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MEMORANDUM

Anchorage

DATE: November 9, 2000

TO: Jim Thomson, P.E., HNTB

Boston

FROM: Barry Chen, P.E., Hart Crowser

RE: **Stability Review of RECo 30% Design**
Third Runway Embankment Project
J-4978-30

Chicago

CC: Mike Bailey, Hart Crowser
John Sankey, RECo
Pete Douglas

Denver

Provided herein is a summary of Hart Crowser's review analyses on RECo's 30% design for NSA, West, and South MSE Walls. The majority of the information was presented in our 30% design review meeting dated September 28, 2000. We also included results of our follow-up analyses for verification of proposed design modifications. At the request of Pete Douglas, we are sending this package to the members of the Technical Review Board in preparation for the first review meetings on November 16 to 18, 2000.

Fairbanks

Jersey City

Prior to RECo's 30% design, Hart Crowser completed a series of preliminary limit equilibrium analyses for NSA, West, and South MSE Walls for the purpose of defining the need and extent of subgrade improvement beneath the walls. Our general approach in reviewing RECo's design is to identify the most critical design sections by examining the proposed wall height, embedment depth, and strip length for each section. Using the computer program SLOPE/W, global and compound stability were examined by limit equilibrium methods. We used the target factor of safety values discussed in Hart Crowser's June 2000 report as preliminary stability analyses for the MSE walls. For sections indicating marginal factors of safety, a displacement-based computer program FLAC was used to evaluate potential deformations.

Juneau

Long Beach

In general, we found satisfactory factors of safety for all the North Wall sections reviewed. We found marginal factors of safety for compound stability in the following sections:

Portland

Station 186+00 (West Wall),
Station 142+75 (South Wall), and
Station 147+25 (South Wall).

Seattle

1910 Fairview Avenue East
Seattle, Washington 98102-3699
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Tel 206.324.9530

AR 046304

We also found marginal factors of safety for global stability in Station 147+25 (South Wall).

In the September 28, 2000, review meeting, we suggested increasing the thickness of steel strips from 50x4 mm to 50x6 mm in the upper tier to address the compound stability issue. We also suggested increasing the embedment depth and/or strip length to address the global stability at Station 147+25. Our follow up analyses indicated that increasing the strip thickness would yield satisfactory factors of safety for compound stability in all cases. For Station 147+25 (South Wall), our analyses indicated that increasing the embedment depth and strip length by 2 feet would yield satisfactory factors of safety for global stability.

We performed FLAC analyses on Station 186+00 (West Wall) and Station 147+25 (South Wall) that incorporate the proposed design modifications. The results indicated that stresses in steel strips did not exceed the allowable tensile strength. Maximum deformations at the end of a 475-year seismic event are summarized as follows:

Station 186+00 (West Wall)
- Horizontal: 10 inches at top of wall
- Upward: 6 inches at toe of wall
- Downward: 4 inches at top of embankment behind MSE wall

Station 147+25 (South Wall)
- Horizontal: 14 inches at top of wall
- Upward: 9 inches at toe of wall
- Downward: 5 inches at top of 2:1 slope

Detailed information regarding stability design assumptions, criteria, analysis methods, and input soil parameters was presented in Appendix A of our "Preliminary Stability and Settlement Analyses, Subgrade Improvements, MSE Wall Support, Third Runway Project" dated June 2000 (J-4978-22).

Detailed information regarding our FLAC modeling for the South Wall section (Station 147+25) is presented in the attached design calculations "Documentation of FLAC Analysis" dated November 3, 2000 (J-4978-30). A similar document is being prepared for the West Wall section (Station 186+00).

Please call if you have questions.

F:\Docs\Jobs\497830\RECO30Memo.doc

TABLE OF CONTENT FOR STABILITY ANALYSIS - MSE WALL 30% DESIGN

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North Safety Area

Station	# of Tiers	Exposed Height, ft	Total Height incl. Embedment, ft	Embedment, ft	Embedment Ratio, H/x	Strip Length, ft	Ratio of Strip Length to Exposed Height	*** is a flag for ratio<0.8
42+25	1	2	3.37	1.37	1.46	10.00	5.00	
42+50	1	5	6.57	1.57	3.18	10.00	2.00	
42+75	1	8	10.24	2.24	3.57	12.00	1.50	
43+00	1	9.6	15.47	5.87	1.64	14.00	1.46	
43+25	1	11.2	15.8	4.60	2.43	14.00	1.25	
43+50	1	12.8	19.86	7.06	1.81	16.00	1.25	
43+75	1	15	20.81	5.81	2.58	18.00	1.20	
44+00	1	17.8	21.61	3.81	4.67	18.00	1.01	
44+25	1	21.5	25.29	3.79	5.67	20.00	0.93	
44+50	1	25.5	32.2	6.70	3.81	26.00	1.02	
44+75	**1**	**30.5**	**39.5**	**9.00**	**3.39**	**30.00**	**0.98**	
45+25	2	49.73	59.73	10.00	4.97	52.00	1.05	
45+50	2	57.86	68.06	10.20	5.67	58.00	1.00	
45+75	2	63.85	75.85	12.00	5.32	64.00	1.00	
46+00	2	68.07	79.07	11.00	6.19	64.00	0.94	
46+25	2	72.01	83.01	11.00	6.55	68.00	0.94	
46+50	2	74.9	86.9	12.00	6.24	70.00	0.93	
46+75	2	76.05	79.85	3.80	20.01	60.00	0.79	***
47+00	**2**	**76.71**	**80.51**	**3.80**	**20.19**	**60.00**	**0.78**	***
47+25	2	77.5	81.5	4.00	19.38	60.00	0.77	***
47+50	2	76.85	82.35	5.50	13.97	62.00	0.81	
47+75	2	75.4	81.2	5.80	13.00	62.00	0.82	
48+00	2	76.29	80.79	4.50	16.95	62.00	0.81	
48+25	2	77.13	81.93	4.80	16.07	62.00	0.80	
48+50	2	78.35	82.85	4.50	17.41	62.00	0.79	***
48+75	2	80.15	85.35	5.20	15.41	64.00	0.80	***
49+00	2	81.64	86.44	4.80	17.01	64.00	0.78	***
49+25	2	82.96	87.46	4.50	18.44	64.00	0.77	***

