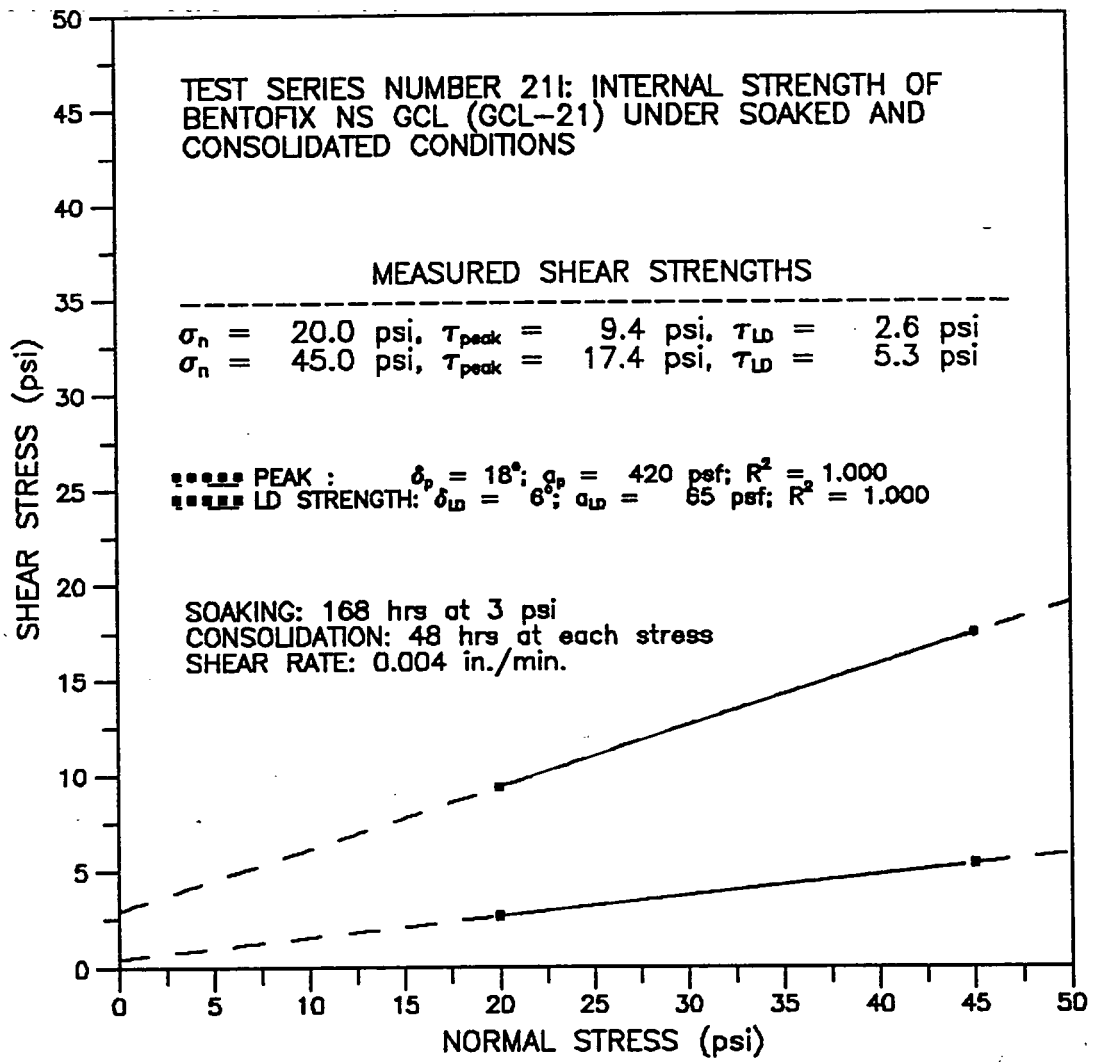
DATE TESTED: 15 TO 24 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730113
FILE NO.	000511

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



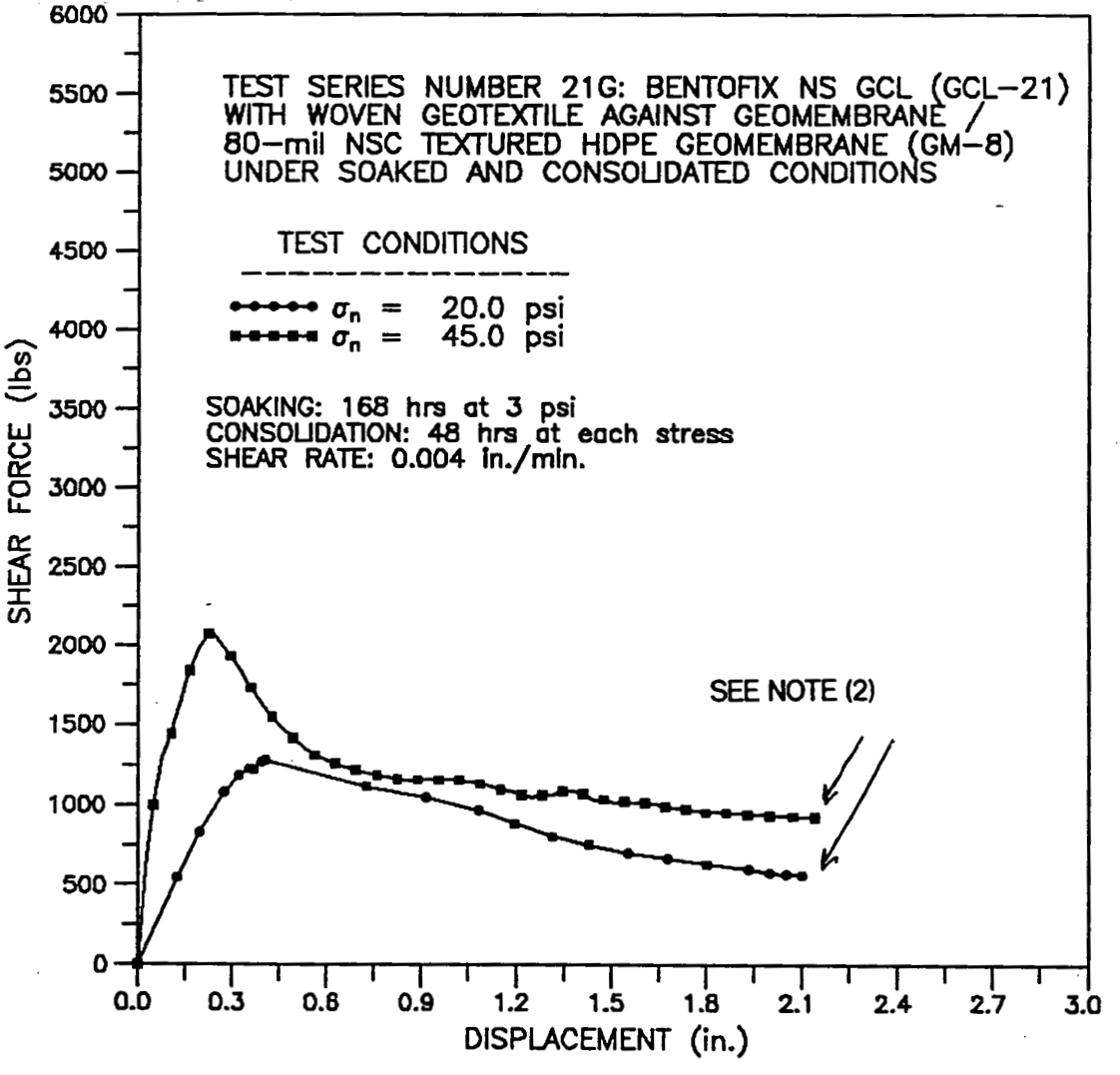
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) For each test, sliding (i.e, internal shear failure) was observed to occur within the GCL.

DATE TESTED: 15 TO 24 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730113
FILE NO.	000512

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



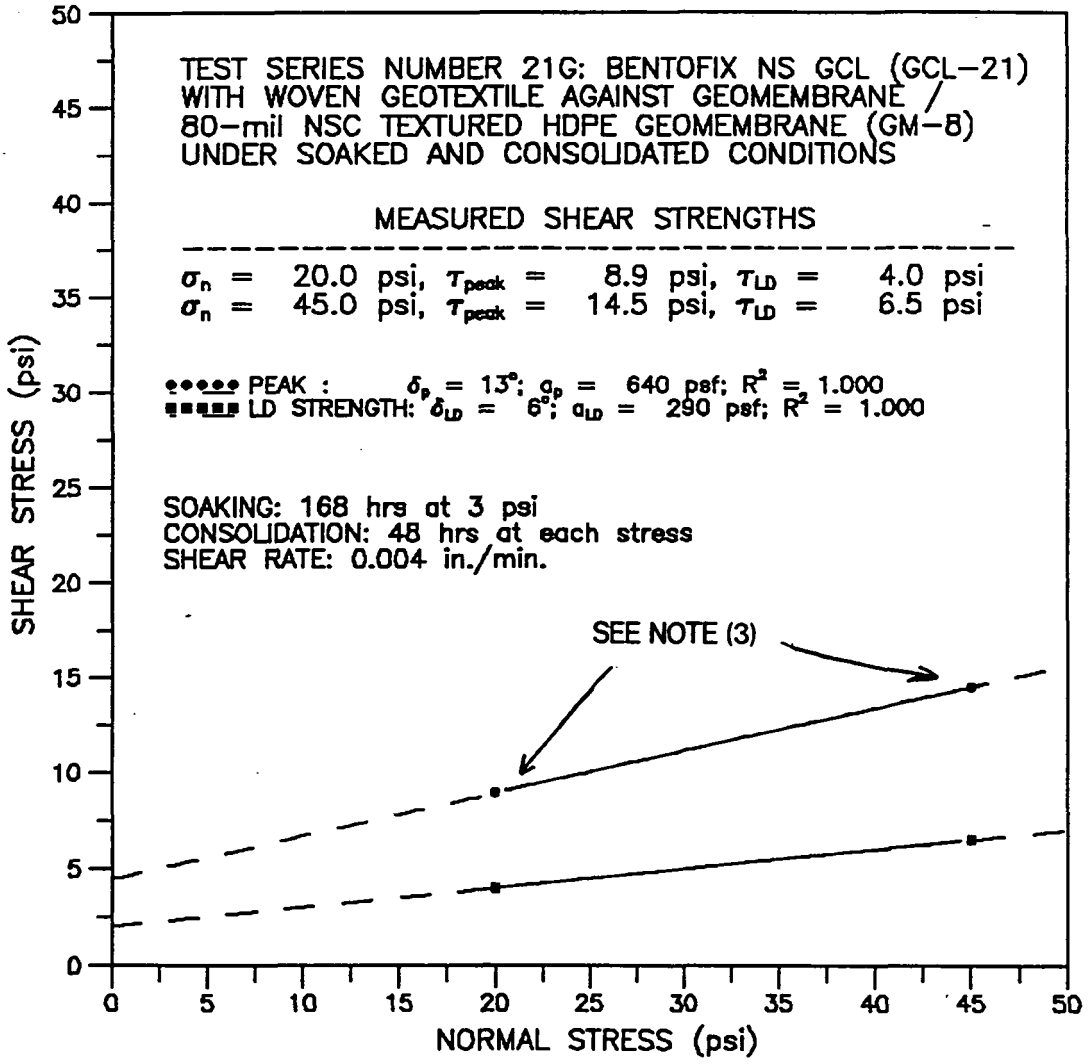
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 15 TO 24 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04-1
DOCUMENT NO.	F9730113
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 15 TO 24 OCTOBER 1997

GEOSYNTEC CONSULTANTS

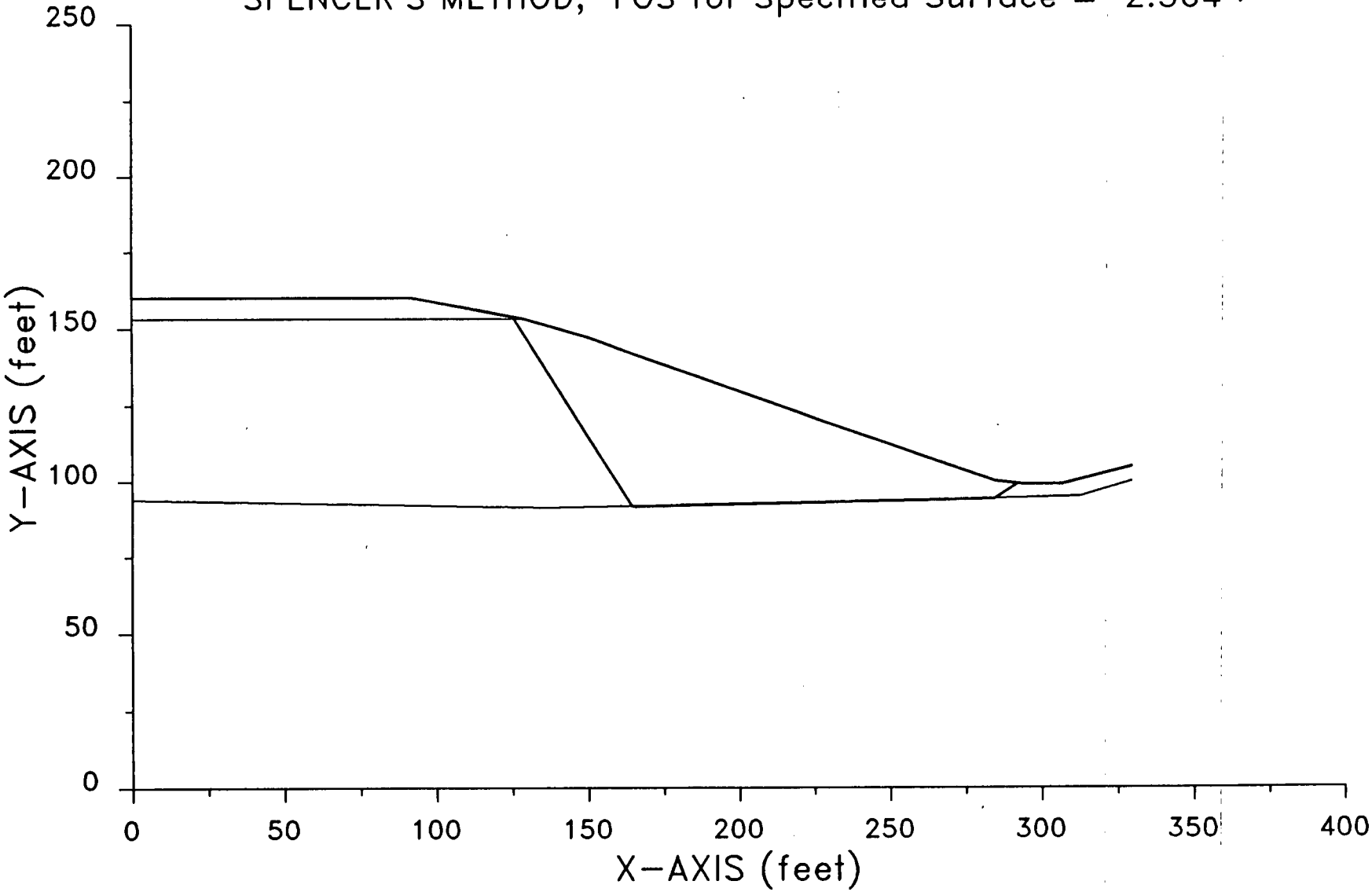
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

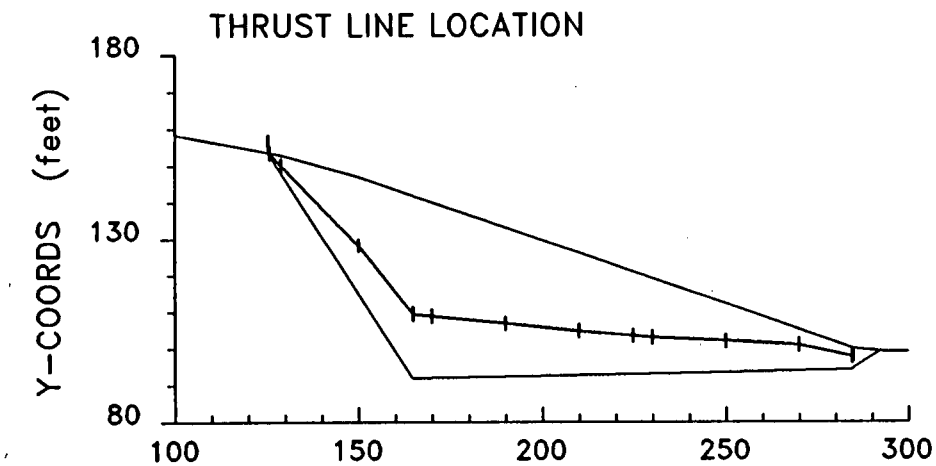
FIGURE NO.	A-4
PROJECT NO.	GO0166-04.1
DOCUMENT NO.	F9730113
FILE NO.	000514