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49+50	2	84.72	90.22	5.50	15.40	68.00	0.80	
49+75	2	86	91	5.00	17.20	68.00	0.79	***
50+00	**2**	**86.36**	**91.16**	**4.80**	**17.99**	**68.00**	**0.79**	***
50+25	2	86.3	90.9	4.60	18.76	68.00	0.75	***
50+50	2	85.56	89.96	4.40	19.45	66.00	0.77	***
50+75	2	84.46	88.76	4.30	19.64	66.00	0.78	***
51+00	2	82.61	87.21	4.60	17.96	66.00	0.80	***
51+25	2	81	86.2	5.20	15.58	64.00	0.79	***
51+50	2	75.47	85.27	9.80	7.70	68.00	0.90	
51+75	2	71.37	83.87	12.50	5.71	70.00	0.98	
52+00	2	67.99	78.99	11.00	6.18	64.00	0.94	
52+25	2	64.5	77.5	13.00	4.96	66.00	1.02	
52+50	2	61.49	72.99	11.50	5.35	62.00	1.01	
52+75	2	56.35	64.85	8.50	6.63	54.00	0.96	
53+00	2	48.19	55.69	7.50	6.43	46.00	0.95	
53+25	2	38.49	47.99	9.50	4.05	44.00	1.14	
53+50	1	22	25.51	3.51	6.27	20.00	0.91	
53+75	1	15.2	19.63	4.43	3.43	16.00	1.05	
53+90	1		15	15.00	0.00	14.00	#DIV/0!	#DIV/0!
54+00	1	8.5	11.28	2.78	3.06	12.00	1.41	
54+25	1	1.6	7	5.40	0.30	10.00	6.25	

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Third Runway Project - NSA Wall Stability Analysis **J-4978-30**
30% Design
September 27, 2000

Summary of Stability Analysis

Section/Station: 50+00
(HC 110+47)

COMPOUND STABILITY

#	Design Scenario	Target FS	Surface 1 (blk)	Surface 2 (cir)	Surface 3 (blk)	Surface 4 (cir)	Surface 5 (blk)	Surface 6 (cir)
1	Steady state (Spencer)	1.5	**2.3 (Bishop & Janbu)**	**2.04**	**2.86 (Spencer) 2.38 (Bishop & Janbu)**	**1.94**	**2.20 (Spencer) 2.00 (Bishop & Janbu)**	**1.95**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.62 (Bishop & Janbu)**	**1.34**	**1.67 (Bishop & Janbu)**	**1.43**	**1.42 (Bishop & Janbu)**	**1.38**
3	Liquefaction (Spencer)	1.1	**2.27 (Bishop & Janbu)**	**2.04**	**2.86**	**1.88**	**2.20**	**1.95**

GLOBAL STABILITY

#	Design Scenario	Target FS	Circle Search	Block Search
1	Steady state (Spencer)	1.5	**1.74**	**1.89**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.24**	**1.44**
3	Liquefaction (Spencer)	1.1	**1.73**	**1.79**

NOTES: (1) Reinforced Fill: γ = 140 pcf, ϕ = 34°; Embankment Fill: γ = 135 pcf, ϕ = 34°
(2) Residual Shear Strength (cumulative mean to the 475-yr event) = 632 psf; SD = 504 psf

Description: 3R Station North Safety Area (60% Design)
Comments: Station 50+00 (HC 110+47) SS Global (Circle Search)
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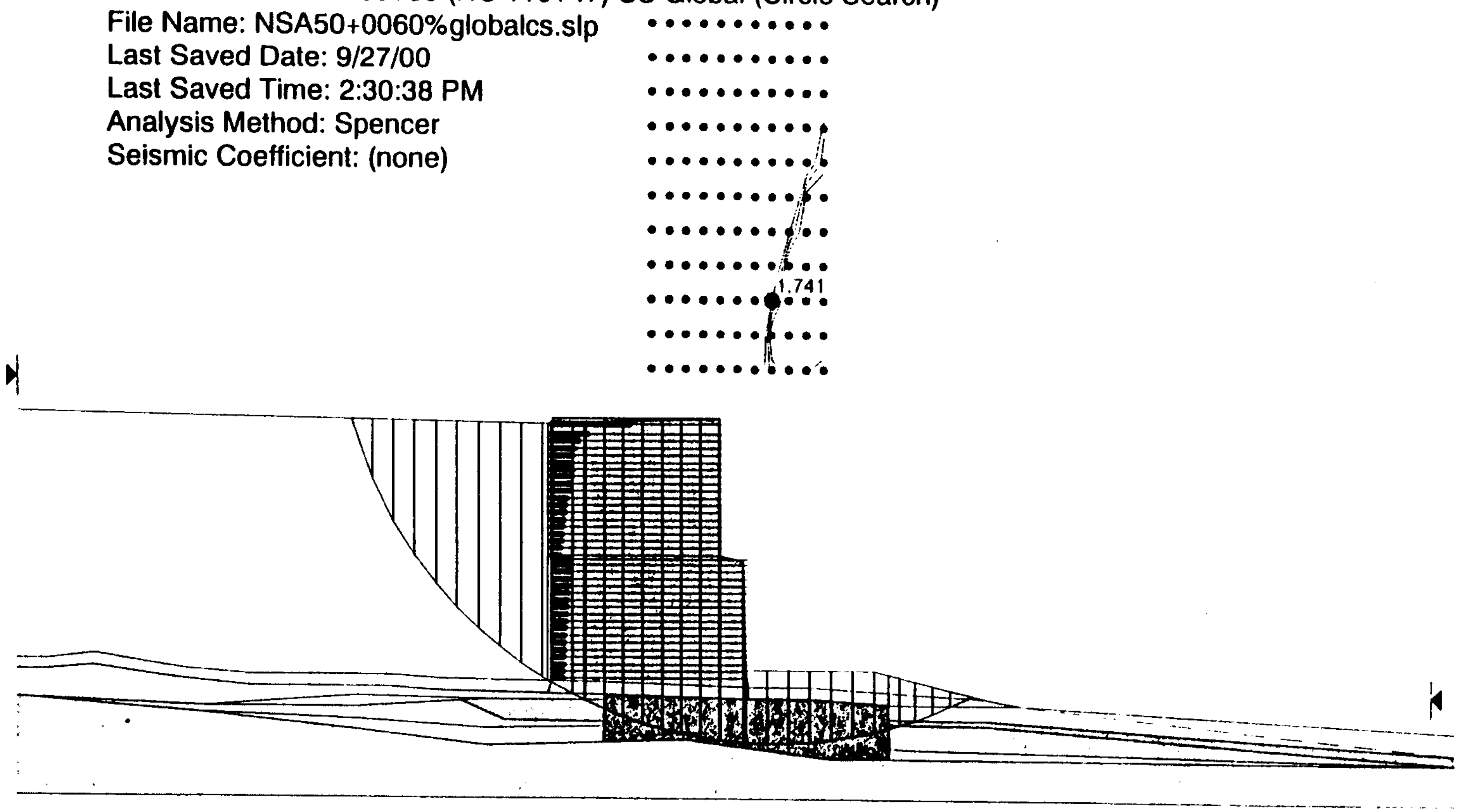
Last Saved Time: 2:30:38 PM
Analysis Method: Spencer
Seismic Coefficient: (none)



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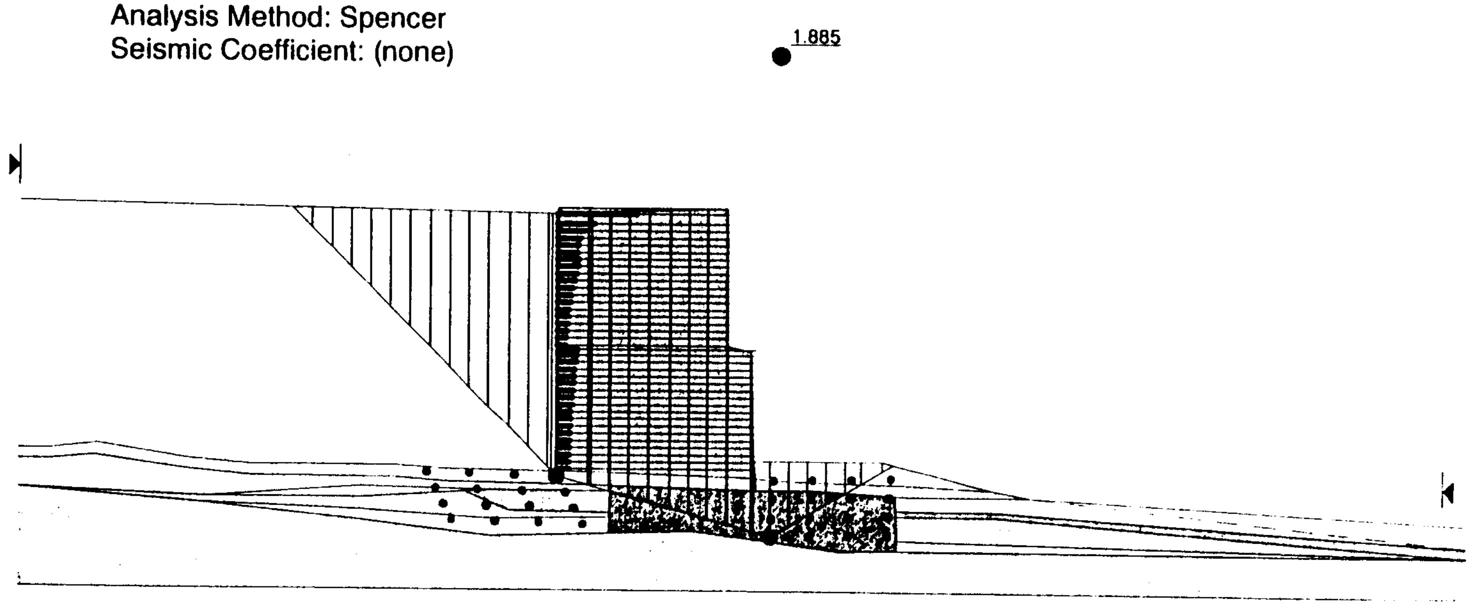
Description: 3R Station North Safety Area (60% Design)
Comments: Station 50+00 (HC 110+47) SS Global (Block Search)
File Name: NSA50+0060%globalbs.slp
Last Saved Date: 9/19/00
Last Saved Time: 6:29:49 PM
Analysis Method: Spencer
Seismic Coefficient: (none)



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Third Runway Project - NSA Wall Stability Analysis **J-4978-30**
30% Design
September 27, 2000

Summary of Stability Analysis

Section/Station: 44+75
(nearby HC 105+20)

COMPOUND STABILITY

#	Design Scenario	Target FS	Surface 1 (blk)	Surface 2 (cir)	Surface 3 (cir)	Surface 4 (cir)	Surface 5 (blk)	Surface 6 (blk)
1	Steady state (Spencer)	1.5	**1.66**	**3.30**	**1.68**	**1.62**	**2.10**	**2.46**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.24**	**1.77**	**1.13**	**1.15**	**1.53**	**1.64**

GLOBAL STABILITY

#	Design Scenario	Target FS	Circle Search	Block Search
1	Steady state (Spencer)	1.5	**1.75**	**1.70**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.26**	**1.23**

NOTES: (1) Reinforced Fill: γ = 140 pcf, ϕ = 34°; Embankment Fill: γ = 135 pcf, ϕ = 35°

Description: NSA Wall Stability
Comments: STA 44+75 60% Design SS
File Name: NSA44+7560%fsss.slp
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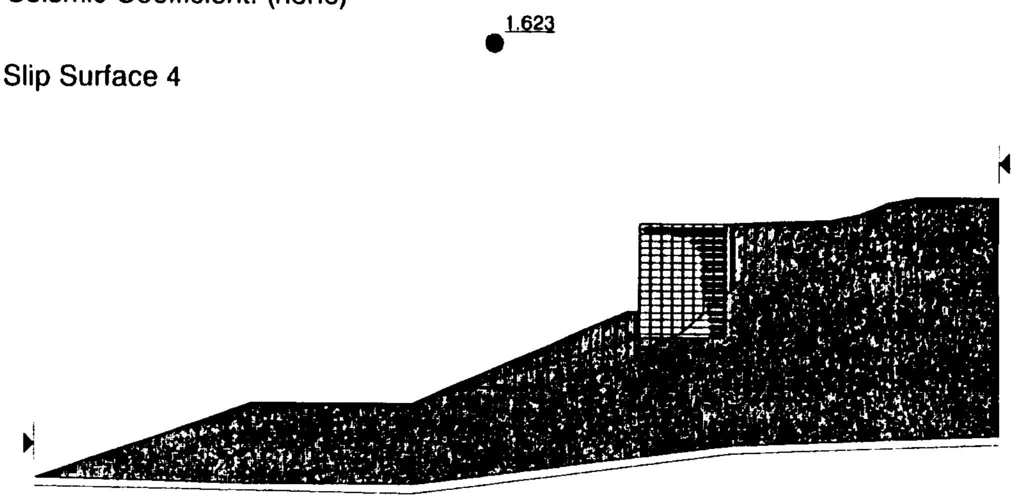
Last Saved Time: 12:24:26 PM
Analysis Method: Spencer
Seismic Coefficient: (none)

Slip Surface 4



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Description: NSA Wall Stability
Comments: STA 44+75 60% Design 475-yr
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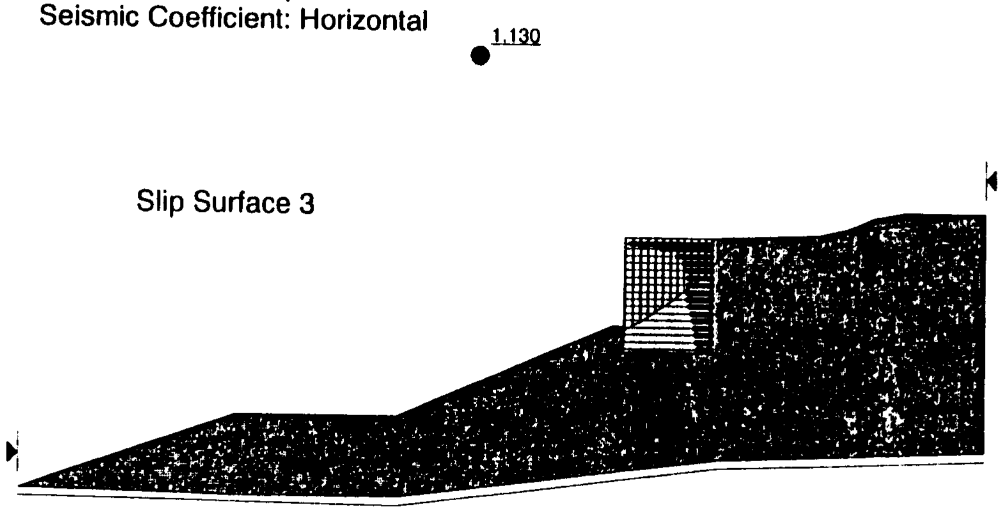
Analysis Method: Spencer
Seismic Coefficient: Horizontal