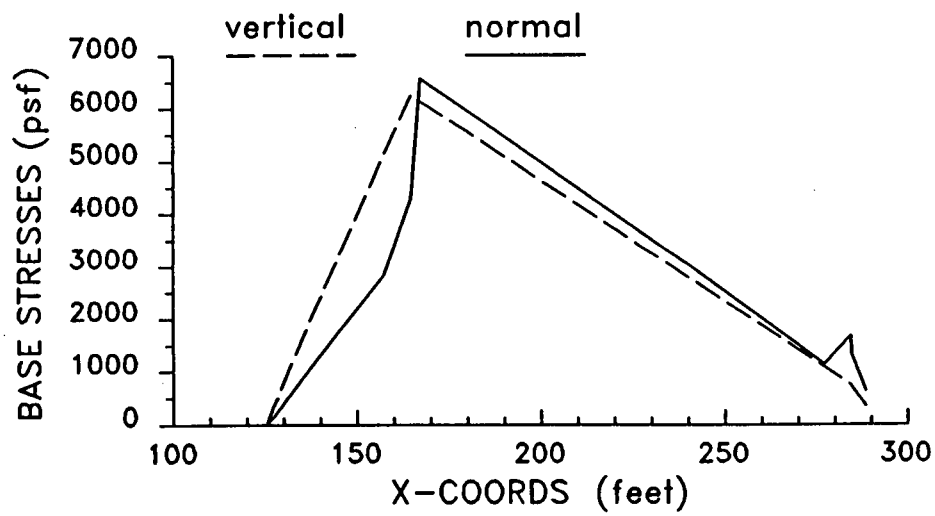
YMCO 6 NOV 1997
RAM 7 NOV 1997

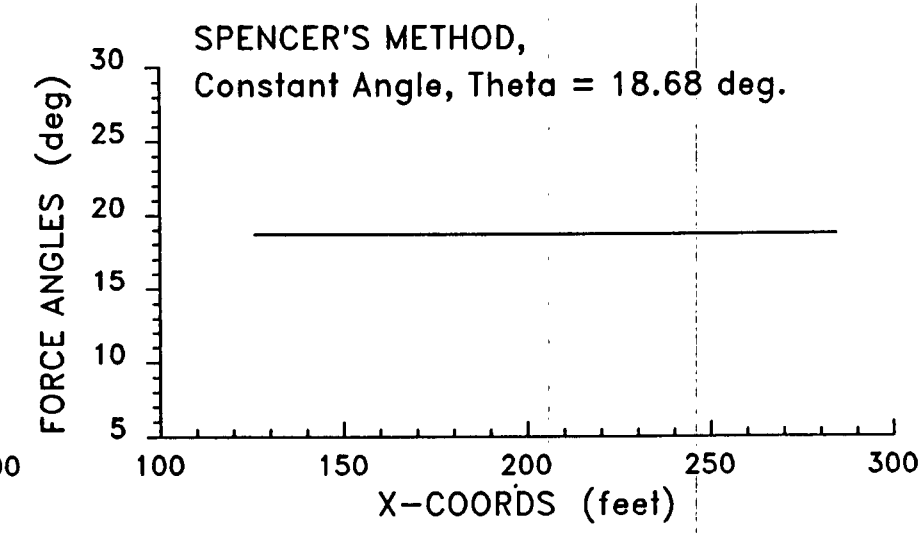
APPENDIX B

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.364 ✓









OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.364

XSTABL File: NPK21AS 10-28-97 12:35

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 - 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.201                 96 - 1202 *
*****************************************
```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	1353.6
5	6480.0	2505.6
6	10080.0	2505.6

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	292.31	99.19
2	284.78	94.40
3	284.58	94.19
4	224.80	93.00
5	164.88	91.78
6	164.69	91.97
7	125.81	153.00
8	125.42	153.68

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.65	96.86	2.73	7.31	-32.45	6.34	2495.
2	284.89	94.47	5.57	.22	-32.45	19.12	156.
3	284.68	94.29	5.82	.20	-46.40	19.12	142.
4	277.29	94.04	8.63	14.58	-1.14	19.12	15724.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37498.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55869.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.17	19.29	56722.
9	200.00	92.50	37.10	20.00	-1.17	19.29	92762.
10	180.00	92.09	44.46	20.00	-1.17	19.03	111155.
11	167.44	91.83	49.06	5.12	-1.17	19.29	31401.
12	164.78	91.88	49.95	.19	45.00	19.29	1205.
13	157.34	103.50	40.93	14.69	57.50	19.29	75139.
14	139.50	131.51	18.49	21.00	57.50	15.95	48534.
15	127.40	150.50	2.81	3.19	57.50	10.71	1119.
16	125.61	153.34	.30	.39	60.07	10.71	15.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.7127	2.3714	2.3483
3	18.7011	2.3710	2.3714

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.6795	2.3639	2.3646

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	18.6795	2.3639	2.3646

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	623.7	.0	30.00	0.	0.	0.	.00
2	1313.3	200.0	25.00	0.	0.	0.	.00
3	1669.0	-451.2	32.07	0.	0.	0.	.00
4	1124.4	-451.2	32.07	0.	0.	0.	.00
5	2011.0	-451.2	32.07	0.	0.	0.	.00
6	3025.9	432.0	17.74	0.	0.	0.	.00
7	3635.9	432.0	17.74	0.	0.	0.	.00
8	4126.7	432.0	17.74	0.	0.	0.	.00
9	4979.5	432.0	17.74	0.	0.	0.	.00
10	5953.1	432.0	17.74	0.	0.	0.	.00
11	6558.1	2505.6	.00	0.	0.	0.	.00
12	4288.5	432.0	17.74	0.	0.	0.	.00
13	2825.7	200.0	25.00	0.	0.	0.	.00
14	1244.3	200.0	25.00	0.	0.	0.	.00
15	139.0	200.0	25.00	0.	0.	0.	.00
16	20.5	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.65	623.7	341.3	.0	152.3
2	284.89	1313.3	696.3	.0	343.7
3	284.68	1669.0	727.4	.0	251.6
4	277.29	1124.4	1078.5	.0	107.2
5	260.00	2011.0	1874.9	.0	342.2
6	240.00	3025.9	2793.4	.0	592.4
7	227.40	3635.9	3369.8	.0	674.9
8	217.40	4126.7	3832.6	.0	741.4
9	200.00	4979.5	4638.1	.0	856.8
10	180.00	5953.1	5557.8	.0	988.6
11	167.44	6558.1	6133.0	.0	1060.0
12	164.78	4288.5	6243.7	.0	763.3
13	157.34	2825.7	5116.0	.0	642.0
14	139.50	1244.3	2311.2	.0	330.1
15	127.40	139.0	350.7	.0	112.0
16	125.61	20.5	37.7	.0	5.0

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	18.68	4235.	3.56	5.46	.652
2	284.78	18.68	4514.	3.55	5.68	.625
3	284.58	18.68	4928.	3.51	5.96	.590
4	270.00	18.68	6923.	6.97	11.30	.617
5	250.00	18.68	14994.	8.45	18.70	.452
6	230.00	18.68	28771.	9.85	26.00	.379

7	224.80	18.68	32873.	10.37	27.92	.371
8	210.00	18.68	45769.	12.00	33.40	.359
9	190.00	18.68	65999.	14.40	40.81	.353
10	170.00	18.68	89430.	16.85	48.12	.350
11	164.88	18.68	95880.	17.49	50.01	.350
12	164.69	18.68	95162.	17.50	49.89	.351
13	150.00	18.68	36349.	13.08	31.97	.409
14	129.00	18.68	368.	2.04	5.01	.407
15	125.81	18.68	10.	.28	.60	.461
16	125.42	.00	-2.	2.72	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 2883.87 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 543.12 (psf)

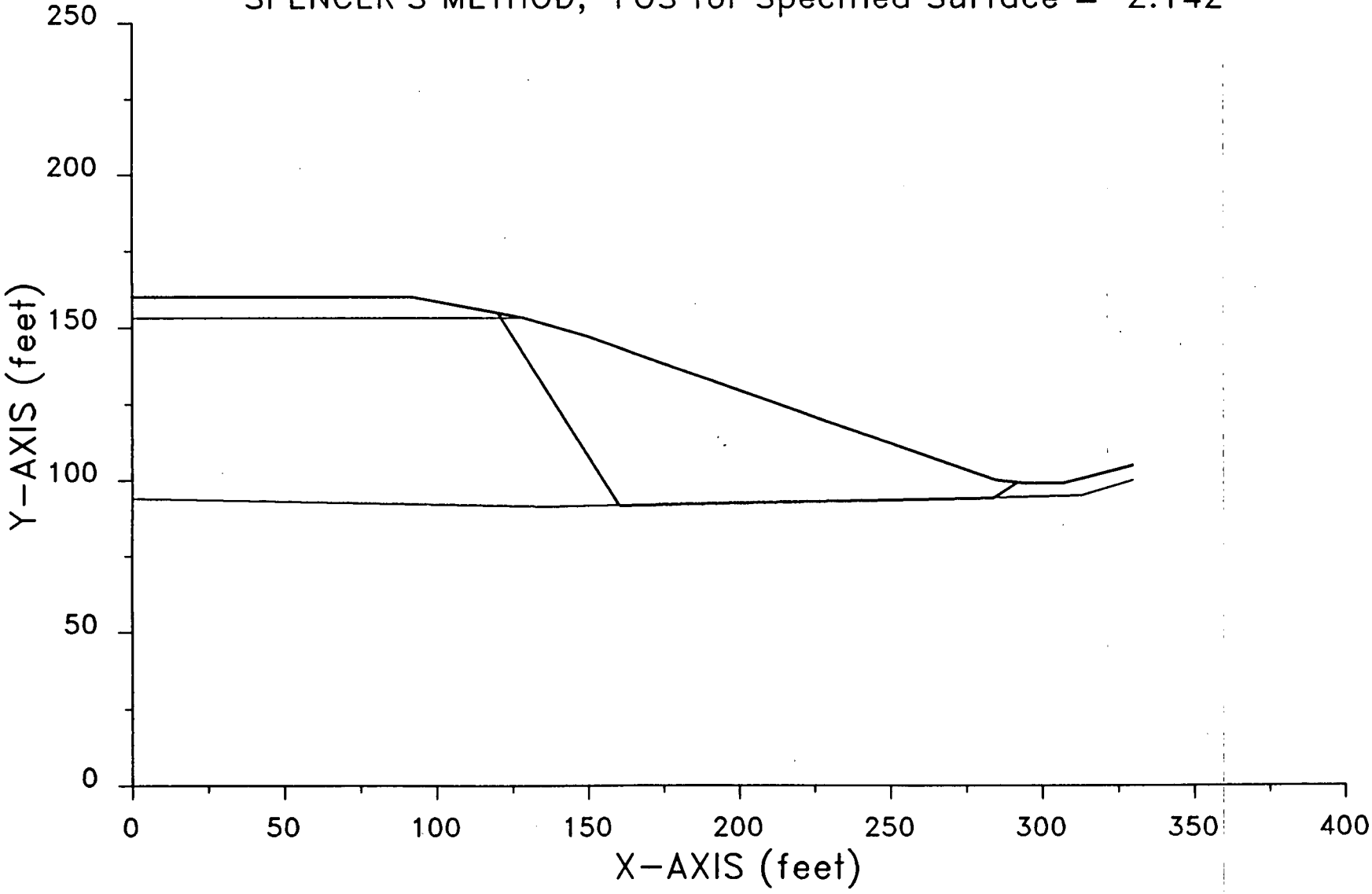
Total Length of failure surface = 202.35 feet

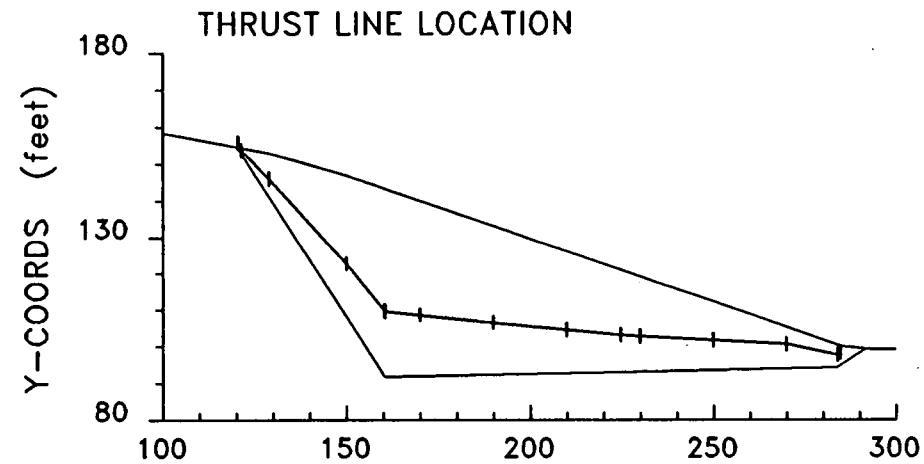
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

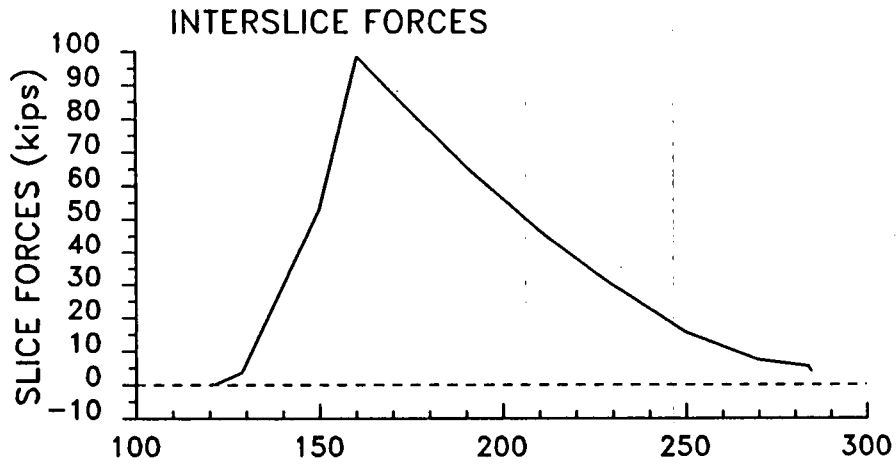
FACTOR OF SAFETY = 2.364

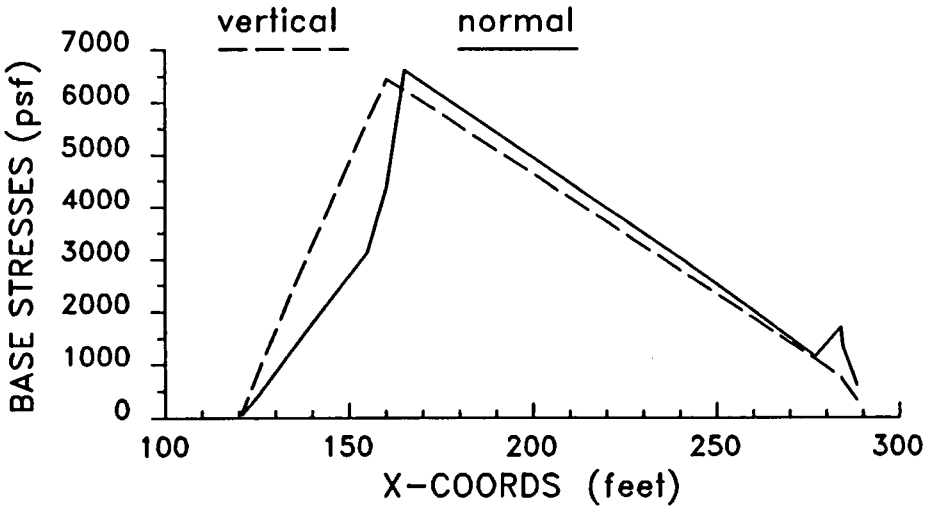
Total shear strength available along specified failure surface = 259.79E+03 lb

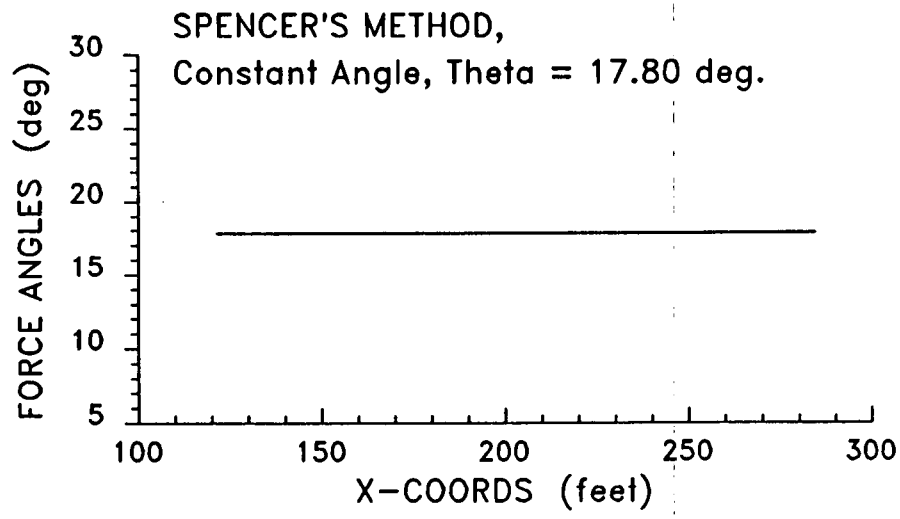
OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.142 ✓











OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.142 ✓

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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	1281.6
5	6480.0	2088.0
6	10080.0	2088.0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	291.87	99.24
2	284.25	94.39
3	284.05	94.18
4	224.80	93.00
5	160.54	91.72
6	160.38	91.89
7	121.44	153.00
8	120.52	154.60

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.43	97.05	2.57	6.87	-32.46	6.34	2204.
2	284.62	94.63	5.50	.75	-32.46	19.12	519.
3	284.15	94.28	6.01	.20	-46.40	19.12	147.
4	277.02	94.04	8.72	14.05	-1.14	19.12	15323.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37497.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55868.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.14	19.29	56716.
9	200.00	92.51	37.09	20.00	-1.14	19.29	92735.
10	180.00	92.11	44.44	20.00	-1.14	19.03	111106.
11	165.27	91.81	49.84	9.46	-1.14	19.29	58937.
12	160.46	91.81	51.53	.16	46.74	19.29	1031.
13	155.19	100.03	45.15	10.38	57.49	19.29	58580.
14	139.50	124.66	25.34	21.00	57.49	15.95	66523.
15	125.22	147.07	6.65	7.56	57.49	10.71	6282.
16	120.98	153.80	.72	.92	60.17	10.71	82.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.8095	2.1509	2.1540
3	17.8113	2.1510	2.1509

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.8023	2.1421	2.1423

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	17.8023	2.1421	2.1423

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	596.5	.0	30.00	0.	0.	0.	.00
2	1323.4	200.0	25.00	0.	0.	0.	.00
3	1689.2	-427.2	30.68	0.	0.	0.	.00
4	1137.3	-427.2	30.68	0.	0.	0.	.00
5	2009.5	-427.2	30.68	0.	0.	0.	.00
6	3021.8	636.5	12.63	0.	0.	0.	.00
7	3623.5	636.5	12.63	0.	0.	0.	.00
8	4106.2	636.5	12.63	0.	0.	0.	.00
9	4946.1	636.5	12.63	0.	0.	0.	.00
10	5905.0	636.5	12.63	0.	0.	0.	.00
11	6604.8	2088.0	.00	0.	0.	0.	.00
12	4385.2	636.5	12.63	0.	0.	0.	.00
13	3112.7	200.0	25.00	0.	0.	0.	.00
14	1718.4	200.0	25.00	0.	0.	0.	.00
15	402.3	200.0	25.00	0.	0.	0.	.00
16	46.2	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.43	596.5	320.8	.0	160.8
2	284.62	1323.4	688.0	.0	381.5
3	284.15	1689.2	751.6	.0	268.5
4	277.02	1137.3	1090.6	.0	115.6
5	260.00	2009.5	1874.9	.0	357.2
6	240.00	3021.8	2793.4	.0	613.1
7	227.40	3623.5	3369.8	.0	676.0
8	217.40	4106.2	3832.2	.0	726.5
9	200.00	4946.1	4636.8	.0	814.4
10	180.00	5905.0	5555.3	.0	914.6
11	165.27	6604.8	6230.2	.0	974.8
12	160.46	4385.2	6441.8	.0	755.7
13	155.19	3112.7	5643.6	.0	771.0
14	139.50	1718.4	3167.8	.0	467.4
15	125.22	402.3	830.9	.0	180.9
16	120.98	46.2	89.4	.0	12.4

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	17.80	3898.	3.29	5.13	.641
2	284.25	17.80	4868.	3.28	5.87	.559
3	284.05	17.80	5286.	3.28	6.15	.533
4	270.00	17.80	7326.	6.49	11.30	.574
5	250.00	17.80	15670.	8.04	18.70	.430
6	230.00	17.80	29813.	9.43	26.00	.363

7	224.80	17.80	33900.	9.96	27.92	.357
8	210.00	17.80	46464.	11.63	33.39	.348
9	190.00	17.80	65640.	14.06	40.79	.345
10	170.00	17.80	87323.	16.54	48.09	.344
11	160.54	17.80	98315.	17.74	51.59	.344
12	160.38	17.80	97659.	17.74	51.48	.345
13	150.00	17.80	52810.	14.34	38.82	.369
14	129.00	17.80	3641.	4.82	11.86	.406
15	121.44	17.80	65.	.66	1.43	.459
16	120.52	.00	-1.	.91	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 2971.95 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 562.90 (psf)

Total Length of failure surface = 207.40 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.142

Total shear strength available along specified failure surface = 250.08E+03 lb

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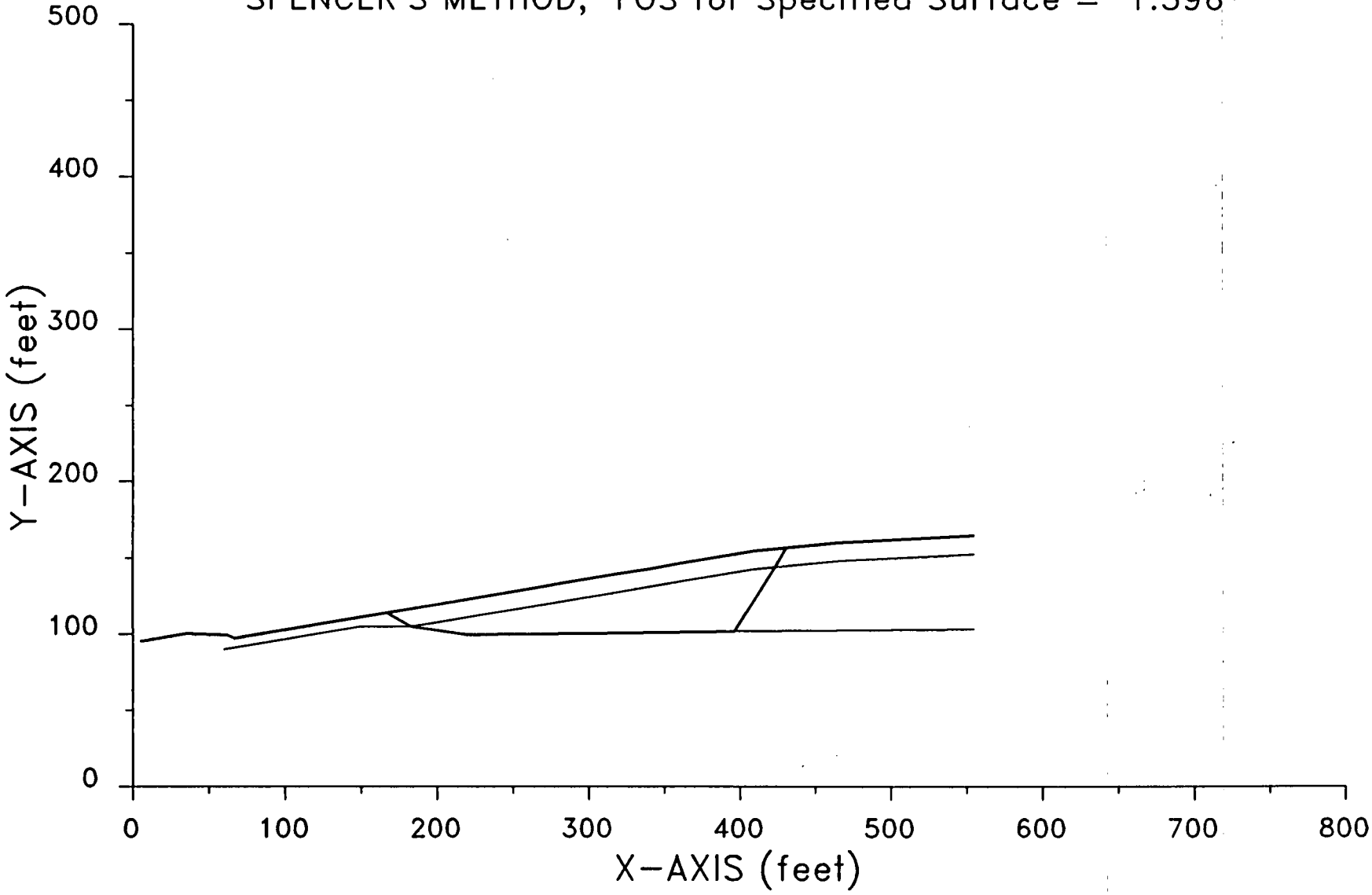
OSDF Final Long Term – Large Displ.

SPENCER'S METHOD, FOS for Specified Surface = 1.596



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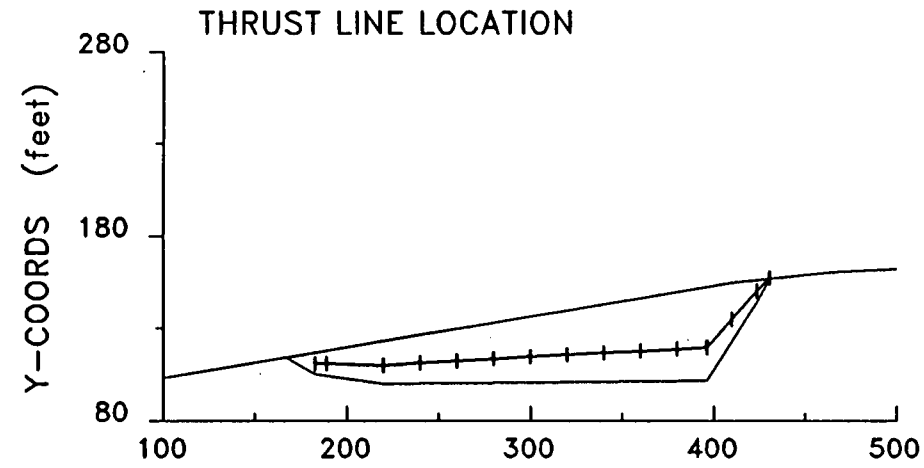

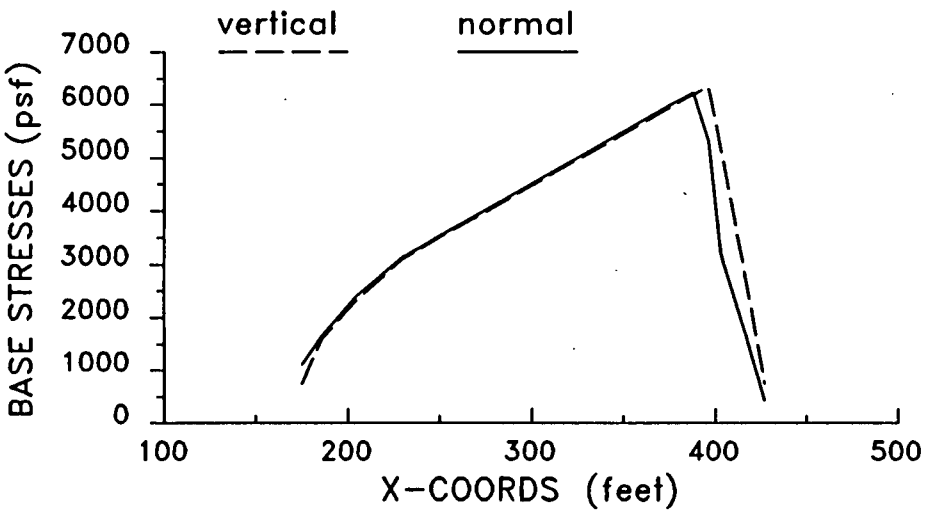

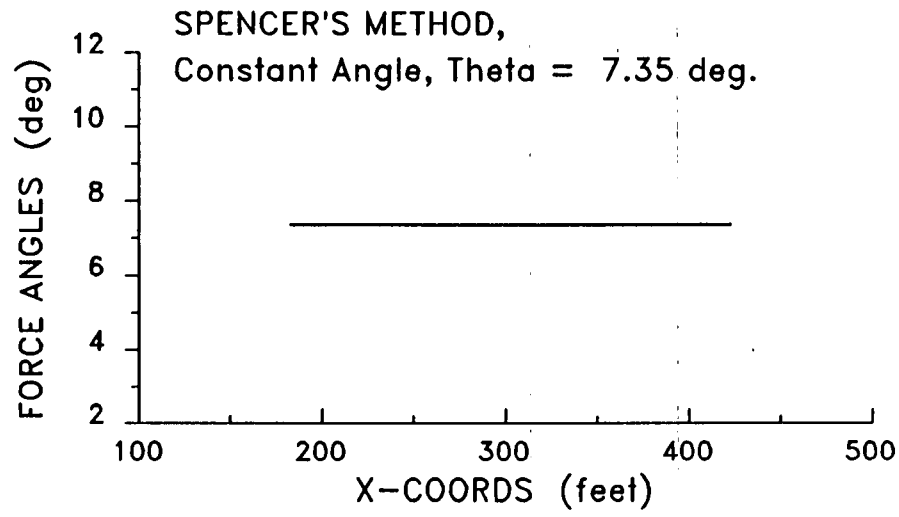

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.596

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*                                       *
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*            Method of Slices           *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	374.4
5	6480.0	763.2
6	10080.0	763.2

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	396.37	101.66
6	396.56	101.85
7	423.51	144.15
8	430.80	156.78

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.63	9.37	93350.
9	330.00	100.93	40.42	20.00	.63	9.37	101050.
10	350.00	101.15	43.55	20.00	.63	9.65	108875.
11	370.00	101.37	46.68	20.00	.63	9.37	116700.
12	388.18	101.57	49.49	16.37	.63	9.46	101277.
13	396.47	101.76	50.69	.19	45.00	9.46	1218.
14	403.28	112.40	41.18	13.44	57.50	9.46	69173.
15	416.76	133.55	21.83	13.51	57.50	5.71	36863.
16	427.16	150.47	5.95	7.29	60.01	5.71	5421.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.2588	1.5938	1.6384
3	7.3557	-----	1.5938
3	7.3073	1.5949	-----
4	7.3533	1.5960	1.5949
5	7.3522	1.5959	1.5960

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.3522	1.5959	1.5960

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta

1	1104.1	.0	30.00	0.	0.	0.	.00
2	1651.6	-124.8	9.83	0.	0.	0.	.00
3	2397.4	-124.8	9.83	0.	0.	0.	.00
4	3125.9	63.4	6.16	0.	0.	0.	.00
5	3522.3	63.4	6.16	0.	0.	0.	.00
6	3912.4	63.4	6.16	0.	0.	0.	.00
7	4308.9	63.4	6.16	0.	0.	0.	.00
8	4703.1	63.4	6.16	0.	0.	0.	.00
9	5090.6	63.4	6.16	0.	0.	0.	.00
10	5484.5	63.4	6.16	0.	0.	0.	.00
11	5878.3	63.4	6.16	0.	0.	0.	.00
12	6232.4	63.4	6.16	0.	0.	0.	.00
13	5304.4	63.4	6.16	0.	0.	0.	.00
14	3170.8	.0	25.00	0.	0.	0.	.00
15	1680.7	.0	25.00	0.	0.	0.	.00
16	412.4	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1104.1	739.6	.0	399.4
2	186.00	1651.6	1594.4	.0	101.2
3	204.50	2397.4	2304.8	.0	182.2
4	230.00	3125.9	3100.0	.0	251.2
5	250.00	3522.3	3493.8	.0	278.1
6	270.00	3912.4	3881.3	.0	304.5
7	290.00	4308.9	4275.0	.0	331.3
8	310.00	4703.1	4667.5	.0	358.0
9	330.00	5090.6	5052.5	.0	384.2
10	350.00	5484.5	5443.8	.0	410.8
11	370.00	5878.3	5835.0	.0	437.5
12	388.18	6232.4	6186.8	.0	461.5
13	396.47	5304.4	6336.0	.0	398.7
14	403.28	3170.8	5147.6	.0	926.5
15	416.76	1680.7	2728.4	.0	491.1
16	427.16	412.4	743.7	.0	149.2

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.35	16627.	5.62	11.83	.475
2	189.00	7.35	18643.	6.54	13.68	.478
3	220.00	7.35	34869.	9.91	23.20	.427
4	240.00	7.35	39305.	11.04	26.40	.418
5	260.00	7.35	44202.	12.06	29.50	.409
6	280.00	7.35	49553.	13.01	32.60	.399
7	300.00	7.35	55364.	13.90	35.80	.388

8	320.00	7.35	61540.	14.75	38.88	.379
9	340.00	7.35	68158.	15.56	41.96	.371
10	360.00	7.35	75227.	16.35	45.14	.362
11	380.00	7.35	82745.	17.12	48.22	.355
12	396.37	7.35	89231.	17.73	50.77	.349
13	396.56	7.35	88280.	17.76	50.61	.351
14	410.00	7.35	33400.	11.67	31.75	.367
15	423.51	7.35	4154.	5.84	11.90	.491
16	430.80	.00	0.	.17	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3557.36 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 384.10 (psf)

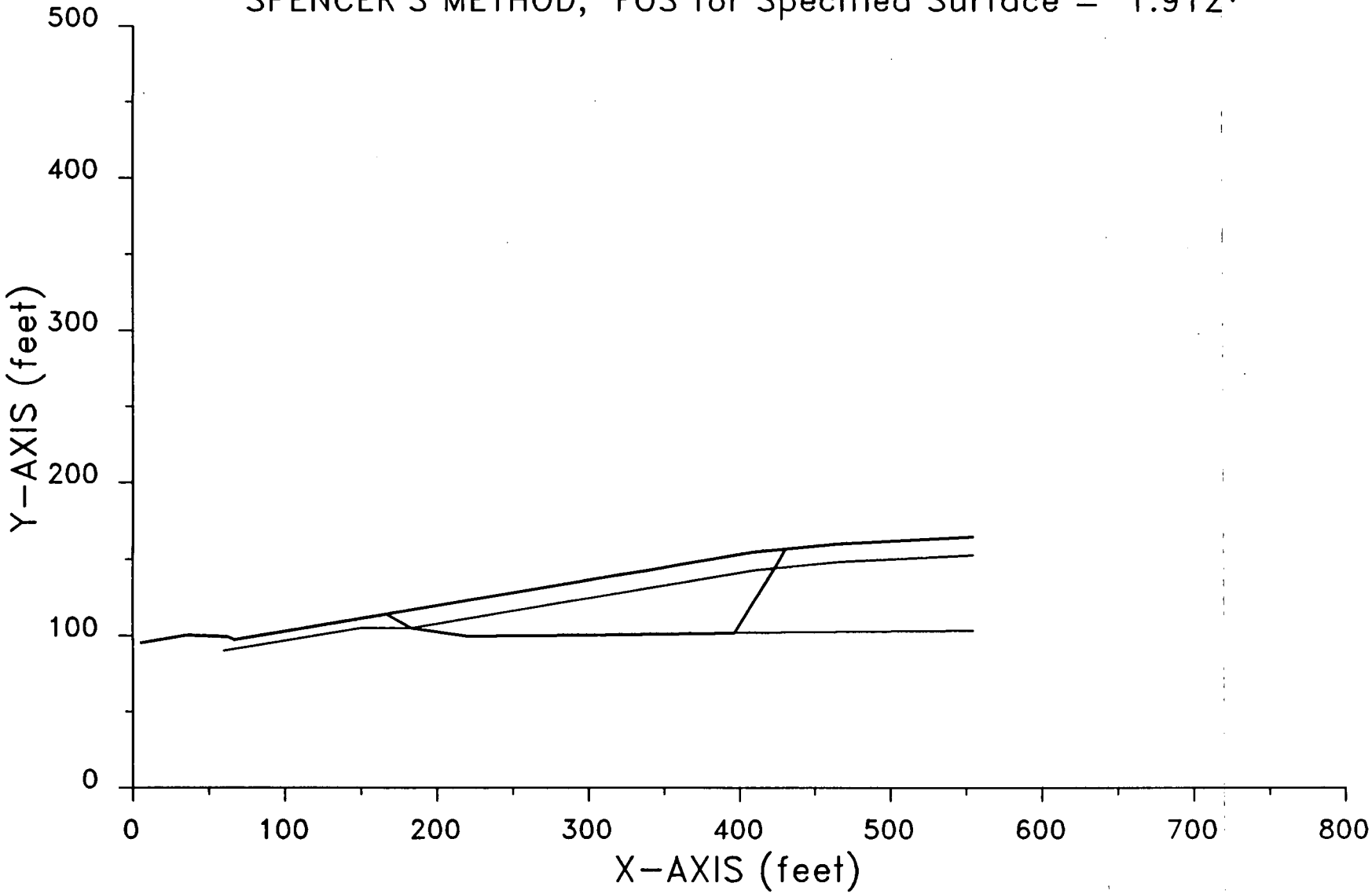
Total Length of failure surface = 297.11 feet

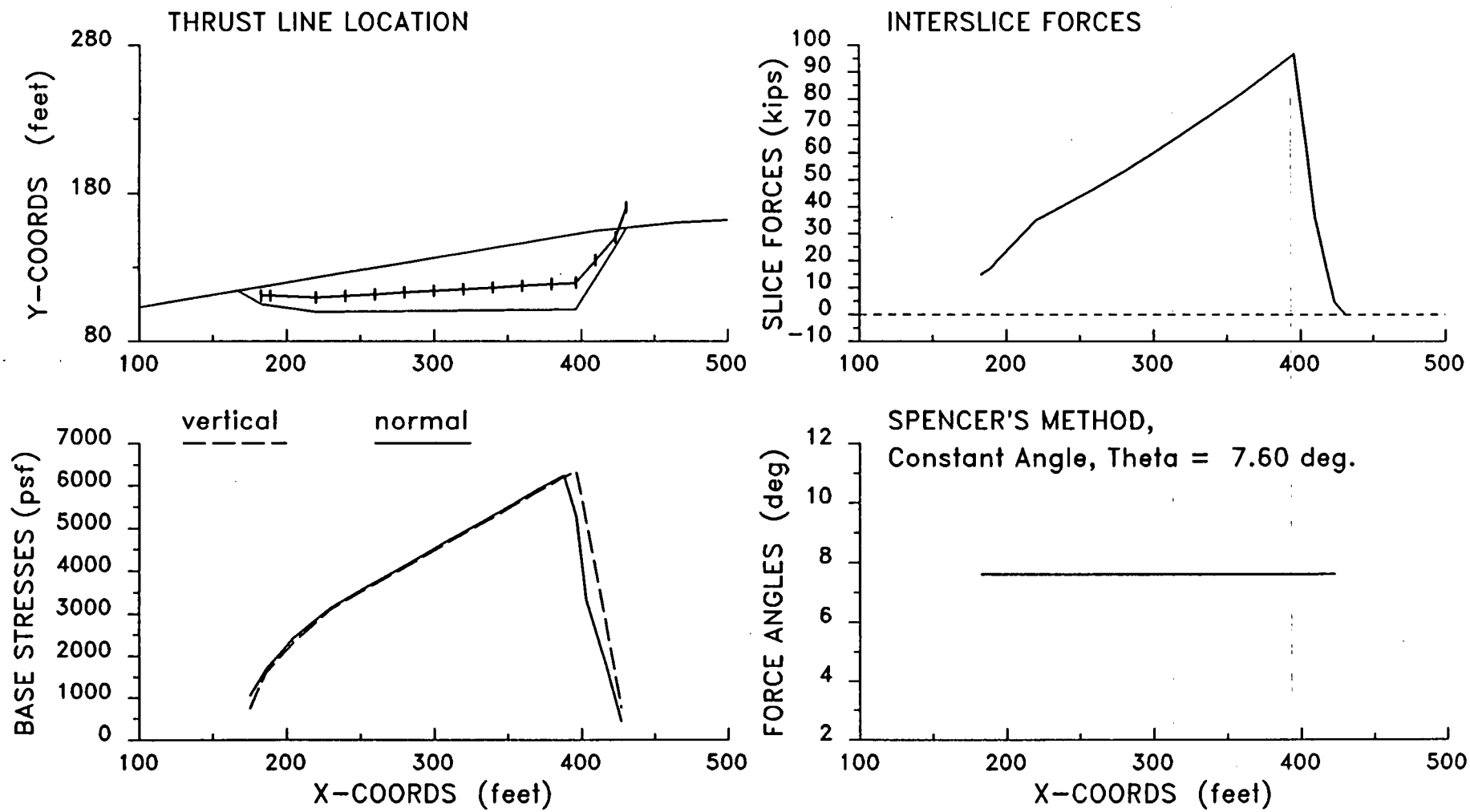
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.596

Total shear strength available along specified failure surface = 182.13E+03 lb

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.912





OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.912 ✓

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*****************************************
*              X S T A B L              *
*                                       *
*       Slope Stability Analysis        *
*              using the                *
*           Method of Slices            *
*                                       *
*        Copyright (C) 1992 - 96        *
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*       Moscow, ID 83843, U.S.A.        *
*                                       *
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*  Ver. 5.201                 96 - 1202 *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	.0
4	2880.0	576.0
5	6480.0	936.0
6	10080.0	936.0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	396.44	101.60
6	396.69	101.85
7	423.64	144.16
8	430.93	156.79

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.70	37.35	20.00	.59	9.37	93366.
9	330.00	100.91	40.44	20.00	.59	9.37	101097.
10	350.00	101.12	43.58	20.00	.59	9.65	108954.
11	370.00	101.33	46.72	20.00	.59	9.37	116810.
12	388.22	101.51	49.56	16.44	.59	9.46	101836.
13	396.57	101.73	50.73	.25	45.00	9.46	1605.
14	403.35	112.30	41.29	13.31	57.50	9.46	68681.
15	416.82	133.45	21.93	13.64	57.50	5.71	37393.
16	427.29	150.48	5.95	7.29	60.01	5.71	5420.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.5233	1.9094	1.9579
3	7.5998	1.9116	1.9094
4	7.5981	1.9116	1.9116

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.5981	1.9116	1.9116

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1044.3	.0	30.00	0.	0.	0.	.00

2	1661.5	-192.0	14.93	0.	0.	0.	.00
3	2414.8	-192.0	14.93	0.	0.	0.	.00
4	3134.6	288.0	5.71	0.	0.	0.	.00
5	3530.4	288.0	5.71	0.	0.	0.	.00
6	3919.9	288.0	5.71	0.	0.	0.	.00
7	4315.7	288.0	5.71	0.	0.	0.	.00
8	4710.6	288.0	5.71	0.	0.	0.	.00
9	5099.2	288.0	5.71	0.	0.	0.	.00
10	5494.0	288.0	5.71	0.	0.	0.	.00
11	5888.8	288.0	5.71	0.	0.	0.	.00
12	6244.5	288.0	5.71	0.	0.	0.	.00
13	5269.5	288.0	5.71	0.	0.	0.	.00
14	3308.9	.0	25.00	0.	0.	0.	.00
15	1757.2	.0	25.00	0.	0.	0.	.00
16	433.9	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1044.3	739.6	.0	315.4
2	186.00	1661.5	1594.4	.0	131.3
3	204.50	2414.8	2304.8	.0	236.4
4	230.00	3134.6	3100.0	.0	314.6
5	250.00	3530.4	3493.8	.0	335.4
6	270.00	3919.9	3881.3	.0	355.7
7	290.00	4315.7	4275.0	.0	376.4
8	310.00	4710.6	4668.3	.0	397.1
9	330.00	5099.2	5054.9	.0	417.4
10	350.00	5494.0	5447.7	.0	438.1
11	370.00	5888.8	5840.5	.0	458.7
12	388.22	6244.5	6194.4	.0	477.3
13	396.57	5269.5	6341.8	.0	426.3
14	403.35	3308.9	5161.3	.0	807.2
15	416.82	1757.2	2740.9	.0	428.6
16	427.29	433.9	743.7	.0	131.0

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.60	14734.	5.65	11.83	.478
2	189.00	7.60	16943.	6.45	13.68	.472
3	220.00	7.60	34951.	9.43	23.20	.407
4	240.00	7.60	40667.	10.40	26.40	.394
5	260.00	7.60	46721.	11.36	29.50	.385
6	280.00	7.60	53108.	12.31	32.60	.378
7	300.00	7.60	59833.	13.26	35.80	.370
8	320.00	7.60	66859.	14.19	38.89	.365
9	340.00	7.60	74215.	15.13	41.99	.360

37/35

10	360.00	7.60	81904.	16.05	45.18	.355
11	380.00	7.60	89928.	16.97	48.27	.352
12	396.44	7.60	96771.	17.72	50.84	.349
13	396.69	7.60	95534.	17.73	50.63	.350
14	410.00	7.60	36632.	11.75	31.95	.368
15	423.64	7.60	4564.	5.83	11.90	.490
16	430.93	.00	0.	13.43	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3579.82 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 392.40 (psf)

Total Length of failure surface = 297.28 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.912

Total shear strength available along specified failure surface = 222.98E+03 lb

GCL 22

COMPUTATION COVER SHEET 1269

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) QA22 and QC08- Compliance Package

Computations By:
(Cognizant Engineer)

Signature [signature] Date 5 NOV 97

Printed Name and Title M. CATALINA OROZCO
STAFF ENGINEER

Assumptions and Procedures Checked By:
(Checker)

Signature [signature] Date 5 NOV 1997

Printed Name and Title ROBERT A. MORGAN III
SR. STAFF ENGINEER

Computations Checked by:

Signature [signature] Date 5 NOV 1997

Printed Name and Title ROBERT A. MORGAN III
SR. STAFF ENGINEER

Computations Backchecked by:
(Cognizant Engineer)

Signature [signature] Date 5 NOV 97

Printed Name and Title M. CATALINA OROZCO
STAFF ENGINEER

Approved by:
(PDP)

Signature [signature] Date 6 Nov 97

Printed Name and Title Gary R. Schmertmann
Sr. Project Engineer

Approved by:
(DTL and TETL)

Signature [signature] Date 10 Nov 97

Printed Name and Title Kenneth W Cargill
Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

Written By : MCO Date: 11 / 5 / 97 Reviewed by: RAM Date: 11 / 5 / 97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL lot number 97101002 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3). The evaluation is based on the shear test results from GCL QA sample no. 22 and GCL QC sample no. 08

METHOD

The method for evaluating the GCL samples is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL samples to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 22 and the results of the GCL internal shear tests performed on QC sample no. 08 are shown in the following table. The results of the GCL internal shear tests for QA sample no. 22 were averaged with the results of the GCL internal shear tests for QC sample no. 08. The averaged values for the GCL internal shear tests were used in the stability analyses. The laboratory test results for GCL QA sample no. 22 are presented in Appendix A. The laboratory test results for GCL QC sample no. 08 are presented in Appendix B.

Test Type	Case	Sample No.	Measured Shear Strengths (psi)		
			5 psi	20 psi	45 psi
GCL Internal	Peak	QA 22	4.6	13.5	20.8
		QC 08	3.55	13.153	17.73
		Average QA22-QC08	**4.075**	**13.327**	**19.265**
	Large-displacement	QA 22	4.0	2.9	5.9
		QC 08	2.29	5.861	3.86
		Average QA22-QC08	**3.145**	**4.381**	**4.880**
GCL/GMB Interface	Peak	QA 22	**2.6**	**9.8**	**16.4**
	Large-displacement	QA 22	**2.2**	**6.1**	**11.0**

Written By : MCO Date: 11 / 5 /97 Reviewed by: RAM Date: 11 / 5 /97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix C.

Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
Average QA22-QC08	GCL Internal	NPP22AS ✓	2.8 ✓	YES ✓
QA 22	GCL/GMB Interface	NPK22BS ✓	2.4 ✓	YES ✓
Baseline	Large-displacement	NA	1.6	NA
Average QA22-QC08	GCL Internal	NPL22ADS ✓	1.8 ✓	YES ✓
QA 22	GCL/GMB Interface	NLD22BS ✓	2.7 ✓	YES ✓

MCD 5 NOV 1997
RAM 5 NOV 1997

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 22I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-22). GCL's initial moisture content was 10.0%. GCL's final moisture content ranged from 55% to 75% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 22G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

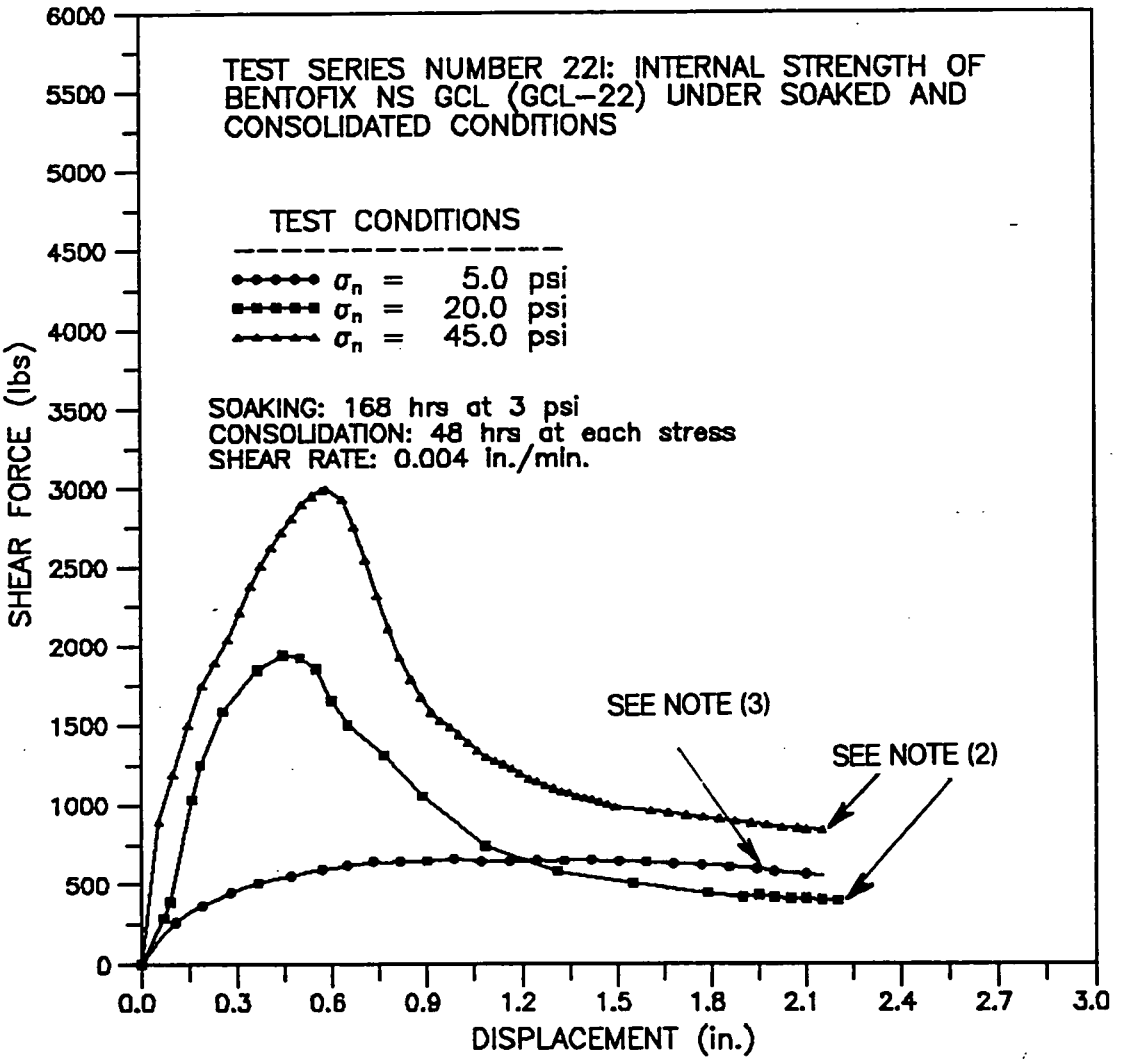
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-22) with woven geotextile against geomembrane. GCL's initial moisture content was 9.1%. GCL's final moisture content ranged from 54 to 82% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-16); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



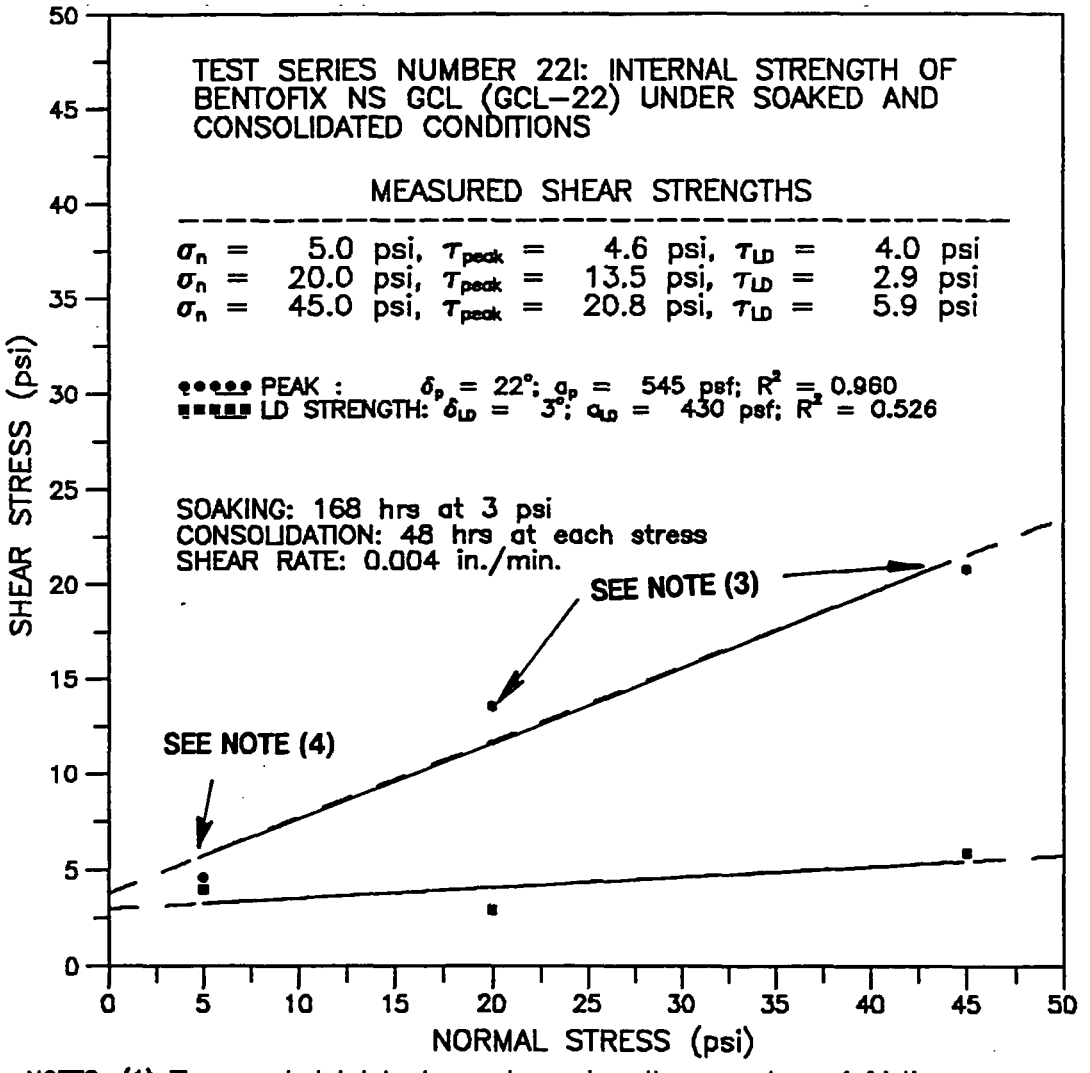
NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.
(2) Internal shear failure within GCL was observed.
(3) Partial internal shear failure within GCL was observed.

DATE TESTED: 23 OCTOBER TO 1 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730117
FILE NO.	000551

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



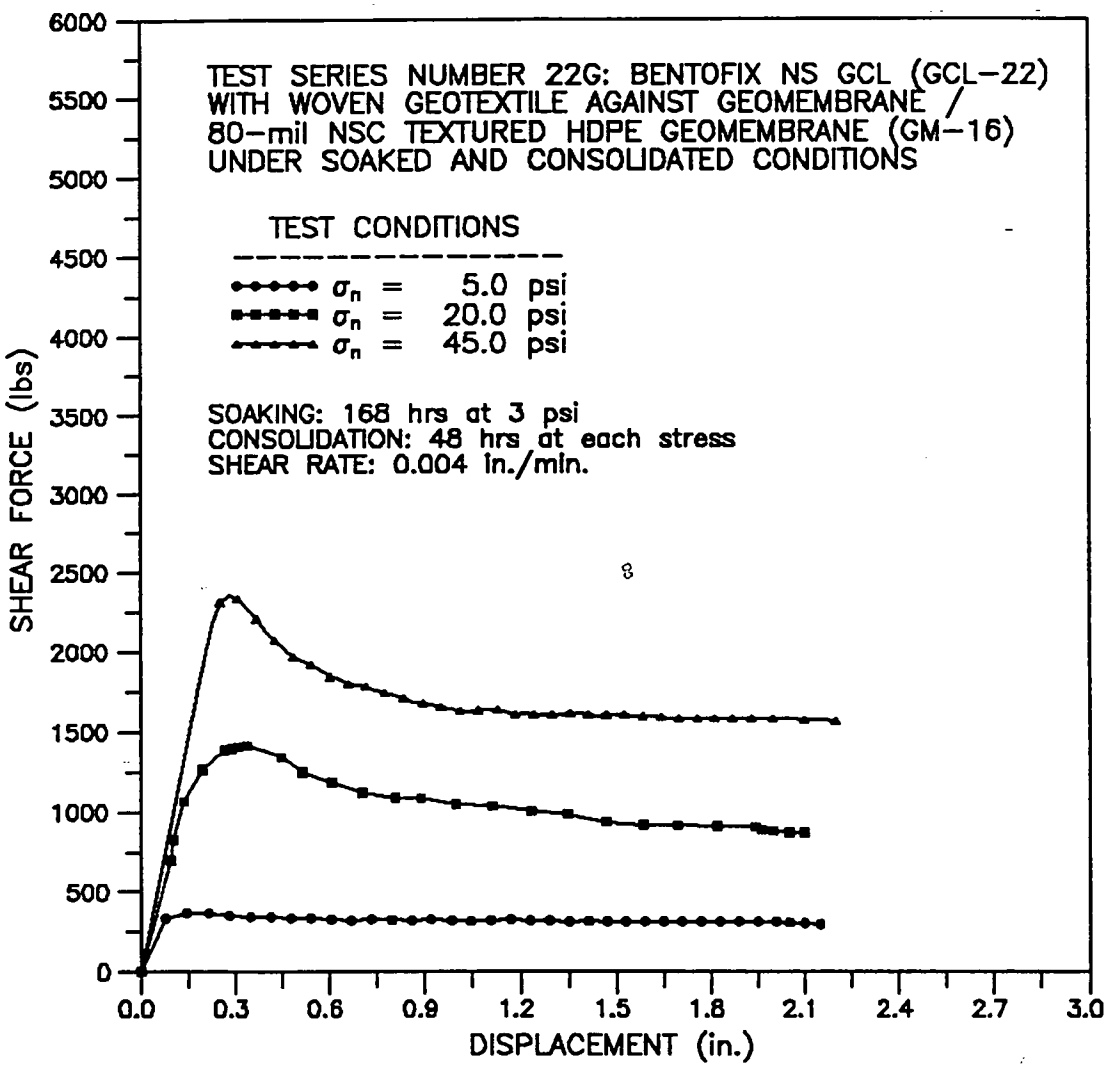
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Internal shear failure within GCL was observed.
(4) Partial internal failure within GCL was observed.

DATE TESTED: 23 OCTOBER TO 1 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730117
FILE NO.	000552

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) For each test, sliding (i.e., shear failure) was observed to occur at the intended interface.

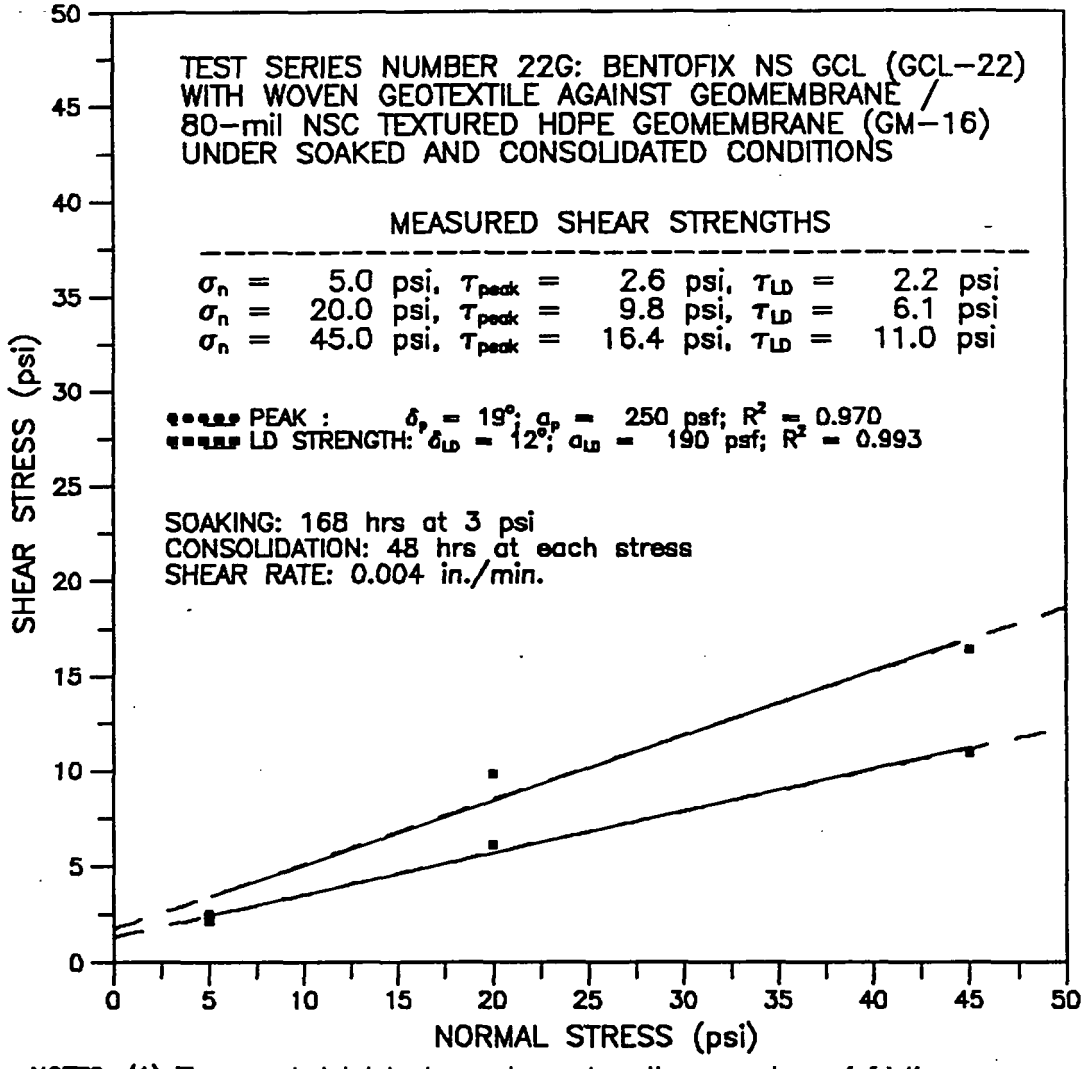
DATE TESTED: 11 TO 21 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730117
FILE NO.	000553

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) For each test, sliding (i.e., shear failure) was observed to occur at the intended interface.

DATE TESTED: 11 TO 21 OCTOBER 1997

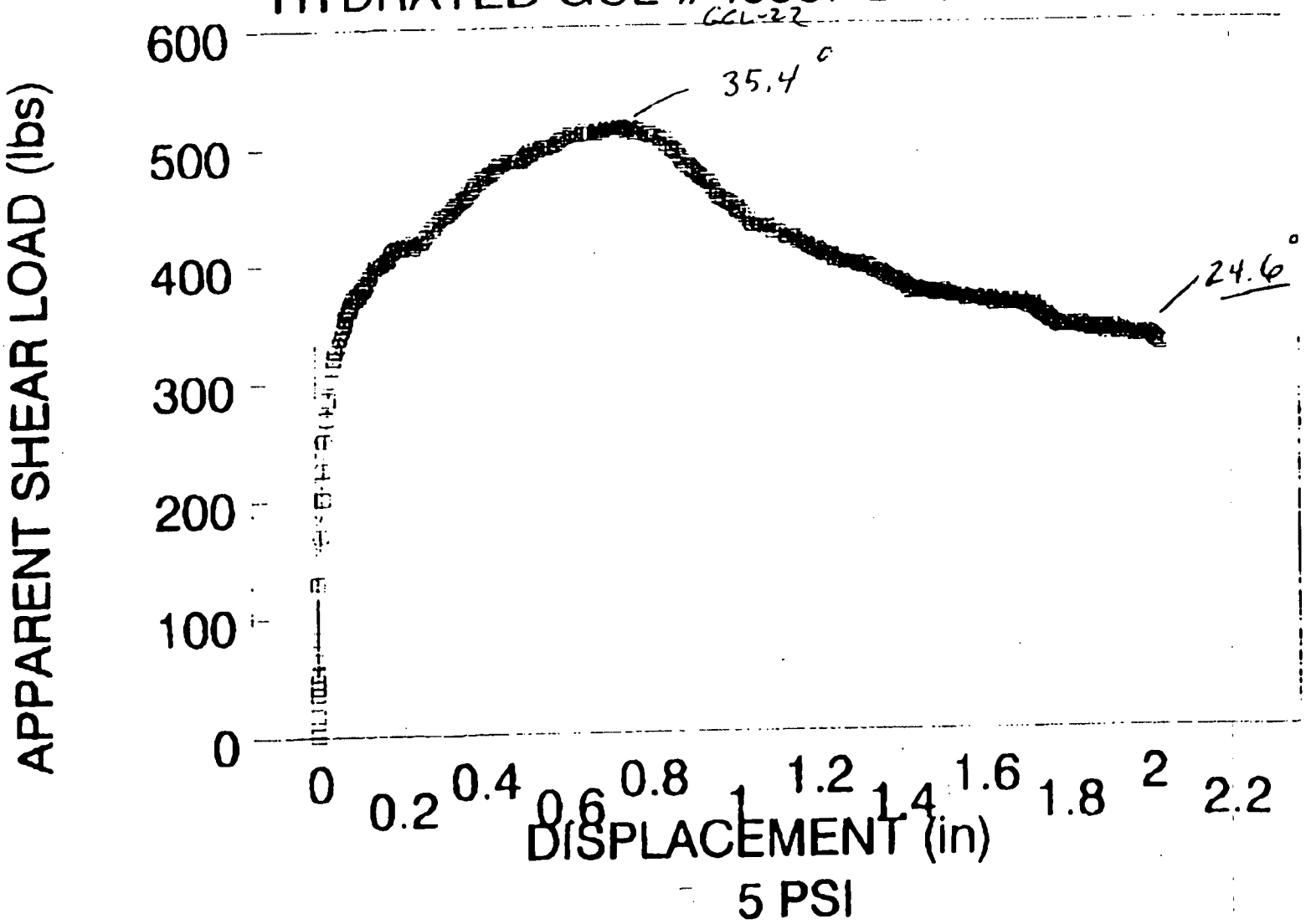
GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730117
FILE NO.	000554

MCO 5 NOV 1997
RAM 5 NOV 1997

APPENDIX B

PETRO ENVIRONMENTAL 54-7239-00
HYDRATED GCL #40667 DIRECT SHEAR



Consulting Engineers
Laboratory Services Group 1969 Techny Road Northbrook, Illinois 60062 Phone: (847) 267-8030 Fax:(847) 272-8320

Determining the Internal Shear Strength of Geosynthetics By the Direct Shear Method ASTM D 5321

Project Name: Petro Enviromental Technologies
Date Tested: 10-20-97

STS Project # 29550

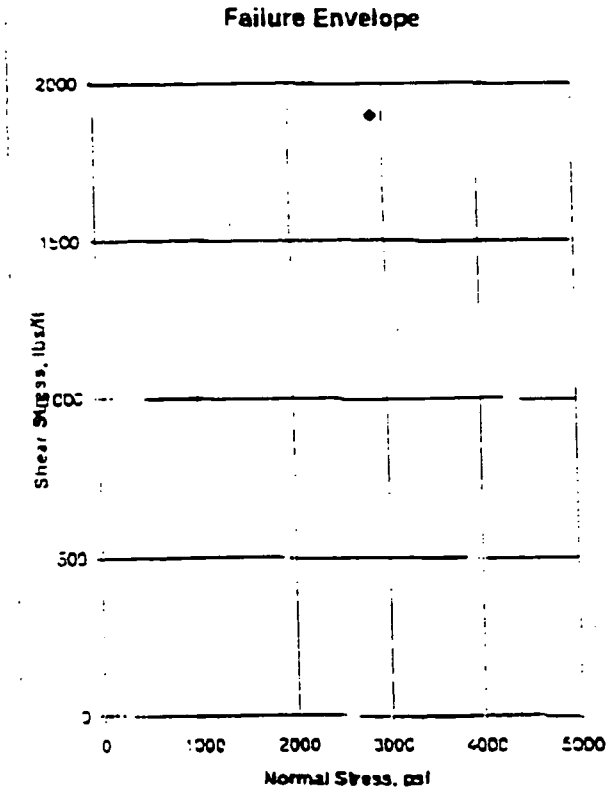
Test Parameters
Material Tested: Geosynthetic Clay Liner
Shear Rate: 0.004 in/min
7 Day Hydration 48 hour Consolidation

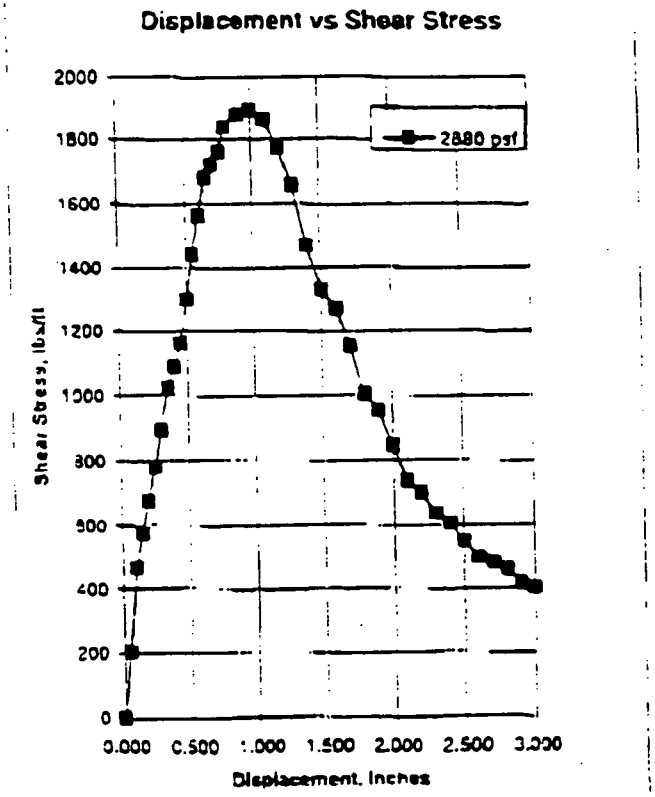
Sample ID Roll No.40667 GCL22

Test Results

Normal Stress psf	Shear Stress lbs/ft
2880	1894
[illegible]	

Summary of Results
Peak Friction Angle: –
Adhesion: –





29550-1.xls

Determining the Internal Shear Strength of Geosynthetics
By the Direct Shear Method
ASTM D 5321

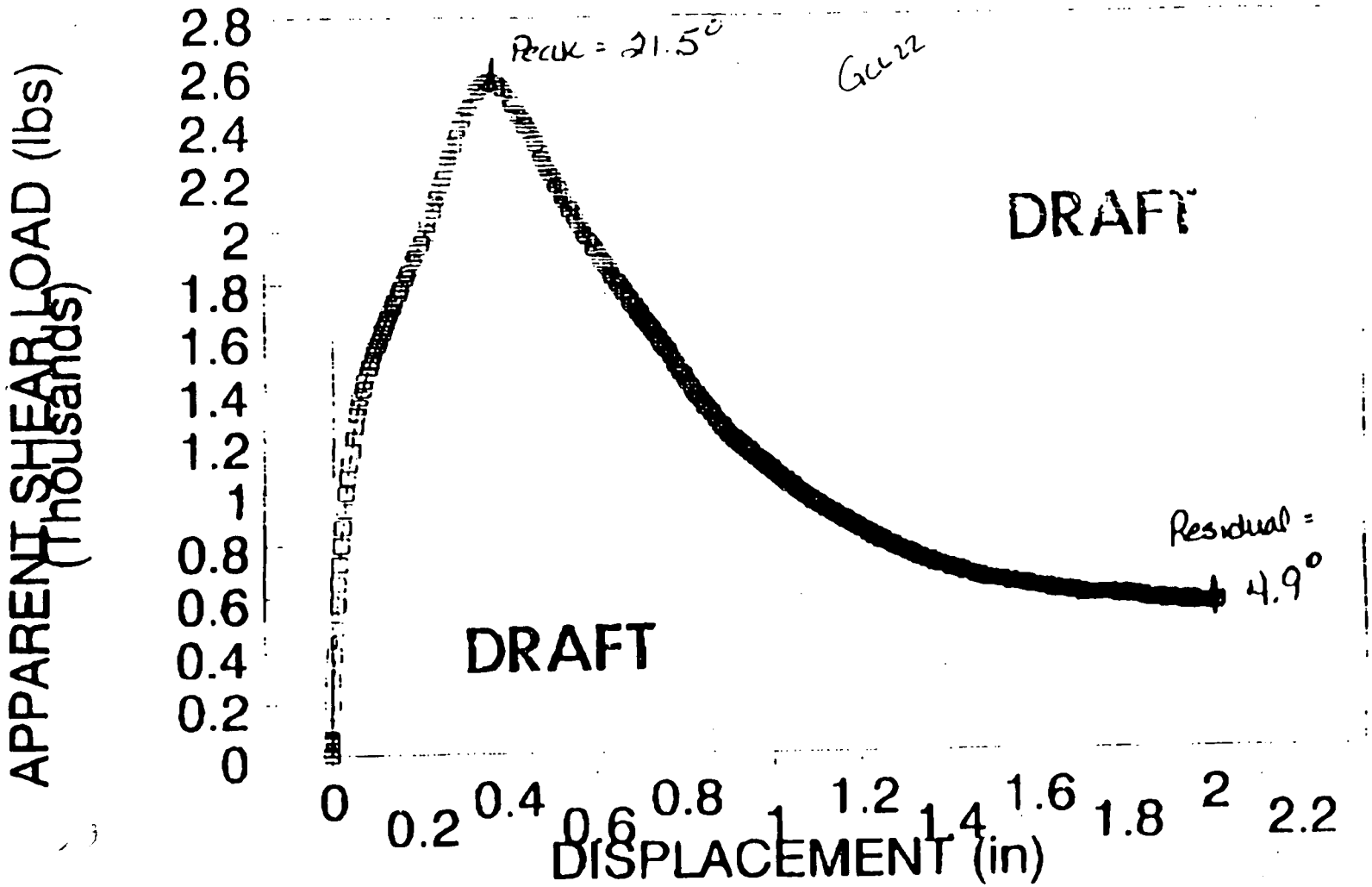
Sample ID Roll No.40667

STS Project # 29550
Date Tested: 10-20-97

Displacement inches	Shear Stress 2880psf lbs/ft
0.000	0
0.050	203
0.100	467
0.150	574
0.200	677
0.250	782
0.300	897
0.350	1025
0.400	1092
0.450	1160
0.500	1299
0.550	1442
0.600	1564
0.650	1679
0.700	1720
0.755	1762
0.800	1835
0.900	1879
1.000	1894 •
1.100	1864
1.200	1775
1.300	1659
1.400	1471
1.500	1331
1.600	1269
1.700	1157
1.800	1003
1.900	954
2.000	844 •
2.100	741
2.200	702
2.300	636
2.400	607
2.500	548
2.600	499
2.700	481
2.800	459
2.900	416
3.000	400

29550-1.xls

PETRO ENVIRONMENTAL 54-7239-00
HYDRATED GCL #40667 DIRECT SHEAR



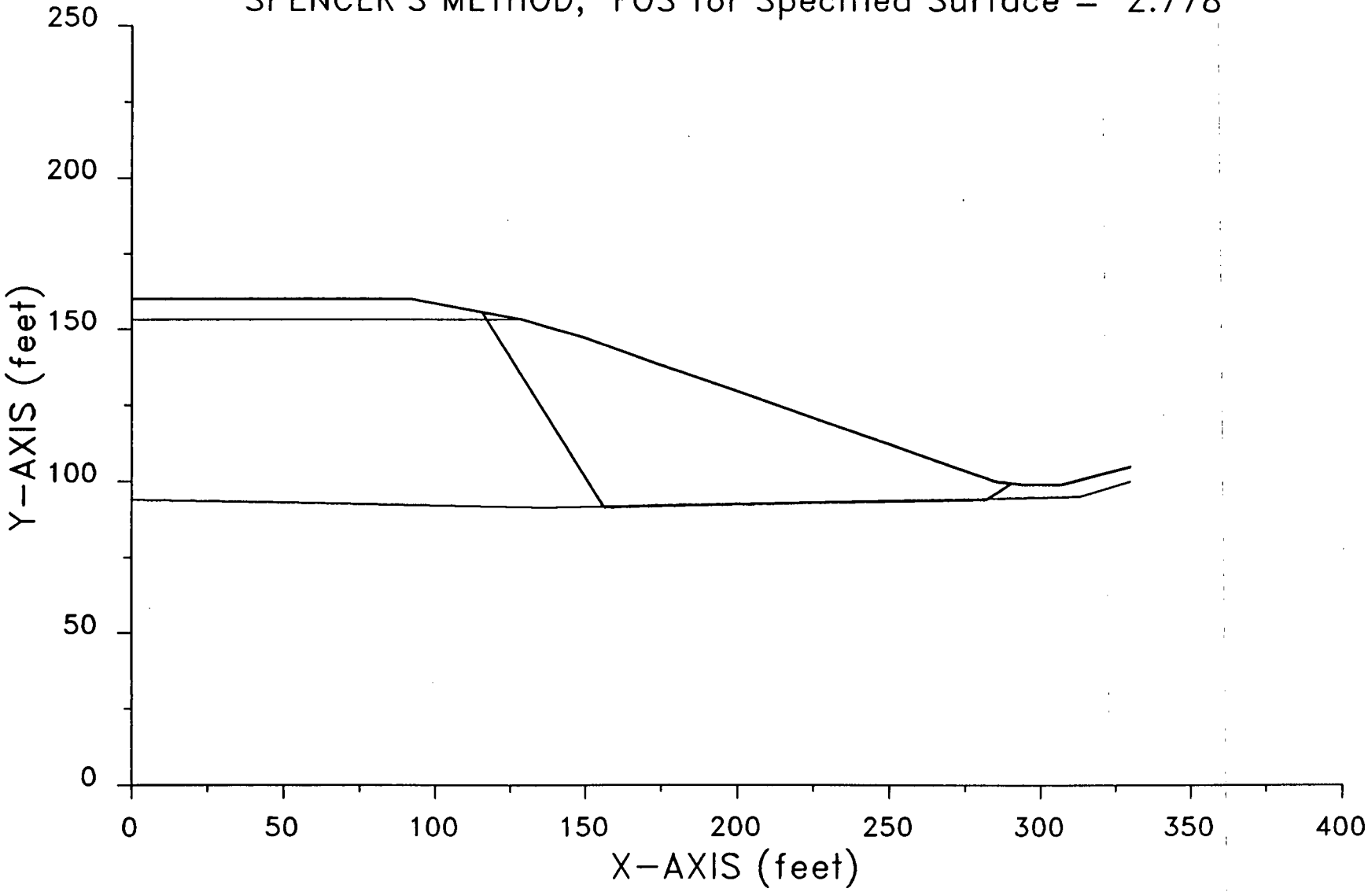
45 PSI

MCO 5 NOV 1997
RAM 5 NOV 1997

APPENDIX C

NPT22AS 11-04-97 8:19

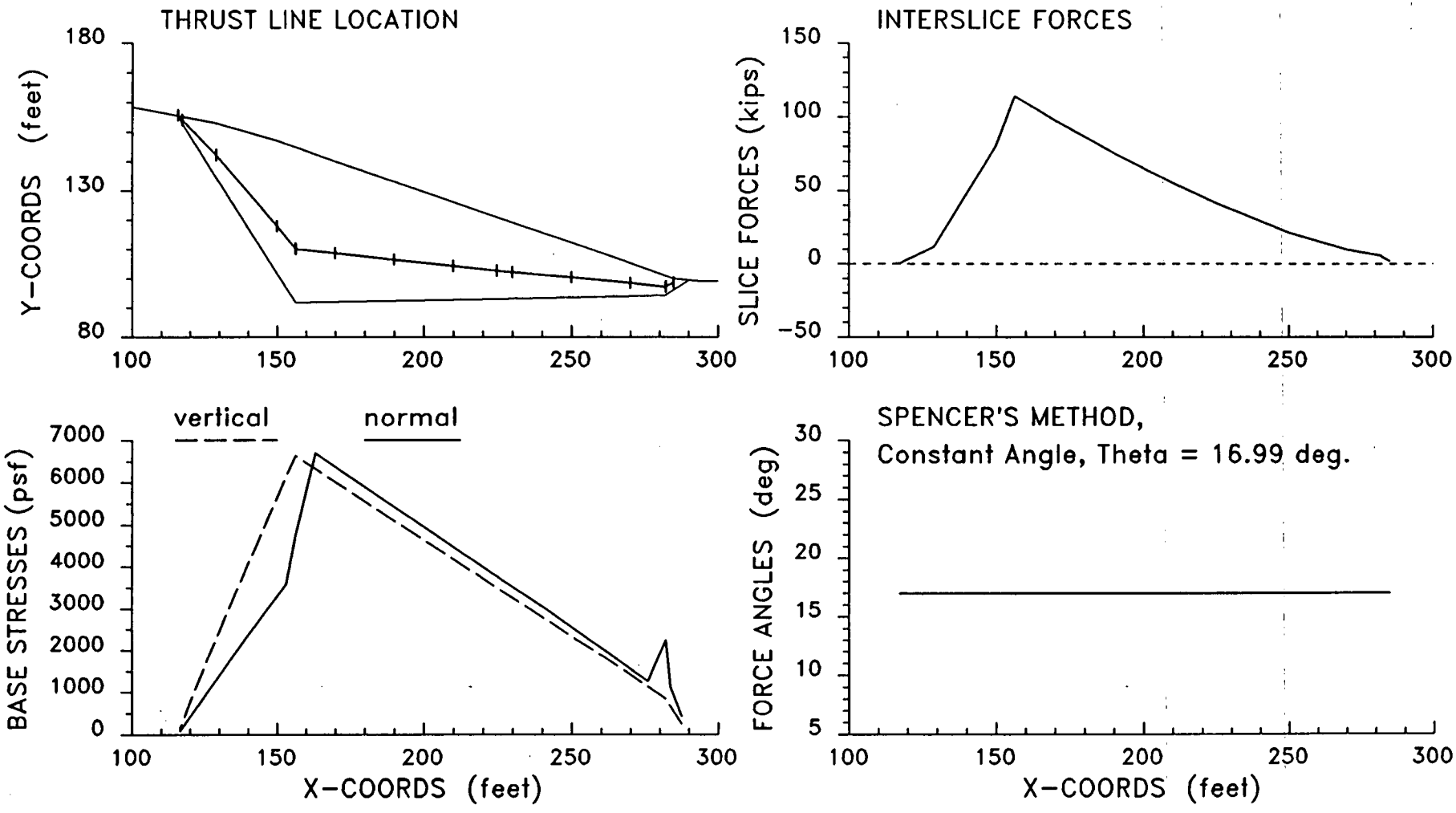
OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.778



000561

1269

16/48



OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.778 ✓

XSTABL File: NPP22AS 11-04-97 8:19

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*           Method of Slices            *
*                                       *
*         Copyright (C) 1992 á 96       *
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*  Ver. 5.201                 96 á 1202 *
*****************************************
```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	586.8
4	2880.0	1919.0
5	6480.0	2774.2
6	10080.0	2774.2