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West Wall

Station	# of Tiers	Exposed Height, ft	Total Height incl. Embedment, ft	Embedment, ft	Embedment Ratio, H/x	Strip Length, ft	Ratio of Strip Length to Exposed Height	*** is a flag for ratio<0.8
172+25	1	3.6	4.55	0.95	3.79	10.00	2.78	
172+50	1	8	9.66	1.66	4.82	12.00	1.50	
172+75	1	12.2	17.23	5.03	2.43	20.00	1.64	
173+00	1	16.5	21.11	4.61	3.58	24.00	1.45	
173+25	1	20.5	25	4.50	4.56	28.00	1.37	
173+50	**2**	**24.19**	**30.99**	**6.80**	**3.56**	**42.00**	**1.74**	
173+75	2	29.09	35.09	6.00	4.85	44.00	1.51	
174+00	2	33.36	38.86	5.50	6.07	48.00	1.44	
174+25	2	37.45	46.45	9.00	4.16	52.00	1.39	
174+50	2	41.63	50.43	8.80	4.73	52.00	1.25	
174+75	2	45.81	54.31	8.50	5.39	54.00	1.18	
175+00	2	49.9	57.9	8.00	6.24	54.00	1.08	
175+25	2	54.25	65.75	11.50	4.72	62.00	1.14	
175+50	2	58.83	69.83	11.00	5.35	64.00	1.09	
175+75	3	63.57	72.57	9.00	7.06	68.00	1.07	
176+00	3	72.79	84.29	11.50	6.33	76.00	1.04	
176+25	3	76.34	87.84	11.50	6.64	76.00	1.00	
176+50	3	84.25	95.25	11.00	7.66	80.00	0.95	
176+75	3	94.67	109.67	15.00	6.31	90.00	0.95	
177+00	4	102.2	112.2	10.00	10.22	88.00	0.86	
177+25	4	106.25	118.25	12.00	8.85	92.00	0.87	
177+50	4	118.81	130.81	12.00	9.90	102.00	0.86	
177+75	4	125.14	138.14	13.00	9.63	108.00	0.86	
178+00	4	128.96	137.96	9.00	14.33	108.00	0.84	
178+25	4	131.24	138.74	7.50	17.50	108.00	0.82	
178+50	4	131.89	138.89	7.00	18.84	108.00	0.82	
178+75	4	132.17	139.17	7.00	18.88	108.00	0.82	

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179+00	4	131.11	138.11	7.00	18.73	108.00	0.82	
179+25	4	132.51	139.51	7.00	18.93	108.00	0.82	
179+50	4	132.62	139.62	7.00	18.95	108.00	0.81	
179+75	4	133.61	140.61	7.00	19.09	108.00	0.81	
180+00	**4**	**133.5**	**140.3**	**6.80**	**19.63**	**108.00**	**0.77**	***
180+25	4	132.04	140.04	8.00	16.51	108.00	0.82	
180+50	4	129.7	140.5	10.80	12.01	110.00	0.85	
180+75	4	127.27	140.77	13.50	9.43	110.00	0.86	
181+00	4	124.72	140.72	16.00	7.80	110.00	0.88	
181+25	4	122.21	141.21	19.00	6.43	110.00	0.90	
181+50	4	118.84	137.34	18.50	6.42	106.00	0.89	
181+75	4	115.22	134.22	19.00	6.06	106.00	0.92	
182+00	4	111.92	130.92	19.00	5.89	102.00	0.91	
182+25	4	107.29	123.29	16.00	6.71	96.00	0.89	
182+50	4	103.75	119.75	16.00	6.48	94.00	0.91	
182+75	4	100.41	116.41	16.00	6.28	92.00	0.92	
183+00	4	96.99	112.99	16.00	6.06	88.00	0.91	
183+25	3	92.77	105.27	12.50	7.42	86.00	0.93	
183+50	3	88.34	98.34	10.00	8.83	82.00	0.93	
183+75	3	82.9	94.9	12.00	6.91	82.00	0.99	
184+00	**3**	**76.33**	**87.33**	**11.00**	**6.94**	**76.00**	**1.00**	
184+25	3	70.1	80.6	10.50	6.68	72.00	1.03	
184+50	3	62.82	70.82	8.00	7.85	66.00	1.05	
184+75	2	56.74	65.74	9.00	6.30	60.00	1.06	
185+00	2	51.06	58.56	7.50	6.81	54.00	1.06	
185+25	2	41.49	47.69	6.20	6.69	50.00	1.21	
185+50	2	33.94	38.94	5.00	6.79	46.00	1.36	
185+75	2	26.71	30.71	4.00	6.68	40.00	1.50	
186+00	**1**	**20.4**	**22.6**	**2.20**	**9.27**	**26.00**	**1.27**	
186+25	1	13.2	18.98	5.78	2.28	22.00	1.67	
186+50	1	5.8	10.54	4.74	1.22	12.00	2.07	

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Third Runway Project - West Wall Stability Analysis **J-4978-30**
30% Design
September 27, 2000

Summary of Stability Analysis

Section/Station: 180+00
(HC F-F')

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COMPOUND STABILITY

#	Design Scenario	Target FS	Surface 1 (blk)	Surface 2 (cir)
1	Steady state (Spencer)	1.5	**1.47**	**1.56**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.11**	**1.13**
3	Liquefaction (Spencer)	1.1	**1.48**	**1.55**

NOTES:

(1) Reinforced Fill: $\gamma = 140$ pcf, $\phi = 37°$; Embankment Fill: $\gamma = 140$ pcf; $\phi = 35°$
(2) Residual Shear Strength (cumulative mean to the 475-yr event) = 779 psf;
SD = 426 psf

GLOBAL STABILITY

#	Design Scenario	Target FS	Circle Search	Block Search
1	Steady state (Spencer)	1.5	**1.62**	**1.52**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.17**	**1.13**
3	Liquefaction (Spencer)	1.1	**1.61**	**1.51**

1C-B

Description: 4978-30 West Wall
Comments: Station 180+00 Steady State
File Name: 180+0030%SSblk.slp
Last Saved Date: 9/27/00
Last Saved Time: 5:13:15 PM
Analysis Method: Spencer
P.W.P. Option: Piezometric Lines / Ru
Seismic Coefficient: (none)