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	290.33	99.41
2	282.39	94.35
3	282.18	94.14
4	224.80	93.00
5	156.43	91.65
6	156.27	91.80
7	117.28	153.00
8	115.85	155.49

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	287.66	97.71	1.99	5.33	-32.50	6.34	1328.
2	283.69	95.18	5.27	2.61	-32.50	19.12	1721.
3	282.28	94.24	6.70	.21	-45.00	19.12	174.
4	276.09	94.02	9.07	12.18	-1.14	19.12	13809.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37502.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55870.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.13	19.29	56714.
9	200.00	92.51	37.09	20.00	-1.13	19.29	92724.
10	180.00	92.12	44.43	20.00	-1.13	19.03	111087.
11	163.21	91.78	50.59	13.57	-1.13	19.29	85815.
12	156.35	91.73	53.05	.16	43.15	19.29	1074.
13	153.13	96.72	49.18	6.27	57.50	19.29	38534.
14	139.50	118.12	31.88	21.00	57.50	15.95	83678.
15	123.14	143.80	10.31	11.72	57.50	10.71	15099.
16	116.57	154.24	1.11	1.43	60.11	10.71	198.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.9486	2.7942	2.8341
3	16.9746	2.7954	2.7942
4	16.9741	2.7954	2.7954

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	16.9949	2.7784	2.7775

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	16.9949	2.7784	2.7775

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	408.9	.0	30.00	0.	0.	0.	.00
2	1123.3	200.0	25.00	0.	0.	0.	.00
3	2235.0	142.7	31.66	0.	0.	0.	.00
4	1248.2	142.7	31.66	0.	0.	0.	.00
5	2052.6	142.7	31.66	0.	0.	0.	.00
6	3041.3	1234.8	13.36	0.	0.	0.	.00
7	3637.8	1234.8	13.36	0.	0.	0.	.00
8	4116.0	1234.8	13.36	0.	0.	0.	.00
9	4948.3	1234.8	13.36	0.	0.	0.	.00
10	5898.6	1234.8	13.36	0.	0.	0.	.00
11	6689.1	2774.2	.00	0.	0.	0.	.00
12	4737.2	1234.8	13.36	0.	0.	0.	.00
13	3579.8	200.0	25.00	0.	0.	0.	.00
14	2301.4	200.0	25.00	0.	0.	0.	.00
15	707.7	200.0	25.00	0.	0.	0.	.00
16	76.0	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	287.66	408.9	249.2	.0	85.0
2	283.69	1123.3	659.0	.0	260.5
3	282.28	2235.0	837.2	.0	547.5
4	276.09	1248.2	1133.7	.0	328.5
5	260.00	2052.6	1875.1	.0	507.0
6	240.00	3041.3	2793.5	.0	704.5
7	227.40	3637.8	3369.8	.0	755.5
8	217.40	4116.0	3832.0	.0	796.4
9	200.00	4948.3	4636.2	.0	867.5
10	180.00	5898.6	5554.3	.0	948.8
11	163.21	6689.1	6323.8	.0	998.5
12	156.35	4737.2	6631.5	.0	849.5
13	153.13	3579.8	6147.6	.0	672.8
14	139.50	2301.4	3984.7	.0	458.2
15	123.14	707.7	1288.3	.0	190.8
16	116.57	76.0	138.6	.0	15.8

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	16.99	1925.	2.51	3.99	.630
2	282.39	16.99	4591.	2.80	6.56	.427
3	282.18	16.99	5196.	2.73	6.84	.399
4	270.00	16.99	9695.	4.51	11.30	.399
5	250.00	16.99	21151.	6.81	18.70	.364

6	230.00	16.99	37148.	8.99	26.00	.346
7	224.80	16.99	41648.	9.62	27.92	.344
8	210.00	16.99	55230.	11.48	33.39	.344
9	190.00	16.99	75416.	14.04	40.79	.344
10	170.00	16.99	97694.	16.60	48.08	.345
11	156.43	16.99	113736.	18.37	53.10	.346
12	156.27	16.99	113128.	18.36	53.00	.346
13	150.00	16.99	80709.	16.22	45.36	.358
14	129.00	16.99	11448.	7.53	18.40	.410
15	117.28	16.99	172.	1.03	2.22	.463
16	115.85	.00	-2.	.06	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3125.24 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 594.37 (psf)

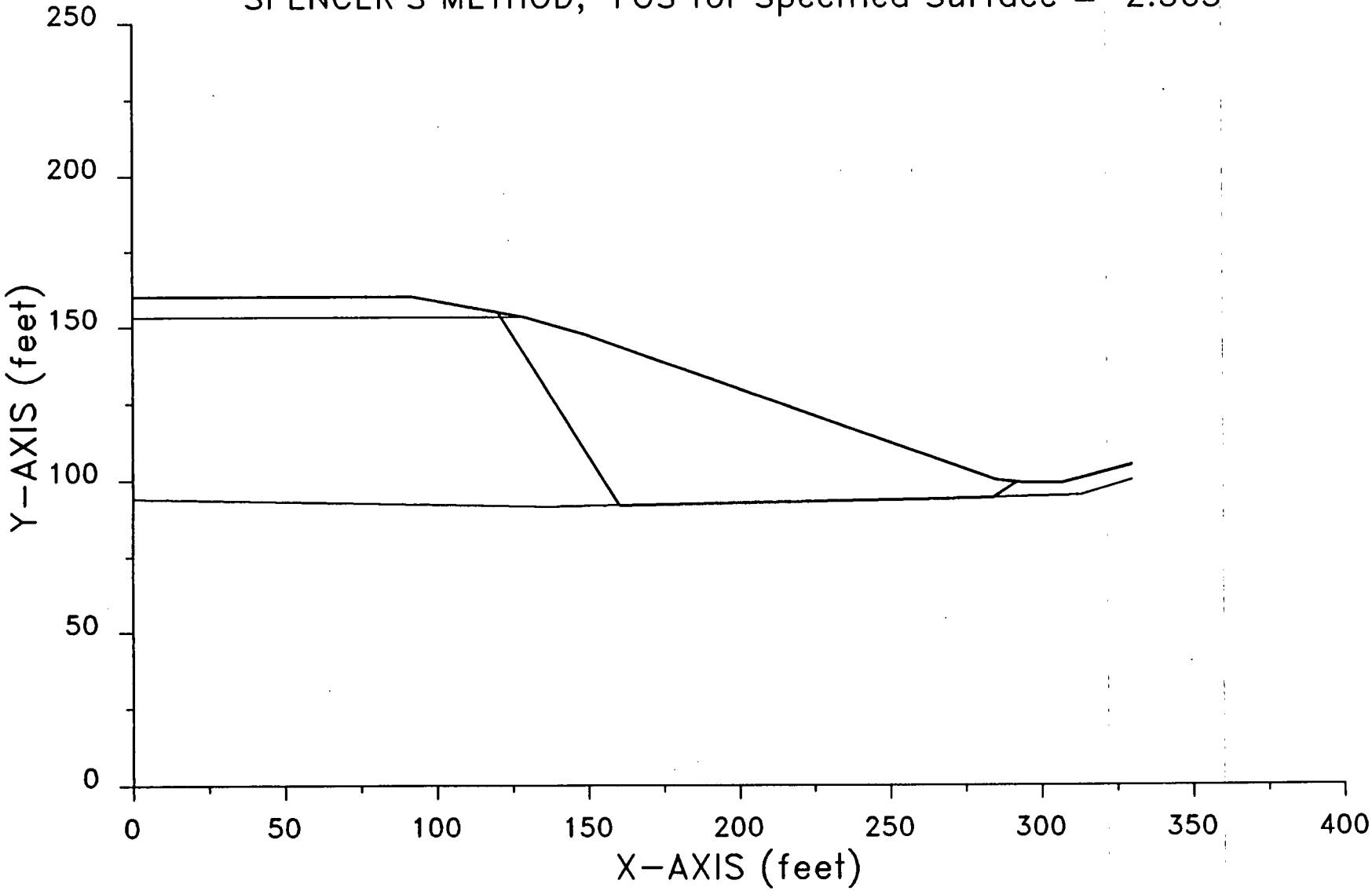
Total Length of failure surface = 211.14 feet

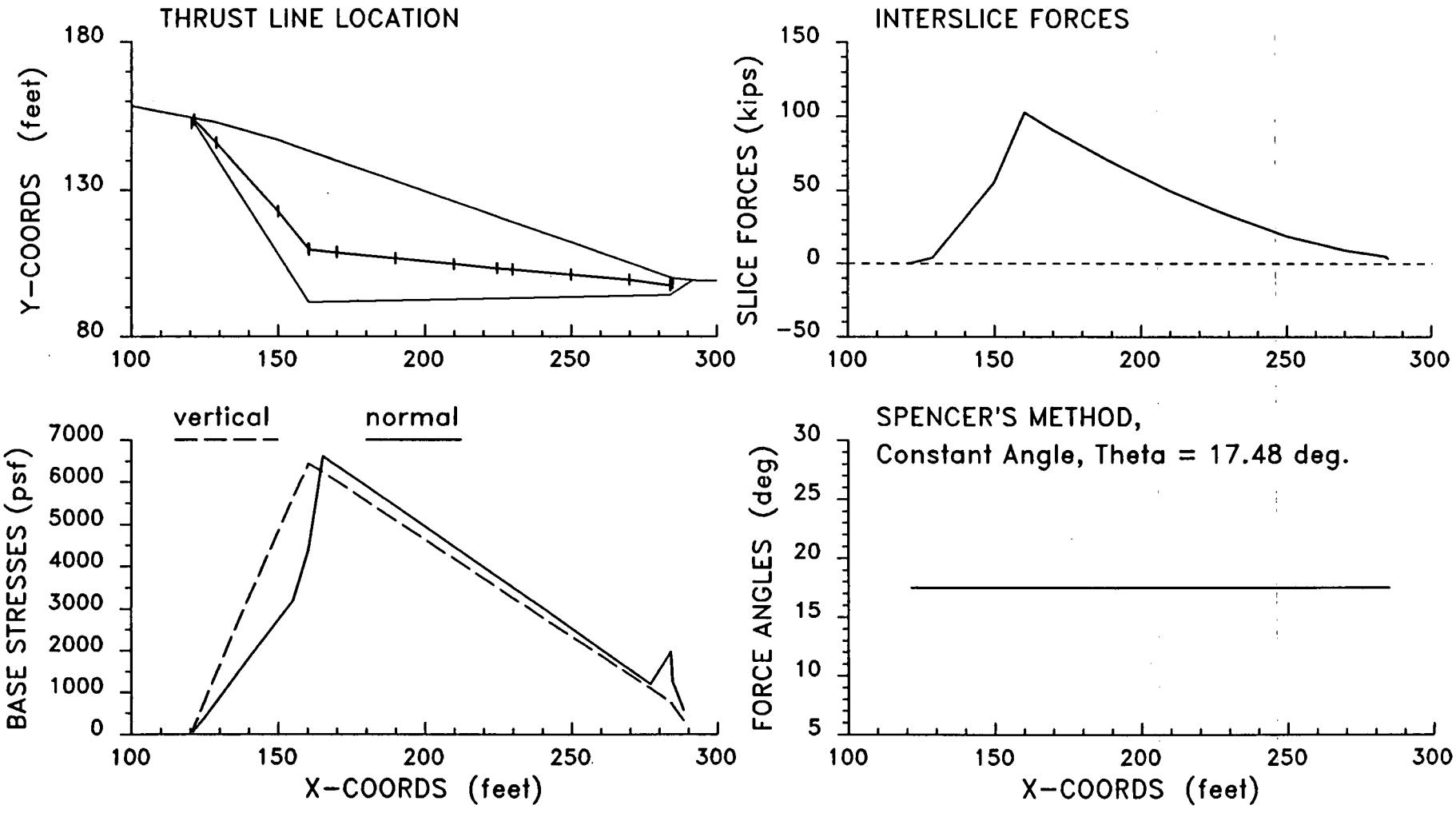
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.778

Total shear strength available along specified failure surface = 348.68E+03 lb

OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.363





OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.363

XSTABL File: NPK22BS 11-04-97 9:50

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*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 - 96       *
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*  Ver. 5.201                 96 - 1202 *
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```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

26/43

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	374.4
4	2880.0	1411.2
5	6480.0	2361.6
6	10080.0	2361.6

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	291.87	99.24
2	284.25	94.39
3	284.05	94.18
4	224.80	93.00
5	160.54	91.72
6	160.38	91.89
7	121.44	153.00
8	120.52	154.60

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.43	97.05	2.57	6.87	-32.46	6.34	2204.
2	284.62	94.63	5.50	.75	-32.46	19.12	519.
3	284.15	94.28	6.01	.20	-46.40	19.12	147.
4	277.02	94.04	8.72	14.05	-1.14	19.12	15323.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37497.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55868.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.14	19.29	56716.
9	200.00	92.51	37.09	20.00	-1.14	19.29	92735.
10	180.00	92.11	44.44	20.00	-1.14	19.03	111106.
11	165.27	91.81	49.84	9.46	-1.14	19.29	58937.
12	160.46	91.81	51.53	.16	46.74	19.29	1031.
13	155.19	100.03	45.15	10.38	57.49	19.29	58580.
14	139.50	124.66	25.34	21.00	57.49	15.95	66523.
15	125.22	147.07	6.65	7.56	57.49	10.71	6282.
16	120.98	153.80	.72	.92	60.17	10.71	82.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.4584	2.3707	2.3869
3	17.4722	2.3712	2.3707

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.4757	2.3632	2.3631

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	17.4757	2.3632	2.3631

SLICE INFORMATION ... continued :

Slice	Sigma	c-value	phi	U-base	U-top	P-top	Delta

	(psf)	(psf)		(lb)	(lb)	(lb)	
1	565.4	.0	30.00	0.	0.	0.	.00
2	1255.4	200.0	25.00	0.	0.	0.	.00
3	1958.6	28.8	25.64	0.	0.	0.	.00
4	1182.5	28.8	25.64	0.	0.	0.	.00
5	2029.7	28.8	25.64	0.	0.	0.	.00
6	3017.4	650.9	14.79	0.	0.	0.	.00
7	3620.0	650.9	14.79	0.	0.	0.	.00
8	4103.6	650.9	14.79	0.	0.	0.	.00
9	4944.9	650.9	14.79	0.	0.	0.	.00
10	5905.4	650.9	14.79	0.	0.	0.	.00
11	6606.1	2361.6	.00	0.	0.	0.	.00
12	4397.4	650.9	14.79	0.	0.	0.	.00
13	3179.5	200.0	25.00	0.	0.	0.	.00
14	1757.9	200.0	25.00	0.	0.	0.	.00
15	416.1	200.0	25.00	0.	0.	0.	.00
16	47.2	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.43	565.4	320.8	.0	138.1
2	284.62	1255.4	688.0	.0	332.3
3	284.15	1958.6	751.6	.0	410.0
4	277.02	1182.5	1090.6	.0	252.4
5	260.00	2029.7	1874.9	.0	424.4
6	240.00	3017.4	2793.4	.0	612.5
7	227.40	3620.0	3369.8	.0	679.8
8	217.40	4103.6	3832.2	.0	733.8
9	200.00	4944.9	4636.8	.0	827.8
10	180.00	5905.4	5555.3	.0	935.1
11	165.27	6606.1	6230.2	.0	999.3
12	160.46	4397.4	6441.8	.0	766.7
13	155.19	3179.5	5643.6	.0	712.0
14	139.50	1757.9	3167.8	.0	431.5
15	125.22	416.1	830.9	.0	166.7
16	120.98	47.2	89.4	.0	11.5

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	17.48	3585.	3.27	5.13	.636
2	284.25	17.48	4480.	3.26	5.87	.555
3	284.05	17.48	4984.	3.18	6.15	.518
4	270.00	17.48	9048.	5.40	11.30	.478
5	250.00	17.48	18796.	7.56	18.70	.404
6	230.00	17.48	32898.	9.58	26.00	.368

7	224.80	17.48	36998.	10.16	27.92	.364
8	210.00	17.48	49652.	11.89	33.39	.356
9	190.00	17.48	69075.	14.30	40.79	.351
10	170.00	17.48	91149.	16.72	48.09	.348
11	160.54	17.48	102365.	17.88	51.59	.347
12	160.38	17.48	101710.	17.88	51.48	.347
13	150.00	17.48	55159.	14.45	38.82	.372
14	129.00	17.48	3922.	4.84	11.86	.408
15	121.44	17.48	68.	.66	1.43	.459
16	120.52	.00	0.	-2.06	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 2989.71 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 569.48 (psf)

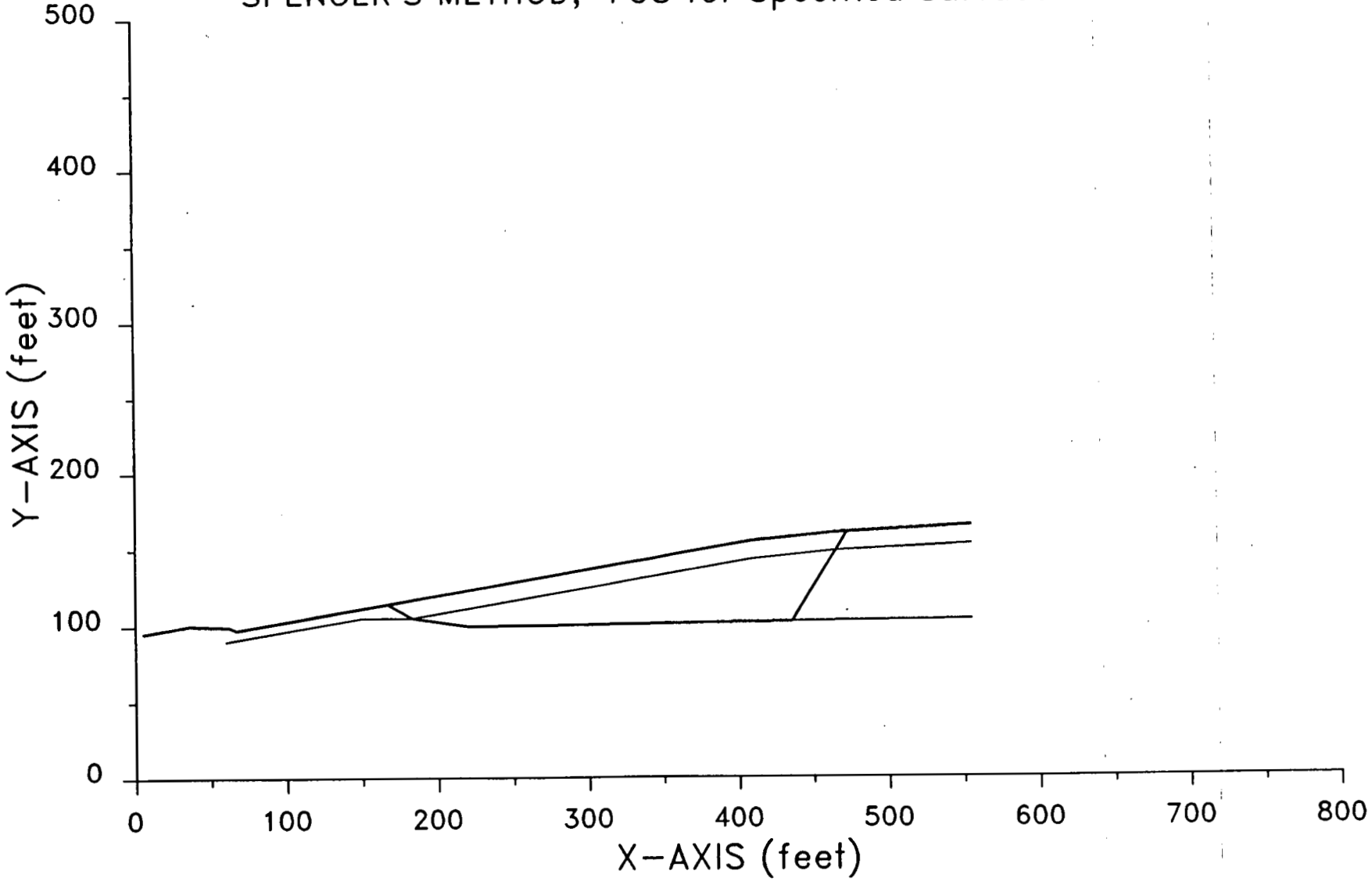
Total Length of failure surface = 207.40 feet

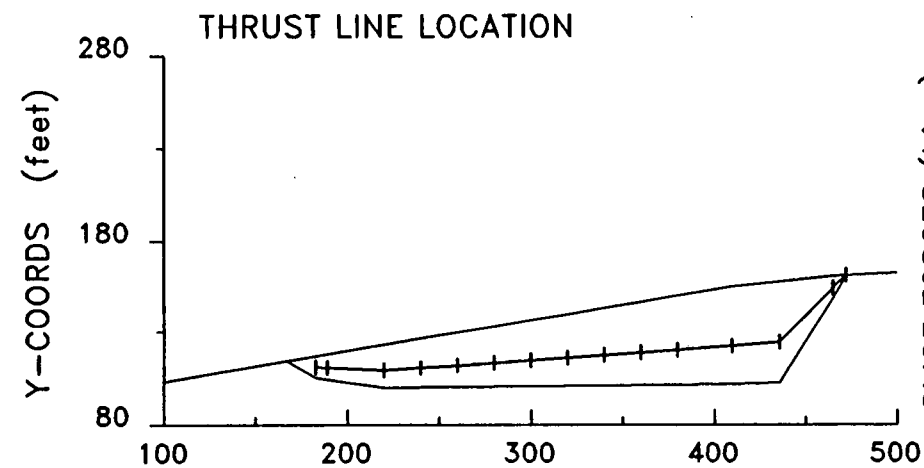
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

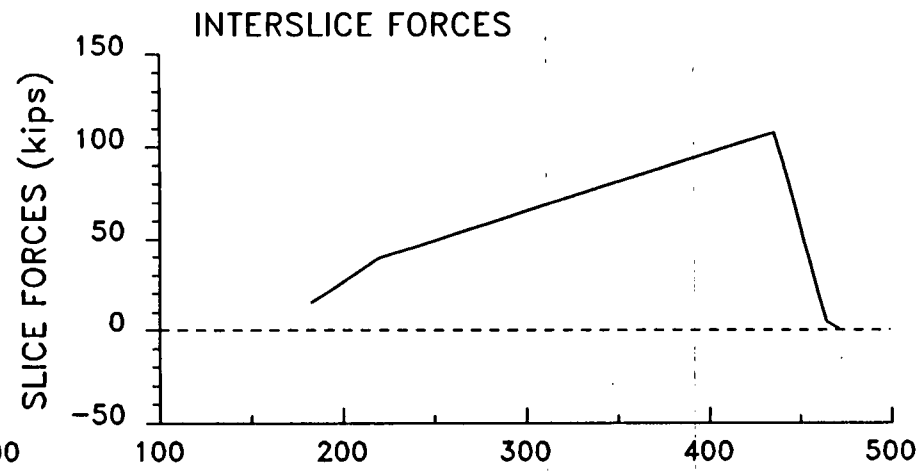
FACTOR OF SAFETY = 2.363 ✓

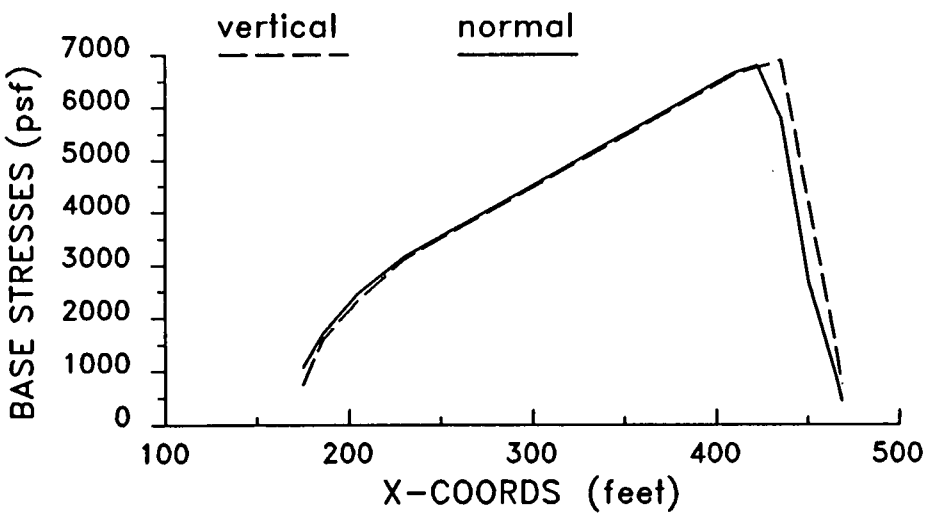
Total shear strength available along specified failure surface = 279.12E+03 lb

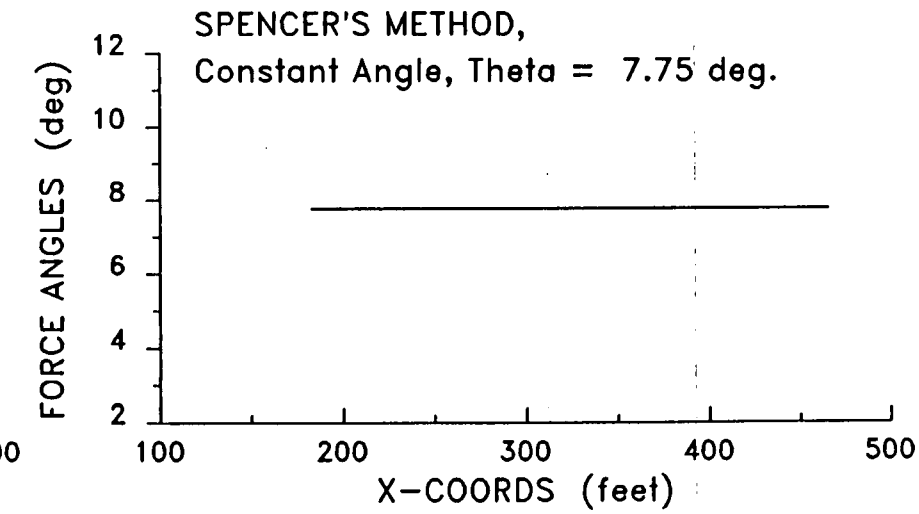
OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.820 ✓











OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.820 ✓

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*                                       *
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*               using the               *
*            Method of Slices           *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	452.9
4	2880.0	630.8
5	6480.0	702.7
6	10080.0	702.7

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 9 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	409.90	101.80
6	435.85	102.13
7	435.99	102.27
8	465.34	148.33
9	472.40	160.57

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.63	9.37	93352.
9	330.00	100.93	40.42	20.00	.63	9.37	101056.
10	350.00	101.15	43.55	20.00	.63	9.65	108885.
11	370.00	101.36	46.69	20.00	.63	9.37	116714.
12	394.95	101.64	50.55	29.90	.63	9.46	188949.
13	409.95	101.80	52.89	.10	.73	9.46	661.
14	422.92	101.97	54.03	25.85	.73	5.71	174574.
15	435.92	102.20	55.09	.14	45.00	5.71	964.
16	450.49	125.03	33.72	29.01	57.49	5.71	122264.
17	465.17	148.07	12.14	.34	57.49	2.86	520.
18	468.87	154.45	5.94	7.06	60.02	2.86	5241.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.7331	1.8198	1.8424
3	7.7506	1.8203	1.8198

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.7506	1.8203	1.8198

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta

1	1064.1	.0	30.00	0.	0.	0.	.00
2	1708.2	393.6	4.71	0.	0.	0.	.00
3	2441.9	393.6	4.71	0.	0.	0.	.00
4	3139.8	573.3	1.14	0.	0.	0.	.00
5	3533.5	573.3	1.14	0.	0.	0.	.00
6	3921.1	573.3	1.14	0.	0.	0.	.00
7	4314.8	573.3	1.14	0.	0.	0.	.00
8	4706.5	573.3	1.14	0.	0.	0.	.00
9	5091.7	573.3	1.14	0.	0.	0.	.00
10	5483.1	573.3	1.14	0.	0.	0.	.00
11	5874.5	573.3	1.14	0.	0.	0.	.00
12	6358.1	573.3	1.14	0.	0.	0.	.00
13	6647.5	702.7	.00	0.	0.	0.	.00
14	6789.2	702.7	.00	0.	0.	0.	.00
15	5773.8	573.3	1.14	0.	0.	0.	.00
16	2666.2	.0	25.00	0.	0.	0.	.00
17	960.2	.0	25.00	0.	0.	0.	.00
18	426.2	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1064.1	739.6	.0	337.5
2	186.00	1708.2	1594.4	.0	293.5
3	204.50	2441.9	2304.8	.0	326.7
4	230.00	3139.8	3100.0	.0	349.4
5	250.00	3533.5	3493.8	.0	353.7
6	270.00	3921.1	3881.3	.0	358.0
7	290.00	4314.8	4275.0	.0	362.3
8	310.00	4706.5	4667.6	.0	366.6
9	330.00	5091.7	5052.8	.0	370.8
10	350.00	5483.1	5444.3	.0	375.1
11	370.00	5874.5	5835.7	.0	379.4
12	394.95	6358.1	6319.4	.0	384.7
13	409.95	6647.5	6611.4	.0	386.0
14	422.92	6789.2	6753.4	.0	386.0
15	435.92	5773.8	6886.5	.0	378.3
16	450.49	2666.2	4214.5	.0	683.0
17	465.17	960.2	1517.9	.0	246.0
18	468.87	426.2	742.7	.0	135.2

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.75	15278.	5.68	11.83	.480
2	189.00	7.75	18509.	6.20	13.68	.453
3	220.00	7.75	39467.	9.21	23.20	.397

4	240.00	7.75	45886.	10.28	26.40	.389
5	260.00	7.75	52312.	11.39	29.50	.386
6	280.00	7.75	58746.	12.53	32.60	.384
7	300.00	7.75	65187.	13.69	35.80	.383
8	320.00	7.75	71549.	14.87	38.88	.383
9	340.00	7.75	77911.	16.07	41.96	.383
10	360.00	7.75	84274.	17.27	45.14	.383
11	380.00	7.75	90637.	18.48	48.23	.383
12	409.90	7.75	100151.	20.30	52.88	.384
13	410.00	7.75	100181.	20.30	52.90	.384
14	435.85	7.75	108000.	21.91	55.15	.397
15	435.99	7.75	107238.	21.95	55.03	.399
16	465.00	7.75	4734.	5.59	12.40	.450
17	465.34	7.75	4298.	5.64	11.88	.474
18	472.40	.00	-2.	-.06	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3951.68 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 402.44 (psf)

Total Length of failure surface = 340.53 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.820

Total shear strength available along specified failure surface = 249.46E+03 lb

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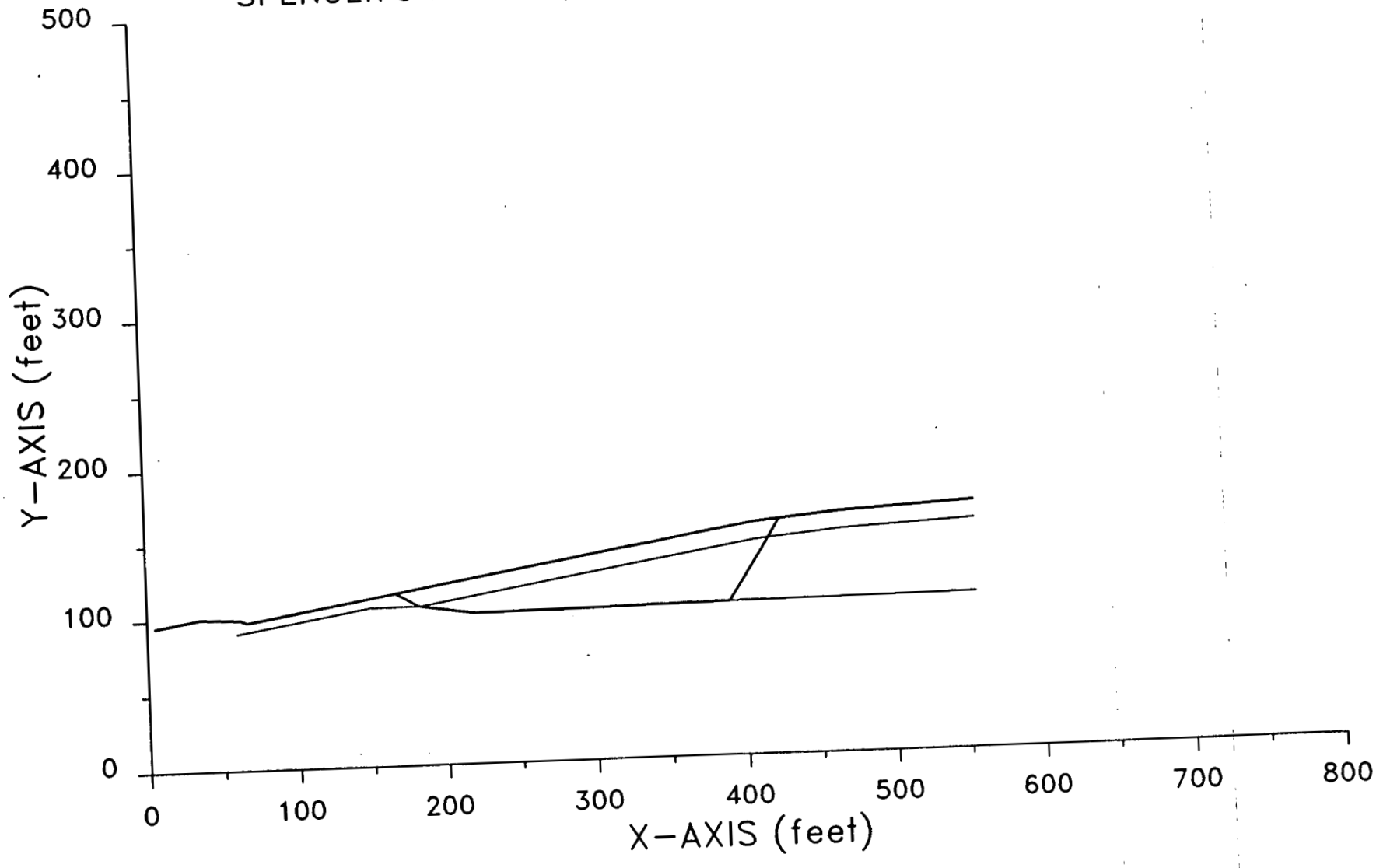
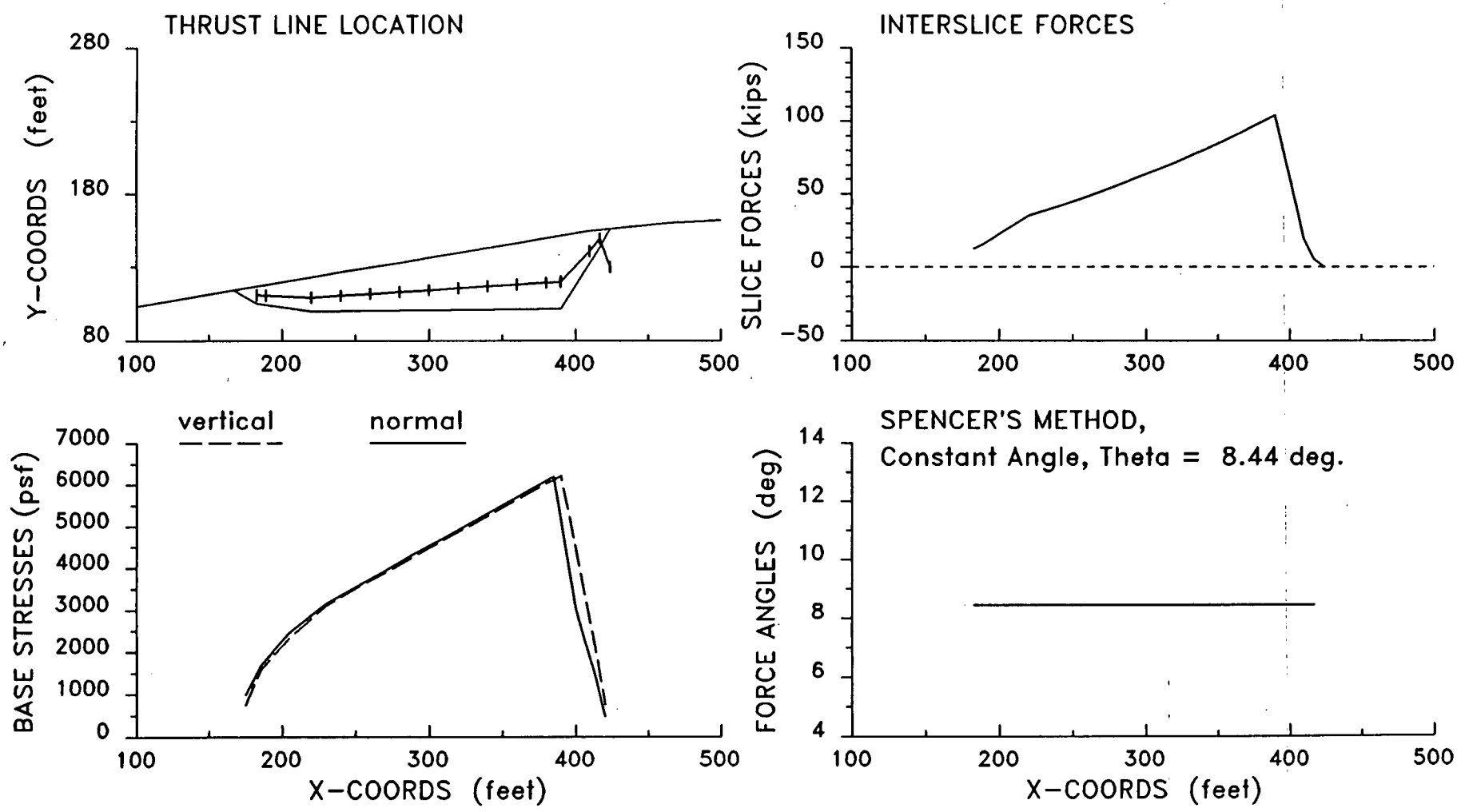
OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.693





OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.693 ✓

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	316.8
4	2880.0	878.4
5	6480.0	1584.0
6	10080.0	1584.0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	390.11	101.63
6	390.27	101.78
7	416.83	143.48
8	424.12	156.11

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.65	9.37	93339.
9	330.00	100.94	40.41	20.00	.65	9.37	101018.
10	350.00	101.17	43.53	20.00	.65	9.65	108821.
11	370.00	101.40	46.65	20.00	.65	9.37	116625.
12	385.05	101.57	48.97	10.11	.65	9.46	61886.
13	390.19	101.71	49.69	.16	43.15	9.46	1013.
14	400.14	117.27	35.79	19.73	57.51	9.46	88242.
15	413.42	138.12	16.92	6.83	57.51	5.71	14451.
16	420.48	149.80	5.95	7.29	60.01	5.71	5420.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	8.4028	2.6916	2.7319
3	8.4430	2.6935	2.6916
4	8.4420	2.6935	2.6935

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	8.4420	2.6935	2.6935

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	974.9	.0	30.00	0.	0.	0.	.00

2	1690.7	129.6	14.57	0.	0.	0.	.00
3	2437.5	129.6	14.57	0.	0.	0.	.00
4	3143.1	313.9	11.09	0.	0.	0.	.00
5	3540.3	313.9	11.09	0.	0.	0.	.00
6	3931.1	313.9	11.09	0.	0.	0.	.00
7	4328.3	313.9	11.09	0.	0.	0.	.00
8	4722.0	313.9	11.09	0.	0.	0.	.00
9	5109.1	313.9	11.09	0.	0.	0.	.00
10	5502.5	313.9	11.09	0.	0.	0.	.00
11	5896.0	313.9	11.09	0.	0.	0.	.00
12	6188.4	313.9	11.09	0.	0.	0.	.00
13	5114.3	313.9	11.09	0.	0.	0.	.00
14	3024.2	.0	25.00	0.	0.	0.	.00
15	1430.0	.0	25.00	0.	0.	0.	.00
16	465.8	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	974.9	739.6	.0	209.0
2	186.00	1690.7	1594.4	.0	211.3
3	204.50	2437.5	2304.8	.0	283.4
4	230.00	3143.1	3100.0	.0	345.3
5	250.00	3540.3	3493.8	.0	374.2
6	270.00	3931.1	3881.3	.0	402.6
7	290.00	4328.3	4275.0	.0	431.5
8	310.00	4722.0	4667.0	.0	460.2
9	330.00	5109.1	5050.9	.0	488.3
10	350.00	5502.5	5441.1	.0	517.0
11	370.00	5896.0	5831.2	.0	545.6
12	385.05	6188.4	6121.3	.0	566.9
13	390.19	5114.3	6211.5	.0	488.7
14	400.14	3024.2	4473.2	.0	523.6
15	413.42	1430.0	2115.2	.0	247.6
16	420.48	465.8	743.7	.0	99.8

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	8.44	12409.	5.77	11.83	.488
2	189.00	8.44	15132.	6.31	13.68	.461
3	220.00	8.44	34750.	9.18	23.20	.396
4	240.00	8.44	41096.	10.31	26.40	.391
5	260.00	8.44	47945.	11.41	29.50	.387
6	280.00	8.44	55291.	12.48	32.60	.383
7	300.00	8.44	63141.	13.52	35.80	.378
8	320.00	8.44	71354.	14.55	38.87	.374
9	340.00	8.44	80046.	15.56	41.94	.371

10	360.00	8.44	89227.	16.56	45.11	.367
11	380.00	8.44	98896.	17.54	48.19	.364
12	390.11	8.44	103967.	18.04	49.75	.363
13	390.27	8.44	103257.	18.03	49.63	.363
14	410.00	8.44	19008.	7.77	21.94	.354
15	416.83	8.44	5211.	5.77	11.90	.485
16	424.12	.00	0.	-26.48	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3542.66 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 396.28 (psf)

Total Length of failure surface = 290.09 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.693

Total shear strength available along specified failure surface = 309.63E+03 lb

GCL 23

COMPUTATION COVER SHEET

1269

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) QA23 and QC09- Compliance Package

Computations By:
(Cognizant Engineer)

Signature [signature] Date 5 NOV 1997

Printed Name and Title M. CATALINA OROZCO
STAFF ENGINEER

Assumptions and Procedures Checked By:
(Checker)

Signature [signature] Date 5 NOV 1997

Printed Name and Title ROBERT A. MORGAN III
SR. STAFF ENGINEER

Computations Checked by:

Signature [signature] Date 5 NOV 1997

Printed Name and Title ROBERT A. MORGAN III
SR. STAFF ENGINEER

Computations Backchecked by:
(Cognizant Engineer)

Signature [signature] Date 5 NOV 1997

Printed Name and Title M. CATALINA OROZCO
STAFF ENGINEER

Approved by:
(PDP)

Signature [signature] Date 6 Nov 97

Printed Name and Title Gary R. Schmertmann
Sr. Project Engineer

Approved by:
(DTL and TETL)

Signature [signature] Date 10 Nov 97

Printed Name and Title Kenneth W. Cargill
Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

GEOSYNTEC CONSULTANTS

Written By: MCD Date: 11 / 5 / 97 Reviewed by: RAM Date: 11 / 5 / 97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL lot number 97101002 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3). The evaluation is based on the shear test results from GCL QA sample no. 23 and GCL QC sample no. 09

METHOD

The method for evaluating the GCL samples is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL samples to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 23 and the results of the GCL internal shear tests performed on QC sample no. 09 are shown in the following table. The results of the GCL internal shear tests for QA sample no. 23 were averaged with the results of the GCL internal shear tests for QC sample no. 09. The averaged values for the GCL internal shear tests were used in the stability analyses. The laboratory test results for GCL QA sample no. 23 are presented in Appendix A. The laboratory test results for GCL QC sample no. 09 are presented in Appendix B.

Test Type	Case	Sample No.	Measured Shear Strengths (psi)		
			5 psi	20 psi	45 psi
GCL Internal	Peak	QA 23	5.2	9.7	19.7
		QC 09	4.44	13.95	21.46
		Average QA23-QC09	**4.820**	**11.825**	**20.580**
	Large-displacement	QA 23	2.5	5.4	7.1
		QC 09	3.02	3.10	4.49
		Average QA23-QC09	**2.760**	**4.250**	**5.795**
GCL/GMB Interface	Peak	QA 23	**2.5**	**8.4**	**18.7**
	Large-displacement	QA 23	**1.7**	**4.5**	**8.3**

Written By : MCO Date: 11/05/97 Reviewed by: RAM Date: 11/5/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

STABILITY ANALYSES RESULTS

The results of the slope stability analyses performed using the computer program XSTABL are shown in the table below. The analyses output files and figures showing critical slip surfaces are presented in Appendix C.

Sample No.	Test Type	Filename	Factor of Safety	Comply ?
Baseline	Peak	NA	1.9	NA
Average QA23-QC09	GCL Internal	NPP23AS ✓	2.8 ✓	YES ✓
QA 23	GCL/GMB Interface	NPK23BS ✓	2.4 ✓	YES ✓
Baseline	Large-displacement	NA	1.6	NA
Average QA23-QC09	GCL Internal	NPL23AS ✓	1.9 ✓	YES ✓
QA 23	GCL/GMB Interface	NLD23BS ✓	2.2 ✓	YES ✓

3/4

MCO 5 NOV 1997
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APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 231

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-23). GCL's initial moisture content was 9.4%. GCL's final moisture content ranged from 56% to 88% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 23G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

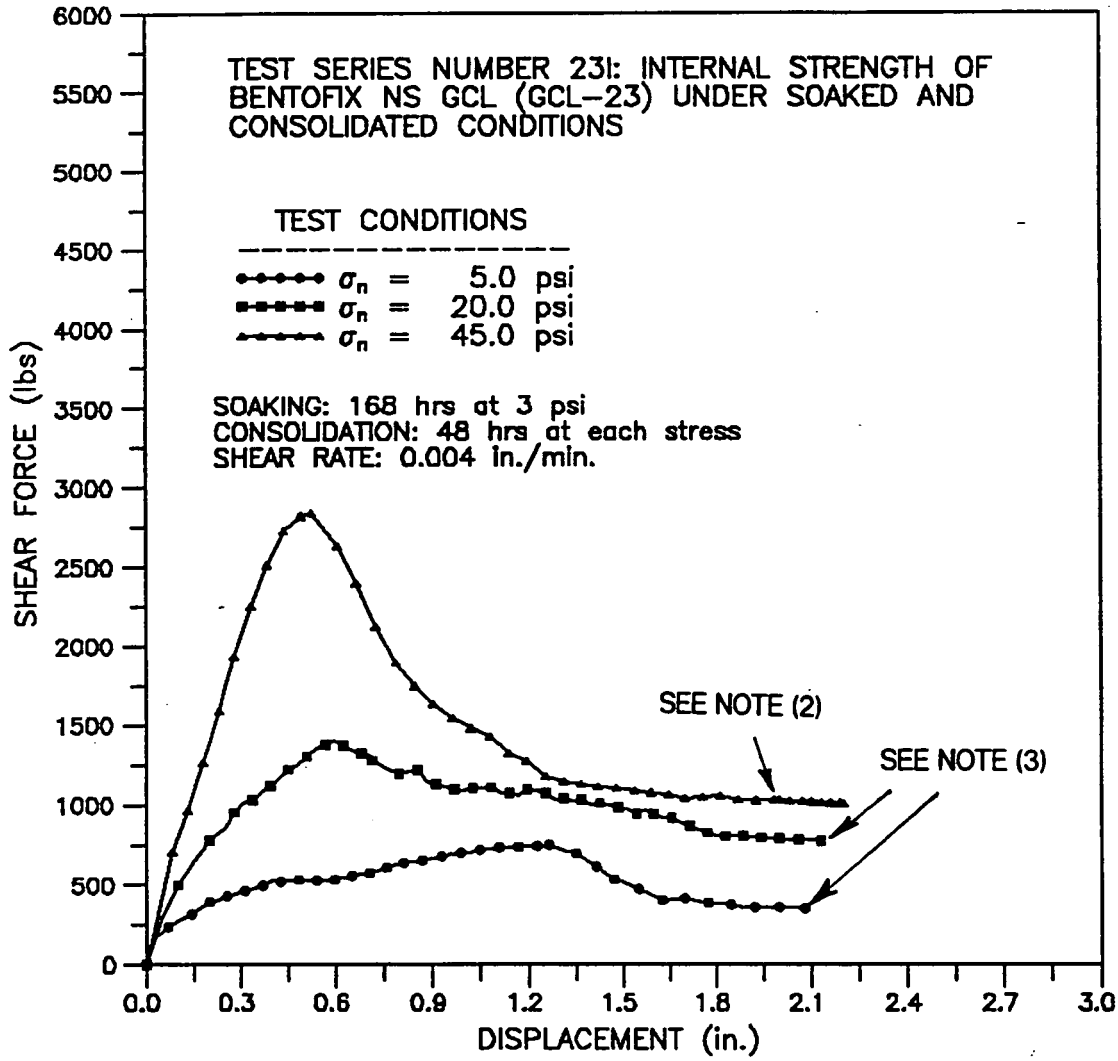
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-23) with woven geotextile against geomembrane. GCL's initial moisture content was 9.4%. GCL's final moisture content ranged from 57 to 84% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-7); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



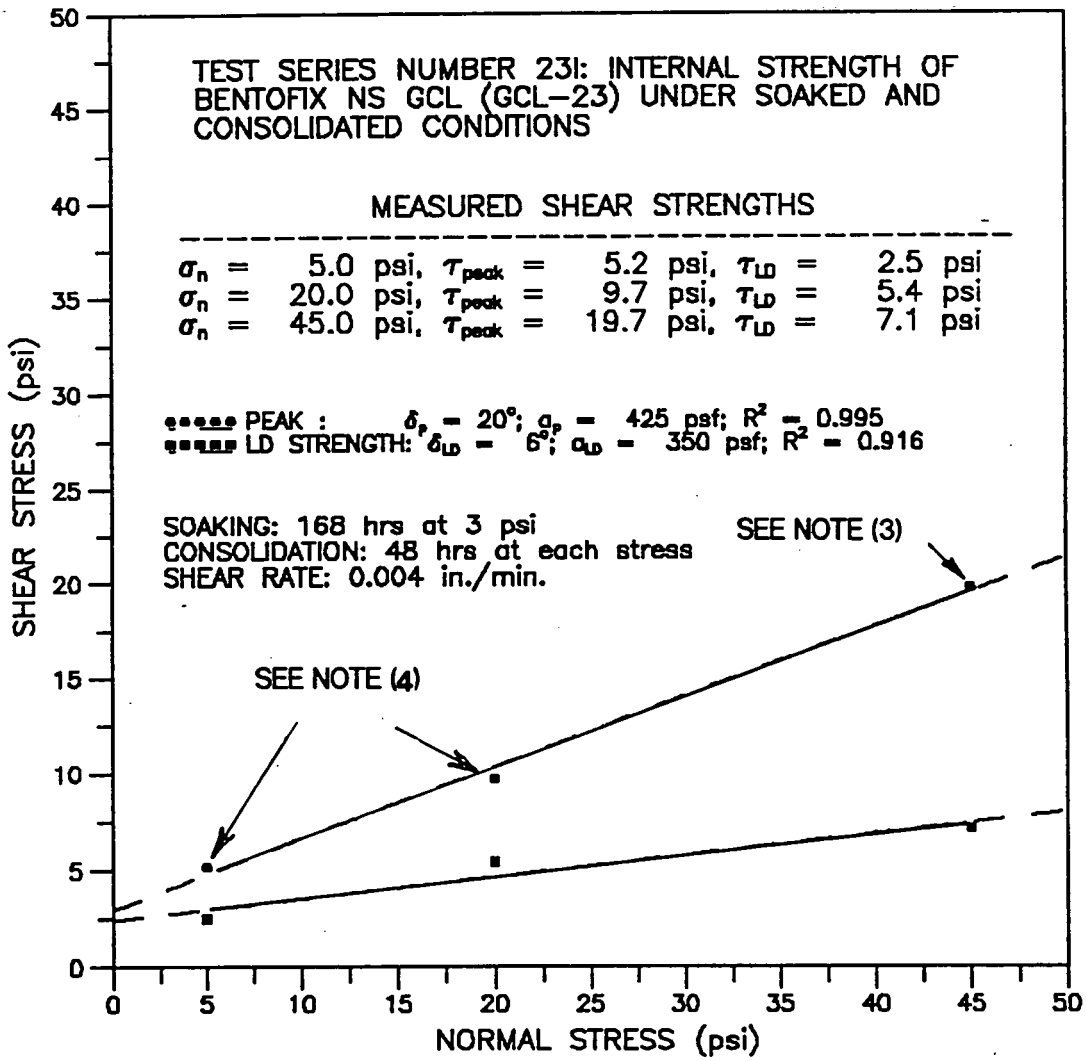
NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.
(2) Internal shear failure within GCL was observed.
(3) Partial internal shear failure within GCL was observed.

DATE TESTED: 13 TO 22 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730114
FILE NO.	000596

FLUOR DANIEL FERNALD ON-SITE DISPOSAL FACILITY PHASE 1 CONSTRUCTION DIRECT SHEAR TESTING



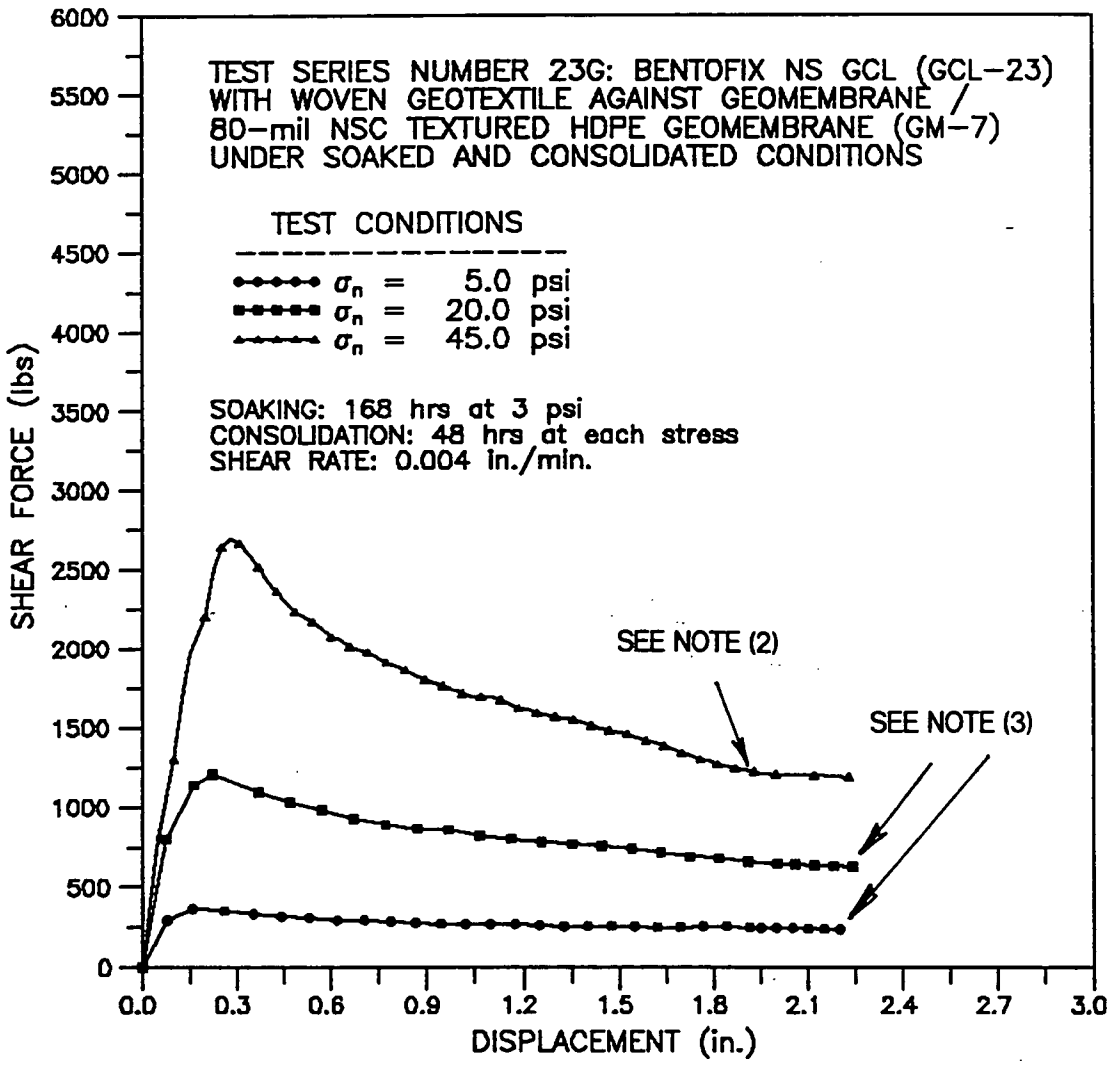
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Internal shear failure within GCL was observed.
(4) Partial internal failure within GCL was observed.

DATE TESTED: 13 TO 22 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730114
FILE NO.	000597

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Partial internal shear failure was observed to occur within the GCL.

(3) Shear failure was observed to occur at the intended interface.

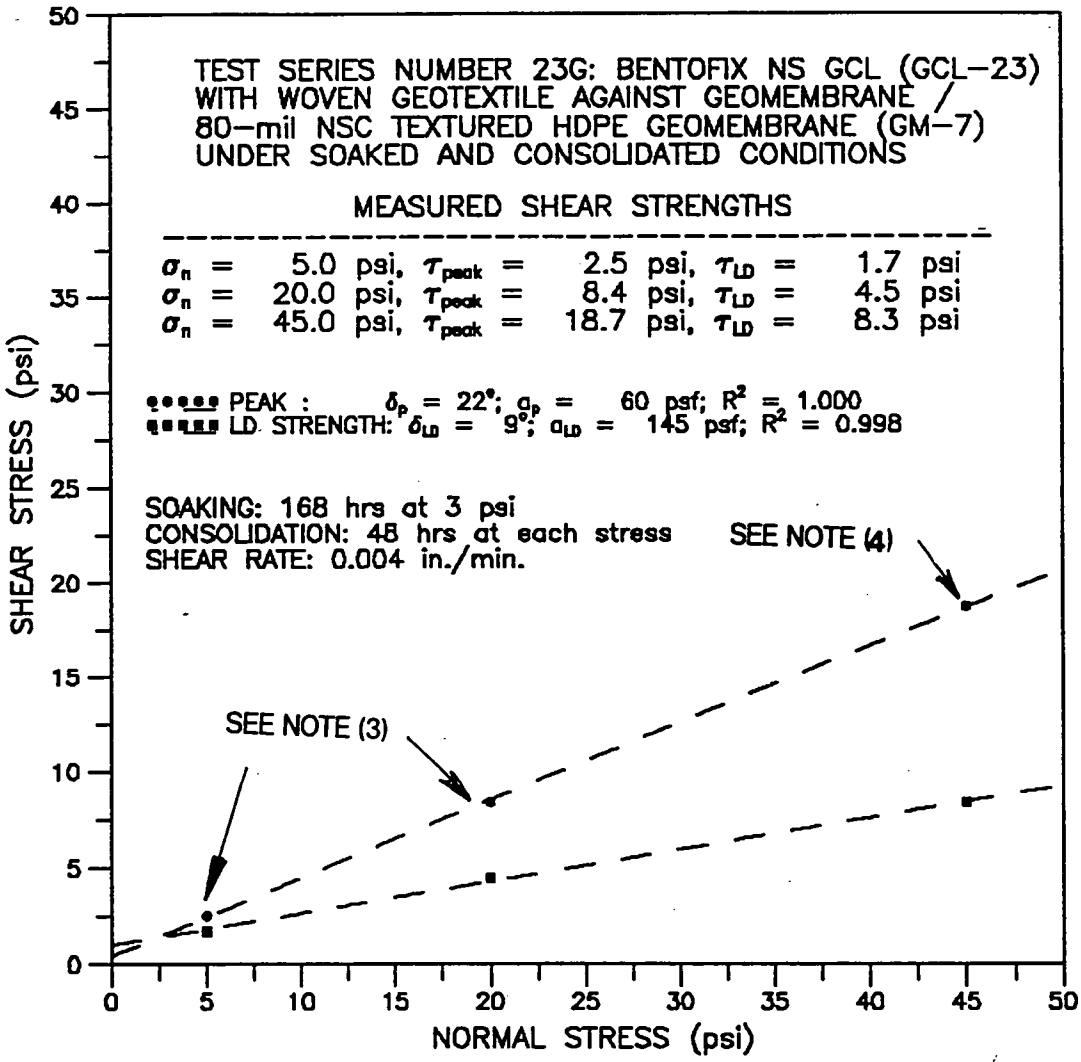
DATE TESTED: 13 TO 23 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730114
FILE NO.	000598

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Shear failure was observed to occur at the intended interface.
(4) Partial internal shear failure was observed to occur within GCL.

DATE TESTED: 13 TO 23 OCTOBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730114
FILE NO.	

10/45

MCO 5 NOV 1997
RAM 5 NOV 1997

APPENDIX B

geotechnics

INTERFACE FRICTION TEST RESULTS

ASTM D 5321-92

CLIENT :	PETRO ENVIRONMENTAL TECHNOLOGIES
CLIENT PROJECT :	GCL INTERNAL SHEAR TESTING
PROJECT NO.	L97212-02 — GCL 23
LAB I.D. NO :	BENTOFIX GCL (roll# 40698) : L97212-02-01
INTERFACE :	BENTOFIX GCL (ROLL NO. 40698) INTERNAL SHEAR

	PEAK SHEAR	SHEAR DATA (at 2" displacement)
FRICTION ANGLE (deg) :	Φ = 41.6	Φ = 31.1
COEFFICIENT OF FRICTION :	= 0.89	= 0.60
ADHESION [Calculated] (psf):	a = 0	a = 0

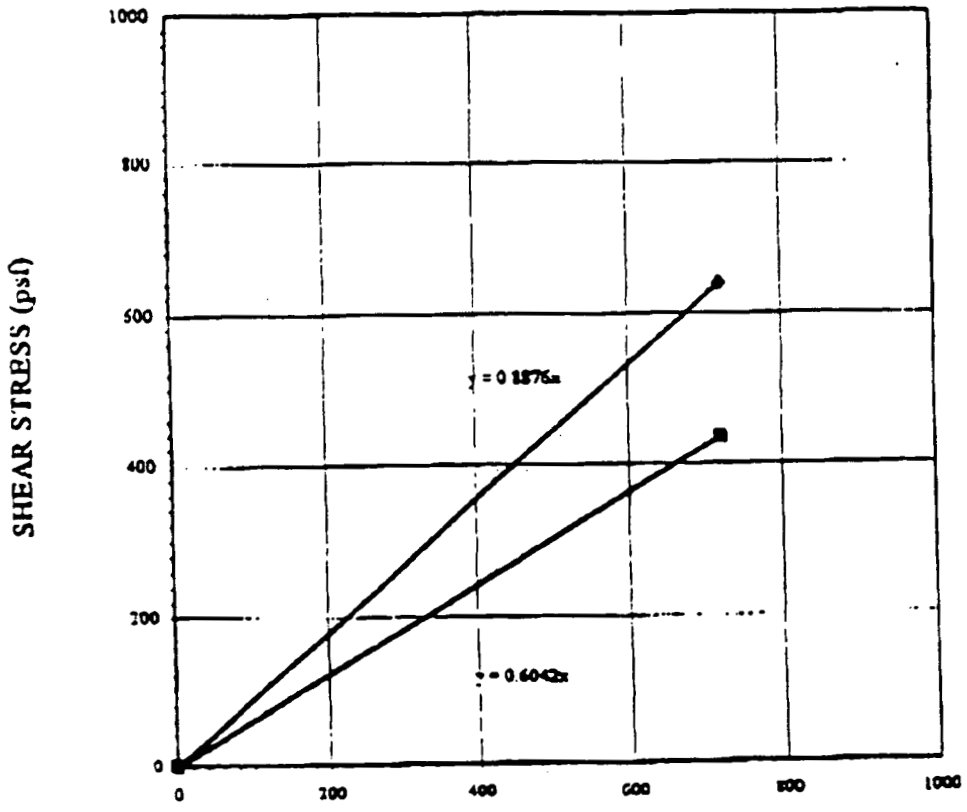
NOTES

1.)A component of the adhesion values reported may be an anomaly of the laboratory procedure and calculation algorithm.

2.)The friction angle was calculated using linear regression having six original data

3.)The GCL specimen was pre-hydrated under 3 psi for 7 days and consolidated under the test load for 2 days.

4.)Fibers slid across woven geotextile, the specimen did not shear internally.



◆ PEAK SHEAR DATA ■ SHEAR DATA (at 2 inches displacement)

CHECKED BY: RJ DATE: 10-29-97

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000601

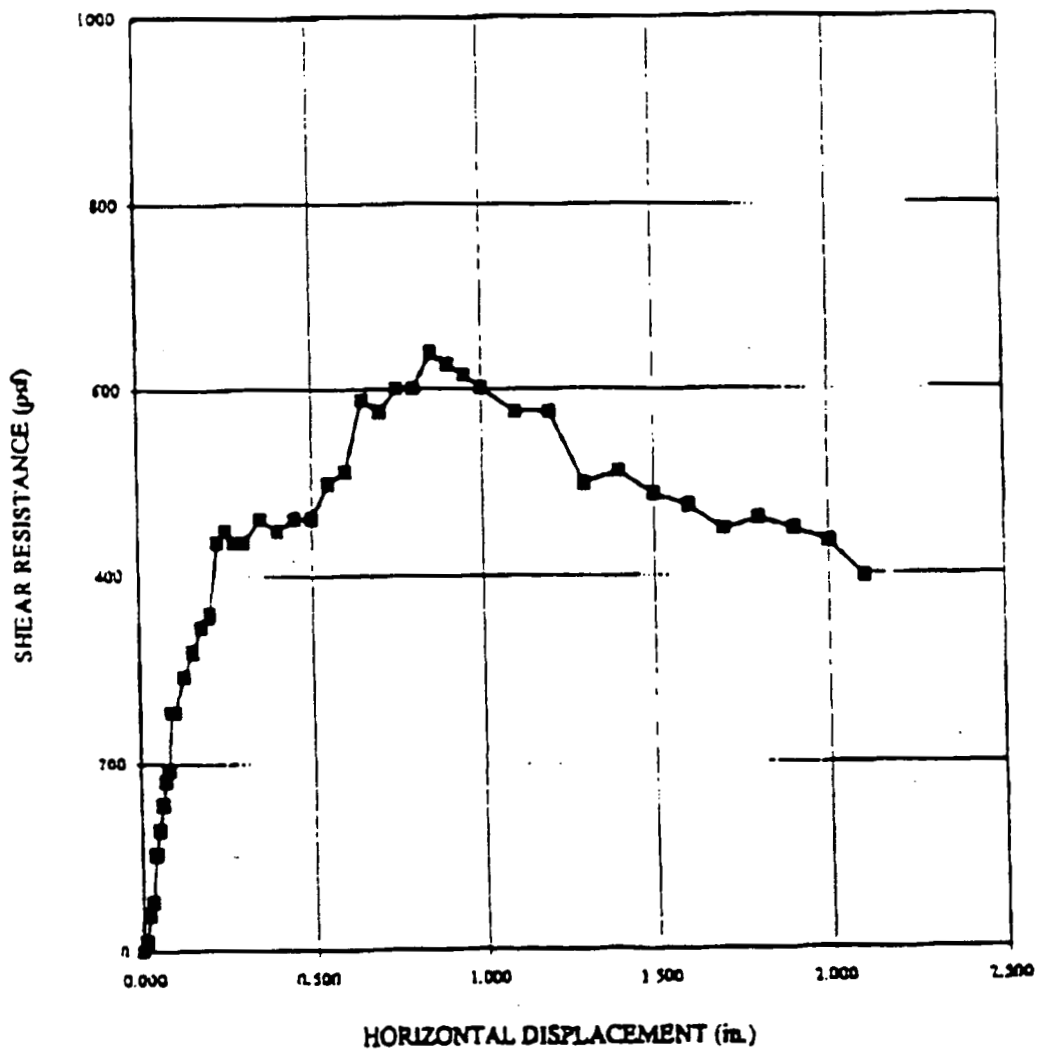
geotechnics

INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

CLIENT: PETRO ENVIRONMENTAL TECHNOLOGIES
CLIENT PROJECT: GCL INTERNAL SHEAR TESTING
PROJECT NO.: L97212-02
LAB I. D. NO.: BENTOFIX GCL (roll# 40698) : L97212-02-01

INTERFACE: **BENTOFIX GCL (ROLL NO. 40698) INTERNAL SHEAR**

SHEAR RESISTANCE VS HORIZONTAL DISPLACEMENT



CHECKED BY: RH DATE: 10-29-97

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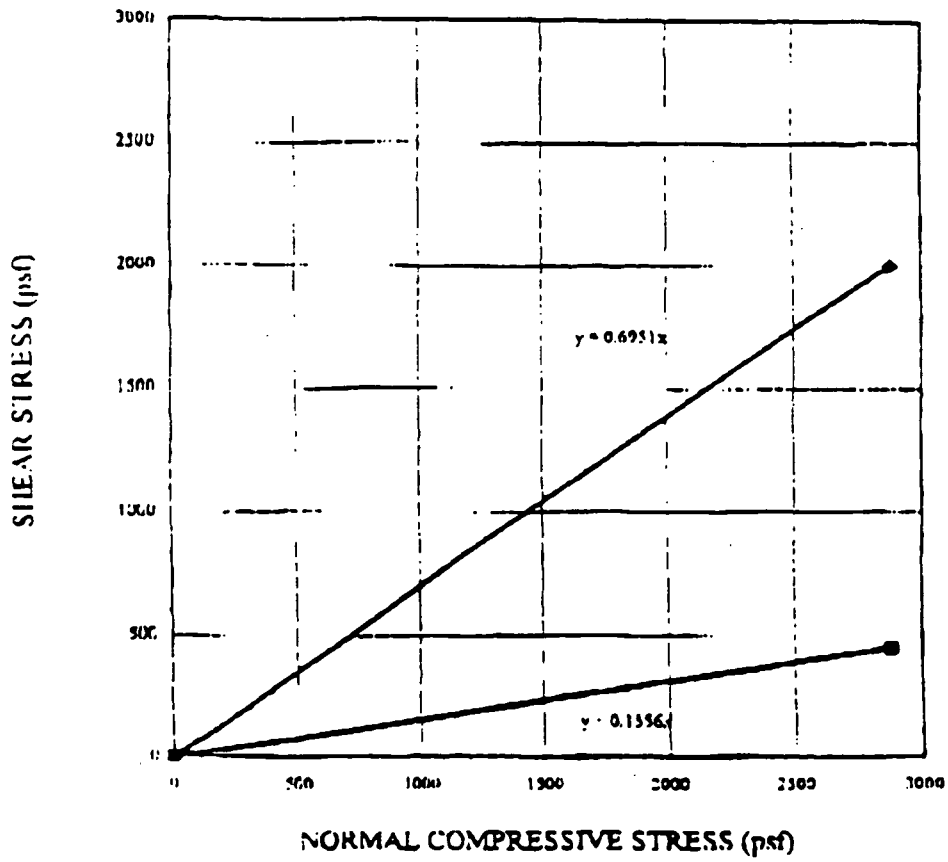
geotechnics

INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

CLIENT: PETRO ENVIRONMENTAL TECHNOLOGIES
CLIENT PROJECT: GCL INTERNAL SHEAR TESTING
PROJECT NO.: L97212-02
LAB I. D. NO.: BENTOFIX GCL (roll# 40698) : L97212-02-01
GCL - 3
INTERFACE: **BENTOFIX GCL (ROLL NO. 40698) INTERNAL SHEAR**

	PEAK SHEAR	SHEAR DATA (at 2" displacement)
FRICTION ANGLE (deg):	Φ = 34.9	Φ = 8.8
COEFFICIENT OF FRICTION	= 0.70	= 0.16
ADHESION (Calculated) (psf):	a = 0	a = 0

NOTES:
1)A component of the adhesion values reported may be an anomaly of the laboratory procedure and calculation algorithm.
2)The friction angle was calculated using linear regression based on original data.
3) The GCL specimen was pre-hydrated under 3 psi for 7 days and consolidated under the test load for 2 days



● PEAK SHEAR DATA ■ SHEAR DATA (at 2 inches displacement)

CHECKED BY: RM DATE: 10-24-97

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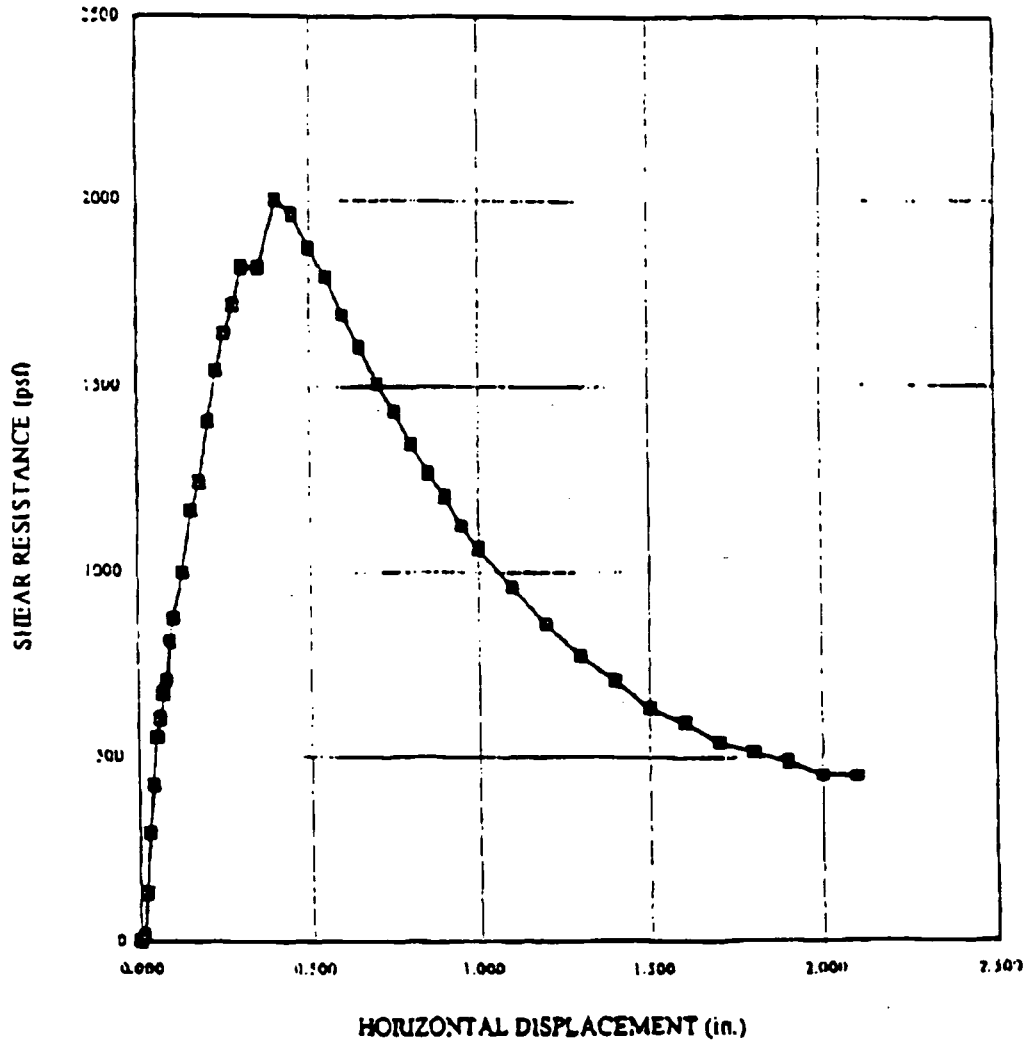
INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

geotechnics

CLIENT:	PETRO ENVIRONMENTAL TECHNOLOGIES
CLIENT PROJECT:	GCL INTERNAL SHEAR TESTING
PROJECT NO.	L97212-02
LAB I.D. NO	BENTOFIX GCL (roll# 40698) : L97212-02-01
	GCL 23
INTERFACE:	**BENTOFIX GCL (ROLL NO. 40698) INTERNAL SHEAR**

SHEAR RESISTANCE VS HORIZONTAL DISPLACEMENT



CHECKED BY: PA DATE: 10-24-97

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INTERFACE FRICTION TEST RESULTS

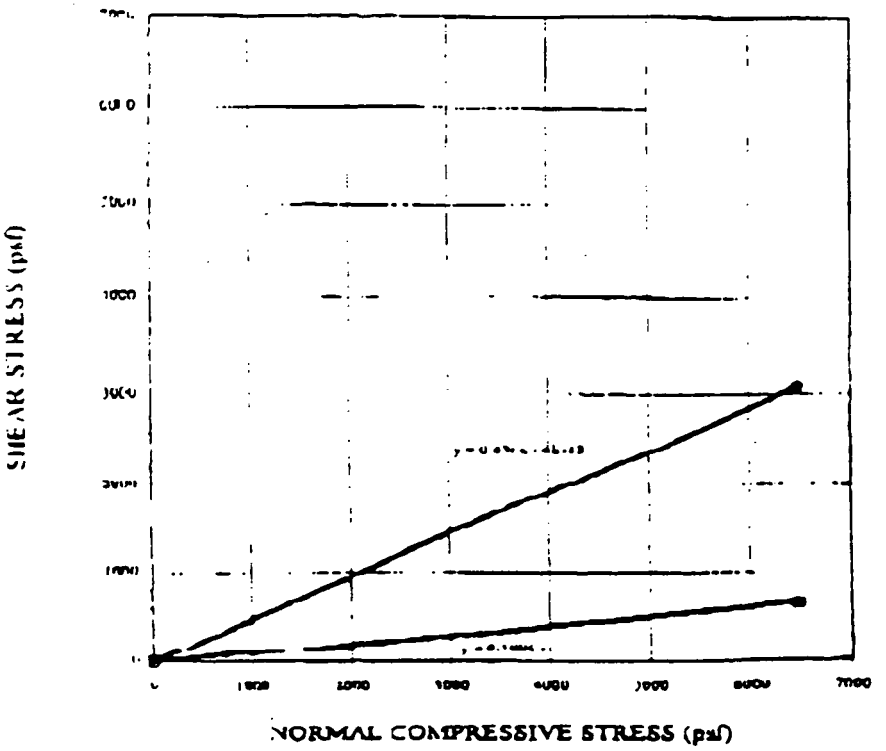
ASTM D 5321-92

geotechnics

CLIENT	PETRO ENVIRONMENTAL TECHNOLOGIES
CLIENT PROJECT	GCL INTERNAL SHEAR TESTING
PROJECT NO.	L97212-02
LAB I.D. NO.	BENTOFIX GCL (roll# 40608) L97212-02-01
INTERFACE	BENTOFIX GCL (ROLL NO. 40608) INTERNAL SHEAR

	PEAK SHEAR	SHEAR DATA (at 2" displacement)
FRICTION ANGLE (deg)	ϕ = 25.5	ϕ = 5.7
COEFFICIENT OF FRICTION	= 0.48	= 0.10
ADHESION (STRESS) (psf)	a = 0	a = 0

NOTES



● PEAK SHEAR DATA ■ SHEAR DATA (at 2 inches displacement)

PAGE 1 OF 1 CHECKED BY RH DATE 10-22-97

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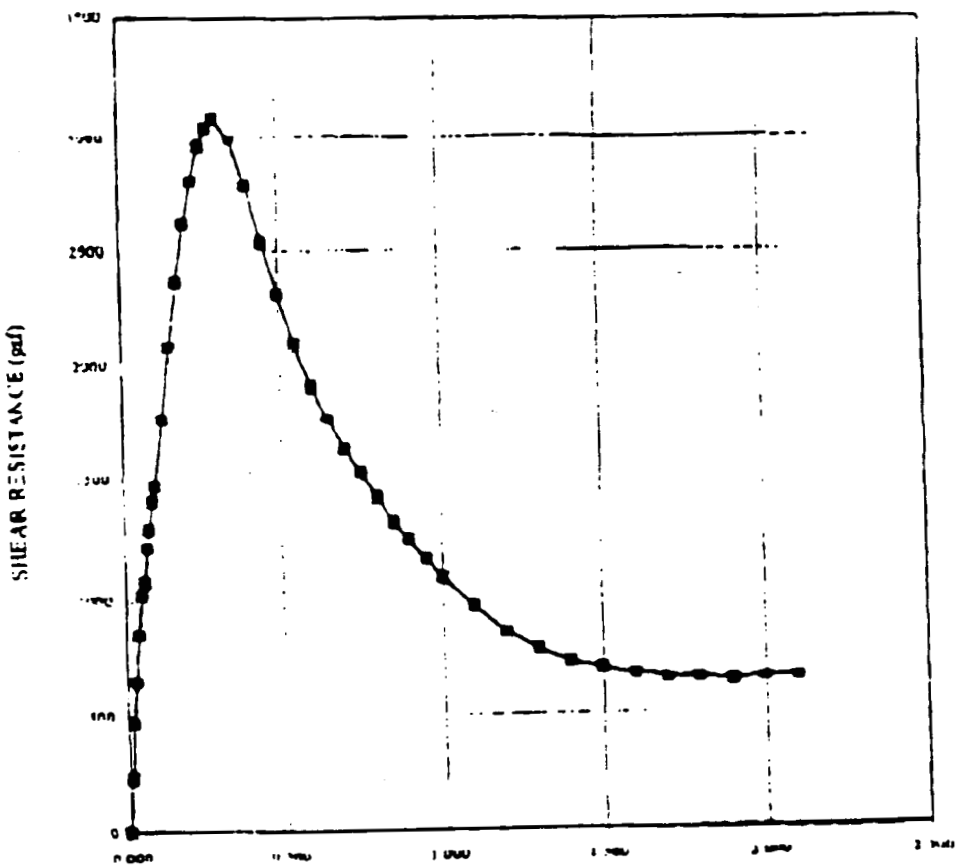
INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

geotechnics

CLIENT	PETRO ENVIRONMENTAL TECHNOLOGIES
CLIENT PROJECT	GCL INTERNAL SHEAR TESTING
PROJECT NO	L97212-02
LAB [illegible]	BENTOFIX GCL ([illegible]) . L97212-02-01
INTERFACE	**BENTOFIX GCL (ROLL NO. [illegible]) INTERNAL SHEAR**

GCL23

SHEAR RESISTANCE VS HORIZONTAL DISPLACEMENT



—●— 65 psi NORMAL COMPRESSIVE STRESS

CHECKED BY: RH DATE: 10-22-97

PAGE 2 OF 3

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17/95

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APPENDIX C

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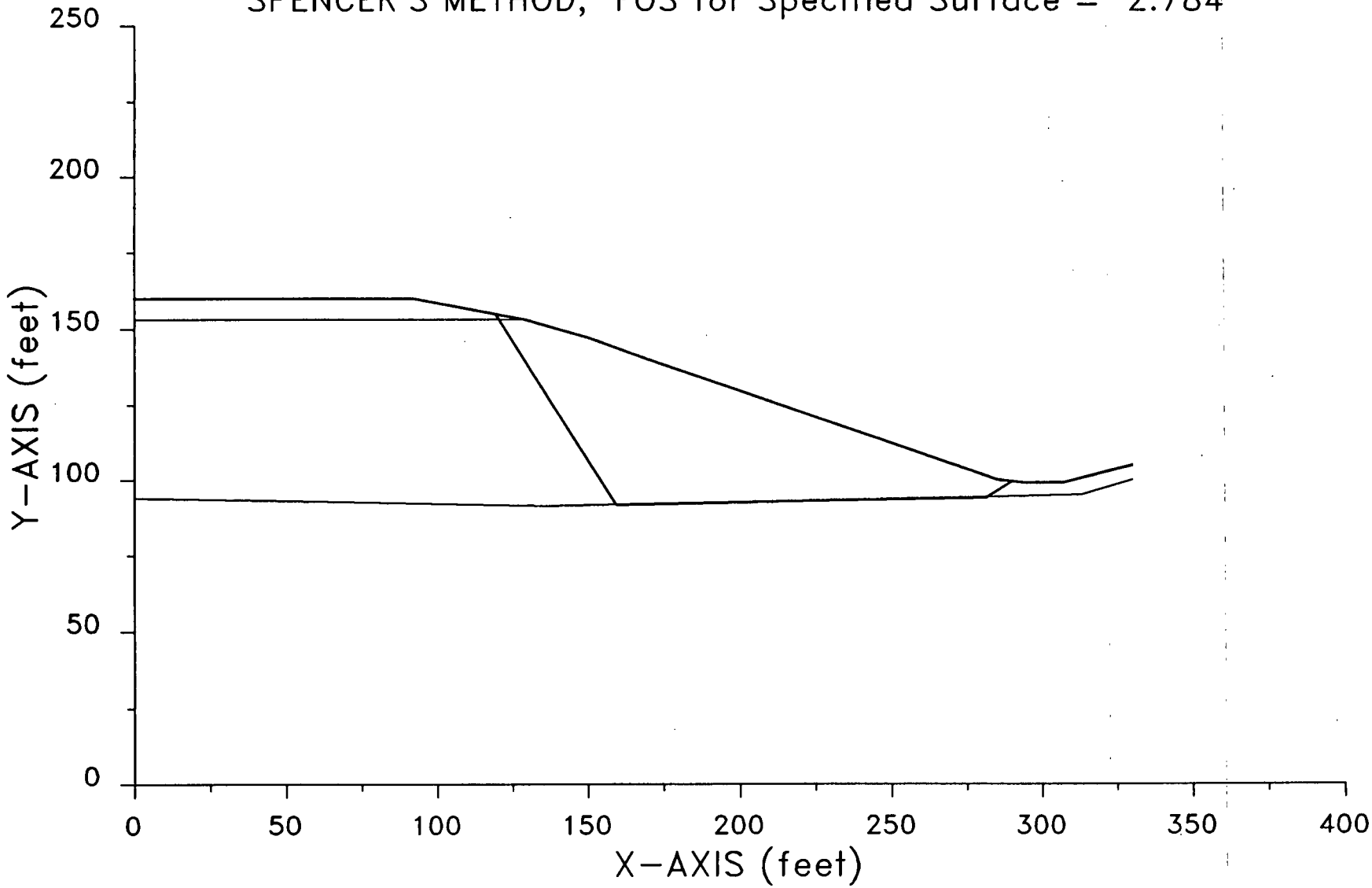
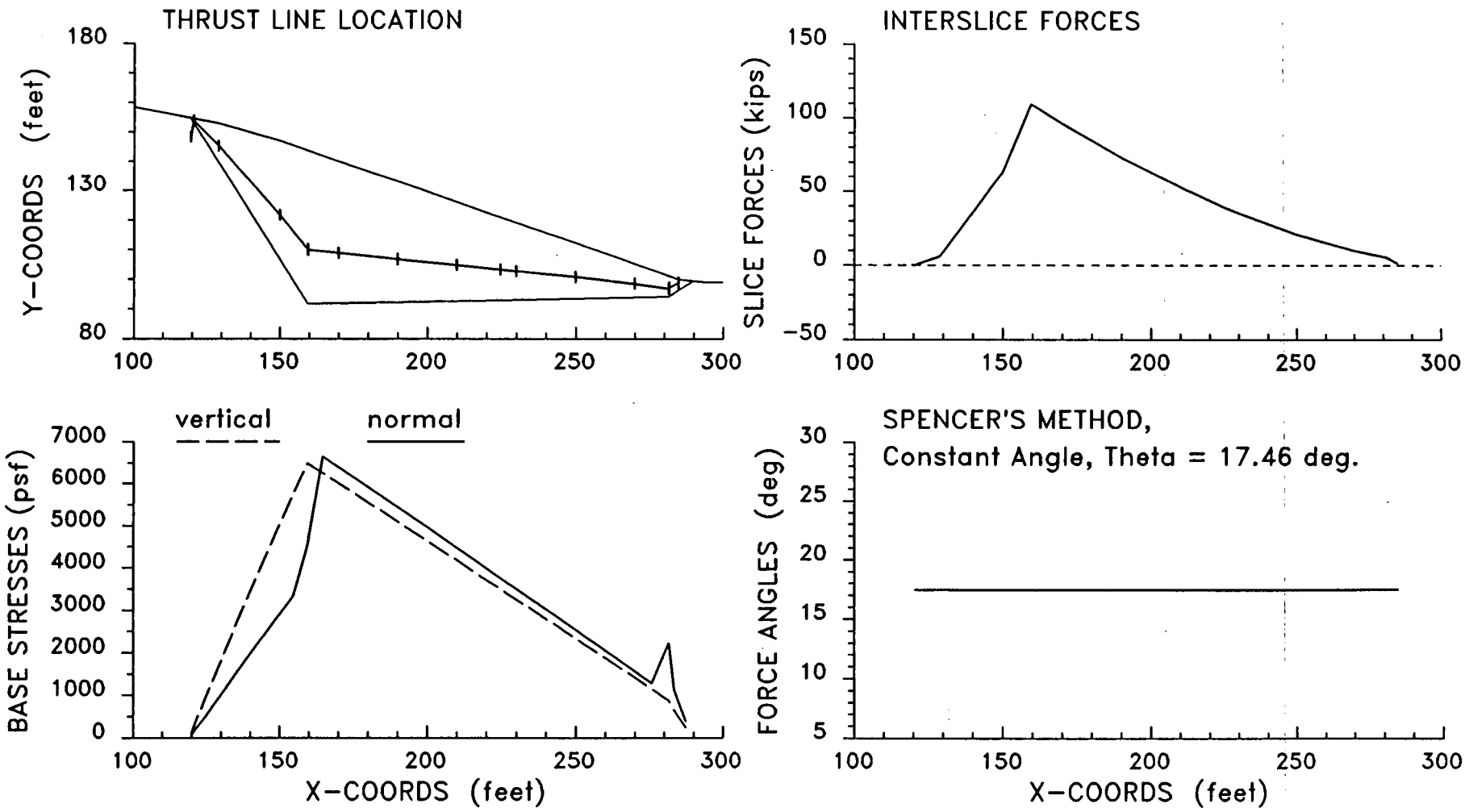
OSDF Interim Closure/Short-Term,Peak

SPENCER'S METHOD, FOS for Specified Surface = 2.784





OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.784

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*           Method of Slices            *
*                                       *
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Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

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ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	694.1
4	2880.0	1702.8
5	6480.0	2963.5
6	10080.0	2963.5

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	289.82	99.46
2	281.78	94.34
3	281.57	94.13
4	224.80	93.00
5	159.65	91.71
6	159.49	91.87
7	120.55	153.00
8	119.51	154.80

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	287.41	97.93	1.80	4.82	-32.51	6.34	1087.
2	283.39	95.36	5.19	3.22	-32.51	19.12	2093.
3	281.67	94.23	6.92	.21	-45.00	19.12	178.
4	275.79	94.01	9.18	11.57	-1.14	19.12	13276.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37498.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55869.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.85	30.66	14.80	-1.13	19.29	56715.
9	200.00	92.51	37.09	20.00	-1.13	19.29	92728.
10	180.00	92.11	44.44	20.00	-1.13	19.03	111093.
11	164.82	91.81	50.00	10.35	-1.13	19.29	64686.
12	159.57	91.79	51.86	.16	45.00	19.29	1037.
13	154.74	99.32	46.02	9.49	57.50	19.29	54592.
14	139.50	123.25	26.75	21.00	57.50	15.95	70215.
15	124.77	146.37	7.43	8.45	57.50	10.71	7850.
16	120.03	153.90	.80	1.04	59.92	10.71	104.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.3835	2.7982	2.8273
3	17.4056	2.7992	2.7982
4	17.4052	2.7992	2.7992

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.4598	2.7844	2.7820
3	17.4590	2.7844	2.7844

Nonlinear M-C Iteration Number - 3

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment

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1	17.4590	2.7839	2.7844

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	17.4590	2.7839	2.7844

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	374.5	.0	30.00	0.	0.	0.	.00
2	1121.1	200.0	25.00	0.	0.	0.	.00
3	2223.9	357.9	25.03	0.	0.	0.	.00
4	1269.6	357.9	25.03	0.	0.	0.	.00
5	2045.5	357.9	25.03	0.	0.	0.	.00
6	3022.9	694.2	19.30	0.	0.	0.	.00
7	3628.5	694.2	19.30	0.	0.	0.	.00
8	4114.1	694.2	19.30	0.	0.	0.	.00
9	4959.2	694.2	19.30	0.	0.	0.	.00
10	5924.0	694.2	19.30	0.	0.	0.	.00
11	6647.1	2963.5	.00	0.	0.	0.	.00
12	4505.8	694.2	19.30	0.	0.	0.	.00
13	3323.0	200.0	25.00	0.	0.	0.	.00
14	1909.3	200.0	25.00	0.	0.	0.	.00
15	492.3	200.0	25.00	0.	0.	0.	.00
16	54.6	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	287.41	374.5	225.5	.0	77.7
2	283.39	1121.1	649.3	.0	259.6
3	281.67	2223.9	865.1	.0	501.6
4	275.79	1269.6	1147.5	.0	341.5
5	260.00	2045.5	1874.9	.0	471.7
6	240.00	3022.9	2793.4	.0	629.6
7	227.40	3628.5	3369.8	.0	705.8
8	217.40	4114.1	3832.1	.0	766.9
9	200.00	4959.2	4636.4	.0	873.2
10	180.00	5924.0	5554.6	.0	994.6
11	164.82	6647.1	6249.8	.0	1064.5
12	159.57	4505.8	6482.6	.0	816.2
13	154.74	3323.0	5752.5	.0	628.4
14	139.50	1909.3	3343.6	.0	391.6
15	124.77	492.3	929.0	.0	154.3
16	120.03	54.6	99.9	.0	11.3

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	17.46	1598.	2.29	3.61	.636
2	281.78	17.46	4891.	2.79	6.78	.411
3	281.57	17.46	5479.	2.73	7.06	.387
4	270.00	17.46	9928.	4.51	11.30	.400
5	250.00	17.46	20670.	7.12	18.70	.381
6	230.00	17.46	35133.	9.51	26.00	.366
7	224.80	17.46	39374.	10.13	27.92	.363
8	210.00	17.46	52536.	11.92	33.39	.357
9	190.00	17.46	72902.	14.34	40.79	.352
10	170.00	17.46	96213.	16.74	48.09	.348
11	159.65	17.46	109191.	18.01	51.91	.347
12	159.49	17.46	108572.	18.00	51.81	.347
13	150.00	17.46	62928.	14.83	40.23	.369
14	129.00	17.46	5568.	5.40	13.27	.407
15	120.55	17.46	89.	.74	1.60	.460
16	119.51	.00	-1.	-6.50	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3058.00 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 581.03 (psf)

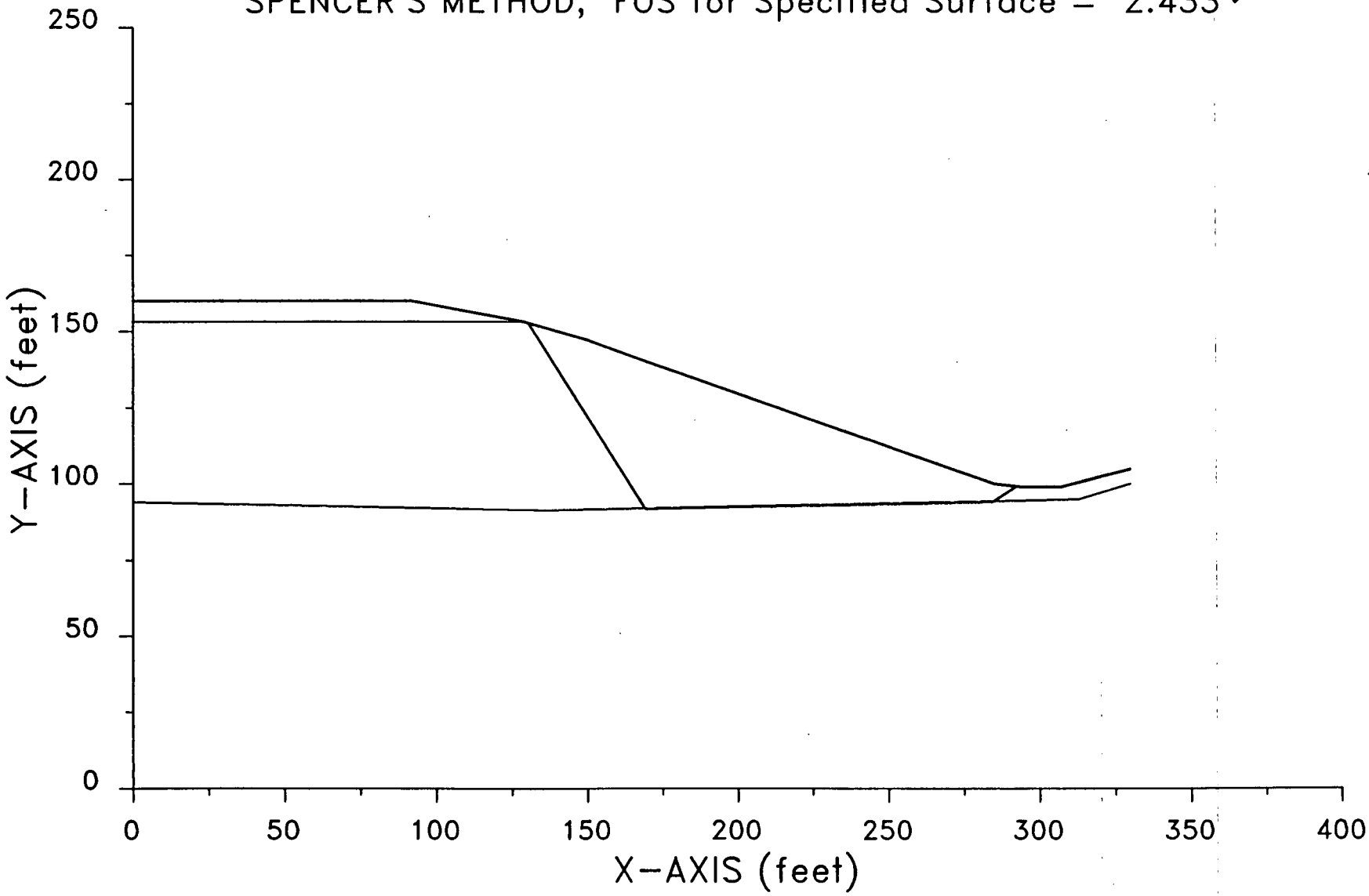
Total Length of failure surface = 206.55 feet