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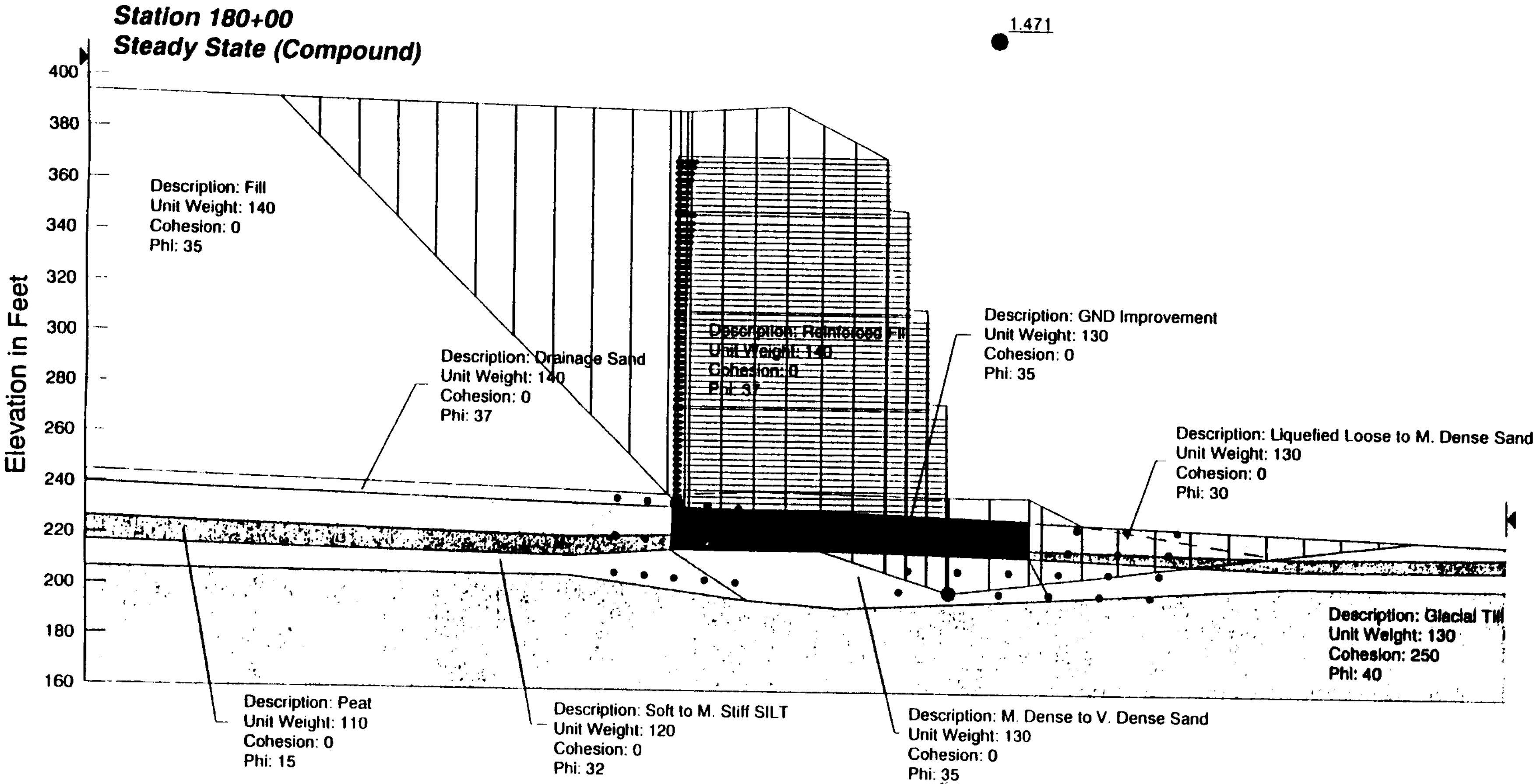

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Third Runway Project - West Wall Stability Analysis **J-4978-30**
30% Design
September 27, 2000

Summary of Stability Analysis

Section/Station: 184+00 (HC 183+80 or C-C')

COMPOUND STABILITY

#	Design Scenario	Target FS	Surface 1 (blk)	Surface 2 (blk)	Surface 3 (blk)	Surface 4 (cir)	Surface 5 (cir)	Surface 6 (cir)
1	Steady state (Spencer)	1.5	**1.70**	**1.68**	**1.53**	**1.46**	**1.73**	**1.48**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.35**	**1.24**	**1.14**	**1.11**	**1.25**	**1.11**

NOTES:

(1) Reinforced Fill: γ = 140 pcf, ϕ = 37°; Embankment Fill: γ = 140 pcf; ϕ = 35°

(2) Residual Shear Strength (cumulative mean to the 475-yr event) = 779 psf; SD = 426 psf

GLOBAL STABILITY

#	Design Scenario	Target FS	Circle Search	Block Search
1	Steady state (Spencer)	1.5	**1.47**	**1.53**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.11**	**1.18**
3	Liquefaction (Spencer)	1.1	**1.47**	**1.53**

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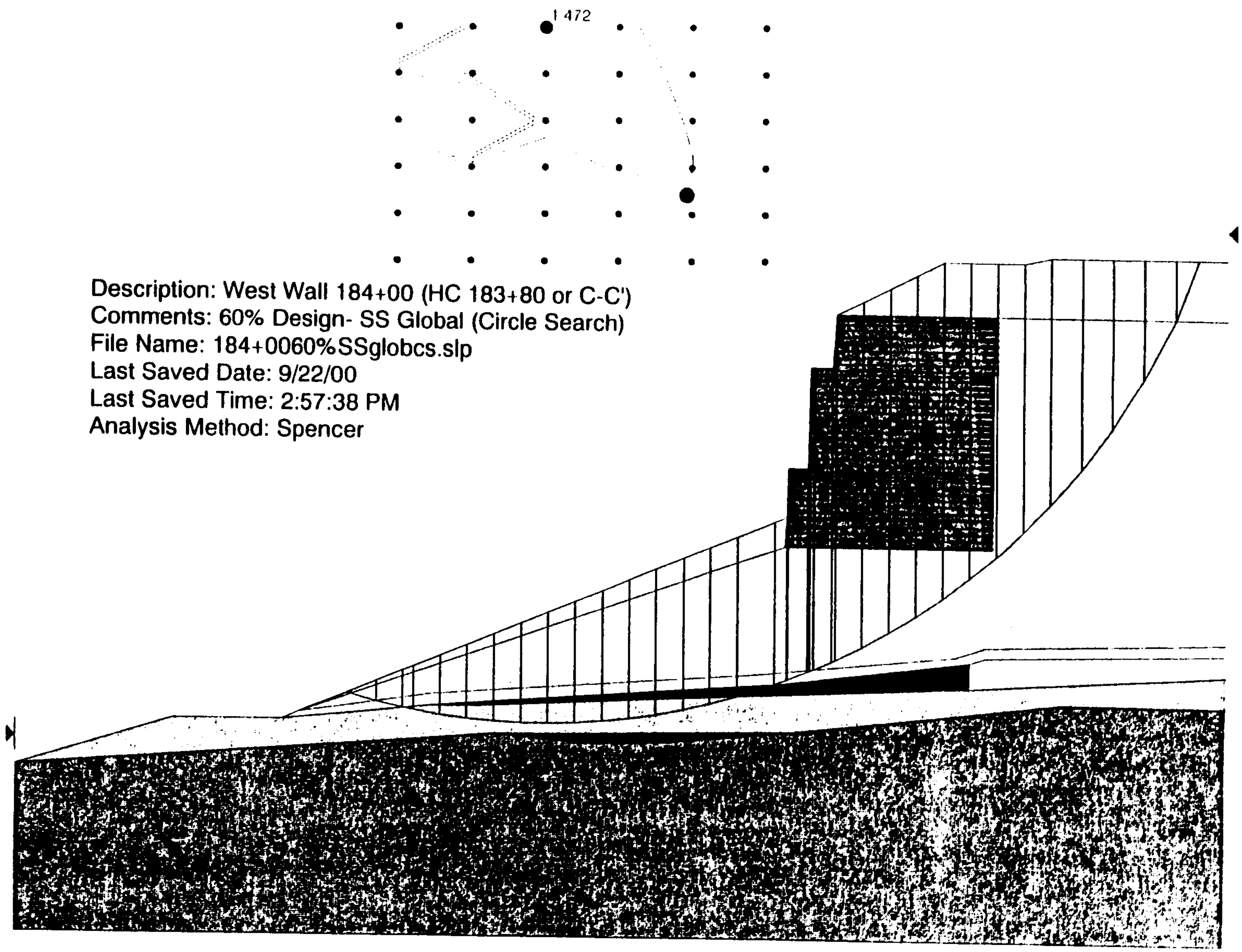