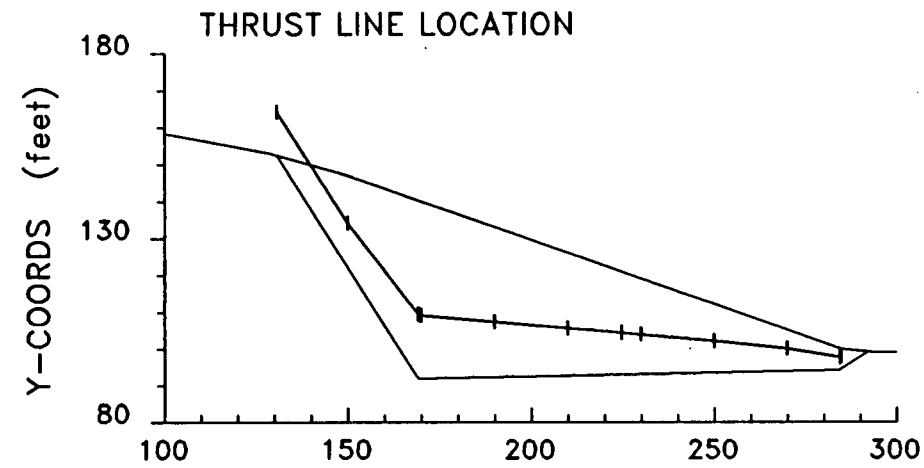
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

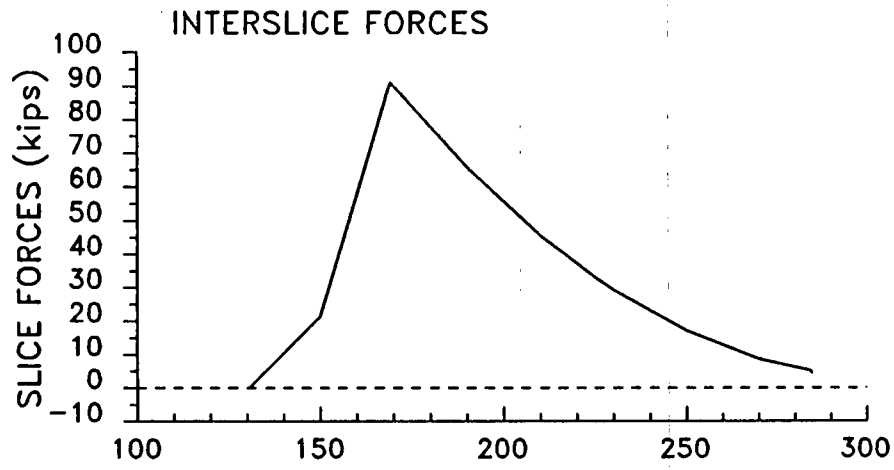
FACTOR OF SAFETY = 2.784

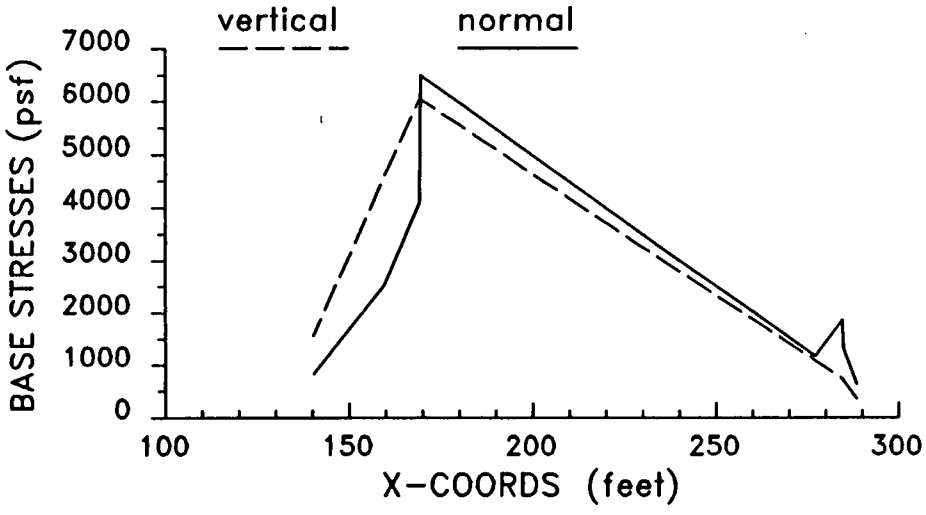
Total shear strength available along specified failure surface = 334.11E+03 lb

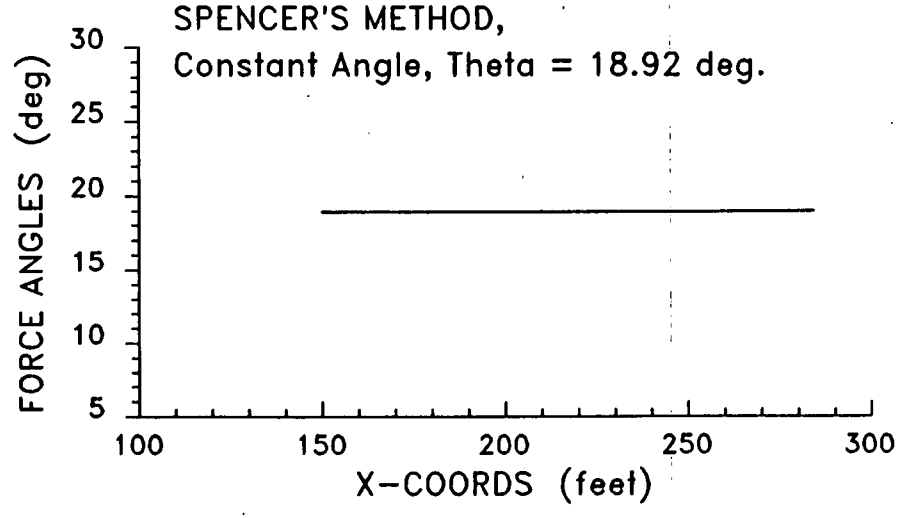
OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.433 ✓











OSDF Interim Closure/Short-Term,Peak
SPENCER'S METHOD, FOS for Specified Surface = 2.433 ✓

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```

Problem Description : OSDF Interim Closure/Short-Term,Peak

SEGMENT BOUNDARY COORDINATES
---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	160.0	92.0	160.0	2
2	92.0	160.0	129.0	153.0	2
3	129.0	153.0	150.0	147.0	1
4	150.0	147.0	170.0	140.0	1
5	170.0	140.0	190.0	133.1	1
6	190.0	133.1	210.0	126.1	1
7	210.0	126.1	230.0	119.1	1
8	230.0	119.1	250.0	112.2	1
9	250.0	112.2	270.0	105.2	1
10	270.0	105.2	285.0	100.0	1
11	285.0	100.0	294.0	99.0	2
12	294.0	99.0	307.0	99.0	2
13	307.0	99.0	330.0	105.0	2

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	153.0	129.0	153.0	1
2	.0	94.1	136.5	91.4	3
3	136.5	91.4	224.8	93.2	3
4	224.8	93.2	285.0	94.4	3
5	285.0	94.4	313.0	95.0	3
6	313.0	95.0	330.0	100.0	3

28/45

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	200.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	360.0
4	2880.0	1209.6
5	6480.0	2692.8
6	10080.0	2692.8

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 7 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	292.35	99.18
2	284.83	94.40
3	284.63	94.19
4	224.80	93.00
5	169.45	91.83
6	169.22	92.07
7	130.71	152.51

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	288.67	96.85	2.75	7.35	-32.46	6.34	2523.
2	284.91	94.45	5.58	.17	-32.46	19.12	121.
3	284.73	94.29	5.80	.20	-46.40	19.12	143.
4	277.32	94.04	8.62	14.63	-1.14	19.12	15763.
5	260.00	93.70	15.00	20.00	-1.14	19.29	37500.
6	240.00	93.30	22.35	20.00	-1.14	19.03	55869.
7	227.40	93.05	26.96	5.20	-1.14	19.29	17523.
8	217.40	92.84	30.67	14.80	-1.21	19.29	56733.
9	200.00	92.48	37.12	20.00	-1.21	19.29	92811.
10	180.00	92.05	44.50	20.00	-1.21	19.03	111242.
11	169.73	91.84	48.26	.55	-1.21	19.29	3318.
12	169.33	91.95	48.28	.23	46.22	19.29	1388.
13	159.61	107.15	36.48	19.22	57.50	19.29	87652.
14	140.36	137.37	12.38	19.29	57.50	15.95	29856.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.9324	2.4338	2.4079
3	18.9205	2.4334	2.4338

Nonlinear M-C Iteration Number - 2

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.9212	2.4325	2.4325

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	18.9212	2.4325	2.4325

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	624.5	.0	30.00	0.	0.	0.	.00

2	1308.4	200.0	25.00	0.	0.	0.	.00
3	1854.1	76.8	21.47	0.	0.	0.	.00
4	1165.2	76.8	21.47	0.	0.	0.	.00
5	2018.6	76.8	21.47	0.	0.	0.	.00
6	3001.7	23.0	22.39	0.	0.	0.	.00
7	3620.3	23.0	22.39	0.	0.	0.	.00
8	4120.6	23.0	22.39	0.	0.	0.	.00
9	4987.5	23.0	22.39	0.	0.	0.	.00
10	5977.3	23.0	22.39	0.	0.	0.	.00
11	6482.4	2692.8	.00	0.	0.	0.	.00
12	4083.4	23.0	22.39	0.	0.	0.	.00
13	2515.0	200.0	25.00	0.	0.	0.	.00
14	816.0	200.0	25.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	288.67	624.5	343.2	.0	148.2
2	284.91	1308.4	697.1	.0	333.0
3	284.73	1854.1	725.1	.0	331.4
4	277.32	1165.2	1077.5	.0	220.0
5	260.00	2018.6	1875.0	.0	358.0
6	240.00	3001.7	2793.5	.0	517.9
7	227.40	3620.3	3369.8	.0	622.6
8	217.40	4120.6	3833.3	.0	707.4
9	200.00	4987.5	4640.5	.0	854.2
10	180.00	5977.3	5562.1	.0	1021.9
11	169.73	6482.4	6032.6	.0	1107.0
12	169.33	4083.4	6035.3	.0	701.1
13	159.61	2515.0	4560.5	.0	564.3
14	140.36	816.0	1547.8	.0	238.6

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	285.00	18.92	4238.	3.60	5.49	.655
2	284.83	18.92	4452.	3.59	5.66	.634
3	284.63	18.92	4925.	3.51	5.94	.590
4	270.00	18.92	8686.	6.15	11.30	.544
5	250.00	18.92	17103.	8.59	18.70	.459
6	230.00	18.92	29314.	10.75	26.00	.414
7	224.80	18.92	33133.	11.29	27.92	.404
8	210.00	18.92	45563.	12.86	33.41	.385
9	190.00	18.92	65852.	15.06	40.84	.369
10	170.00	18.92	90128.	17.30	48.16	.359
11	169.45	18.92	90851.	17.36	48.36	.359
12	169.22	18.92	89986.	17.37	48.20	.360
13	150.00	18.92	21250.	11.83	24.76	.478

31/45

14	130.71	.00	0.	11.57	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 2785.38 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 524.57 (psf)

Total Length of failure surface = 196.41 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.433

Total shear strength available along specified failure surface = 250.62E+03 lb

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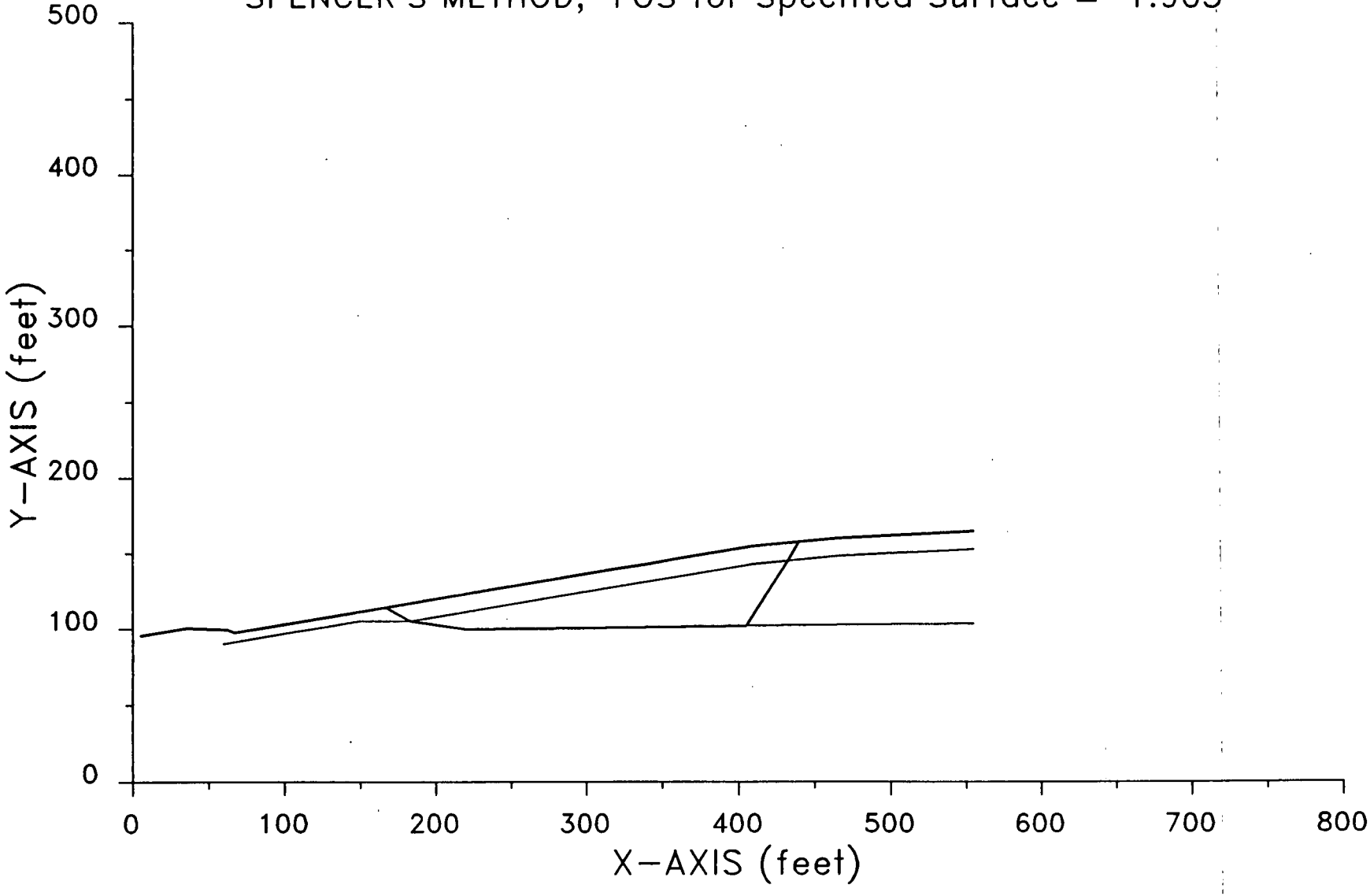
OSDF Final Long Term – Large Displ.

SPENCER'S METHOD, FOS for Specified Surface = 1.905



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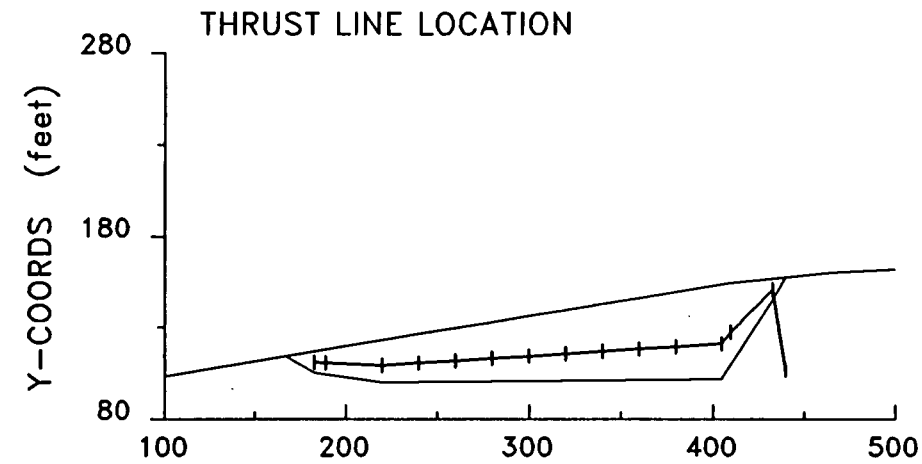

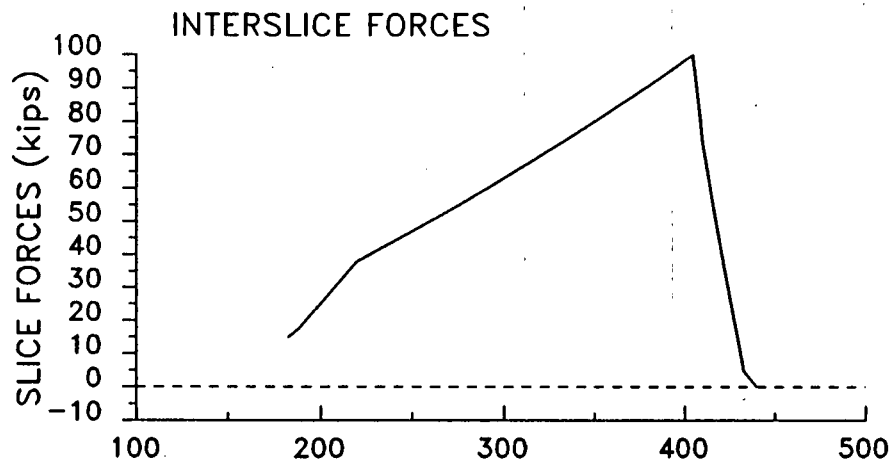

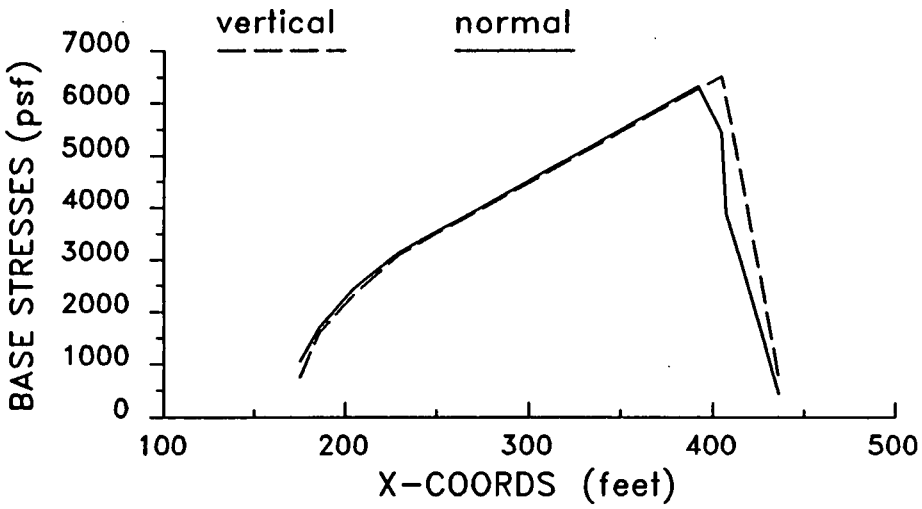

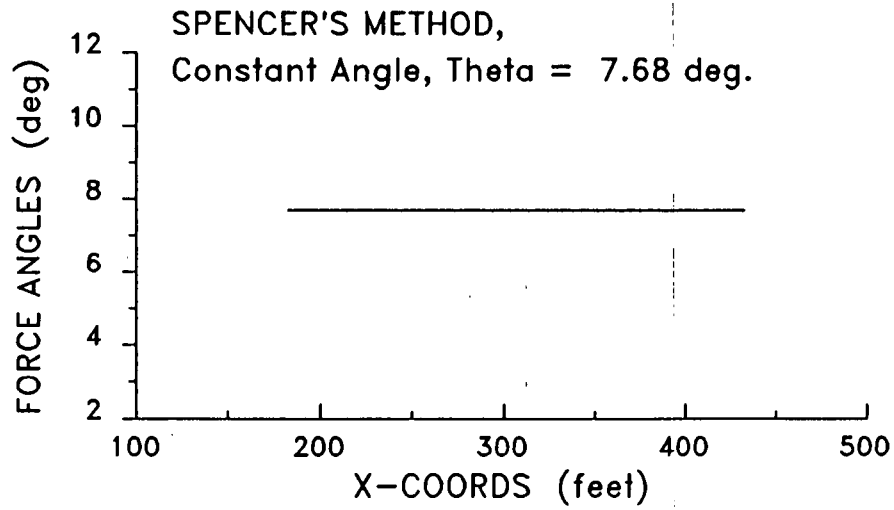

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 1.905 ✓

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

35/45

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	397.4
4	2880.0	612.0
5	6480.0	834.5
6	10080.0	834.5

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	404.92	101.70
6	405.17	101.95
7	432.64	145.06
8	439.93	157.69

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.70	37.35	20.00	.60	9.37	93363.
9	330.00	100.91	40.44	20.00	.60	9.37	101089.
10	350.00	101.12	43.58	20.00	.60	9.65	108939.
11	370.00	101.33	46.72	20.00	.60	9.37	116790.
12	392.46	101.57	50.21	24.92	.60	9.46	156396.
13	405.05	101.82	52.05	.25	45.00	9.46	1627.
14	407.59	105.74	48.56	4.83	57.49	9.46	29317.
15	421.32	127.30	28.54	22.64	57.49	5.71	80764.
16	436.29	151.38	5.95	7.29	60.01	5.71	5420.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.6488	1.9041	1.9439
3	7.6785	1.9050	1.9041

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.6785	1.9050	1.9041

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1047.2	.0	30.00	0.	0.	0.	.00
2	1698.0	325.9	5.67	0.	0.	0.	.00

3	2432.9	325.9	5.67	0.	0.	0.	.00
4	3136.9	434.0	3.54	0.	0.	0.	.00
5	3531.7	434.0	3.54	0.	0.	0.	.00
6	3920.3	434.0	3.54	0.	0.	0.	.00
7	4315.1	434.0	3.54	0.	0.	0.	.00
8	4708.8	434.0	3.54	0.	0.	0.	.00
9	5096.1	434.0	3.54	0.	0.	0.	.00
10	5489.7	434.0	3.54	0.	0.	0.	.00
11	5883.3	434.0	3.54	0.	0.	0.	.00
12	6320.8	434.0	3.54	0.	0.	0.	.00
13	5425.3	434.0	3.54	0.	0.	0.	.00
14	3884.0	.0	25.00	0.	0.	0.	.00
15	2282.5	.0	25.00	0.	0.	0.	.00
16	432.9	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1047.2	739.6	.0	317.4
2	186.00	1698.0	1594.4	.0	259.6
3	204.50	2432.9	2304.8	.0	297.9
4	230.00	3136.9	3100.0	.0	329.6
5	250.00	3531.7	3493.8	.0	342.4
6	270.00	3920.3	3881.3	.0	355.0
7	290.00	4315.1	4275.0	.0	367.8
8	310.00	4708.8	4668.1	.0	380.6
9	330.00	5096.1	5054.4	.0	393.2
10	350.00	5489.7	5447.0	.0	405.9
11	370.00	5883.3	5839.5	.0	418.7
12	392.46	6320.8	6275.9	.0	432.9
13	405.05	5425.3	6506.1	.0	403.8
14	407.59	3884.0	6069.7	.0	950.7
15	421.32	2282.5	3566.9	.0	558.7
16	436.29	432.9	743.7	.0	131.2

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.68	14796.	5.67	11.83	.479
2	189.00	7.68	17813.	6.22	13.68	.455
3	220.00	7.68	37828.	9.22	23.20	.397
4	240.00	7.68	43847.	10.29	26.40	.390
5	260.00	7.68	50044.	11.36	29.50	.385
6	280.00	7.68	56417.	12.45	32.60	.382
7	300.00	7.68	62969.	13.53	35.80	.378
8	320.00	7.68	69654.	14.61	38.89	.376
9	340.00	7.68	76510.	15.68	41.98	.374
10	360.00	7.68	83540.	16.75	45.17	.371

11	380.00	7.68	90745.	17.82	48.26	.369
12	404.92	7.68	99964.	19.15	52.15	.367
13	405.17	7.68	98697.	19.17	51.94	.369
14	410.00	7.68	73624.	17.60	45.17	.390
15	432.64	7.68	4549.	5.82	11.90	.489
16	439.93	.00	-3.	-51.16	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3665.30 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 396.22 (psf)

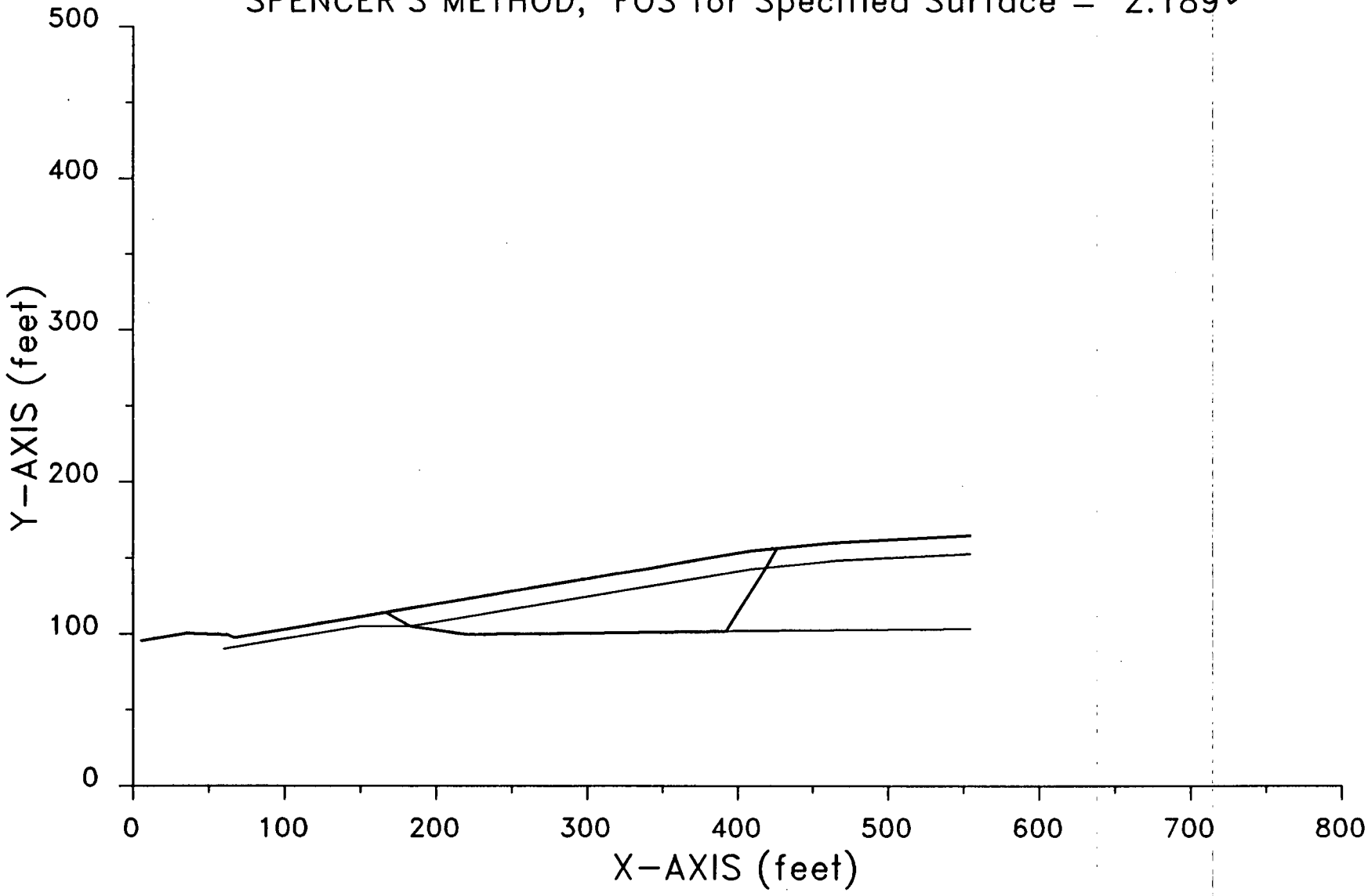
Total Length of failure surface = 306.71 feet

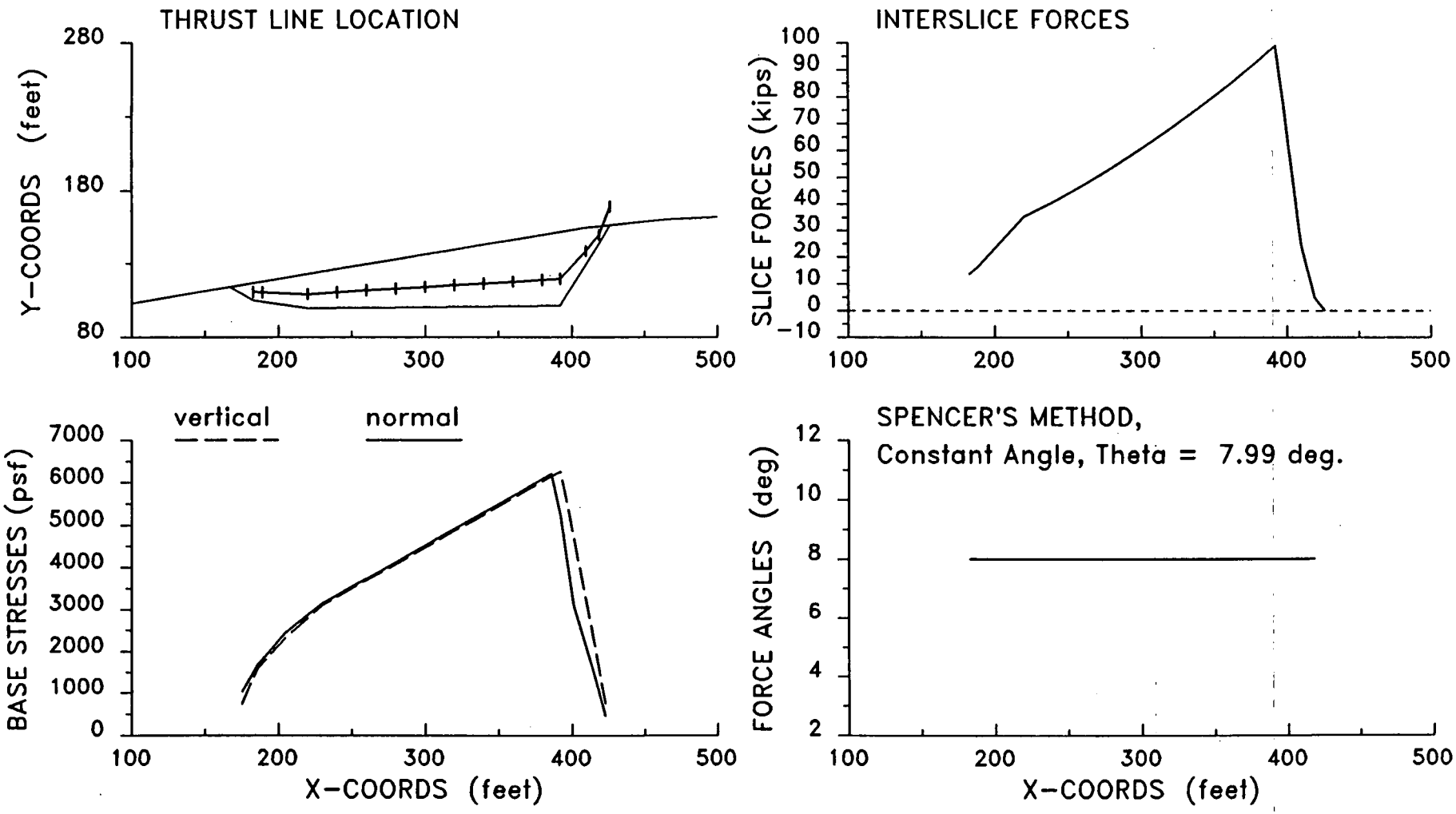
For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.905 ✓

Total shear strength available along specified failure surface = 231.51E+03 lb

OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.189





OSDF Final Long Term – Large Displ.
SPENCER'S METHOD, FOS for Specified Surface = 2.189

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 - 96       *
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Problem Description : OSDF Final Long Term - Large Displ.

SEGMENT BOUNDARY COORDINATES
---

15 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.5	95.6	35.5	100.6	2
2	35.5	100.6	62.5	99.4	2
3	62.5	99.4	67.0	97.5	2
4	67.0	97.5	220.0	123.0	2
5	220.0	123.0	240.0	126.4	2
6	240.0	126.4	260.0	129.7	2
7	260.0	129.7	280.0	133.0	2
8	280.0	133.0	300.0	136.4	2
9	300.0	136.4	320.0	139.7	2
10	320.0	139.7	340.0	143.0	2
11	340.0	143.0	360.0	146.4	2
12	360.0	146.4	380.0	149.7	2
13	380.0	149.7	410.0	154.7	2
14	410.0	154.7	465.0	160.2	2
15	465.0	160.2	555.0	164.7	2

11 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	60.0	90.0	120.0	100.0	2
2	120.0	100.0	150.0	105.0	2
3	150.0	105.0	183.0	105.0	2
4	183.0	105.0	189.0	106.0	1

5	189.0	106.0	410.0	142.8	1
6	410.0	142.8	467.0	148.5	1
7	467.0	148.5	555.0	152.9	1
8	183.0	105.0	220.0	100.0	3
9	220.0	100.0	300.0	100.8	3
10	300.0	100.8	410.0	102.0	3
11	410.0	102.0	555.0	103.5	3

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	125.0	125.0	.0	25.00	.000	.0	0
2	125.0	125.0	.0	30.00	.000	.0	0
3	125.0	125.0	.0	.00	.000	.0	0

NON-LINEAR MOHR-COULOMB envelope has been specified for 1 soil(s)

Soil Unit # 3

Point No.	Normal Stress (psf)	Shear Stress (psf)
1	-1000.0	.0
2	.0	.0
3	720.0	244.8
4	2880.0	648.0
5	6480.0	1195.2
6	10080.0	1195.2

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 8 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	167.10	114.18
2	183.00	105.00
3	220.00	99.80
4	300.00	100.60
5	392.34	101.66
6	392.50	101.81
7	419.20	143.72
8	426.49	156.35

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	175.05	109.59	5.92	15.90	-30.01	9.46	11759.
2	186.00	104.58	12.75	6.00	-8.00	9.46	9566.
3	204.50	101.98	18.44	31.00	-8.00	9.46	71448.
4	230.00	99.90	24.80	20.00	.57	9.65	62000.
5	250.00	100.10	27.95	20.00	.57	9.37	69875.
6	270.00	100.30	31.05	20.00	.57	9.37	77625.
7	290.00	100.50	34.20	20.00	.57	9.65	85500.
8	310.00	100.71	37.34	20.00	.66	9.37	93338.
9	330.00	100.94	40.41	20.00	.66	9.37	101014.
10	350.00	101.17	43.53	20.00	.66	9.65	108815.
11	370.00	101.40	46.65	20.00	.66	9.37	116616.
12	386.17	101.59	49.14	12.34	.66	9.46	75797.
13	392.42	101.73	50.04	.16	43.15	9.46	1001.
14	401.25	115.54	37.70	17.50	57.50	9.46	82462.
15	414.60	136.50	18.66	9.20	57.50	5.71	21460.
16	422.85	150.03	5.95	7.29	60.00	5.71	5422.

Nonlinear M-C Iteration Number - 1

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	7.9348	2.1872	2.2329
3	7.9950	2.1893	2.1872
4	7.9936	2.1893	2.1893

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
1	7.9936	2.1893	2.1893

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1013.8	.0	30.00	0.	0.	0.	.00

2	1682.0	110.4	10.57	0.	0.	0.	.00
3	2424.9	110.4	10.57	0.	0.	0.	.00
4	3136.5	210.2	8.64	0.	0.	0.	.00
5	3533.3	210.2	8.64	0.	0.	0.	.00
6	3923.8	210.2	8.64	0.	0.	0.	.00
7	4320.6	210.2	8.64	0.	0.	0.	.00
8	4713.9	210.2	8.64	0.	0.	0.	.00
9	5100.5	210.2	8.64	0.	0.	0.	.00
10	5493.5	210.2	8.64	0.	0.	0.	.00
11	5886.4	210.2	8.64	0.	0.	0.	.00
12	6200.3	210.2	8.64	0.	0.	0.	.00
13	5204.7	210.2	8.64	0.	0.	0.	.00
14	3090.2	.0	25.00	0.	0.	0.	.00
15	1529.7	.0	25.00	0.	0.	0.	.00
16	447.2	.0	30.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	175.05	1013.8	739.6	.0	267.3
2	186.00	1682.0	1594.4	.0	193.8
3	204.50	2424.9	2304.8	.0	257.2
4	230.00	3136.5	3100.0	.0	313.8
5	250.00	3533.3	3493.8	.0	341.4
6	270.00	3923.8	3881.3	.0	368.5
7	290.00	4320.6	4275.0	.0	396.0
8	310.00	4713.9	4666.9	.0	423.3
9	330.00	5100.5	5050.7	.0	450.2
10	350.00	5493.5	5440.8	.0	477.4
11	370.00	5886.4	5830.8	.0	504.7
12	386.17	6200.3	6142.4	.0	526.5
13	392.42	5204.7	6254.4	.0	457.4
14	401.25	3090.2	4712.1	.0	658.2
15	414.60	1529.7	2332.6	.0	325.8
16	422.85	447.2	743.7	.0	117.9

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	183.00	7.99	13694.	5.71	11.83	.482
2	189.00	7.99	16300.	6.35	13.68	.464
3	220.00	7.99	35020.	9.34	23.20	.402
4	240.00	7.99	40724.	10.45	26.40	.396
5	260.00	7.99	46904.	11.51	29.50	.390
6	280.00	7.99	53553.	12.53	32.60	.384
7	300.00	7.99	60679.	13.51	35.80	.377
8	320.00	7.99	68135.	14.47	38.87	.372
9	340.00	7.99	76044.	15.41	41.94	.367

10	360.00	7.99	84413.	16.33	45.11	.362
11	380.00	7.99	93242.	17.24	48.18	.358
12	392.34	7.99	98916.	17.80	50.10	.355
13	392.50	7.99	98202.	17.80	49.97	.356
14	410.00	7.99	24115.	9.06	25.42	.356
15	419.20	7.99	4835.	5.80	11.90	.488
16	426.49	.00	0.	12.37	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 3547.71 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 393.00 (psf)

Total Length of failure surface = 292.57 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.189

Total shear strength available along specified failure surface = 251.72E+03 lb

GCL 24

COMPUTATION COVER SHEET

1269

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 24 - Compliance Package

Computations By:
(Cognizant Engineer)

Signature [signature] Date Nov 21 1997

Printed Name and Title M. CATALINA CROZCO
STAFF ENGINEER

Assumptions and Procedures Checked By:
(Checker)

Signature [signature] Date 19 Dec 97

Printed Name and Title Gary R. Schmertmann
Senior Proj. Engineer

Computations Checked by:

Signature NO COMPUTATIONS Date

Printed Name and Title

Computations Backchecked by:
(Cognizant Engineer)

Signature NO COMPUTATIONS Date

Printed Name and Title

Approved by:
(PDP)

Signature [signature] Date 19 Dec 97

Printed Name and Title Gary R. Schmertmann
Sr. Project Engineer

Approved by:
(DTL and TETL)

Signature [signature] Date 20 Dec 97

Printed Name and Title Kenneth W. Cargill
Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

Written By: MCO Date: 11/21/97 Reviewed by: GES Date: 12/19/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 24 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

Note: Whenever the shear test results for the GCL sample are higher than the shear strengths defined to obtain the baseline factor of safety, the slope stability analysis is not performed since it would necessarily result in a factor of safety higher than the baseline factor of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 24 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample	Case	Test Type	Measured Shear Strengths			Comply? (see note above)
			5 psi	20 psi	45 psi	
Baseline	Peak		1.5	6.1	13.8	NA
24		GCL Internal	5.3psi	8.0psi	17.2psi	YES
		GCL/GMB Interface	2.5	8.4	16.8	YES
Baseline	Large-displacement		1.1	2.5	5.1	NA
24		GCL Internal	5.3	3.5	6.1	YES
		GCL/GMB Interface	2.0	6.2	6.3	YES

YMCO Nov 21 1997
GRS 19 Dec 97

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 24I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-24). GCL's initial moisture content was 8.3%. GCL's final moisture content ranged from 56% to 90% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 24G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

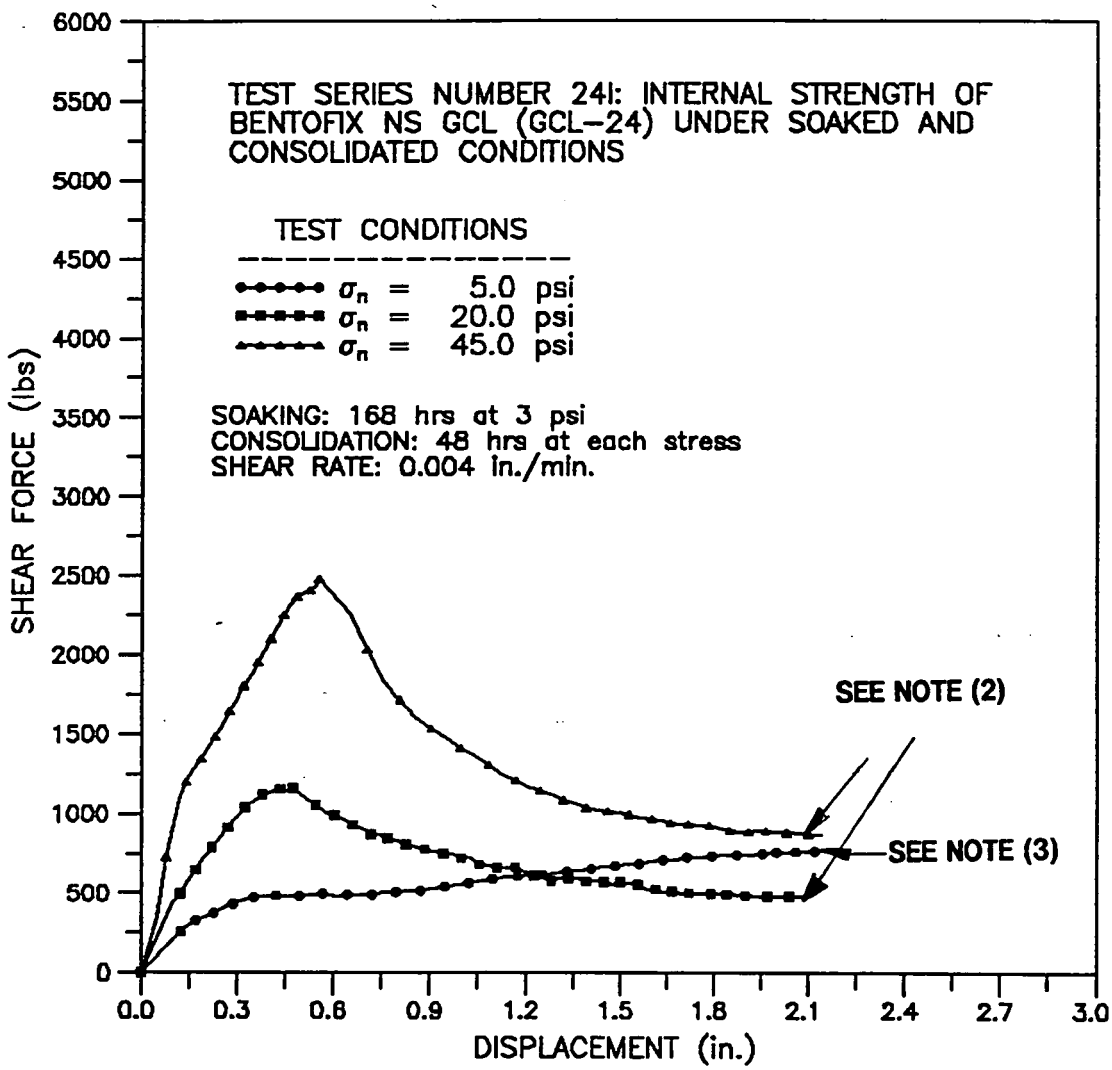
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-24) with woven geotextile against geomembrane. GCL's initial moisture content was 8.4%. GCL's final moisture content ranged from 61 to 100% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-16); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



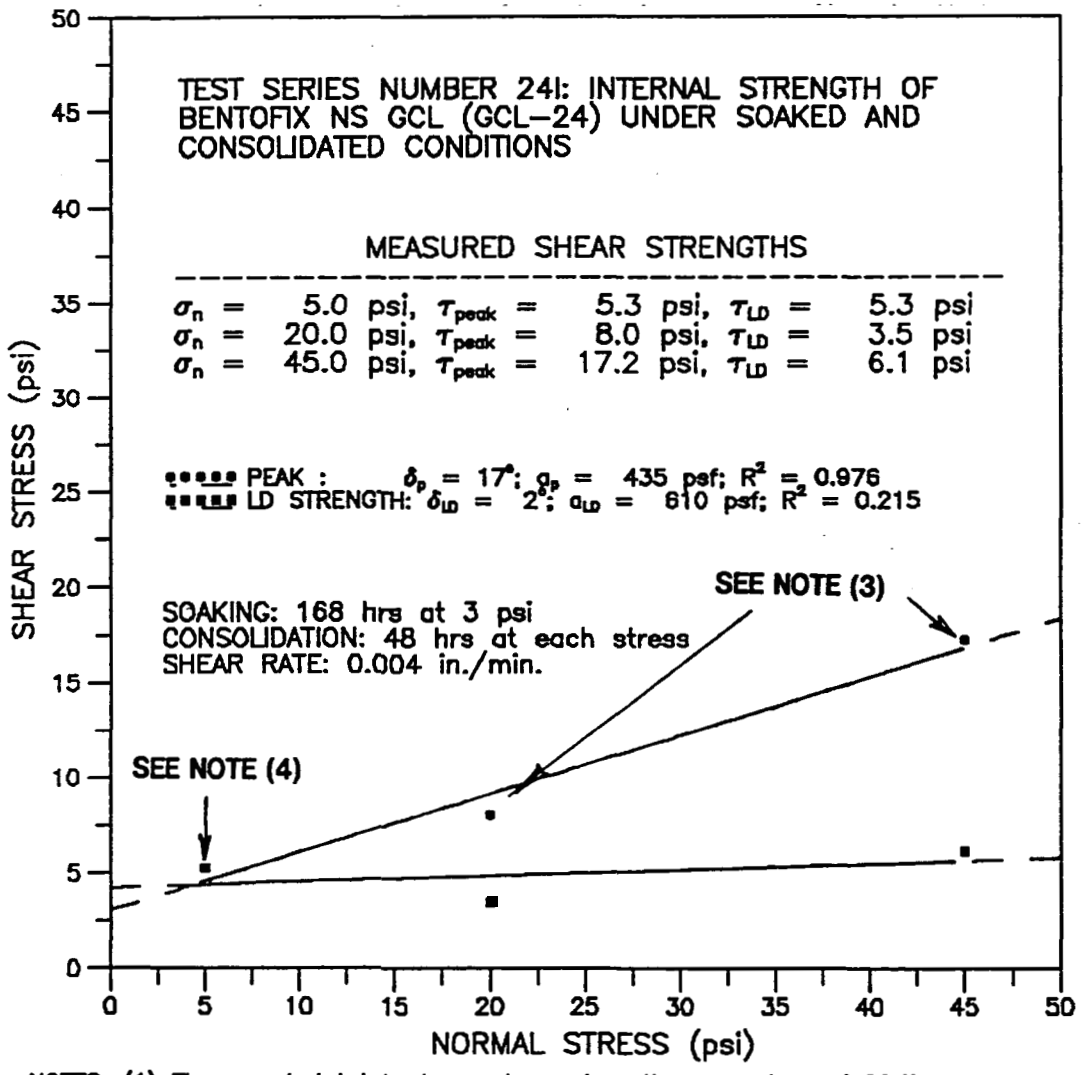
NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.
(2) Internal shear failure within GCL was observed.
(3) No internal shear failure within GCL was observed.

DATE TESTED: 25 OCTOBER TO 3 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730124
FILE NO.	000642

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



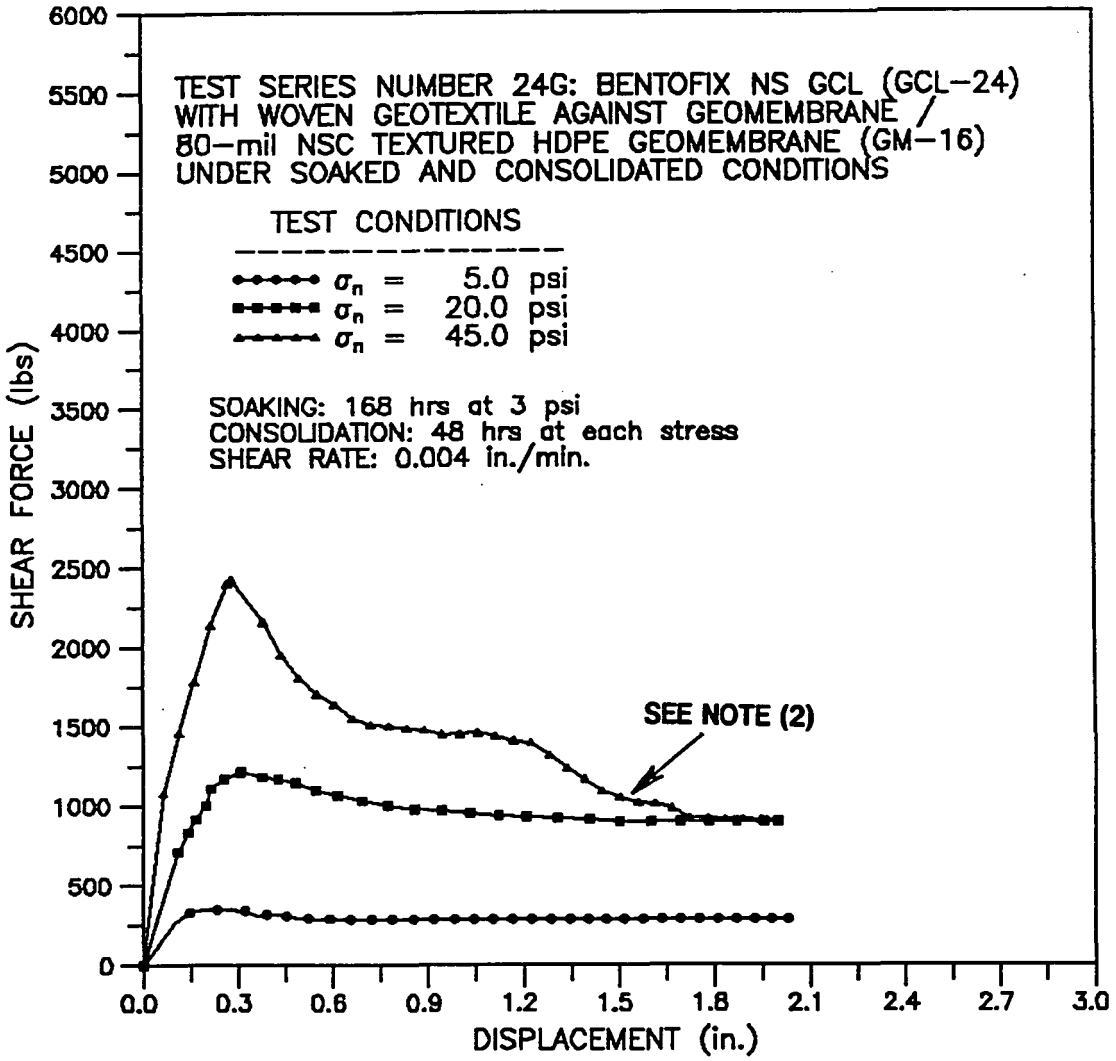
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Internal shear failure within GCL was observed.
(4) No internal failure within GCL was observed.

DATE TESTED: 25 OCTOBER TO 3 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730124
FILE NO.	000643

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

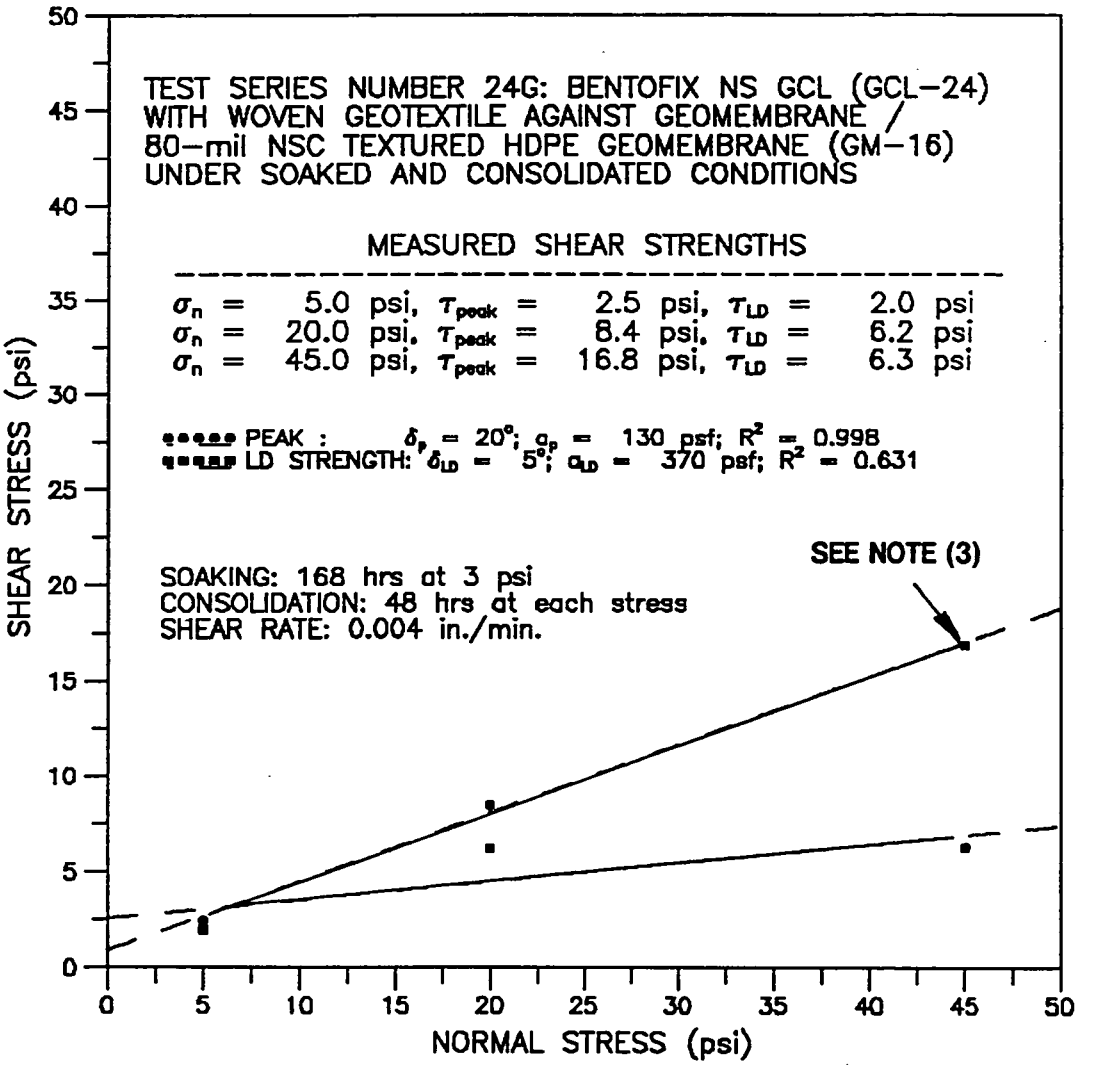
DATE TESTED: 25 OCTOBER TO 3 NOVEMBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730124
FILE NO.	000644

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 25 OCTOBER TO 3 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730124
FILE NO.	000645

GCL 25

COMPUTATION COVER SHEET

1269

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 25 - Compliance Package

Computations By: (Cognizant Engineer)
Signature [signature] Date NOV 21 1997
Printed Name and Title M. CATALINA OROZCO STAFF ENGINEER

Assumptions and Procedures Checked By: (Checker)
Signature [signature] Date 19 Dec 97
Printed Name and Title Gary R. Schmertmann Sr. Project Engr.

Computations Checked by:
Signature NO COMPUTATIONS Date
Printed Name and Title

Computations Backchecked by: (Cognizant Engineer)
Signature NO COMPUTATIONS Date
Printed Name and Title

Approved by: (PDP)
Signature [signature] Date 19 Dec 97
Printed Name and Title Gary R. Schmertmann Sr. Project Engr.

Approved by: (DTL and TETL)
Signature [signature] Date 20 Dec 97
Printed Name and Title Kenneth W Cargill Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

GEOSYNTEC CONSULTANTS

Written By : MCD Date: 11/21/97 Reviewed by: GRS Date: 12/19/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 25 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

Note: Whenever the shear test results for the GCL sample are higher than the shear strengths defined to obtain the baseline factor of safety, the slope stability analysis is not performed since it would necessarily result in a factor of safety higher than the baseline factor of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 25 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample	Case	Test Type	Measured Shear Strengths			Comply? (see note above)
			5 psi	20 psi	45 psi	
Baseline	Peak		1.5	6.1	13.8	NA
25		GCL Internal	4.2psi	9.1psi	17.6psi	YES
		GCL/GMB Interface	2.6	8.7	16.0	YES
Baseline	Large-displacement		1.1	2.5	5.1	NA
25		GCL Internal	3.9	5.6	7.4	YES
		GCL/GMB Interface	1.8	5.6	6.0	YES

2/8

YCO Nov 21 1997
GRS 19 Dec 97

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 25I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-25). GCL's initial moisture content was 9.0%. GCL's final moisture content ranged from 62% to 76% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 25G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

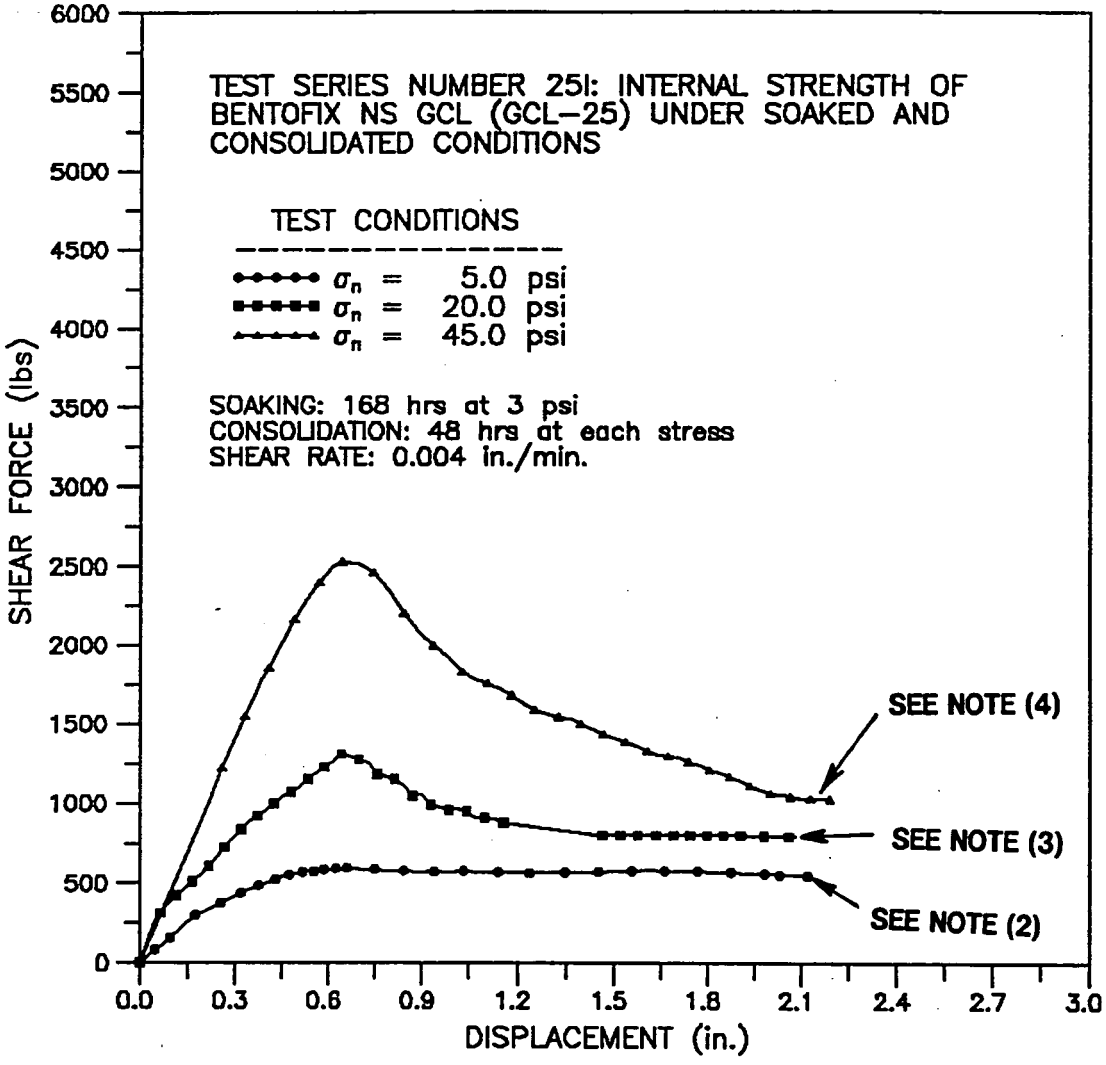
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-25) with woven geotextile against geomembrane. GCL's initial moisture content was 9.4%. GCL's final moisture content ranged from 55 to 84% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-11); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



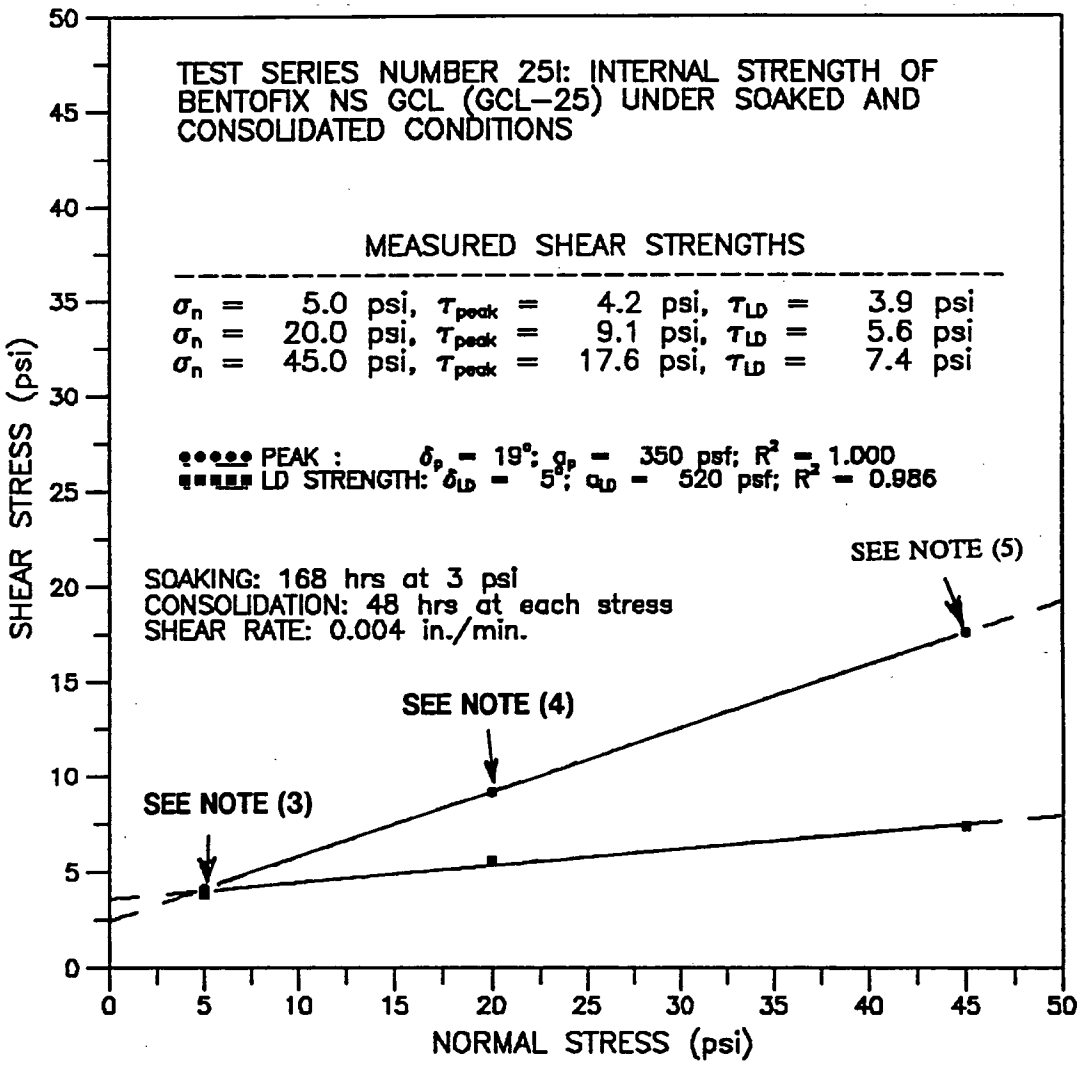
NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.
(2) No internal shear failure within GCL was observed.
(3) Partial internal shear failure within GCL was observed.
(4) Internal shear failure within GCL was observed.

DATE TESTED: 27 OCTOBER TO 5 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730125
FILE NO.	000632

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



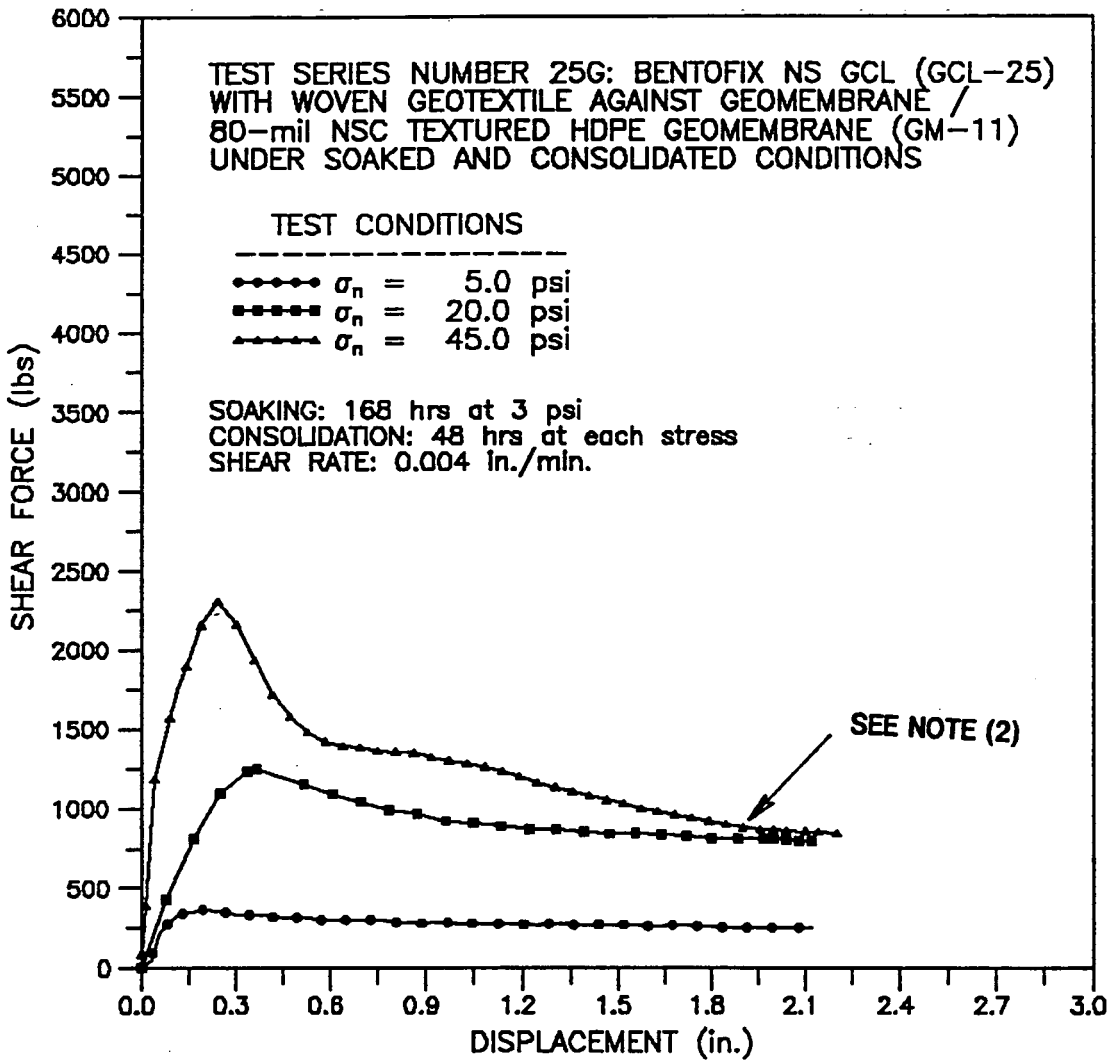
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) No internal shear failure within GCL was observed.
(4) Partial internal failure within GCL was observed.
(5) Internal shear failure within GCL was observed.

DATE TESTED: 27 OCTOBER TO 5 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730125
FILE NO.	000653

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

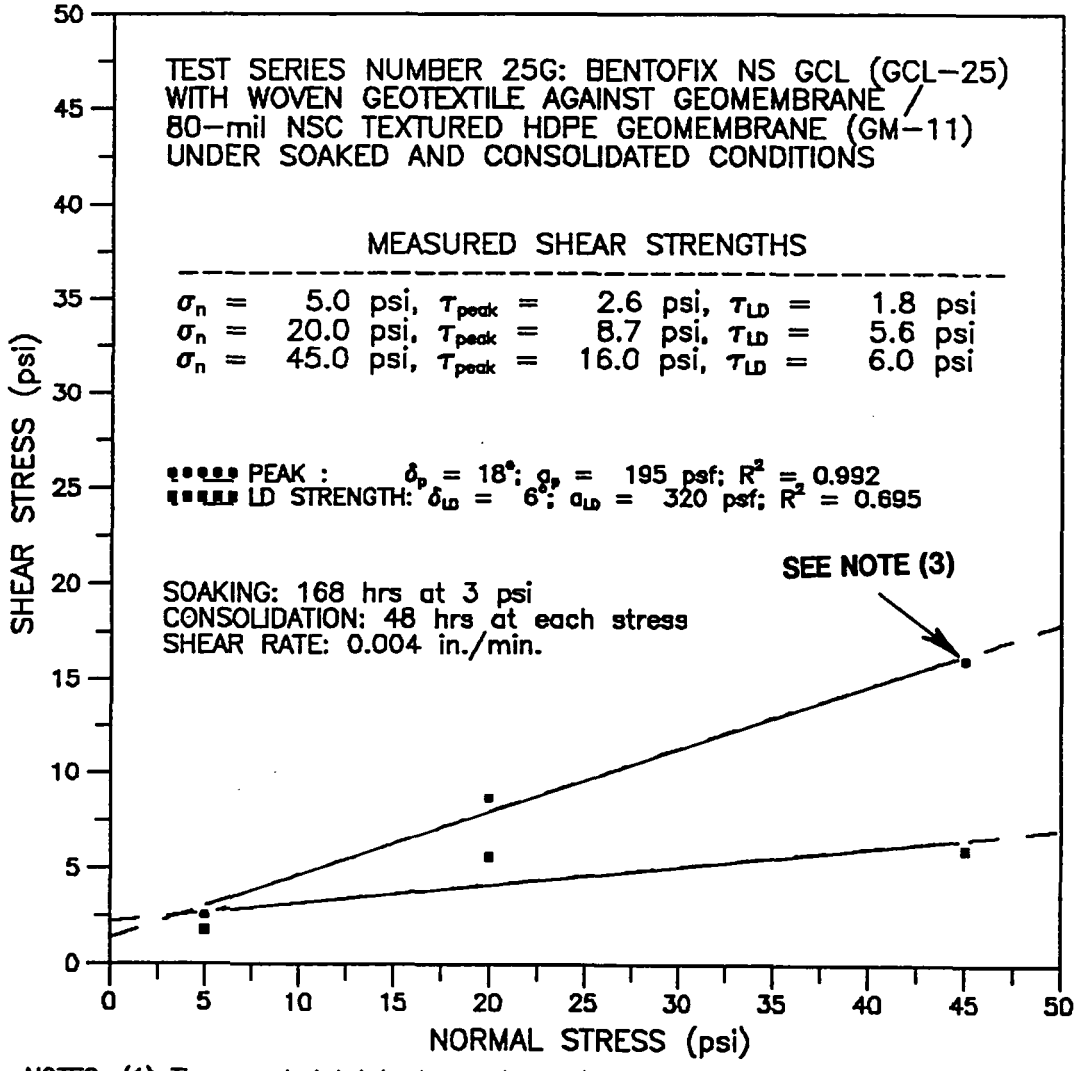
DATE TESTED: 27 OCTOBER TO 5 NOVEMBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730125
FILE NO.	000654

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 27 OCTOBER TO 5 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730125
FILE NO.	000655

GCL 26

COMPUTATION COVER SHEET

1269

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 26 - Compliance Package

Computations By: (Cognizant Engineer)
Signature [signature] Date Nov 21 1997
Printed Name and Title M. CATALINA OROZCO STAFF ENGINEER

Assumptions and Procedures Checked By: (Checker)
Signature [signature] Date 19 Dec 97
Printed Name and Title Gary R. Schmertmann Sr. Project Engr.

Computations Checked by:
Signature NO COMPUTATION Date
Printed Name and Title

Computations Backchecked by: (Cognizant Engineer)
Signature NO COMPUTATIONS Date
Printed Name and Title

Approved by: (PDP)
Signature [signature] Date 19 Dec 97
Printed Name and Title Gary R. Schmertmann Sr. Project Engr.

Approved by: (DTL and TETL)
Signature [signature] Date 20 Dec 97
Printed Name and Title Kenneth W. Cargill

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

000657

Written By : MCO Date: 11/21/97 Reviewed by: GRS Date: 12/19/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 26 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

Note: Whenever the shear test results for the GCL sample are higher than the shear strengths defined to obtain the baseline factor of safety, the slope stability analysis is not performed since it would necessarily result in a factor of safety higher than the baseline factor of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 26 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample	Case	Test Type	Measured Shear Strengths			Comply? (see note above)
			5 psi	20 psi	45 psi	
Baseline	Peak		1.5	6.1	13.8	NA
26		GCL Internal	4.7psi	9.5psi	17.9psi	YES
		GCL/GMB Interface	2.5	8.6	17.7	YES
Baseline	Large-displacement		1.1	2.5	5.1	NA
26		GCL Internal	4.3	4.0	5.6	YES
		GCL/GMB Interface	2.0	5.5	6.2	YES

MCO NOV 21 1997
GRJ 18 Dec 97

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 26I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-26). GCL's initial moisture content was 10.0%. GCL's final moisture content ranged from 49% to 70% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 26G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

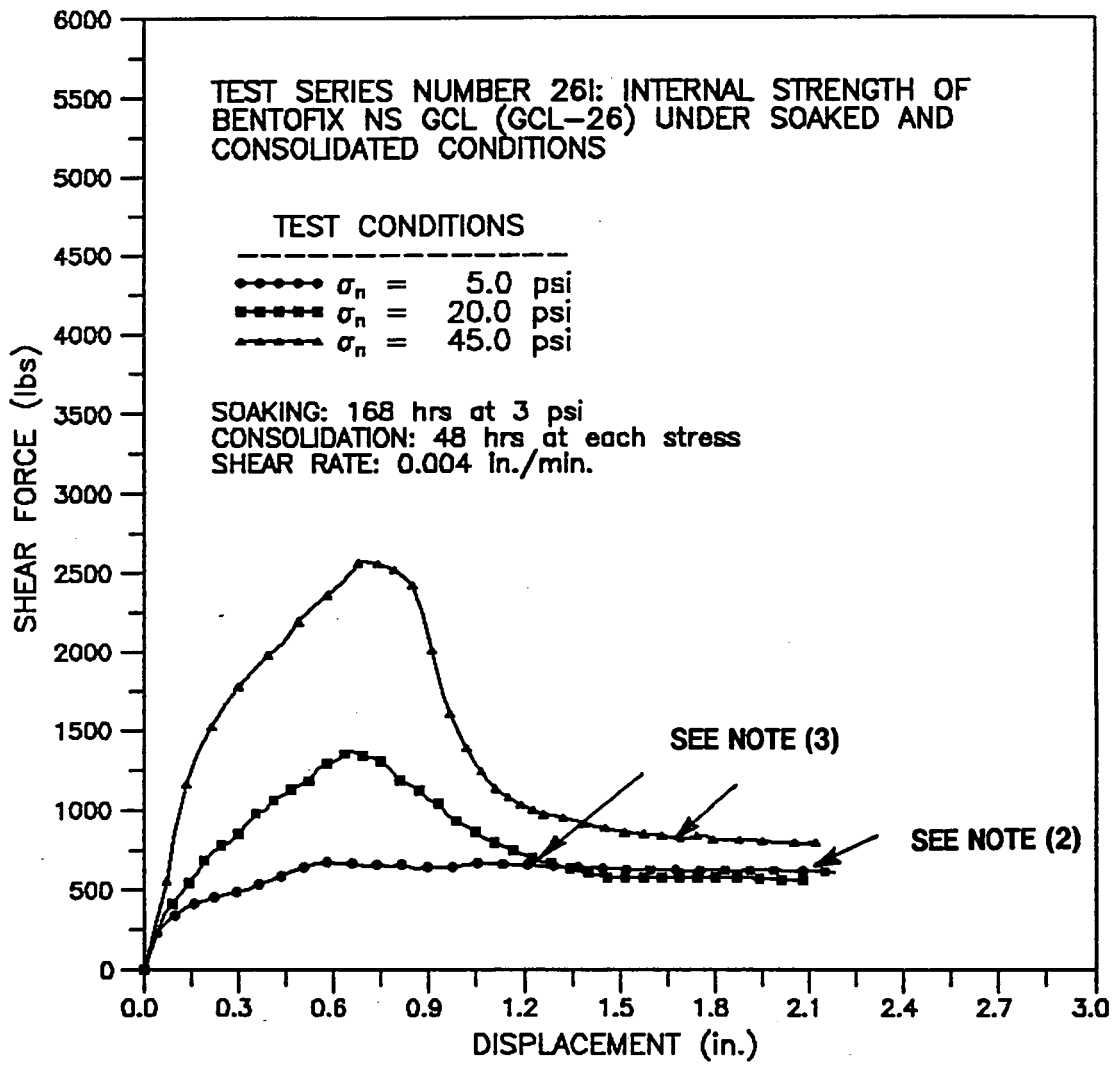
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-26) with woven geotextile against geomembrane. GCL's initial moisture content was 9.1%. GCL's final moisture content ranged from 49 to 91% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-11); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



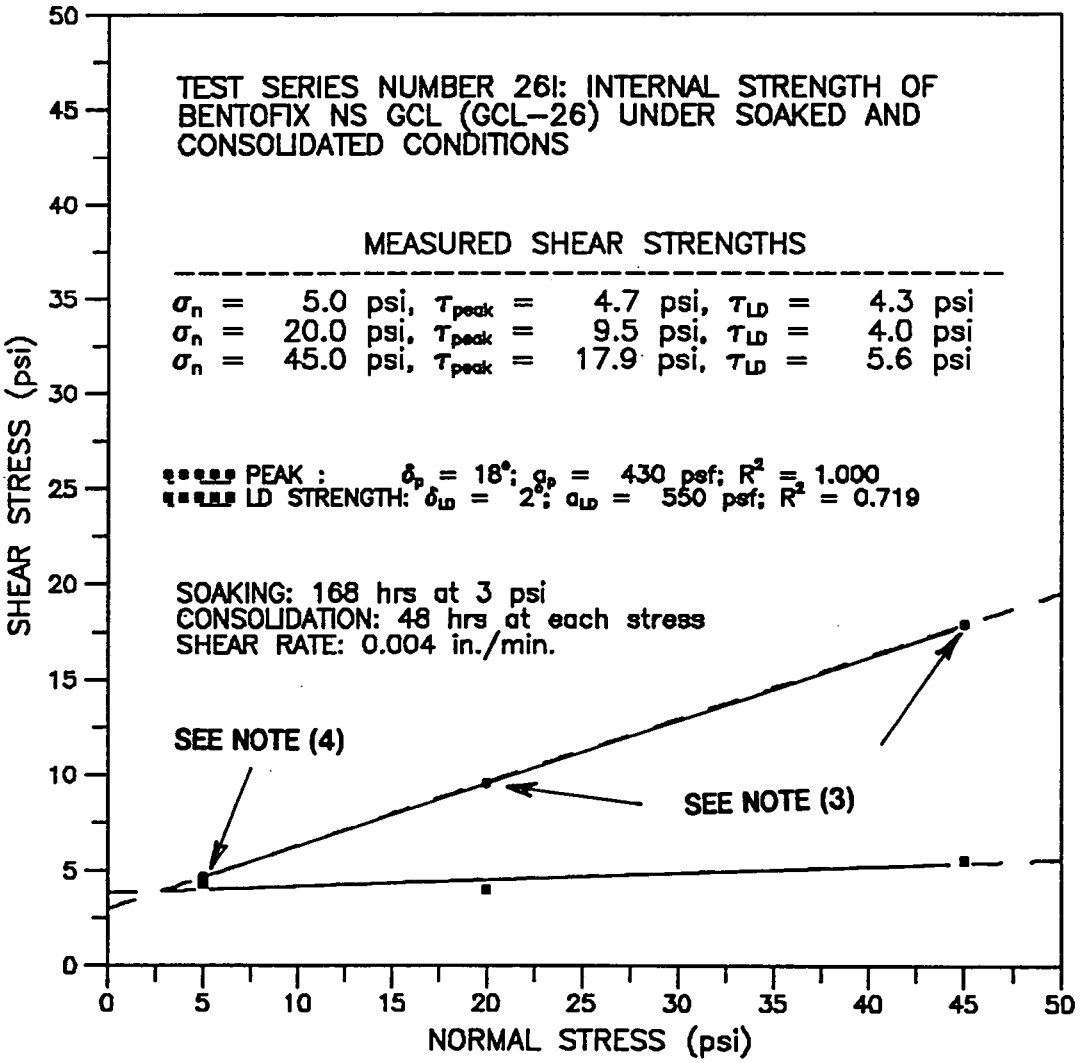
NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.
(2) No internal shear failure within GCL was observed.
(3) Internal shear failure within GCL was observed.

DATE TESTED: 29 OCTOBER TO 7 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730128
FILE NO.	

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



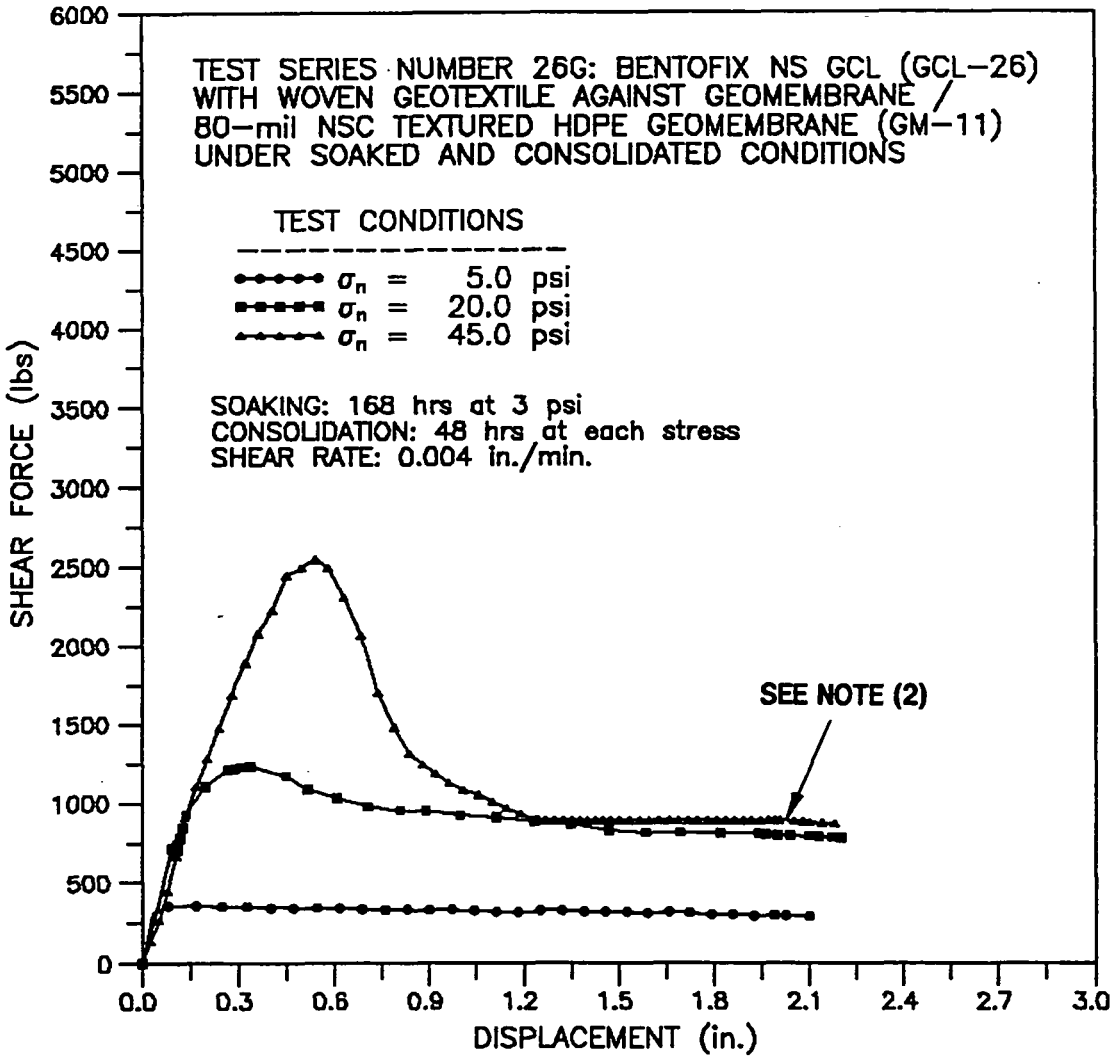
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Internal shear failure within GCL was observed.
(4) No internal failure within GCL was observed.

DATE TESTED: 29 OCTOBER TO 7 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730128
FILE NO.	000663

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

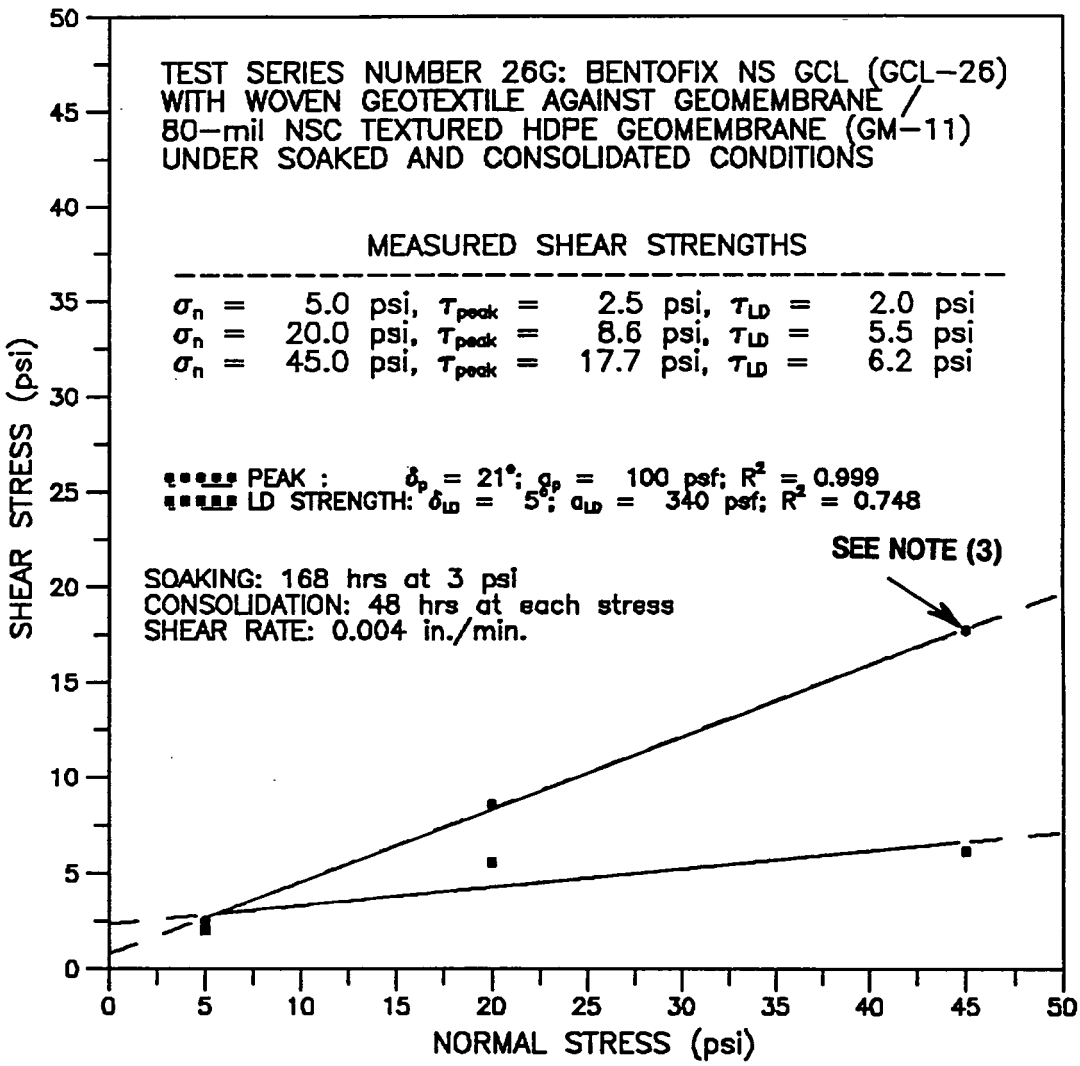
DATE TESTED: 29 OCTOBER TO 7 NOVEMBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730128
FILE NO.	000664

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 29 OCTOBER TO 7 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730128
FILE NO.	000665

GCL 27

COMPUTATION COVER SHEET

SUBJECT OF COMPUTATIONS Geosynthetic Clay Liner (GCL) 27 - Compliance Package

Computations By: (Cognizant Engineer)
Signature: M. OROZCO — Date: NOV 21 1997
Printed Name and Title: M. CATALINA OROZCO, STAFF ENGINEER

Assumptions and Procedures Checked By: (Checker)
Signature: [signature] — Date: 19 Dec 97
Printed Name and Title: Gary R. Schmertmann, Sr. Project Engineer

Computations Checked by:
Signature: NO COMPUTATIONS — Date:
Printed Name and Title:

Computations Backchecked by: (Cognizant Engineer)
Signature: NO COMPUTATIONS — Date:
Printed Name and Title:

Approved by: (PDP)
Signature: [signature] — Date: 19 Dec 97
Printed Name and Title: Gary R. Schmertmann, Sr. Project Engineer

Approved by: (DTL and TETL)
Signature: [signature] — Date: 20 Dec 97
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval

GEOSYNTEC CONSULTANTS

Written By: MCD Date: 11/21/97 Reviewed by: GES Date: 12/19/97

Client: FDF Project: OSDF Project/Proposal No.: GQ0166 Task No.: 04

PURPOSE

Evaluate whether GCL QA sample no. 27 complies with the shear strength requirements given in the GCL specification (Section 02772, Paragraph 2.01.E.3).

METHOD

The method for evaluating the GCL sample is outlined in RCI number 1702-006R. The method involves the following basic steps.

1. Use shear test results from the GCL sample to establish the envelopes of measured peak and large-displacement internal and interface shear strength.
2. Reanalyze two slope stability cases that were included in the OSDF design calculations using the measured peak and large-displacement strength envelopes established in Step 1. Obtain the slope stability factors of safety for the critical potential slip surface for each analysis case.
3. Compare the slope stability factors of safety computed in Step 2 to the baseline factors of safety.

Note: Whenever the shear test results for the GCL sample are higher than the shear strengths defined to obtain the baseline factor of safety, the slope stability analysis is not performed since it would necessarily result in a factor of safety higher than the baseline factor of safety.

SHEAR TEST RESULTS

The results of the GCL internal shear and GCL/geomembrane interface shear tests performed on QA sample no. 27 are shown in the following table. The laboratory test results are presented in Appendix A.

QA Sample	Case	Test Type	Measured Shear Strengths			Comply? (see note above)
			5 psi	20 psi	45 psi	
Baseline	Peak		1.5	6.1	13.8	NA
27		GCL Internal	4.8 psi	8.3 psi	17.4 psi	YES
		GCL/GMB Interface	2.7	8.4	17.4	YES
Baseline	Large-displacement		1.1	2.5	5.1	NA
27		GCL Internal	4.7	4.2	7.6	YES
		GCL/GMB Interface	1.6	5.0	6.1	YES

MCO NOV 21 1997
GRS 19 Dec 97

APPENDIX A

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 27I

Test Specimen Configuration (from top to bottom) and Placement Conditions:

- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-27). GCL's initial moisture content was 10.0%. GCL's final moisture content ranged from 55% to 71% for the test series; and
- lower shear box: rigid substrate with textured steel gripping surface.

Designated Shear Plane: Within GCL

Test Procedures for Each Normal Stress Condition:

- A fresh GCL specimen was trimmed from the bulk sample of the GCL and placed between two rigid wooden substrates with textured steel gripping surfaces. The ends of each geotextile were then sandwiched between a second rigid wooden substrate prior to testing. The entire test specimen was then placed in the shear box to provide confinement for the exposed bentonite component. The textured steel gripping surfaces were employed to minimize slippage between each geotextile component of the GCL and rigid wood substrate, therefore providing a relatively uniform transfer of shear load onto the GCL specimen.
- Soaking conditions: The GCL specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the GCL specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the Bentofix NS GCL sample.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

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TEST PROCEDURES AND CONDITIONS
TEST SERIES NUMBER: 27G

Test Specimen Configuration (from top to bottom) and Placement Conditions:

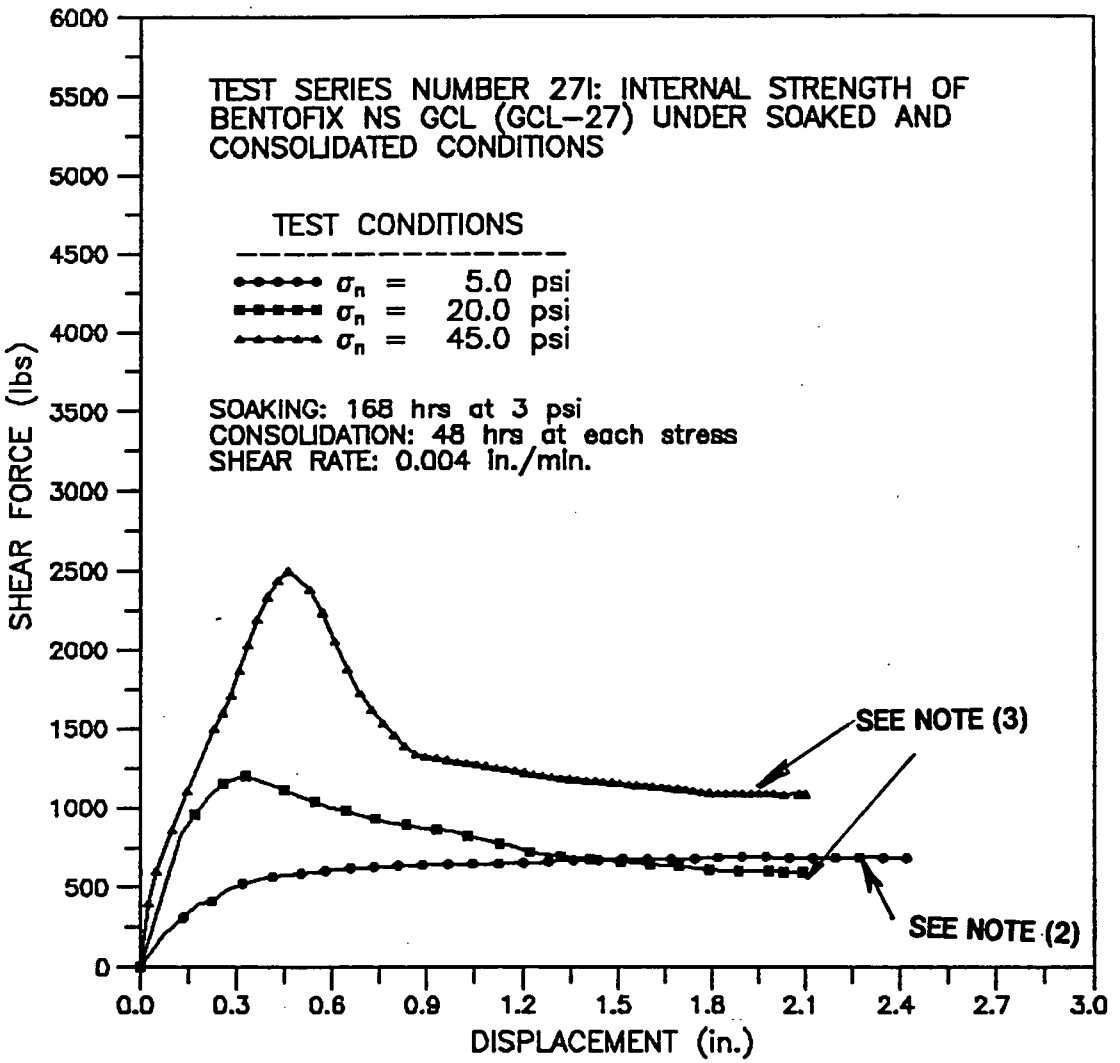
- upper shear box: rigid substrate with textured steel gripping surface;
- Bentofix NS GCL (GCL-27) with woven geotextile against geomembrane. GCL's initial moisture content was 8.1%. GCL's final moisture content ranged from 53 to 80% for the test series;
- 80-mil NSC textured HDPE geomembrane (GM-11); and
- lower shear box: bedding layer of compacted concrete sand.