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Comments: 60% Design- SS Global (Circle Search)
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Last Saved Date: 9/22/00
Last Saved Time: 2:57:38 PM
Analysis Method: Spencer

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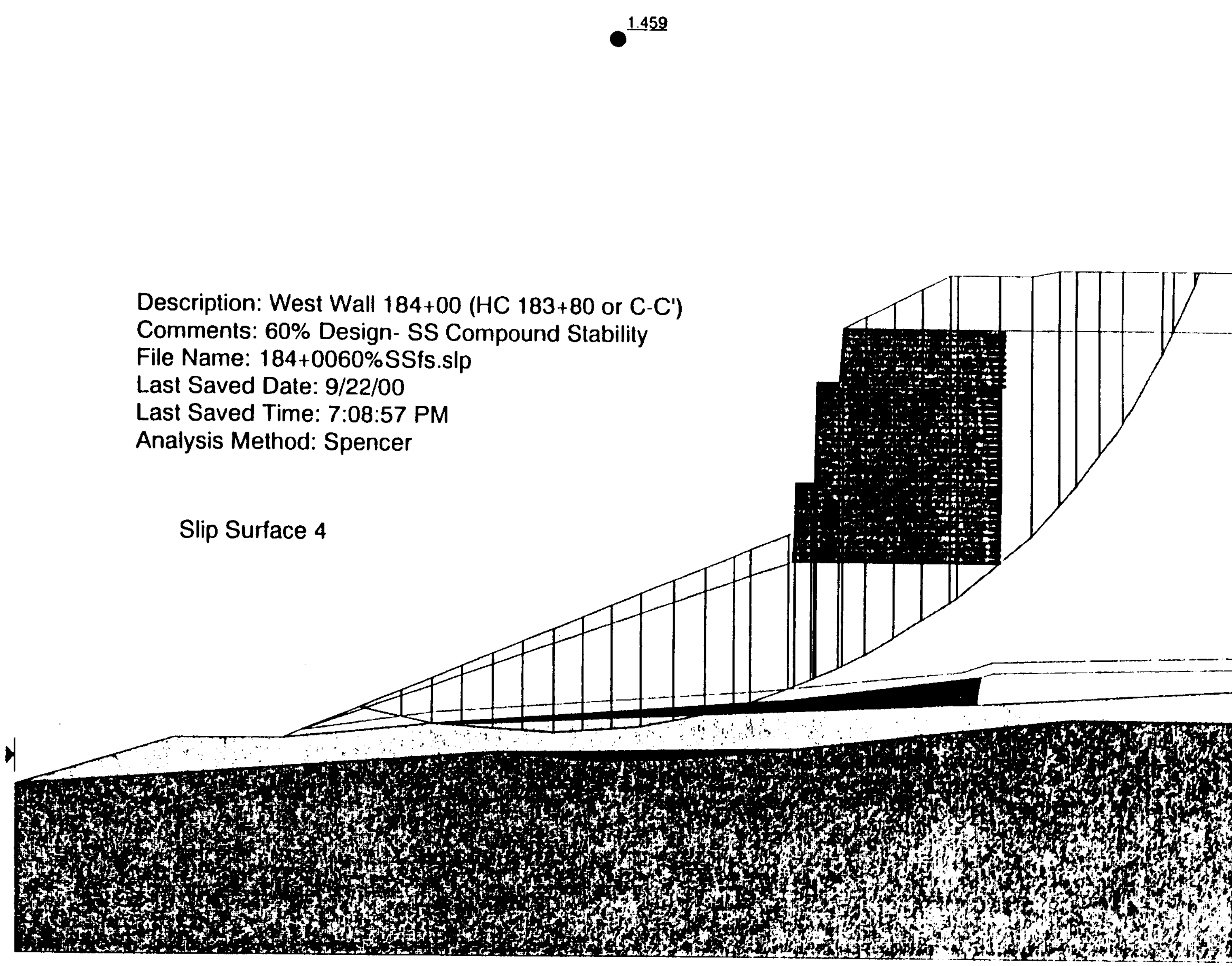

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Comments: 60% Design- SS Compound Stability
File Name: 184+0060%SSfs.slp
Last Saved Date: 9/22/00
Last Saved Time: 7:08:57 PM
Analysis Method: Spencer