Test Interface: GCL against geomembrane

Test Procedures for Each Normal Stress Condition:

- A fresh specimen of concrete sand was compacted into the lower shear box by hand tamping to a relatively dense state under dry conditions forming a 3 in. thick bedding layer.
- A fresh specimen of geomembrane was trimmed from the bulk sample and attached to the lower shear box with mechanical compression clamps.
- A fresh specimen of GCL was trimmed from the bulk sample and attached to the upper shear box with mechanical compression clamps. The GCL was oriented so that the woven geotextile component of the GCL was in contact with the geomembrane.
- A rigid substrate with a textured steel gripping surface was placed on top of the GCL. The textured steel gripping surface was used to minimize slippage between the upper geotextile component of the GCL and rigid wooden substrate, therefore providing a relatively uniform transfer of shear load onto the test interface.
- Soaking conditions: The entire test specimen was soaked in tap water for 168 hours under a normal stress of 3 psi.
- Consolidation conditions: After the 168 hour soaking period, the tap water was drained, and the entire test specimen was consolidated for 48 hours under each test normal stress.
- Test normal stresses: 5, 20, and 45 psi.
- Constant shear displacement rate: 0.004 in/min.
- The direction of shear for each interface direct shear test was in the direction of manufacture (machine direction) of the geosynthetic samples.
- Each test was sheared until a minimum total shear displacement of 2 in. was achieved.

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



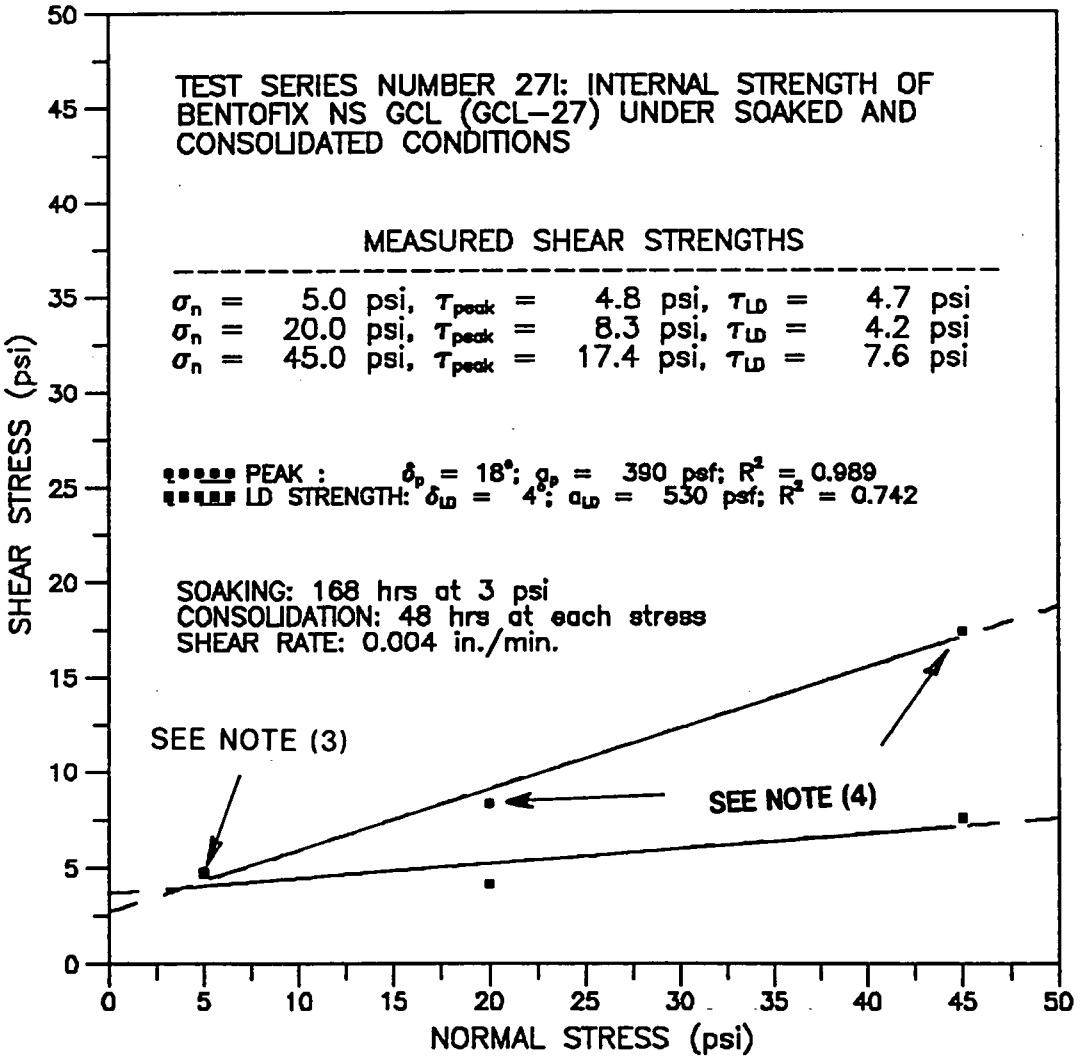
NOTES: (1) A constant area of 1 ft^2 was assumed when computing normal and shear stresses.
(2) No internal shear failure within GCL was observed.
(3) Internal shear failure within GCL was observed.

DATE TESTED: 1 TO 10 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-1
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730130
FILE NO.	000672

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



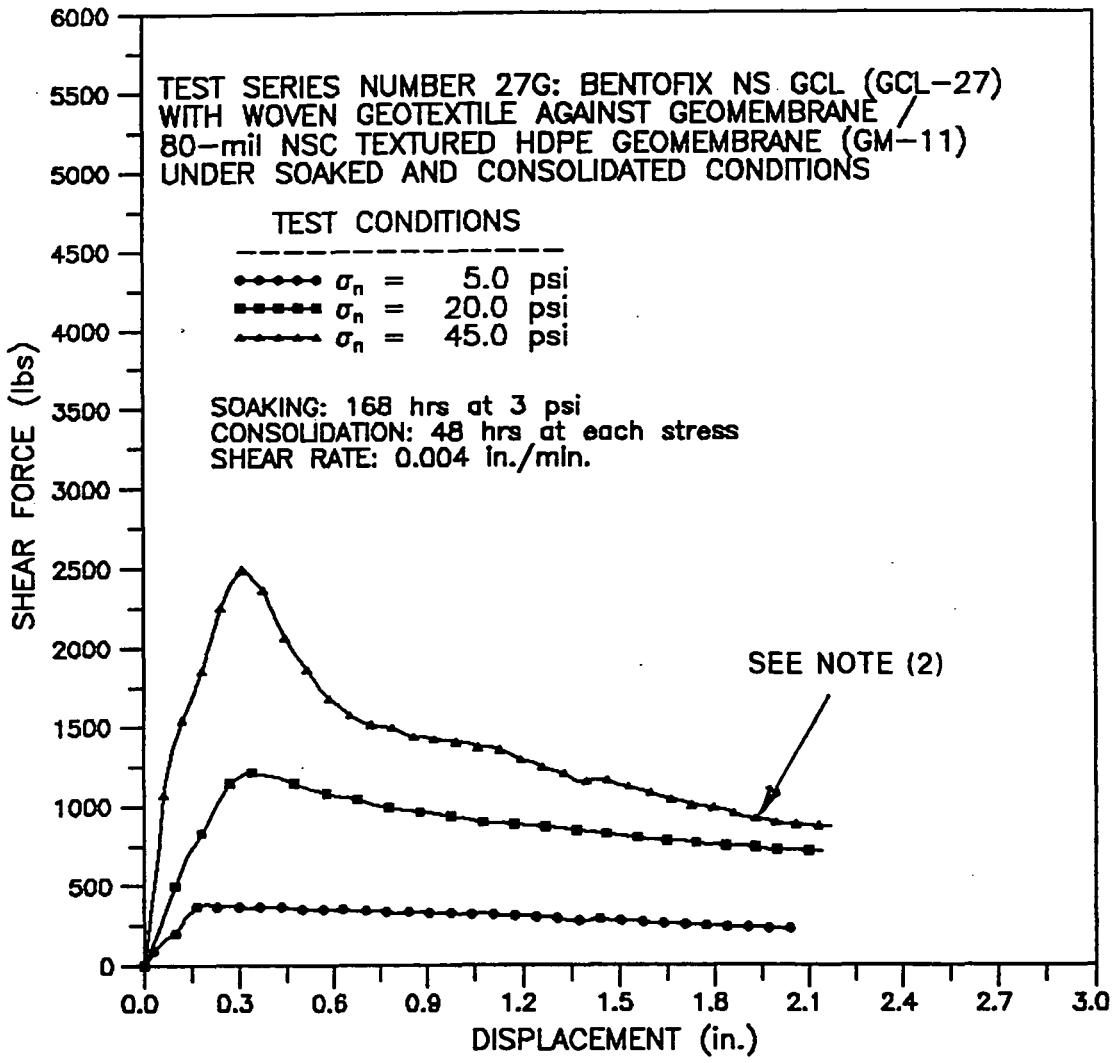
NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) No internal shear failure within GCL was observed.
(4) Internal failure within GCL was observed.

DATE TESTED: 1 TO 10 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-2
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730130
FILE NO.	000673

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The shear box size was 12 in. by 12 in. (300 mm by 300 mm), and the contact area remained constant throughout the entire test.

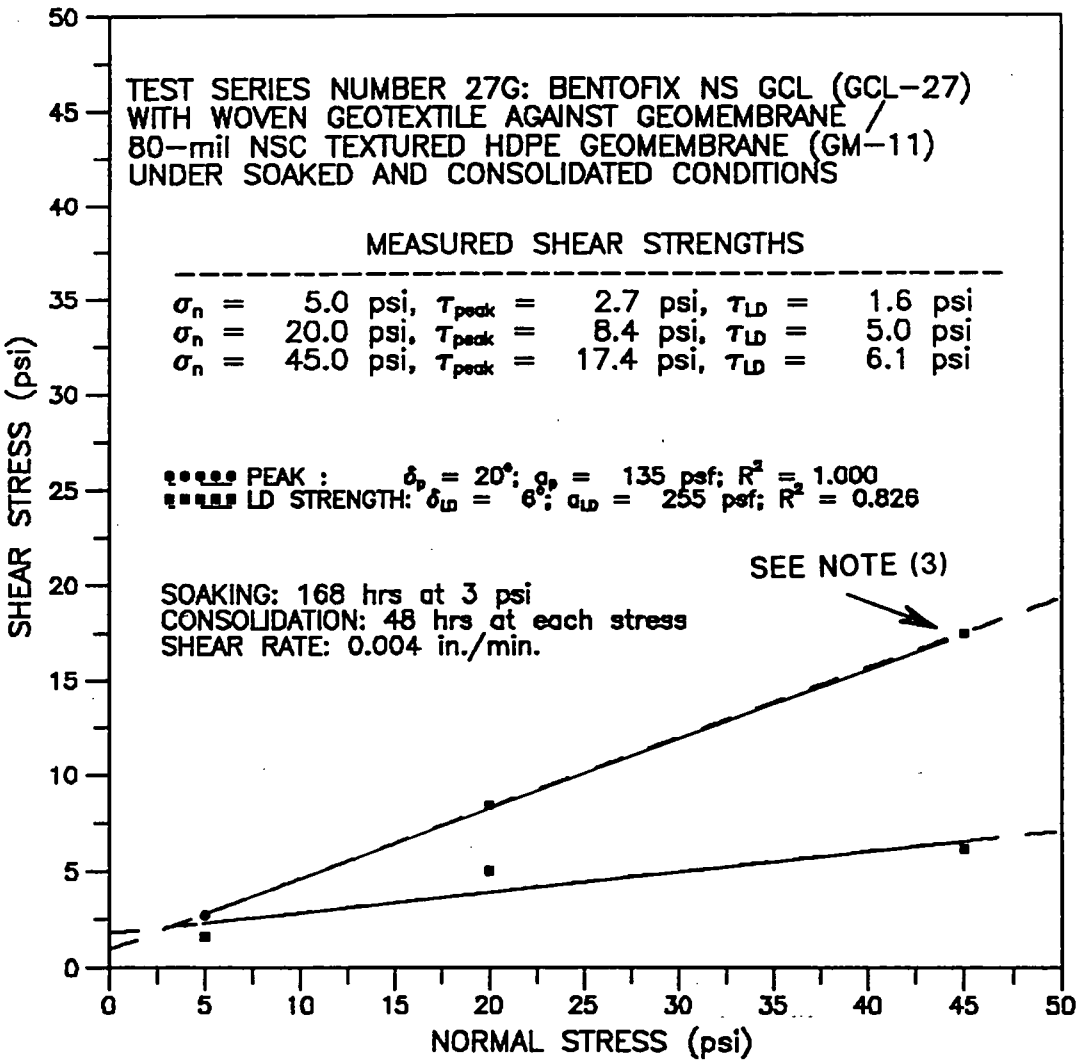
(2) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 1 TO 10 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-3
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730130
FILENO.	000674

FLUOR DANIEL FERNALD
ON-SITE DISPOSAL FACILITY
PHASE 1 CONSTRUCTION
DIRECT SHEAR TESTING



NOTES: (1) The reported total-stress shear strength parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using the strength parameters for applications involving normal stresses outside the range of stresses covered by the test series.
(2) The large displacement shear strength (τ_{LD}) was calculated using the shear force at a shear displacement of 2 in. for each test.
(3) Sliding (i.e., shear failure) was observed to occur within the GCL rather than the intended interface.

DATE TESTED: 1 TO 10 NOVEMBER 1997

GEOSYNTEC CONSULTANTS
SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	A-4
PROJECT NO.	GQ0166-04.1
DOCUMENT NO.	F9730130
FILE NO.	000675

Geomembrane

Geomembrane Test Results

GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-01 , ROLL- SO8F917B-6K0911AA3
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2510-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9524	0.9495	0.9512	0.9514	0.9507					
0.9500	0.9471	0.9488	0.9490	0.9483					
2.04	2.04	2.03	2.03	2.04	2.03	2.03	2.03	2.04	2.07
80.5	80.5	80.0	80.0	80.5	80.0	80.0	80.0	80.5	81.5
227.5	227.5	226.5	221.0	214.0					
218.5	224.0	222.5	218.5	219.5					
19.9	20.4	21.1	21.8	21.8					
22.3	17.2	19.2	19.8	19.2					
314.5	265.5	252.4	281.0	288.4					
291.3	258.2	225.0	228.0	289.0					
1143	963	923	1031	1097					
1108	343	878	882	1112					
2.55	2.52								
Cat.-1	Cat.-1	Cat.-1	Cat.-2	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9510	0.00106	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9487	0.00106	N/A	
THICKNESS (ASTM D5199)	mm	2.04	0.012	N/A	
	mil	80.4	0.47	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		223.3	5.86	≥ 168	PASS
XD		220.6	2.51	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		21.0	0.84	≥ 12	PASS
XD		19.6	1.82	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		280.4	23.63	≥ 120	PASS
XD		258.3	31.85	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		1031	91.2	≥ 200	PASS
XD		865	313.4	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.54	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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QC I.D. 117 DATE: 12-16-97

000678

1269

GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-02 , ROLL- SO8F103A-7B0904AA3
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2511-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9514	0.9499	0.9501	0.9509	0.9507					
0.9490	0.9475	0.9477	0.9485	0.9483					
2.07	2.03	2.08	2.03	2.07	2.04	2.01	2.04	2.01	2.02
81.5	80.0	82.0	80.0	81.5	80.5	79.0	80.5	79.0	79.5
214.5	204.0	210.0	206.5	204.0					
205.0	216.5	214.0	206.5	209.0					
21.8	19.2	19.7	19.1	19.1					
19.9	17.8	17.9	21.1	19.1					
329.8	337.5	326.8	356.9	332.8					
292.5	253.5	293.9	250.9	278.5					
1178	1201	1160	1266	1184					
1091	963	1087	956	1060					
2.50	2.55								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9506	0.00061	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9482	0.00061	N/A	
THICKNESS (ASTM D5199)	mm	2.04	0.027	N/A	
	mil	80.4	1.06	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		207.8	4.48	≥ 168	PASS
XD		210.2	4.91	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		19.8	1.15	≥ 12	PASS
XD		19.2	1.39	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		336.8	11.93	≥ 120	PASS
XD		273.9	20.69	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		1198	40.8	≥ 200	PASS
XD		1031	66.7	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.53	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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QC I.D. 17 DATE: 12-16-97

000679

1269

GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-03 , ROLL- SO8F116C-7C1604AA3
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2512-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9517	0.9513	0.9525	0.9516	0.9527					
0.9493	0.9489	0.9501	0.9492	0.9503					
2.04	2.10	2.11	2.07	2.12	2.13	2.08	2.06	2.06	2.11
80.5	82.5	83.0	81.5	83.5	84.0	82.0	81.0	81.0	83.0
225.5	230.0	230.5	222.5	228.5					
231.8	236.6	237.2	242.6	234.8					
19.8	20.4	19.9	21.3	21.7					
18.0	20.4	17.2	19.1	16.5					
325.3	248.0	415.5	312.0	289.0					
297.7	271.8	241.2	304.5	321.8					
1111	806	1331	1039	986					
1036	939	867	1051	1125					
2.54	2.65								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9520	0.00061	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9496	0.00061	N/A	
THICKNESS (ASTM D5199)	mm	2.09	0.030	N/A	
	mil	82.2	1.18	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		227.4	3.36	≥ 168	PASS
XD		236.6	3.96	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		20.6	0.85	≥ 12	PASS
XD		18.2	1.54	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		318.0	61.92	≥ 120	PASS
XD		287.4	31.46	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		1055	191.3	≥ 200	PASS
XD		1004	101.0	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.60	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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QC I.D. 117 DATE: 12-16-97

GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-04 , ROLL- SO8F103A-7B0804AA3
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2513-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9505	0.9491	0.9517	0.9509	0.9515					
0.9481	0.9467	0.9493	0.9485	0.9491					
1.97	2.04	2.04	2.03	2.03	2.04	2.04	2.02	2.04	2.03
77.5	80.5	80.5	80.0	80.0	80.5	80.5	79.5	80.5	80.0
206.4	221.4	223.4	219.6	218.2					
204.2	213.4	209.2	209.6	211.0					
20.5	20.4	19.7	19.9	19.1					
22.3	22.5	21.1	21.6	21.8					
378.8	369.6	391.8	391.1	359.6					
287.0	323.4	313.8	338.4	235.9					
1314	1243	1323	1311	1235					
1070	1193	1179	1233	898					
2.52	2.45								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9507	0.00103	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9484	0.00103	N/A	
THICKNESS (ASTM D5199)	mm	2.03	0.024	N/A	
	mil	80.0	0.93	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		217.8	6.66	≥ 168	PASS
XD		209.5	3.38	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		19.9	0.58	≥ 12	PASS
XD		21.8	0.57	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		378.2	13.89	≥ 120	PASS
XD		299.7	40.28	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		1285	42.5	≥ 200	PASS
XD		1115	135.3	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.49	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-05 , ROLL- SO8F117C-7C1606AA3
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2514-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9525	0.9532	0.9535	0.9538	0.9531					
0.9501	0.9508	0.9511	0.9514	0.9507					
2.06	2.08	2.04	2.07	2.04	2.07	2.08	2.06	2.08	2.03
81.0	82.0	80.5	81.5	80.5	81.5	82.0	81.0	82.0	80.0
218.0	221.5	213.0	221.0	211.5					
216.0	209.0	214.5	205.5	214.0					
19.9	20.4	21.8	19.7	20.4					
18.6	20.5	17.3	16.6	17.9					
394.0	378.8	271.0	305.5	298.0					
349.1	321.4	242.4	350.0	258.4					
1370	1326	1010	1068	1059					
1276	1188	911	1290	979					
2.52	2.67								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9532	0.00049	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9508	0.00049	N/A	
THICKNESS (ASTM D5199)	mm	2.06	0.018	N/A	
	mil	81.2	0.71	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		217.0	4.57	≥ 168	PASS
XD		211.8	4.40	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		20.4	0.82	≥ 12	PASS
XD		18.2	1.51	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		329.5	53.81	≥ 120	PASS
XD		304.3	50.81	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		1167	167.8	≥ 200	PASS
XD		1129	173.8	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.60	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-06 , ROLL- SO8F915D-6K0601AA3
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2523-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9533	0.9533	0.9520	0.9511	0.9510					
0.9509	0.9509	0.9496	0.9487	0.9486					
2.06	2.07	2.04	2.02	2.04	2.06	2.06	2.10	2.07	2.06
81.0	81.5	80.5	79.5	80.5	81.0	81.0	82.5	81.5	81.0
215.4	237.2	228.8	236.2	232.7					
215.2	224.1	241.2	224.8	225.8					
19.4	20.1	19.0	19.1	19.1					
20.7	21.6	19.1	19.1	19.1					
328.5	290.1	304.6	263.7	281.4					
319.7	309.2	253.5	294.8	242.7					
1139	1004	1075	927	996					
1161	1099	935	1081	891					
2.25	2.23								
Cat.-1	Cat.-2	Cat.-2	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9521	0.00113	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9498	0.00113	N/A	
THICKNESS (ASTM D5199)	mm	2.06	0.020	N/A	
	mil	81.0	0.78	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		230.1	8.83	≥ 168	PASS
XD		226.2	9.39	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		19.3	0.44	≥ 12	PASS
XD		19.9	1.17	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		293.7	24.46	≥ 120	PASS
XD		284.0	34.14	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		1028	81.2	≥ 200	PASS
XD		1033	114.9	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.24	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-07 , ROLL- SO8F305A-7C1803AA3
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2524-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9520	0.9529	0.9521	0.9529	0.9514					
0.9496	0.9505	0.9497	0.9505	0.9490					
2.03	2.04	2.06	2.04	2.04	2.08	2.06	2.07	2.03	2.06
80.0	80.5	81.0	80.5	80.5	82.0	81.0	81.5	80.0	81.0
213.0	221.3	223.6	223.4	241.9					
223.5	222.9	237.2	230.0	218.1					
19.1	19.7	19.0	21.5	19.1					
19.1	19.4	19.0	19.1	20.1					
277.1	239.3	253.5	240.1	269.9					
210.4	203.1	171.8	162.5	221.7					
1000	826	931	805	925					
695	691	402	498	754					
2.60	2.41								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9523	0.00064	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9499	0.00064	N/A	
THICKNESS (ASTM D5199)	mm	2.05	0.016	N/A	
	mil	80.8	0.63	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		224.6	10.57	≥ 168	PASS
XD		226.3	7.40	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		19.7	1.04	≥ 12	PASS
XD		19.3	0.43	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		256.0	17.15	≥ 120	PASS
XD		193.9	25.52	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		897	80.6	≥ 200	PASS
XD		608	150.3	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.51	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-08 , ROLL- SO8F116B-7C0808BA6
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2525-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9528	0.9524	0.9499	0.9499	0.9508					
0.9504	0.9500	0.9475	0.9475	0.9484					
2.08	2.07	2.11	2.04	2.13	2.10	2.08	2.12	2.15	2.16
82.0	81.5	83.0	80.5	84.0	82.5	82.0	83.5	84.5	85.0
244.4	240.8	251.6	247.2	244.8					
247.8	235.8	238.8	237.6	223.6					
19.8	17.9	20.4	19.1	19.1					
17.9	17.8	16.5	17.8	19.2					
333.8	350.9	305.3	314.9	292.6					
314.0	166.4	231.6	300.3	360.7					
1087	1126	1020	1029	986					
1083	292	810	1060	1260					
2.58	2.63								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9512	0.00137	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9488	0.00137	N/A	
THICKNESS (ASTM D5199)	mm	2.10	0.036	N/A	
	mil	82.9	1.42	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		245.8	3.99	≥ 168	PASS
XD		236.7	8.67	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		19.3	0.91	≥ 12	PASS
XD		17.9	0.95	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		319.5	23.11	≥ 120	PASS
XD		274.6	76.13	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		1050	56.0	≥ 200	PASS
XD		901	376.2	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.61	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-09 , ROLL- SO8F116C-7C1101AA6
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2526-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9528	0.9519	0.9528	0.9530	0.9518					
0.9504	0.9495	0.9504	0.9506	0.9494					
2.08	2.06	2.06	2.08	2.07	2.06	2.07	2.08	2.04	2.01
82.0	81.0	81.0	82.0	81.5	81.0	81.5	82.0	80.5	79.0
235.4	228.0	233.8	230.4	232.5					
237.0	235.0	235.5	232.5	231.0					
18.6	18.5	17.9	19.1	17.3					
17.3	18.0	18.6	19.8	19.1					
278.0	267.6	249.8	305.6	165.3					
263.8	282.5	283.3	352.3	335.5					
1011	979	908	1118	218					
908	956	968	1161	1145					
2.50	2.58								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-2	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9525	0.00056	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9501	0.00056	N/A	
THICKNESS (ASTM D5199)	mm	2.06	0.023	N/A	
	mil	81.2	0.91	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		232.0	2.90	≥ 168	PASS
XD		234.2	2.41	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		18.3	0.70	≥ 12	PASS
XD		18.6	0.95	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		253.3	53.17	≥ 120	PASS
XD		303.5	38.18	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		847	359.6	≥ 200	PASS
XD		1027	116.9	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.54	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-10 , ROLL- SO8F102A-7B0907AA3
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2527-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9489	0.9503	0.9493	0.9505	0.9493					
0.9465	0.9479	0.9469	0.9481	0.9469					
2.04	2.04	2.03	2.06	2.06	2.04	2.08	2.03	2.03	2.03
80.5	80.5	80.0	81.0	81.0	80.5	82.0	80.0	80.0	80.0
204.4	205.8	218.4	204.6	216.6					
217.4	216.2	215.6	219.4	220.6					
18.5	17.2	19.7	18.5	19.1					
18.6	19.7	19.1	19.1	19.8					
349.2	302.6	349.5	331.1	360.0					
272.2	289.0	148.6	297.7	161.2					
1227	1080	1210	1172	1246					
1008	1067	444	1089	475					
2.51	2.45								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9497	0.00070	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9473	0.00070	N/A	
THICKNESS (ASTM D5199)	mm	2.05	0.016	N/A	
	mil	80.6	0.64	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		210.0	6.93	≥ 168	PASS
XD		217.8	2.12	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		18.6	0.94	≥ 12	PASS
XD		19.3	0.51	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		338.5	22.59	≥ 120	PASS
XD		233.7	72.69	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		1187	65.7	≥ 200	PASS
XD		817	327.6	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.48	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-11 , ROLL- SO8F307A-7C2507AA3
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2546-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9542	0.9540	0.9532	0.9540	0.9528					
0.9518	0.9516	0.9508	0.9516	0.9504					
2.04	2.01	2.07	2.03	2.06	2.02	2.06	2.06	2.06	2.07
80.5	79.0	81.5	80.0	81.0	79.5	81.0	81.0	81.0	81.5
236.5	236.5	233.5	236.0	228.0					
225.0	216.0	214.0	223.0	222.5					
18.5	19.9	18.6	19.1	19.1					
19.2	18.7	19.9	18.6	18.5					
230.4	218.6	216.0	260.8	258.2					
162.8	209.0	240.0	262.5	227.0					
774	744	752	927	940					
597	737	895	979	806					
2.81	2.99								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9536	0.00061	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9513	0.00061	N/A	
THICKNESS (ASTM D5199)	mm	2.05	0.021	N/A	
	mil	80.6	0.84	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		234.1	3.63	≥ 168	PASS
XD		220.1	4.80	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		19.0	0.56	≥ 12	PASS
XD		19.0	0.59	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		236.8	21.44	≥ 120	PASS
XD		220.3	37.58	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		827	97.4	≥ 200	PASS
XD		803	146.8	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.90	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-12 , ROLL- SO8F117A-7C1704AA6
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2547-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9527	0.9524	0.9524	0.9528	0.9528					
0.9503	0.9500	0.9500	0.9504	0.9504					
2.07	2.06	2.06	2.06	2.08	2.07	2.06	2.06	2.04	2.04
81.5	81.0	81.0	81.0	82.0	81.5	81.0	81.0	80.5	80.5
229.8	225.8	230.8	228.2	237.2					
224.0	229.4	228.2	219.8	224.8					
19.9	19.1	19.1	19.9	19.1					
20.4	21.2	18.6	19.7	18.6					
347.4	356.6	266.2	278.6	325.7					
308.9	166.8	256.2	200.0	163.4					
1182	1208	939	995	1127					
1126	312	947	724	428					
2.49	2.44								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9526	0.00020	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9502	0.00020	N/A	
THICKNESS (ASTM D5199)	mm	2.06	0.012	N/A	
	mil	81.1	0.46	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		230.4	4.26	≥ 168	PASS
XD		225.2	3.79	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		19.4	0.43	≥ 12	PASS
XD		19.7	1.15	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		314.9	40.62	≥ 120	PASS
XD		219.1	62.54	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		1090	117.9	≥ 200	PASS
XD		707	341.9	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.47	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
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GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-13 , ROLL- SO8F308A-7C2805AA3
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2548-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9525	0.9528	0.9525	0.9525	0.9531					
0.9501	0.9504	0.9501	0.9501	0.9507					
2.04	2.07	2.03	2.06	2.07	2.03	2.06	2.07	2.03	2.03
80.5	81.5	80.0	81.0	81.5	80.0	81.0	81.5	80.0	80.0
230.8	219.2	228.4	219.8	229.0					
227.4	223.0	228.0	217.2	224.4					
19.2	21.7	19.1	19.8	21.2					
18.4	18.5	19.2	20.5	19.1					
332.4	174.5	350.1	289.8	290.6					
239.0	304.6	255.0	228.8	163.0					
1165	448	1202	1026	1010					
881	1121	936	834	636					
2.73	2.89								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9527	0.00027	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9503	0.00027	N/A	
THICKNESS (ASTM D5199)	mm	2.05	0.017	N/A	
	mil	80.7	0.67	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		225.4	5.50	≥ 168	PASS
XD		224.0	4.33	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		20.2	1.18	≥ 12	PASS
XD		19.1	0.84	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		287.5	68.41	≥ 120	PASS
XD		238.1	51.08	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		970	303.6	≥ 200	PASS
XD		882	175.3	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.81	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
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GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-14 , ROLL- SO8F304A-7C2710AA3
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2549-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9512	0.9515	0.9512	0.9513	0.9512					
0.9488	0.9491	0.9488	0.9489	0.9488					
2.10	2.10	2.08	2.06	2.08	2.07	2.04	2.04	2.06	2.04
82.5	82.5	82.0	81.0	82.0	81.5	80.5	80.5	81.0	80.5
234.4	224.2	220.2	223.6	211.0					
223.3	223.8	215.2	220.4	232.0					
21.2	21.0	19.9	20.4	21.0					
20.5	21.1	22.4	19.1	21.0					
354.4	301.5	248.6	171.4	301.8					
188.6	302.6	269.2	195.0	349.8					
1174	1028	851	444	1043					
684	1091	996	691	1210					
2.56	2.34								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-2	Cat.-2

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9513	0.00013	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9489	0.00013	N/A	
THICKNESS (ASTM D5199)	mm	2.07	0.021	N/A	
	mil	81.4	0.81	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		222.7	8.41	≥ 168	PASS
XD		222.9	6.11	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		20.7	0.55	≥ 12	PASS
XD		20.9	1.19	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		275.5	69.20	≥ 120	PASS
XD		261.0	69.43	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		908	283.9	≥ 200	PASS
XD		934	237.6	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.45	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
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GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-15 , ROLL- SO8F916D-6K0711BA3
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2550-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9492	0.9499	0.9484	0.9483	0.9500					
0.9468	0.9475	0.9460	0.9459	0.9476					
2.06	2.04	2.06	2.06	2.11	2.06	2.04	2.06	2.07	2.06
81.0	80.5	81.0	81.0	83.0	81.0	80.5	81.0	81.5	81.0
234.2	231.4	229.4	227.8	228.2					
218.0	221.0	219.0	221.0	218.0					
18.5	18.5	19.1	18.5	19.1					
20.4	17.9	17.3	18.6	19.7					
276.0	329.8	291.2	299.3	242.2					
240.0	231.0	200.0	318.0	315.0					
986	1132	1015	1062	871					
909	857	715	1180	1158					
2.26	2.42								
Cat.-1	Cat.-3	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9492	0.00080	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9468	0.00080	N/A	
THICKNESS (ASTM D5199)	mm	2.06	0.018	N/A	
	mil	81.2	0.71	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		230.2	2.64	≥ 168	PASS
XD		219.4	1.52	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		18.7	0.36	≥ 12	PASS
XD		18.8	1.27	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		287.7	32.12	≥ 120	PASS
XD		260.8	52.98	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		1013	96.8	≥ 200	PASS
XD		964	200.6	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.34	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
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GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166 - 04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-16 , ROLL- SO8F304A-7C1820AA6
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 2551-FLQC-1251-I
DATE TESTED: 8/13/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9501	0.9520	0.9504	0.9518	0.9502					
0.9477	0.9496	0.9480	0.9494	0.9478					
2.04	2.04	2.04	2.04	2.04	2.06	2.07	2.06	2.03	2.03
80.5	80.5	80.5	80.5	80.5	81.0	81.5	81.0	80.0	80.0
238.0	230.0	214.0	219.5	220.0					
224.0	227.5	219.0	213.5	228.0					
19.8	19.1	19.9	19.9	19.9					
19.8	20.4	19.1	19.2	19.8					
246.1	256.2	310.7	313.5	276.1					
152.0	162.3	294.4	275.0	209.0					
794	869	1057	1085	969					
309	345	1077	997	743					
2.41	2.39								
Cat.-1	Cat.-1	Cat.-3	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-3

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9509	0.00092	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9485	0.00092	N/A	
THICKNESS (ASTM D5199)	mm	2.05	0.012	N/A	
	mil	80.6	0.46	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		224.3	9.59	≥ 168	PASS
XD		222.4	6.14	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		19.7	0.34	≥ 12	PASS
XD		19.7	0.53	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		280.5	30.80	≥ 120	PASS
XD		218.5	64.47	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		955	123.4	≥ 200	PASS
XD		694	357.6	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.40	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
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GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0409-04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-17 , ROLL- 7J1203AA3-508F926A
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 4082-FLQC-1251-I
DATE TESTED: 12/8/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9486	0.9493	0.9485	0.9483	0.9509					
0.9462	0.9469	0.9461	0.9459	0.9485					
2.06	2.06	2.06	2.07	2.04	2.06	2.10	2.04	2.13	2.08
81.0	81.0	81.0	81.5	80.5	81.0	82.5	80.5	84.0	82.0
223.8	215.0	216.6	208.4	220.0					
215.4	225.0	225.4	216.6	223.4					
17.8	16.7	19.3	19.7	18.6					
18.4	18.0	19.1	17.8	18.0					
169.9	180.8	259.3	308.2	321.4					
230.8	251.9	223.3	163.7	228.4					
1034	813	992	1057	1030					
869	928	810	404	855					
2.91	2.78								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9491	0.00106	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9467	0.00106	N/A	
THICKNESS (ASTM D5199)	mm	2.07	0.027	N/A	
	mil	81.5	1.08	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		216.8	5.77	≥ 168	PASS
XD		221.2	4.79	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		18.4	1.21	≥ 12	PASS
XD		18.3	0.53	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		247.9	70.28	≥ 120	PASS
XD		219.6	33.11	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		985	99.0	≥ 200	PASS
XD		773	210.6	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.85	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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GEOSYNTEC CONSULTANTS
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GEOMEMBRANE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0409-04.1

MATERIAL: HDPE (Textured)
CLIENT ID: GM-18 , ROLL- 7J0801AA3-508F925A926A
SAMPLER ID: KIRK WILLS
GEOSYNTEC ID: 4086-FLQC-1251-I
DATE TESTED: 12/8/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
0.9525	0.9518	0.9524	0.9528	0.9531					
0.9501	0.9494	0.9500	0.9504	0.9507					
2.10	2.16	2.20	2.11	2.10	2.13	2.17	2.06	2.24	2.21
82.5	85.0	86.7	83.0	82.5	84.0	85.3	81.0	88.0	87.0
232.6	222.4	226.0	225.8	229.8					
230.2	220.2	228.0	229.8	229.2					
17.8	16.7	16.7	17.8	18.5					
17.2	15.8	16.7	17.8	16.7					
282.8	227.4	270.5	287.8	283.6					
155.8	226.6	237.9	241.0	335.2					
1034	813	992	1057	1030					
444	832	870	901	1234					
2.65	2.53								
Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1	Cat.-1

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
SPECIFIC GRAVITY (ASTM D792)	n/a	0.9525	0.00049	≥ 0.940	PASS
DENSITY (ASTM D792)	g/cc	0.9501	0.00049	N/A	
THICKNESS (ASTM D5199)	mm	2.15	0.058	N/A	
	mil	84.5	2.28	≥ 76 / 80	PASS
YIELD TENSION (ASTM D638)	lb/in.				
RD		227.3	3.95	≥ 168	PASS
XD		227.5	4.15	≥ 168	PASS
YIELD ELONGATION (ASTM D638)	%				
RD		17.5	0.78	≥ 12	PASS
XD		16.8	0.77	≥ 12	PASS
BREAK TENSION (ASTM D638)	lb/in.				
RD		270.4	24.90	≥ 120	PASS
XD		239.3	63.90	≥ 120	PASS
BREAK ELONGATION (ASTM D638)	%				
RD		985	99.0	≥ 200	PASS
XD		856	280.9	≥ 200	PASS
CARBON BLACK CONTENT (ASTM D1603)	%	2.59	N/A	2-3	PASS
CARBON BLACK DISPERSION (ASTM D5596)	N/A	Cat.-1	N/A	CAT-1 or 2	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
N/A = NOT APPLICABLE

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Geotextile

- Nonwoven Geotextile Filter

GEOSYNTEC CONSULTANTS

FLUOR DANIEL FERNALD

MATERIAL INVENTORY

PROJECT: ON-SITE DISPOSAL FACILITY (OSDF)

LOCATION: FERNALD, OHIO PROJECT NO: GQ0166 TASK NO.: 04-1

DESCRIPTION: PHASE I CONSTRUCTION YEAR: 1997

PRODUCT TYPE: 7 oz GEOTEXTILE MANUFACTURER: TNS MILLS, INC.

INVENTORY			Q.A. CONFORMANCE				Q.C. DOCUMENTS			
DATE (day/mo)	BATCH / ROLL NO. 740	QA ID	DATE SAMPLED (day/mo)	SAMPLE NO.	PASS/ FAIL	QA ID	DATE RECEIVED (day/mo)	DATE CHECKED (day/mo)	PASS/ FAIL	QA ID
25 JUNE	965579 BOLT 10806	BE					25 JUNE	12 SEPT	P	RL
	965580		27 JUNE	GT-7-02	P	BE/BN			P	
	965581								P	
	965582								P	
	965583								P	
	965584								P	
	965585								P	
	965586								P	
	965587								P	
	965588		27 JUNE	GT-7-01	P	BE/BN			P	
	965589								P	
	965591								P	
	140,400 FT²									

AVG. ROLL WIDTH: 15 FT AVG. ROLL LENGTH: 780 FT

NUMBER OF ROLLS ABOVE: 12 ACCUMULATIVE NUMBER OF ROLLS: 12

CUMULATIVE AREA: 140,400 FT² NO. OF CONFORMANCE TESTS (page/total): 2 / 2

GEOSYNTEC CONSULTANTS

FLUOR DANIEL FERNALD

MATERIAL INVENTORY

PROJECT: ON-SITE DISPOSAL FACILITY (OSDF)

LOCATION: FERNALD, OHIO PROJECT NO: GQ0166 TASK NO.: 04.1

DESCRIPTION: PHASE I CONSTRUCTION YEAR: 1997

PRODUCT TYPE: 7 OZ GEOTEXTILE MANUFACTURER: TNS MILLS INC.

INVENTORY			Q.A. CONFORMANCE				Q.C. DOCUMENTS			
DATE (day/mo)	BATCH / ROLL NO. 842	QA ID	DATE SAMPLED (day/mo)	SAMPLE NO.	PASS/ FAIL	QA ID	DATE RECEIVED (day/mo)	DATE CHECKED (day/mo)	PASS/ FAIL	QA ID
28/AUG	972981 BOL 11155	RL					28 AUG	12 SEPT	P	RL
↓	972982	↓					↓	↓	P	↓
	972983								P	
↓	972984	↓	29 AUG	GT-07-03	P	RL/BN	↓	↓	P	↓
						ACCUMULATIVE NO. OF ROLLS ON THIS PAGE FOR LOT = 842 = 4				
						CUMULATIVE AREA FOR LOT = 842 = 46,800 SQ. FT.				
	46,800 FT²									

AVG. ROLL WIDTH: 15 FT. AVG. ROLL LENGTH: 780 FT.

NUMBER OF ROLLS ABOVE: 4 ACCUMULATIVE NUMBER OF ROLLS: 16

CUMULATIVE AREA: 187,200 ft² / NO. OF CONFORMANCE TESTS (page/total): 1 / 3

GEOSYNTEC CONSULTANTS

FLUOR DANIEL FERNALD

MATERIAL INVENTORY

PROJECT: ON-SITE DISPOSAL FACILITY (OSDF)

LOCATION: FERNALD, OHIO PROJECT NO: G00166 TASK NO.: 04.1

DESCRIPTION: PHASE I CONSTRUCTION YEAR: 1997

PRODUCT TYPE: 7 oz. GEOTEXTILE MANUFACTURER: TNS-ADVANCED TECHNOLOGIES

INVENTORY			Q.A. CONFORMANCE				Q.C. DOCUMENTS			
DATE (day/mo)	BATCH / ROLL NO. BOL# 11647	QA ID	DATE SAMPLED (day/mo)	SAMPLE NO.	PASS/ FAIL	QA ID	DATE RECEIVED (day/mo)	DATE CHECKED (day/mo)	PASS/ FAIL	QA ID
15 DEC	987/980765	BE					12 DEC	12 DEC	P	NM
	980766									
	980767		15 DEC	GT-07-04						
	980768									
	980769									
	980774									
	980783									
	980786									
	980792									
	980794		15 DEC	GT-07-05						
	980795									
	980796									
	980797		15 DEC	GT-07-06						
	980798									
	980799									
	980802									
	980803									
	980804									
	980805									
	980806									
	980807									
	980808									
	980809									
	980810		15 DEC	GT-07-07						
	980811									

AVG. ROLL WIDTH: 15.0 ft. AVG. ROLL LENGTH: 780 ft.

NUMBER OF ROLLS ABOVE: 25 ACCUMULATIVE NUMBER OF ROLLS: 41

CUMULATIVE AREA: 479,700 ft² NO. OF CONFORMANCE TESTS (page/total): 4 / 7

GEOSYNTEC CONSULTANTS

FLUOR DANIEL FERNALD

MATERIAL INVENTORY

PROJECT: ON-SITE DISPOSAL FACILITY (OSDF)

LOCATION: FERNALD, OHIO PROJECT NO: G00166 TASK NO.: 04.1

DESCRIPTION: PHASE I CONSTRUCTION YEAR: 1997

PRODUCT TYPE: 7 oz. GEOTEXTILE MANUFACTURER: TNS-ADVANCED TECHNOLOGIES

INVENTORY			Q.A. CONFORMANCE				Q.C. DOCUMENTS			
DATE (day/mo)	BATCH / ROLL NO. BOL # 11647	QA ID	DATE SAMPLED (day/mo)	SAMPLE NO.	PASS/ FAIL	QA ID	DATE RECEIVED (day/mo)	DATE CHECKED (day/mo)	PASS/ FAIL	QA ID
15 DEC	987/ 980812	BE					12 DEC	12 DEC	P	NM

AVG. ROLL WIDTH: 15.0 ft. AVG. ROLL LENGTH: 780 ft.

NUMBER OF ROLLS ABOVE: 1 ACCUMULATIVE NUMBER OF ROLLS: 42

CUMULATIVE AREA: 491,400 ft² NO. OF CONFORMANCE TESTS (page/total): 0 / 7

7 oz. Geotextile Test Results

GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166

MATERIAL: TNS Polyesther
CLIENT ID: GT-7-1, Roll # 0965588, Lot # 740
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 2227-FLQC 1251-I
DATE TESTED: 7/7/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
83	96	79	80	105	93	94	84	82	80
96	110	105	116	99	90	130	109	106	105
205.1	202.1	236.6	207.0	217.5	229.0	193.2	216.7	219.2	244.5
258.8	273.6	226.0	236.3	262.6	255.8	240.7	250.1	240.8	270.5
52.3	54.0	60.7	56.0	57.3	66.3	59.3	54.3	61.7	55.3
86.0	86.0	79.3	84.3	87.0	82.0	92.7	75.3	71.7	79.7
138.1	162.3	144.7	141.3	148.2	161.2	135.8	132.5	160.0	137.8
244.6	251.4	257.7	252.8	257.2	249.5	234.9	240.7	262.5	284.3
7.21	7.41	7.59	7.45	7.58	7.35	6.92	7.09	7.74	8.38
0.050	0.051	0.053	0.052	0.053	0.051	0.048	0.049	0.054	0.058
450.0	430.0	410.0	470.0	360.0	400.0	380.0	380.0	410.0	360.0
0.075	0.075	0.075	0.090	0.075					
1.414	1.522	1.298	1.375						
104.1	112.0	95.6	101.3						
0.361	0.412	0.343	0.351						

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		88	8.81	≥ 75	PASS
XD		107	11.08	≥ 75	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		217.1	16.05	≥ 180	PASS
XD		251.5	15.49	≥ 180	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		57.7	4.27	N/A	N/A
XD		82.4	6.13	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833)	lb	146.2	11.24	≥ 75	PASS
MASS PER UNIT AREA (ASTM D5261)	g/m²	253.6	13.63		
	oz/yd²	7.47	0.402	≥ 7	PASS
	lb/ft²	0.052	0.0028		
MULLEN BURST STRENGTH (ASTM D3786)	psi	405.0	36.9	≥ 350	PASS
APPARENT OPENING SIZE* (ASTM D4751)	bead size (mm)	0.078	N/A	≤ 0.21	PASS
CONSTANT HEAD PERMITTIVITY* (ASTM D4491)	1/s	1.402	0.0933	≥ 0.5	PASS
FLOW RATE (ASTM D4491)	gal/min ft²	103.3	6.82		
PERMEABILITY (ASTM D4491) *	cm/s	0.367	0.0311		

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
* PERMEABILITY VALUES ARE CALCULATED BY MULTIPLYING THE INDIVIDUAL SPECIMEN THICKNESS (ASTM D1777, 2kPa LOADING) TIMES THE PERMITTIVITY AND MAY NOT CORRELATE WITH THE PERMEABILITY VALUES UNDER FIELD CONDITIONS.

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QC I.D. WM DATE: 12-16-97

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GEOSYNTEC CONSULTANTS
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GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166

MATERIAL: TNS Polyesther
CLIENT ID: GT-7-2, Roll # 0965580,Lot # 740
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 2228-FLQC 1251-I
DATE TESTED: 7/7/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
94	116	90	107	138	111	117	102	115	102
91	110	108	75	91	93	164	103	107	115
258.6	220.7	225.6	232.3	203.7	266.3	209.6	214.2	285.0	184.5
228.5	275.1	229.1	236.1	228.6	238.5	242.5	256.3	230.0	246.2
64.3	54.7	64.7	59.3	60.7	67.3	59.3	53.3	72.0	56.3
64.7	77.7	66.7	71.3	73.3	73.7	70.0	75.0	71.0	92.7
141.5	169.2	167.1	137.8	152.3	170.3	162.1	120.3	154.3	150.0
265.0	248.5	243.2	265.0	248.0	287.7	264.0	258.7	259.1	270.3
7.81	7.32	7.17	7.81	7.31	8.48	7.78	7.62	7.64	7.96
0.054	0.051	0.050	0.054	0.051	0.059	0.054	0.053	0.053	0.055
410.0	410.0	410.0	380.0	390.0	410.0	370.0	390.0	420.0	330.0
0.075	0.075	0.075	0.090	0.075					
1.491	1.244	1.452	1.379						
109.8	91.6	106.9	101.6						
0.389	0.351	0.398	0.367						

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		109	13.67	≥ 75	PASS
XD		106	23.70	≥ 75	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		230.1	31.09	≥ 180	PASS
XD		241.1	15.01	≥ 180	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		61.2	5.88	N/A	N/A
XD		73.6	7.71	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833)	lb	152.5	15.93	≥ 75	PASS
MASS PER UNIT AREA (ASTM D5261)	g/m²	260.9	12.88		
	oz/yd²	7.69	0.380	≥ 7	PASS
	lb/ft²	0.053	0.0026		
MULLEN BURST STRENGTH (ASTM D3786)	psi	392.0	27.0	≥ 350	PASS
APPARENT OPENING SIZE* (ASTM D4751)	bead size (mm)	0.078	N/A	≤ 0.21	PASS
CONSTANT HEAD PERMITTIVITY* (ASTM D4491)	1/s	1.392	0.1087	≥ 0.5	PASS
FLOW RATE (ASTM D4491)	gal/min ft²	102.5	8.01		
PERMEABILITY (ASTM D4491) *	cm/s	0.376	0.0213		

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
* PERMEABILITY VALUES ARE CALCULATED BY MULTIPLYING THE INDIVIDUAL SPECIMEN THICKNESS (ASTM D1777, 2kPa LOADING) TIMES THE PERMITTIVITY AND MAY NOT CORRELATE WITH THE PERMEABILITY VALUES UNDER FIELD CONDITIONS.