Slip Surface 4

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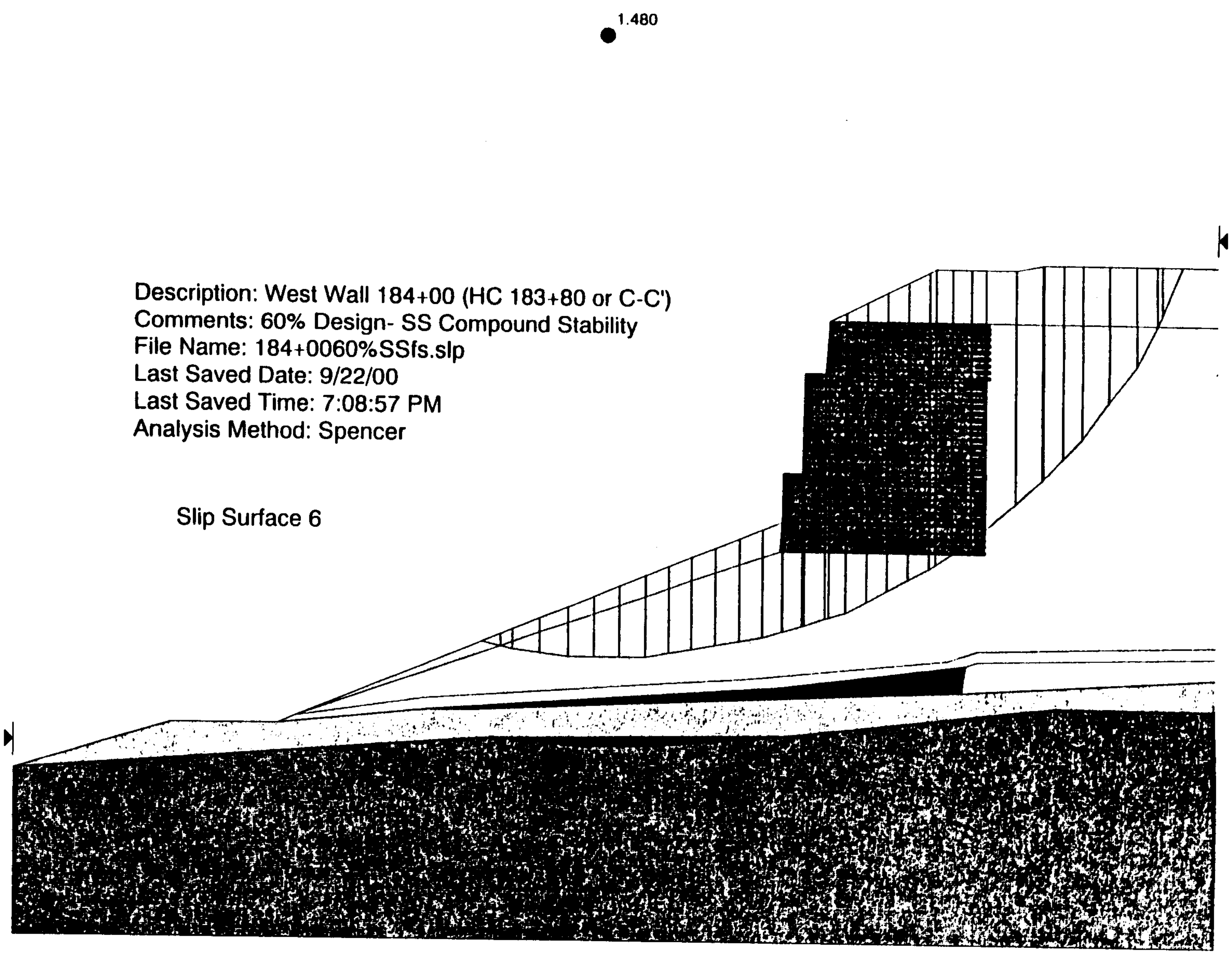

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Comments: 60% Design- SS Compound Stability
File Name: 184+0060%SSfs.slp
Last Saved Date: 9/22/00
Last Saved Time: 7:08:57 PM
Analysis Method: Spencer

Slip Surface 6

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Third Runway Project - West Wall Stability Analysis **J-4978-30**
30% Design
September 27, 2000

Summary of Stability Analysis

Section/Station: 173+50
(HC 1+82)

COMPOUND STABILITY

#	Design Scenario	Target FS	Surface 1 (blk)	Surface 2 (blk)	Surface 3 (blk)	Surface 4 (cir)	Surface 5 (cir)	Surface 6 (cir)
1	Steady state (Spencer)	1.5	**1.82**	**1.74**	**1.60**	**1.73**	**1.67**	**1.60**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.39**(2)	**1.32**(2)	**1.13**(2)	**1.22**(2)	**1.21**(2)	**1.10**(2)
3	Liquefaction (Spencer)	1.1	**1.82**	**1.74**	**1.69**	**1.73**	**1.67**	**1.64**

NOTES:

(1) Reinforced Fill: $\gamma = 140$ pcf, $\phi = 37°$; Embankment Fill: $\gamma = 135$ pcf; $\phi = 34°$

(2) Reinforced Fill: $\gamma = 140$ pcf, $\phi = 37°$; Embankment Fill: $\gamma = 135$ pcf; $\phi = 35°$

(3) Residual Shear Strength (cumulative mean to the 475-yr event) = 779 psf;
SD = 426 psf

GLOBAL STABILITY

#	Design Scenario	Target FS	Circle Search	Block Search
1	Steady state (Spencer)	1.5	**1.52**	**1.60**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.07**(2)	**1.10**(2)
3	Liquefaction (Spencer)	1.1	**1.52**	**1.62**

DRAFT

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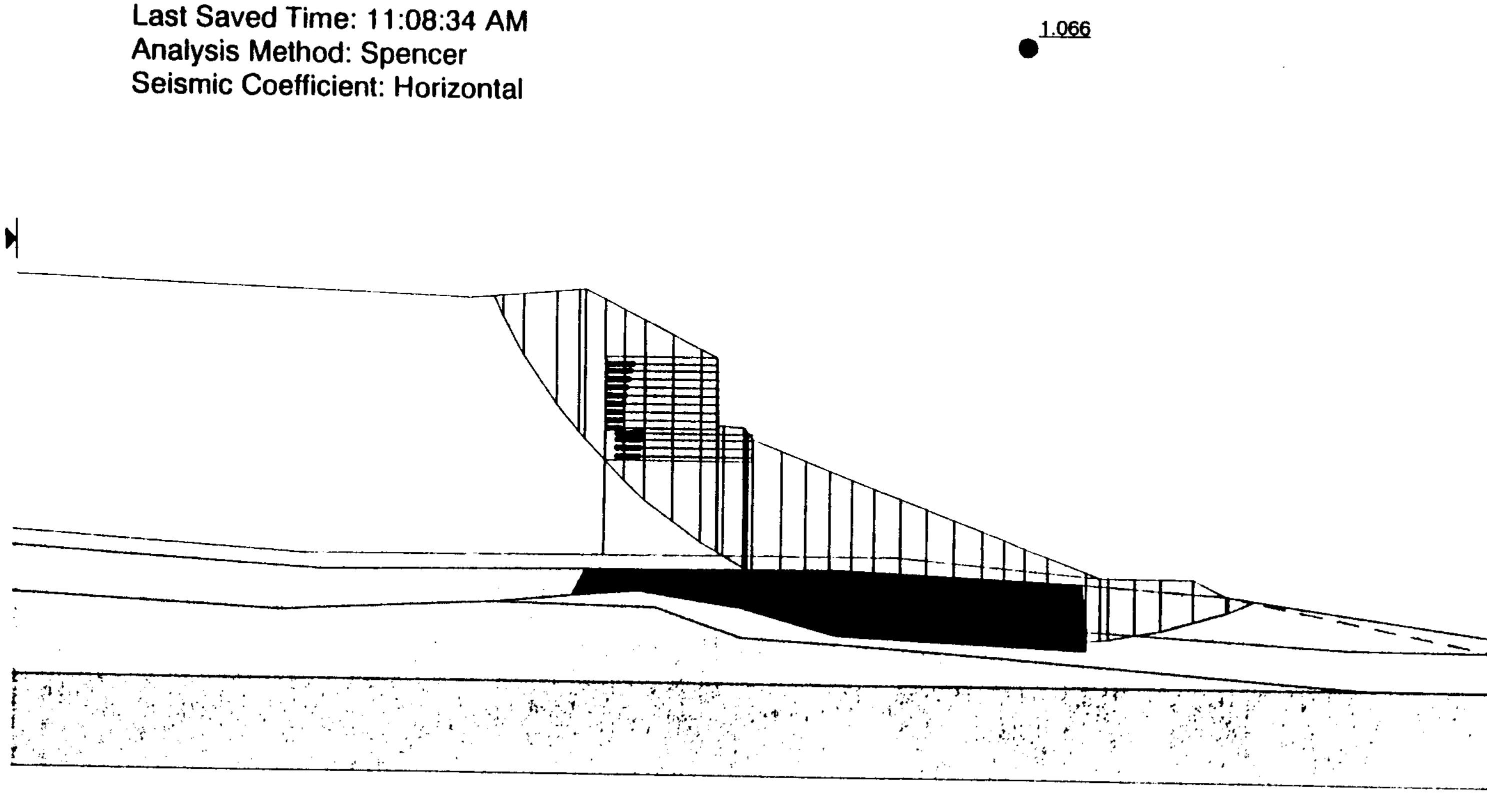
Description: West Wall 173+50 (HC 1+82 or A-A')
Comments: 60% Design- Pseudostatic Global (Circle)
File Name: 173+5060%475globcs.slp
Last Saved Date: 9/27/00
Last Saved Time: 11:08:34 AM
Analysis Method: Spencer
Seismic Coefficient: Horizontal