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QC I.D. WM DATE: 12-16-97

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166

MATERIAL: TNS Polyesther
CLIENT ID: GT-07-03, Roll # 972984
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 2785-FLQC 1251-I
DATE TESTED: 9/5/1997 - 9/12/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
127	86	129	179	86	81	98	89	105	102
114	149	160	98	77	127	134	107	131	125
251.7	178.0	255.5	204.2	197.2	275.0	184.5	202.2	268.7	184.2
207.2	185.0	224.2	218.2	255.7	207.7	215.0	255.5	220.7	263.5
64.3	64.0	79.0	58.7	70.3	39.3	32.7	67.7	72.0	54.7
80.0	53.3	77.3	75.3	50.3	74.7	86.7	44.0	68.3	85.3
119.5	102.5	140.3	145.2	127.0	167.0	117.6	151.6	141.6	122.1
253.3	225.7	249.5	246.5	259.6	270.8	271.3	281.9	271.7	246.1
7.47	6.65	7.35	7.27	7.65	7.98	7.99	8.31	8.01	7.25
0.052	0.046	0.051	0.050	0.053	0.055	0.056	0.058	0.056	0.050
440	370	400	330	320	340	400	360	370	420
0.171	0.176	0.166	0.147	0.146					
1.577	1.797	1.724	1.191						
116.1	132.3	126.9	87.7						
0.467	0.465	0.465	0.349						

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		108	29.90	≥ 75	PASS
XD		122	24.32	≥ 75	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		220.1	38.08	≥ 180	PASS
XD		225.3	25.24	≥ 180	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		60.3	14.56	N/A	N/A
XD		69.5	15.12	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833)	lb	133.4	19.09	≥ 75	PASS
MASS PER UNIT AREA (ASTM D5261)	g/m²	257.6	16.70		
	oz/yd²	7.59	0.492	≥ 7	PASS
	lb/ft²	0.053	0.0034		
MULLEN BURST STRENGTH (ASTM D3786)	psi	375	39.5	≥ 350	PASS
APPARENT OPENING SIZE* (ASTM D4751)	bead size (mm)	0.078	N/A	≤ 0.21	PASS
CONSTANT HEAD PERMITTIVITY* (ASTM D4491)	1/s	1.572	0.2701	≥ 0.5	PASS
FLOW RATE (ASTM D4491)	gal/min ft²	115.8	19.88		
PERMEABILITY (ASTM D4491) *	cm/s	0.437	0.0583		

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0409

MATERIAL: TNS Polyesther
CLIENT ID: GT-04, Roll # 980767
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 4168-FLQC 1251-I
DATE TESTED: 12/19/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
102	95	131	106	77	102	96	110	98	88
111	111	96	125	115	129	112	117	100	103
187.1	182.3	193.6	242.0	225.6	233.3	210.8	231.5	134.0	208.3
210.0	217.2	216.3	205.1	213.3	210.0	217.0	202.1	224.0	242.3
67.3	63.7	49.3	59.7	63.3	65.0	63.0	60.7	51.7	64.0
89.3	77.0	70.7	80.0	82.0	81.0	88.3	72.3	75.0	77.7
115.7	123.6	114.3	129.7	114.6	119.8	142.1	132.5	141.3	110.0
5.1	5.2	5.1	4.7	4.8	5.1	4.9	5.0	4.9	5.2
246.1	250.4	247.0	227.2	230.6	247.0	238.3	243.2	238.3	249.9
7.25	7.38	7.28	6.69	6.79	7.28	7.02	7.17	7.02	7.37
0.050	0.051	0.051	0.046	0.047	0.051	0.049	0.050	0.049	0.051
440.0	440.0	370.0	350.0	390.0	300.0	340.0	330.0	300.0	340.0
0.144	0.141	0.124	0.168	0.140					
1.324	1.493	1.629	1.347						
97.5	110.0	119.9	99.2						
3.085	3.540	3.535	3.353						

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		101	14.22	≥ 75	PASS
XD		112	10.33	≥ 75	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		204.9	32.23	≥ 180	PASS
XD		215.7	11.30	≥ 180	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		60.8	5.83	N/A	N/A
XD		79.3	6.17	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833)	lb	124.4	11.53	≥ 75	PASS
MASS PER UNIT AREA (ASTM D5261)	g/m²	241.8	8.03		
	oz/yd²	7.13	0.237	≥ 7	PASS
	lb/ft²	0.049	0.0016		
MULLEN BURST STRENGTH (ASTM D3786)	psi	360.0	50.3	≥ 350	PASS
APPARENT OPENING SIZE* (ASTM D4751)	mm.*	0.143	0.0158	≤ 0.21	PASS
CONSTANT HEAD PERMITTIVITY* (ASTM D4491)	1/s	1.448	0.1418	≥ 0.5	PASS
FLOW RATE (ASTM D4491)	gal/min ft²	106.7	10.42		
PERMEABILITY (ASTM D4491) *	cm/s	3.378	0.2140		

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
* PERMEABILITY VALUES ARE CALCULATED BY MULTIPLYING THE INDIVIDUAL SPECIMEN THICKNESS (ASTM D1777, 2kPa LOADING) TIMES THE PERMITTIVITY AND MAY NOT CORRELATE WITH THE PERMEABILITY VALUES UNDER FIELD CONDITIONS.

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QC I.D. 17 DATE: 12/30/97

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0409

MATERIAL: TNS Polyesther
CLIENT ID: GT-05, Roll # 980794
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 4169-FLQC 1251-1
DATE TESTED: 12/19/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
81	80	69	75	99	84	69	83	82	130
102	62	79	76	82	141	107	97	116	118
283.2	205.5	147.0	190.7	167.6	252.7	180.6	180.0	175.5	149.8
223.6	234.6	195.0	189.8	189.5	216.8	200.3	207.7	224.6	220.6
63.3	66.7	58.7	66.3	60.7	68.0	54.3	70.7	68.3	83.7
75.3	80.3	83.3	70.0	75.0	77.7	72.3	77.0	82.7	81.7
156.7	153.1	132.7	98.1	129.0	114.1	119.2	115.2	155.8	140.3
262.0	246.1	280.9	237.8	285.8	246.5	268.3	285.8	234.4	234.4
7.72	7.25	8.28	7.01	8.42	7.27	7.91	8.42	6.91	6.91
0.054	0.050	0.057	0.049	0.058	0.050	0.055	0.058	0.048	0.048
320.0	380.0	390.0	320.0	390.0	340.0	350.0	340.0	320.0	360.0
0.141	0.175	0.222	0.140	0.139					
1.798	1.512	1.516	1.633						
132.4	111.3	111.6	120.2						
4.136	3.690	3.532	3.886						

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		85	17.90	≥ 75	PASS
XD		98	23.64	≥ 75	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		193.3	43.61	≥ 180	PASS
XD		210.3	16.03	≥ 180	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		66.1	7.95	N/A	N/A
XD		77.5	4.48	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833)	lb	131.4	20.03	≥ 75	PASS
MASS PER UNIT AREA (ASTM D5261)	g/m²	258.2	21.04		
	oz/yd²	7.61	0.620	≥ 7	PASS
	lb/ft²	0.053	0.0043		
MULLEN BURST STRENGTH (ASTM D3786)	psi	351.0	28.1	≥ 350	PASS
APPARENT OPENING SIZE* (ASTM D4751)	sieve no.*	0.163	0.0361	≤ 0.21	PASS
CONSTANT HEAD PERMITTIVITY* (ASTM D4491)	1/s	1.615	0.1344	≥ 0.5	PASS
FLOW RATE (ASTM D4491)	gal/min ft²	118.9	9.92		
PERMEABILITY (ASTM D4491) *	cm/s	3.811	0.2606		

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
* PERMEABILITY VALUES ARE CALCULATED BY MULTIPLYING THE INDIVIDUAL SPECIMEN THICKNESS (ASTM D1777, 2kPa LOADING) TIMES THE PERMITTIVITY AND MAY NOT CORRELATE WITH THE PERMEABILITY VALUES UNDER FIELD CONDITIONS.

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QC I.D. AT DATE: 12/30/97

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0409

MATERIAL: TNS Polyesther
CLIENT ID: GT-06, Roll # 980797
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 4170-FLQC 1251-I
DATE TESTED: 12/19/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
76	98	119	114	116	79	74	100	92	94
99	114	113	117	101	158	163	123	132	118
238.1	300.7	208.5	323.0	162.0	166.0	186.0	181.8	192.6	215.3
212.0	229.0	232.0	235.0	238.1	224.6	249.3	239.3	263.5	225.0
70.7	70.3	75.0	73.0	68.3	73.0	66.7	70.3	62.7	63.7
79.3	87.3	70.3	75.3	75.7	87.3	76.3	77.0	78.0	72.7
142.0	135.8	118.0	159.2	159.6	132.6	135.2	146.7	157.0	143.3
258.2	254.3	265.4	262.0	255.8	253.3	246.5	265.4	253.8	258.2
7.61	7.49	7.82	7.72	7.54	7.47	7.27	7.82	7.48	7.61
0.053	0.052	0.054	0.054	0.052	0.052	0.050	0.054	0.052	0.053
370.0	350.0	340.0	340.0	340.0	310.0	350.0	340.0	360.0	420.0
0.144	0.139	0.141	0.138	0.139					
1.772	1.445	1.403	1.531						
130.5	106.4	103.3	112.7						
3.810	3.814	3.634	3.828						

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		96	16.57	≥ 75	PASS
XD		124	21.71	≥ 75	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		217.4	54.96	≥ 180	PASS
XD		234.8	14.25	≥ 180	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		69.4	4.05	N/A	N/A
XD		77.9	5.57	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833)	lb	142.9	13.31	≥ 75	PASS
MASS PER UNIT AREA (ASTM D5261)	g/m²	257.3	5.88		
	oz/yd²	7.58	0.173	≥ 7	PASS
	lb/ft²	0.053	0.0012		
MULLEN BURST STRENGTH (ASTM D3786)	psi	352.0	28.6	≥ 350	PASS
APPARENT OPENING SIZE* (ASTM D4751)	sieve no.*	0.140	0.0024	≤ 0.21	PASS
CONSTANT HEAD PERMITTIVITY* (ASTM D4491)	1/s	1.538	0.1650	≥ 0.5	PASS
FLOW RATE (ASTM D4491)	gal/min ft²	113.2	12.16		
PERMEABILITY (ASTM D4491) *	cm/s	3.772	0.0920		

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
* PERMEABILITY VALUES ARE CALCULATED BY MULTIPLYING THE INDIVIDUAL SPECIMEN THICKNESS (ASTM D1777, 2kPa LOADING) TIMES THE PERMITTIVITY AND MAY NOT CORRELATE WITH THE PERMEABILITY VALUES UNDER FIELD CONDITIONS.

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QC I.D. BT DATE: 12/31/97

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0409

MATERIAL: TNS Polyesther
CLIENT ID: GT-07, Roll # 980810
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 4171-FLQC 1251-1
DATE TESTED: 12/19/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
96	114	117	101	122	74	80	77	84	69
147	154	125	130	151	125	127	128	162	115
232.5	241.0	234.0	230.3	229.6	228.2	215.8	264.8	225.7	218.1
245.7	255.2	253.8	258.1	233.6	261.1	241.1	230.6	237.3	258.6
60.3	57.0	56.3	61.7	60.3	69.3	65.0	67.0	67.7	61.0
71.0	64.0	72.0	71.0	72.0	71.6	68.0	71.3	66.0	77.3
147.0	140.3	151.1	131.2	109.8	135.8	162.1	152.8	147.3	102.8
264.5	271.7	272.7	276.1	262.0	279.5	290.6	292.1	287.7	280.9
7.79	8.01	8.04	8.14	7.72	8.24	8.56	8.61	8.48	8.28
0.054	0.056	0.056	0.056	0.054	0.057	0.059	0.060	0.059	0.057
390.0	370.0	350.0	410.0	360.0	350.0	390.0	360.0	390.0	390.0
0.212	0.121	0.230	0.233	0.206					
1.351	1.324	1.512	1.407						
99.4	97.5	111.3	103.6						
3.525	3.483	3.478	3.560						

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		93	19.40	≥ 75	PASS
XD		136	15.61	≥ 75	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		232.0	13.66	≥ 180	PASS
XD		247.5	11.29	≥ 180	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		62.6	4.48	N/A	N/A
XD		70.4	3.69	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833)	lb	138.0	18.94	≥ 75	PASS
MASS PER UNIT AREA (ASTM D5261)	g/m²	277.8	10.39		
	oz/yd²	8.19	0.306	≥ 7	PASS
	lb/ft²	0.057	0.0021		
MULLEN BURST STRENGTH		374.3	23.0	≥ 350	PASS
APPARENT OPENING SIZE* (ASTM D4751)	sieve no.*	0.200	0.0459	≤ 0.21	PASS
CONSTANT HEAD PERMITTIVITY* (ASTM D4491)	1/s	1.399	0.0832	≥ 0.5	PASS
FLOW RATE (ASTM D4491)	gal/min ft²	103.0	6.12		
PERMEABILITY (ASTM D4491) *	cm/s	3.512	0.0386		

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
* PERMEABILITY VALUES ARE CALCULATED BY MULTIPLYING THE INDIVIDUAL SPECIMEN THICKNESS (ASTM D1777, 2kPa LOADING) TIMES THE PERMITTIVITY AND MAY NOT CORRELATE WITH THE PERMEABILITY VALUES UNDER FIELD CONDITIONS.

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QC I.D. 87 DATE: 12/30/97

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0409

MATERIAL: TNS Polyesther
CLIENT ID: GT-08, Roll # 0980788
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 4181-FLQC 1251-I
DATE TESTED: 12/19/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
63	82	78	77	88	113	69	78	83	83
101	101	120	135	132	107	102	109	94	140
169.5	185.5	150.8	168.0	169.8	238.3	198.8	224.7	204.0	158.0
240.5	237.6	236.6	221.1	227.5	253.3	232.7	233.3	239.0	261.7
59.0	71.0	74.0	57.0	58.0	64.0	61.0	61.0	67.0	62.0
65.3	64.0	67.0	69.0	66.7	31.0	66.0	68.0	62.0	63.3
167.5	160.3	142.8	142.0	149.7	146.8	129.1	140.6	160.0	170.0
247.0	245.6	232.0	245.6	241.7	293.0	249.5	252.8	255.3	263.0
7.28	7.24	6.84	7.24	7.12	8.64	7.35	7.45	7.52	7.75
0.051	0.050	0.047	0.050	0.049	0.060	0.051	0.052	0.052	0.054
360.0	350.0	430.0	450.0	400.0	460.0	400.0	400.0	490.0	340.0
0.168	0.132	0.169	0.137	0.106					
1.437	1.477	1.397	1.481						
105.8	108.8	102.8	109.0						
3.750	4.048	3.673	3.880						

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		81	13.17	≥ 75	PASS
XD		114	16.44	≥ 75	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		186.7	29.05	≥ 180	PASS
XD		238.3	11.79	≥ 180	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		63.4	5.64	N/A	N/A
XD		62.2	11.18	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833)	lb	150.9	13.15	≥ 75	PASS
MASS PER UNIT AREA (ASTM D5261)	g/m²	252.6	16.44		
	oz/yd²	7.44	0.485	≥ 7	PASS
	lb/ft²	0.052	0.0034		
MULLEN BURST STRENGTH (ASTM D3786)	psi	408.0	49.6	≥ 350	PASS
APPARENT OPENING SIZE* (ASTM D4751)	sieve no.*	0.142	0.0266	≤ 0.21	PASS
CONSTANT HEAD PERMITTIVITY* (ASTM D4491)	1/s	1.448	0.0394	≥ 0.5	PASS
FLOW RATE (ASTM D4491)	gal/min ft²	106.6	2.93		
PERMEABILITY (ASTM D4491) *	cm/s	3.838	0.1641		

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
* PERMEABILITY VALUES ARE CALCULATED BY MULTIPLYING THE INDIVIDUAL SPECIMEN THICKNESS (ASTM D1777, 2kPa LOADING) TIMES THE PERMITTIVITY AND MAY NOT CORRELATE WITH THE PERMEABILITY VALUES UNDER FIELD CONDITIONS.

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QC I.D. B7 DATE: 12/31/97

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- Nonwoven Geotextile Cushion

GEOSYNTEC CONSULTANTS

FLUOR DANIEL FERNALD

MATERIAL INVENTORY

PROJECT: ON-SITE DISPOSAL FACILITY (OSDF)

LOCATION: FERNALD, OHIO PROJECT NO: GQ0166 TASK NO.: 04

DESCRIPTION: PHASE I CONSTRUCTION YEAR: 1997

PRODUCT TYPE: 10 oz. GEOTEXTILE MANUFACTURER: TNS MILLS, INC.

INVENTORY			Q.A. CONFORMANCE				Q.C. DOCUMENTS			
DATE (day/mo)	BATCH / ROLL NO. 809	QA ID	DATE SAMPLED (day/mo)	SAMPLE NO.	PASS/ FAIL	QA ID	DATE RECEIVED (day/mo)	DATE CHECKED (day/mo)	PASS/ FAIL	QA ID
12 AUG	971261 BOL # 11070	RL					12 AUG	13 AUG	P	RL
	971262								P	
	971263								P	
	971264								P	
	971265								P	
	971266								P	
	971267								P	
	971268		21 AUG	GT-10-02	P	BN/RL			P	
	971269								P	
	971271								P	
	971272								P	
	971273								P	
	971274								P	
	971275								P	
	971276								P	
	971277								P	
	971278								P	
	971279								P	
	971280								P	
	971282								P	
	971283		21 AUG	GT-10-05	P	BN/RL			P	
	971284								P	
	971285								P	
	971286								P	
	971287								P	

AVG. ROLL WIDTH: 15.0 ft AVG. ROLL LENGTH: 570 ft

NUMBER OF ROLLS ABOVE: 25 ACCUMULATIVE NUMBER OF ROLLS: 25

CUMULATIVE AREA: 213,750 ft² NO. OF CONFORMANCE TESTS (page/total): 2 / 2

GEOSYNTEC CONSULTANTS

FLUOR DANIEL FERNALD

MATERIAL INVENTORY

PROJECT: ON-SITE DISPOSAL FACILITY (OSDF)

LOCATION: FERNALD, OHIO PROJECT NO: GQ0166 TASK NO.: 04

DESCRIPTION: PHASE I CONSTRUCTION YEAR: 1997

PRODUCT TYPE: 10 oz. GEOTEXTILE MANUFACTURER: TNS MILLS, INC.

INVENTORY			Q.A. CONFORMANCE				Q.C. DOCUMENTS			
DATE (day/mo)	BATCH / ROLL NO. 809	QA ID	DATE SAMPLED (day/mo)	SAMPLE NO.	PASS/ FAIL	QA ID	DATE RECEIVED (day/mo)	DATE CHECKED (day/mo)	PASS/ FAIL	QA ID
12 AUG	971288 Bol# 11070	RL					12 AUG	13 AUG	P	RL
	971289 Bol# 11068								P	
	971290								P	
	971291 Bol# 11070								P	
	971292								P	
	971293								P	
	971294		21 AUG	GT-10-03	P	BN/RL			P	
	971295								P	
	971296								P	
	971297								P	
	971298								P	
	971299 Bol# 11068								P	
	971300 Bol# 11070								P	
	971301 Bol# 11068								P	
	971302								P	
	971303								P	
	971304		12AUG	GT-10-01	P	RL			P	
	971305								P	
	971306								P	
	971307								P	
	971308								P	
	971309								P	
	971310								P	
	971311								P	
	971312								P	

AVG. ROLL WIDTH: 15.0 ft AVG. ROLL LENGTH: 570'

NUMBER OF ROLLS ABOVE: 25 ACCUMULATIVE NUMBER OF ROLLS: 50

CUMULATIVE AREA: 427,500 ft² / NO. OF CONFORMANCE TESTS (page/total): 2 / 4

GEOSYNTEC CONSULTANTS

FLUOR DANIEL FERNALD

MATERIAL INVENTORY

PROJECT: ON-SITE DISPOSAL FACILITY (OSDF)

LOCATION: FERNALD, OHIO PROJECT NO: GQ0166 TASK NO.: 04

DESCRIPTION: PHASE I CONSTRUCTION YEAR: 1997

PRODUCT TYPE: 10 oz. GEOTEXTILE MANUFACTURER: TNS MILLS, INC.

INVENTORY			Q.A. CONFORMANCE				Q.C. DOCUMENTS			
DATE (day/mo)	BATCH / ROLL NO. 809	QA ID	DATE SAMPLED (day/mo)	SAMPLE NO.	PASS/ FAIL	QA ID	DATE RECEIVED (day/mo)	DATE CHECKED (day/mo)	PASS/ FAIL	QA ID
12 AUG	971313 BOL # 11068	RL					12 AUG	13 AUG	P	RL
	971314								P	
	971315								P	
	971316								P	
	971317								P	
	971318								P	
	971319		21 AUG	GT-10-04	P	BN/RL			P	

AVG. ROLL WIDTH: 15.0 ft AVG. ROLL LENGTH: 570 ft

NUMBER OF ROLLS ABOVE: 7 ACCUMULATIVE NUMBER OF ROLLS: 57

CUMULATIVE AREA: 487,350 ft²/NO. OF CONFORMANCE TESTS (page/total): 1 / 5

GEOSYNTEC CONSULTANTS

FLUOR DANIEL FERNALD

MATERIAL INVENTORY

PROJECT: ON-SITE DISPOSAL FACILITY (OSDF)

LOCATION: FERNALD, OHIO PROJECT NO: GQ0166 TASK NO.: 04.1

DESCRIPTION: PHASE I CONSTRUCTION YEAR: 1997

PRODUCT TYPE: 10 oz. GEOTEXTILE MANUFACTURER: INS MILLS, INC.

INVENTORY			Q.A. CONFORMANCE				Q.C. DOCUMENTS			
DATE (day/mo)	BATCH / ROLL NO. 843	QA ID	DATE SAMPLED (day/mo)	SAMPLE NO.	PASS/ FAIL	QA ID	DATE RECEIVED (day/mo)	DATE CHECKED (day/mo)	PASS/ FAIL	QA ID
28/AUG.	962253 ROLL # 11155	RL					28 AUG	12 SEPT	P	RL
	972997								P	
	972998								P	
	972999								P	
	973000								P	
	973001								P	
	973002								P	
	973003								P	
	973004								P	
	973005								P	
	973006								P	
	973007		28/AUG.	GT-10-07	P	RL/BN			P	
	973008								P	
	973009								P	
	973010								P	
	973011								P	
	973012								P	
	973013								P	
	973014								P	
	973015								P	
	973016								P	
	973017					ACCUMULATIVE NO. OF ROLLS ON THIS PAGE FOR LOT # 843 = 25			P	
	973018								P	
	973019		28/AUG.	GT-10-06	P	CUMULATIVE AREA ON THIS PAGE = 213,750 sq ft RL/BN			P	
	973020			213,750 ft²					P	

AVG. ROLL WIDTH: 15.0 FT. AVG. ROLL LENGTH: 570 FT

NUMBER OF ROLLS ABOVE: 25 ACCUMULATIVE NUMBER OF ROLLS: 82

CUMULATIVE AREA: 701,100 ft² NO. OF CONFORMANCE TESTS (page/total): 2 / 7

GEOSYNTEC CONSULTANTS

FLUOR DANIEL FERNALD

MATERIAL INVENTORY

PROJECT: ON-SITE DISPOSAL FACILITY (OSDF)

LOCATION: FERNALD, OHIO PROJECT NO: GQ0166 TASK NO.: 04.1

DESCRIPTION: PHASE 1 CONSTRUCTION YEAR: 1997

PRODUCT TYPE: 10 oz GEOTEXTILE MANUFACTURER: TNS MILLS, INC.

INVENTORY			Q.A. CONFORMANCE				Q.C. DOCUMENTS			
DATE (day/mo)	BATCH / ROLL NO. 843	QA ID	DATE SAMPLED (day/mo)	SAMPLE NO.	PASS/ FAIL	QA ID	DATE RECEIVED (day/mo)	DATE CHECKED (day/mo)	PASS/ FAIL	QA ID
28 AUG	973021 BOL# 11155	RL					28 AUG	12 SEPT	P	RL
↓	973022	↓					↓	↓	P	↓
	973023								P	
	973024								P	
29 AUG.	973025 BOL# 11159	RL	29 AUG	GT-10-08	P	RL/BN	28 AUG	12 SEPT	P	RL
↓	973027	↓					↓	↓	P	↓
	973028								P	
	973029								P	
	973030								P	
	973031								P	
	973032								P	
	973033								P	
	973034		29 AUG	GT-10-09	P	RL/BN			P	
	111,150 FT²									

AVG. ROLL WIDTH: 15 FT. AVG. ROLL LENGTH: 570 FT

NUMBER OF ROLLS ABOVE: 13 ACCUMULATIVE NUMBER OF ROLLS: 95

CUMULATIVE AREA: 812,250 ft² NO. OF CONFORMANCE TESTS (page/total): 2 / 9

10 oz. Geotextile Test Results

GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166

MATERIAL: TNS Polyesther
CLIENT ID: GT-10-01, Roll # 971304,Lot # 809
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 2572-FLQC 1251-I
DATE TESTED: 9/2/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
100.3	120.8	116.3	133.7	152.0	135.5	142.8	169.0	121.6	154.6
199.7	175.5	175.7	178.1	141.0	130.0	163.0	152.2	136.0	181.8
357.1	349.3	379.3	365.2	333.6	303.8	331.6	324.6	380.2	351.1
343.1	330.2	328.1	366.7	311.1	293.0	310.3	309.5	309.6	336.3
77.7	77.0	78.0	74.7	68.3	68.0	71.7	70.0	76.7	79.0
90.0	92.0	88.0	91.0	88.3	82.3	86.3	88.7	85.3	89.0
154.0	193.5	166.7	163.5	172.0	153.5	192.2	162.5	211.2	221.0
369.6	363.3	365.2	343.4	337.6	351.7	382.7	374.4	379.8	360.4
10.89	10.71	10.76	10.12	9.95	10.36	11.28	11.03	11.19	10.62
0.076	0.074	0.075	0.070	0.069	0.072	0.078	0.077	0.078	0.074
530	570	450	450	570	470	460	520	510	510

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		134.7	20.62	≥ 90	PASS
XD		163.3	22.76	≥ 90	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		347.6	24.45	≥ 225	PASS
XD		323.8	21.41	≥ 225	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		74.1	4.22	N/A	N/A
XD		88.1	2.84	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833	lb	179.0	23.98	≥ 120	PASS
MASS PER UNIT AREA (ASTM D5261	g/m²	362.8	14.94		
	oz/yd²	10.69	0.440	≥ 10	PASS
	lb/ft²	0.074	0.0031		
MULLEN BURST STRENGTH (ASTM D3786)	psi	504	45.5	≥ 450	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION

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QC I.D. WM DATE: 12-16-97

GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166

MATERIAL: TNS Polyesther
CLIENT ID: GT-10-02, Roll # 971268,Lot # 809
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 2707-FLQC 1251-I
DATE TESTED: 9/2/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
130.2	137.1	152.5	141.6	154.6	162.7	162.9	197.3	206.1	220.3
133.2	146.4	117.6	151.0	150.5	138.0	155.8	168.6	180.4	209.8
303.5	327.6	384.8	351.0	335.3	314.6	342.3	335.5	375.8	340.6
324.1	310.1	328.1	363.0	334.8	349.2	311.7	321.3	335.0	318.8
65.7	65.0	68.7	65.0	62.3	63.0	62.3	61.3	67.3	65.0
75.3	73.7	78.3	82.0	74.0	73.3	71.7	76.3	73.7	69.3
204.7	204.7	196.8	211.5	225.7	199.6	191.8	175.0	220.1	187.8
365.7	363.8	385.1	385.1	392.8	361.3	368.6	367.2	367.6	404.0
10.78	10.72	11.35	11.35	11.58	10.65	10.86	10.82	10.83	11.90
0.075	0.074	0.079	0.079	0.080	0.074	0.075	0.075	0.075	0.083
620	600	500	600	550	430	500	520	530	550

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		166.5	30.87	≥ 90	PASS
XD		155.1	26.05	≥ 90	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		341.1	24.89	≥ 225	PASS
XD		329.6	16.58	≥ 225	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		64.6	2.34	N/A	N/A
XD		74.8	3.53	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833	lb	201.8	15.13	≥ 120	PASS
MASS PER UNIT AREA (ASTM D5261	g/m²	376.1	14.54		
	oz/yd²	11.08	0.429	≥ 10	PASS
	lb/ft²	0.077	0.0030		
MULLEN BURST STRENGTH (ASTM D3786)	psi	540	57.3	≥ 450	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION

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QC I.D. WM DATE: 12-16-97

GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: *GeoSyntec Consultants*
PROJECT: *FLUOR DANIEL FERNALD*
CONTACT: *Mr. Dave Phillips*
GEOSYNTEC JOB NO.: *GQ0166*

MATERIAL: *TNS Polyesther*
CLIENT ID: *GT-10-03, Roll # 971294,Lot # 809*
SAMPLER ID: *N. Meekins*
GEOSYNTEC ID: *2706-FLQC 1251-I*
DATE TESTED: *9/2/97*

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
140.0	131.0	138.0	113.0	213.0	143.0	158.0	143.0	142.0	153.0
167.0	180.0	174.0	198.0	214.0	185.0	147.0	148.0	170.0	150.0
361.5	324.0	308.7	335.1	352.0	324.0	366.1	365.2	284.6	340.0
329.5	362.7	340.5	336.2	322.5	340.8	366.3	329.2	321.0	334.7
74.3	66.3	60.3	67.3	45.7	62.0	73.7	70.0	68.0	61.7
80.0	73.0	74.7	74.0	69.7	77.7	73.3	64.3	73.3	80.0
196.1	197.6	204.0	173.6	191.5	182.6	199.2	231.6	208.3	191.2
352.1	345.8	324.0	330.3	351.7	361.3	372.0	350.2	349.2	367.2
10.38	10.19	9.55	9.73	10.36	10.65	10.96	10.32	10.29	10.82
0.072	0.071	0.066	0.068	0.072	0.074	0.076	0.072	0.071	0.075
400	420	560	560	540	600	560	560	620	480

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		147.4	26.06	≥ 90	PASS
XD		173.3	22.05	≥ 90	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		336.1	26.58	≥ 225	PASS
XD		338.3	15.34	≥ 225	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		64.9	8.29	N/A	N/A
XD		74.0	4.71	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833	lb	197.6	15.62	≥ 120	PASS
MASS PER UNIT AREA (ASTM D5261	g/m²	350.4	14.87		
	oz/yd²	10.33	0.438	≥ 10	PASS
	lb/ft²	0.072	0.0030		
MULLEN BURST STRENGTH (ASTM D3786)	psi	530	73.2	≥ 450	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION

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QC I.D. WM DATE: 12-16-97

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Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166

MATERIAL: TNS Polyesther
CLIENT ID: GT-10-04, Roll # 971319,Lot # 809
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 2705-FLQC 1251-I
DATE TESTED: 9/2/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
126.5	122.3	140.0	135.1	148.3	123.2	126.7	144.2	163.5	200.0
173.6	163.7	166.7	198.9	185.0	178.9	216.8	203.5	210.6	166.2
310.1	338.5	330.7	322.2	288.0	321.7	323.8	330.1	308.2	300.6
334.5	362.0	326.7	319.1	313.2	304.6	302.7	326.8	343.6	322.2
72.0	64.7	65.3	67.3	65.3	63.3	59.3	61.7	60.3	66.7
84.3	85.0	81.7	78.3	84.0	80.3	76.0	77.0	88.7	76.3
162.3	158.8	158.0	188.6	182.3	184.1	174.2	163.1	222.1	189.7
349.2	351.2	336.6	342.0	339.5	352.1	344.4	331.8	344.9	351.7
10.29	10.35	9.92	10.08	10.01	10.38	10.15	9.78	10.16	10.36
0.071	0.072	0.069	0.070	0.069	0.072	0.070	0.068	0.071	0.072
500	530	450	500	460	500	510	520	450	520

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		143.0	23.87	≥ 90	PASS
XD		186.4	19.70	≥ 90	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		317.4	15.46	≥ 225	PASS
XD		325.5	17.96	≥ 225	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		64.6	3.71	N/A	N/A
XD		81.2	4.29	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833	lb	178.3	19.72	≥ 120	PASS
MASS PER UNIT AREA (ASTM D5261	g/m²	344.3	6.92		
	oz/yd²	10.15	0.204	≥ 10	PASS
	lb/ft²	0.070	0.0014		
MULLEN BURST STRENGTH (ASTM D3786)	psi	494	29.9	≥ 450	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION

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QC I.D. WM DATE: 12-16-97

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GEOSYNTEC CONSULTANTS
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GEOTEXTILE TEST RESULTS

CLIENT: *GeoSyntec Consultants*
PROJECT: *FLUOR DANIEL FERNALD*
CONTACT: *Mr. Dave Phillips*
GEOSYNTEC JOB NO.: *GQ0166*

MATERIAL: *TNS Polyesther*
CLIENT ID: *GT-10-05, Roll # 971283,Lot # 809*
SAMPLER ID: *N. Meekins*
GEOSYNTEC ID: *2704-FLQC 1251-I*
DATE TESTED: *9/2/97*

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
117.5	145.5	104.2	143.5	143.8	121.8	118.4	127.9	128.3	156.8
192.9	164.0	126.0	116.7	165.1	159.4	152.0	191.7	182.3	140.2
313.7	311.5	388.7	331.0	406.1	416.8	330.6	361.8	359.5	351.2
371.7	375.3	346.0	398.0	370.0	360.5	376.6	313.5	349.6	314.8
62.3	58.7	74.7	72.7	77.7	84.3	72.7	70.7	77.0	79.0
82.3	80.3	70.7	77.3	78.7	78.3	74.3	74.7	67.7	67.3
190.5	202.2	191.1	219.0	176.3	191.7	193.6	193.8	166.3	165.3
420.9	335.7	355.5	360.4	344.9	377.8	366.7	367.2	359.4	352.1
12.40	9.89	10.48	10.62	10.16	11.13	10.81	10.82	10.59	10.38
0.086	0.069	0.073	0.074	0.071	0.077	0.075	0.075	0.074	0.072
540	520	640	540	540	600	530	590	590	560

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		130.8	16.18	≥ 90	PASS
XD		159.0	26.04	≥ 90	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		357.1	37.08	≥ 225	PASS
XD		357.6	27.17	≥ 225	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		73.0	7.67	N/A	N/A
XD		75.2	5.20	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833	lb	189.0	16.23	≥ 120	PASS
MASS PER UNIT AREA (ASTM D5261	g/m²	364.1	23.24		
	oz/yd²	10.73	0.685	≥ 10	PASS
	lb/ft²	0.074	0.0048		
MULLEN BURST STRENGTH (ASTM D3786)	psi	565	38.4	≥ 450	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION

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QC I.D. WM DATE: 12-16-97

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166

MATERIAL: TNS Polyesther
CLIENT ID: GT-10-06, Roll # 973019
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 2781-FLQC 1251-I
DATE TESTED: 9/5/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
141	149	173	131	158	174	125	129	139	148
158	202	188	206	234	176	212	188	221	205
317.0	287.2	334.7	313.0	355.5	403.0	331.7	398.7	390.2	342.5
379.2	382.5	327.6	363.0	368.2	366.7	348.7	362.6	349.1	390.3
57.0	70.0	70.0	65.3	72.0	71.0	55.0	78.3	62.3	57.7
76.0	73.0	82.0	76.0	82.0	83.3	73.0	70.7	75.7	80.3
214.8	207.3	216.7	223.3	221.3	193.8	192.7	194.7	209.2	198.1
403.5	364.7	357.5	358.4	398.6	396.7	410.8	400.6	397.7	407.4
11.89	10.75	10.53	10.56	11.75	11.69	12.10	11.80	11.72	12.00
0.083	0.075	0.073	0.073	0.082	0.081	0.084	0.082	0.081	0.083
570	580	640	520	570	640	580	530	600	510

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		147	17.30	≥ 90	PASS
XD		199	22.17	≥ 90	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		347.4	39.13	≥ 225	PASS
XD		363.8	18.48	≥ 225	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		65.9	7.68	N/A	N/A
XD		77.2	4.43	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833)	lb	207.2	11.73	≥ 120	PASS
MASS PER UNIT AREA (ASTM D5261)	g/m²	389.6	20.80		
	oz/yd²	11.48	0.613	≥ 10	PASS
	lb/ft²	0.080	0.0043		
MULLEN BURST STRENGTH (ASTM D3786)	psi	574	45.3	≥ 450	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION

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QC I.D. WM DATE: 12-16-97

GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166

MATERIAL: TNS Polyesther
CLIENT ID: GT-10-07, Roll # 973007
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 2782-FLQC 1251-I
DATE TESTED: 9/5/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
132	125	132	121	117	107	120	150	109	153
176	130	170	141	200	152	98	187	162	130
478.2	342.7	365.5	374.7	415.5	355.7	255.7	392.0	353.5	382.5
301.5	325.0	302.2	508.5	346.2	310.0	331.7	322.5	296.0	302.2
52.0	63.0	74.3	73.0	68.0	63.7	20.3	56.7	72.0	66.3
82.3	78.3	86.0	117.3	85.0	93.3	83.0	85.3	96.3	89.7
167.5	189.8	209.5	170.0	196.2	186.7	181.0	207.2	206.6	178.3
354.1	366.2	317.8	343.4	346.3	353.6	368.6	377.8	352.6	406.9
10.43	10.79	9.36	10.12	10.21	10.42	10.86	11.13	10.39	11.99
0.072	0.075	0.065	0.070	0.071	0.072	0.075	0.077	0.072	0.083
530	590	540	540	530	520	540	510	540	550

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		127	15.51	≥ 90	PASS
XD		155	30.67	≥ 90	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		371.6	56.49	≥ 225	PASS
XD		334.6	63.17	≥ 225	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		60.9	15.93	N/A	N/A
XD		89.7	11.07	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833)	lb	189.3	15.35	≥ 120	PASS
MASS PER UNIT AREA (ASTM D5261)	g/m²	358.7	23.54		
	oz/yd²	10.57	0.694	≥ 10	PASS
	lb/ft²	0.073	0.0048		
MULLEN BURST STRENGTH (ASTM D3786)	psi	539	21.3	≥ 450	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION

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QC I.D. WM DATE: 12-16-97

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166

MATERIAL: TNS Polyesther
CLIENT ID: GT-10-08, Roll # 973025
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 2783-FLQC 1251-I
DATE TESTED: 9/5/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
132	126	120	126	122	155	113	116	159	116
231	258	181	165	172	150	149	155	217	183
287.2	320.5	484.5	344.5	344.2	339.2	290.5	332.7	319.0	345.0
380.2	344.0	388.5	360.5	383.7	348.2	398.7	341.0	378.2	358.2
63.7	70.3	69.7	64.7	71.0	59.7	56.7	65.7	77.7	67.0
82.0	80.3	74.3	87.7	94.7	76.0	77.3	81.7	84.3	83.3
223.2	183.1	176.2	182.5	174.0	20.3	200.2	190.0	205.7	205.6
439.8	401.6	387.0	364.7	354.1	346.3	369.1	356.5	381.2	357.5
12.96	11.83	11.40	10.75	10.43	10.21	10.88	10.51	11.23	10.53
0.090	0.082	0.079	0.075	0.072	0.071	0.076	0.073	0.078	0.073
510	530	510	570	550	670	600	550	540	480

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		129	16.07	≥ 90	PASS
XD		186	37.22	≥ 90	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		340.7	54.82	≥ 225	PASS
XD		368.1	20.31	≥ 225	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		66.6	6.01	N/A	N/A
XD		82.2	5.95	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833)	lb	176.1	56.87	≥ 120	PASS
MASS PER UNIT AREA (ASTM D5261)	g/m²	375.8	28.15		
	oz/yd²	11.07	0.830	≥ 10	PASS
	lb/ft²	0.077	0.0058		
MULLEN BURST STRENGTH (ASTM D3786)	psi	551	53.6	≥ 450	PASS

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COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION

QC I.D. WM DATE: 12-16-97

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GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166

MATERIAL: TNS Polyesther
CLIENT ID: GT-10-09, Roll # 973034
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 2784-FLQC 1251-I
DATE TESTED: 9/5/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
135	146	209	125	135	134	151	135	132	123
165	144	165	181	138	177	147	184	171	178
342.7	378.0	383.0	335.7	362.7	330.7	349.2	346.0	334.0	314.5
293.2	365.0	471.0	443.2	344.5	313.5	270.0	285.5	348.0	351.0
82.0	92.0	84.0	80.0	92.0	81.7	85.0	83.0	76.0	75.0
65.7	66.7	65.3	69.0	66.7	86.3	72.0	64.3	62.3	66.3
209.3	170.1	187.2	231.3	197.1	200.8	192.6	170.0	236.6	200.6
338.1	358.0	363.8	375.9	356.0	416.1	454.8	362.3	369.6	388.5
9.96	10.55	10.72	11.08	10.49	12.26	13.40	10.68	10.89	11.45
0.069	0.073	0.074	0.077	0.073	0.085	0.093	0.074	0.076	0.079
580	530	520	500	610	550	540	490	550	620

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		143	24.82	≥ 90	PASS
XD		165	16.53	≥ 90	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		347.7	21.45	≥ 225	PASS
XD		348.5	65.56	≥ 225	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		83.1	5.69	N/A	N/A
XD		68.5	6.79	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833)	lb	199.6	22.18	≥ 120	PASS
MASS PER UNIT AREA (ASTM D5261)	g/m²	378.3	34.10		
	oz/yd²	11.15	1.005	≥ 10	PASS
	lb/ft²	0.077	0.0070		
MULLEN BURST STRENGTH (ASTM D3786)	psi	549	43.3	≥ 450	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION

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QC I.D. WM DATE: 12-16-97

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- **Nonwoven Geotextile**

Supplemental Cushion Separator

GEOSYNTEC CONSULTANTS

FLUOR DANIEL FERNALD

MATERIAL INVENTORY

PROJECT: ON-SITE DISPOSAL FACILITY (OSDF)

LOCATION: FERNALD, OHIO PROJECT NO: GQ0166 TASK NO.: 04.1

DESCRIPTION: PHASE I CONSTRUCTION YEAR: 1997

PRODUCT TYPE: 16 oz. GEOTEXTILE MANUFACTURER: TNS MILLS, INC.

INVENTORY			Q.A. CONFORMANCE				Q.C. DOCUMENTS			
DATE (day/mo)	BATCH / ROLL NO. 810	QA ID	DATE SAMPLED (day/mo)	SAMPLE NO.	PASS/ FAIL	QA ID	DATE RECEIVED (day/mo)	DATE CHECKED (day/mo)	PASS/ FAIL	QA ID
12 AUG	971320 Roll # 1362	RL					12 AUG	12 SEPT	P	RL
	971321								P	
	971322								P	
	971323								P	
	971324		12 AUG	GT-16-01	P	RL/BN			P	
	971325								P	
	971326								P	
	971327								P	
	971328								P	
	971329								P	
	971330								P	
	971331								P	

AVG. ROLL WIDTH: 15.0 ft AVG. ROLL LENGTH: 360 ft

NUMBER OF ROLLS ABOVE: 12 ACCUMULATIVE NUMBER OF ROLLS: 12

CUMULATIVE AREA: 64,800 ft² NO. OF CONFORMANCE TESTS (page/total): 1 / 1

16 oz. Geotextile Test Results

GEOSYNTEC CONSULTANTS
Materials Testing Laboratory

GEOTEXTILE TEST RESULTS

CLIENT: GeoSyntec Consultants
PROJECT: FLUOR DANIEL FERNALD
CONTACT: Mr. Dave Phillips
GEOSYNTEC JOB NO.: GQ0166

MATERIAL: TNS Polyesther
CLIENT ID: GT-16-01, Roll # 971324,Lot # 810
SAMPLER ID: N. Meekins
GEOSYNTEC ID: 2573-FLQC 1251-1
DATE TESTED: 9/2/97

INDIVIDUAL SPECIMENS

1	2	3	4	5	6	7	8	9	10
186.6	307.1	233.0	181.2	236.1	211.2	195.6	246.8	231.7	190.8
332.8	265.5	349.2	235.2	380.6	347.6	309.5	414.2	354.5	360.5
642.7	542.7	567.2	544.7	519.0	578.2	577.0	597.5	585.5	460.5
548.5	539.2	627.2	586.7	580.7	583.0	615.5	567.0	683.2	572.5
82.7	76.0	100.0	93.0	85.0	80.7	84.3	91.3	84.3	82.7
88.0	89.3	109.0	132.0	96.7	102.0	103.0	97.7	96.0	96.0
338.0	319.2	326.2	356.2	335.0	326.5	283.0	288.7	276.5	339.7
607.4	613.7	603.5	594.3	620.5	604.0	595.3	641.8	621.9	585.1
17.90	18.08	17.79	17.51	18.28	17.80	17.54	18.91	18.33	17.24
0.124	0.126	0.124	0.122	0.127	0.124	0.122	0.131	0.127	0.120
790	940	900	780	770	1000	750	1000	940	730

SUMMARY RESULTS

PROPERTY (STANDARD)	UNIT	MEAN	STD	SPEC.	PASS/FAIL
TRAPEZOID TEARING STRENGTH (ASTM D4533)	lb				
RD		222.0	37.97	≥ 120	PASS
XD		335.0	52.90	≥ 120	PASS
GRAB TENSILE STRENGTH (ASTM D4632)	lb				
RD		561.5	49.06	≥ 350	PASS
XD		590.4	42.17	≥ 350	PASS
GRAB ELONGATION (ASTM D4632)	%				
RD		86.0	6.92	N/A	N/A
XD		101.0	12.54	N/A	N/A
PUNCTURE STRENGTH (ASTM D4833	lb	318.9	26.99	≥ 180	PASS
MASS PER UNIT AREA (ASTM D5261	g/m²	608.8	16.42		
	oz/yd²	17.94	0.484	≥ 16	PASS
	lb/ft²	0.125	0.0034		
MULLEN BURST STRENGTH (ASTM D3786)	psi	860	106.5	≥ 700	PASS

COMMENTS:
RD = ROLL DIRECTION
XD = CROSS-ROLL DIRECTION
** RETAINED STRENGTH AFTER 500 HOURS EXPOSURE.

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QC I.D. WM DATE: 12-16-97

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APPENDIX J:

CONTRACTOR'S CERTIFICATE OF ACCEPTANCE - OF SUBGRADE SURFACE

CERTIFICATE OF ACCEPTANCE SUBGRADE SURFACE

INSTALLER	PROJECT
NAME: Ground Safe Inc.	NAME: Fernald - OSDF, Phase One
ADDRESS: 2071 Clary Connector East Anollee, GA. 30538 (G.S.I)	LOCATION: Fernald, Ohio
INSTALLER AUTHORIZED REPRESENTATIVE: Kevin Allen	OWNER: U.S. Dept. of Energy (D.O.E.)

I, The undersigned, duly authorized representive of _____ do hereby accept the surface on which the geosynthetics will be installed and shall be responsible for maintaining the suitability of this surface, in accordance with the project specifications. (i.e., The contractor shall not install the geosynthetics until the subgrade surface is acceptable. Installation of the geosynthetics will be considered acceptance of the subgrade.)

PRIMARY: ☐ SECONDARY: ■ OTHER: ☐ _____

DATE	PANEL NOS.	SIGNATURE
21 October '97	S-1 Through S-17	
22 October '97	S-18 Through S-37A	
23 October '97	S-38 Through S-42	
24 October '97	S-43 Through S-47	
29 October '97	S-48 Through S-52	
30 October '97	S-53 Through S-61	
31 October '97	S-62 Through S-67	
6 November '97	S-68 Through S-73	
10 November '97	S-74 Through S-~~78~~ 82	
11 November '97	S-84 Through S-93	
12 November '97	S-94 Through S-121	(SEE PAGE 2 OF 2)
13 November '97	S-122 Through S-134	(SEE PAGE 2 OF 2)

CERTIFICATE OF ACCEPTANCE SUBGRADE SURFACE

INSTALLER	PROJECT
NAME: Environmental Development & Construction	NAME: Fernald - OSDF, Phase One
ADDRESS: 104 Wholesale Ave. Huntsville AL. 35811 (E.D.C.)	LOCATION: Fernald, Ohio
INSTALLER AUTHORIZED REPRESENTATIVE: DARYL BRINKMAN	OWNER: U.S. Dept. of Energy (DOE)

I, The undersigned, duly authorized representive of _____ do hereby accept the surface on which the geosynthetics will be installed and shall be responsible for maintaining the suitability of this surface, in accordance with the project specifications. (i.e., The contractor shall not install the geosynthetics until the subgrade surface is acceptable. Installation of the geosynthetics will be considered acceptance of the subgrade.)

PRIMARY: ☐ SECONDARY: ■ OTHER: ☐ _____

DATE	PANEL NOS.	SIGNATURE
12 November	S-94 through S-121	
13 November	S-122 through S-134	

CERTIFICATE OF ACCEPTANCE SUBGRADE SURFACE

INSTALLER	PROJECT
NAME: ENVIRONMENTAL DEVELOPMENT AND CONSTRUCTION, INC. (EDCI)	NAME: FERNALD - OSDF PHASE I CONST.
ADDRESS: 104 WHOLESALE AVE HUNTSVILLE, ALABAMA 35811	LOCATION: FERNALD, OHIO
INSTALLER AUTHORIZED REPRESENTATIVE: DARYL BRINKMAN MIKE HARRIS	OWNER: U.S. DEPARTMENT OF ENERGY (US DOE)

I, The undersigned, duly authorized representive of EDCI do hereby accept the surface on which the geosynthetics will be installed and shall be responsible for maintaining the suitability of this surface, in accordance with the project specifications. (i.e., The contractor shall not install the geosynthetics until the subgrade surface is acceptable. Installation of the geosynthetics will be considered acceptance of the subgrade.)

PRIMARY: ☐ SECONDARY: ☑ OTHER: ☐

DATE	PANEL NOS.	SIGNATURE
20 NOV 1997	S-113 THROUGH S-114 AND LINER PENETRATION BOX AREA LOCATION	Mike Harris

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