Third Runway Project - West Wall Stability Analysis **J-4978-30**
30% Design
September 27, 2000

Summary of Stability Analysis Section/Station: 186+00

COMPOUND STABILITY

#	Design Scenario	Target FS	Surface 1 (cir)	Surface 2 (blk)	Surface 3 (blk)	Surface 4 (blk)	Surface 5 (cir)	Surface 6 (cir)
1	Steady state (Spencer)	1.5	**1.73**	**1.50**	**1.51**	**1.65**	**1.54**	**1.57**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.18**	**1.13**	**1.03**	**1.09**	**1.09**	**1.12**

NOTES:

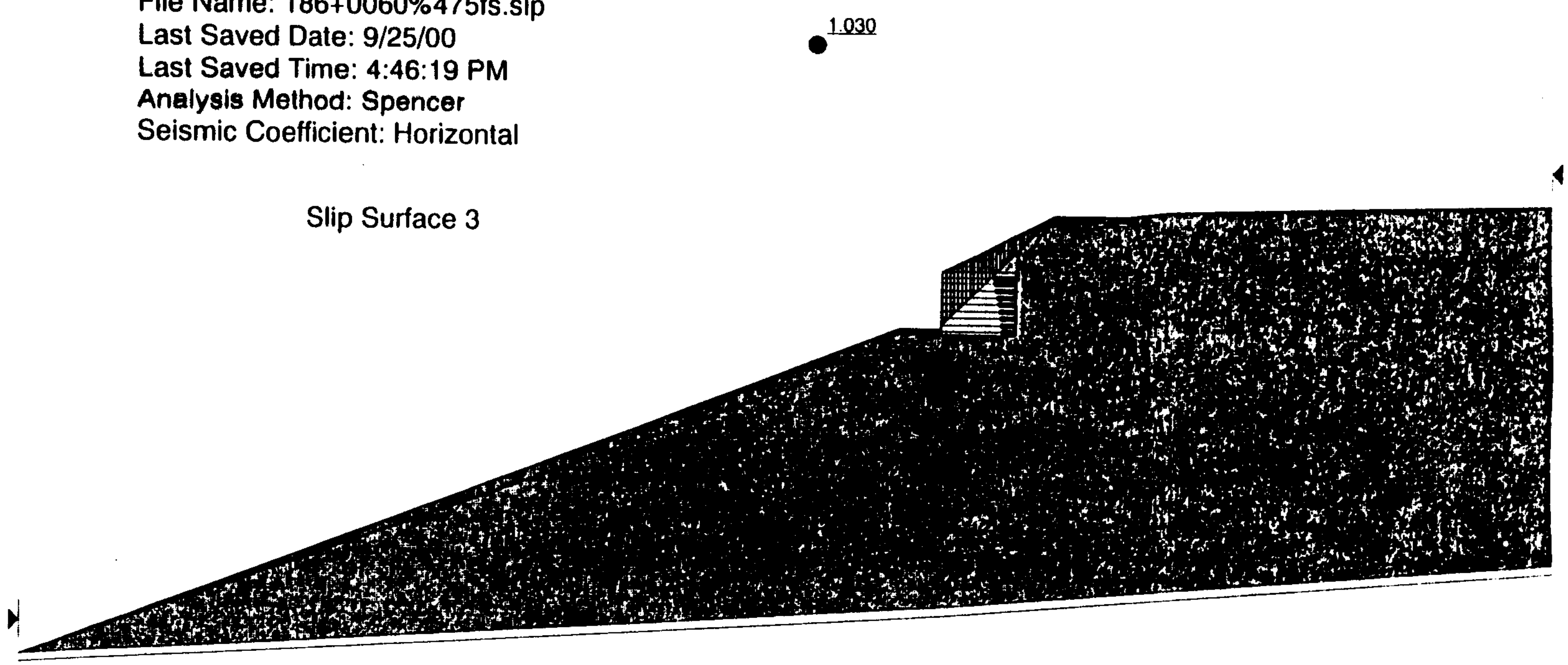
(1) Reinforced Fill: γ = 140 pcf, ϕ = 37°; Embankment Fill: γ = 135 pcf; ϕ = 35°

(2) Residual Shear Strength (cumulative mean to the 475-yr event) = 779 psf;
SD = 426 psf

GLOBAL STABILITY

#	Design Scenario	Target FS	Circle Search	Block Search
1	Steady state (Spencer)	1.5	**1.60**	**1.57**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.15**	**1.31**

Description: West Wall Stability
Comments: STA 186+00 60% Design Pseudostatic (Block)
File Name: 186+0060%475fs.slp
Last Saved Date: 9/25/00
Last Saved Time: 4:46:19 PM
Analysis Method: Spencer
Seismic Coefficient: Horizontal



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AR 046326

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South Wall

Station	# of Tiers	Exposed Height, ft	Total Height incl. Embedment, ft	Embedment, ft	Embedment Ratio, H/x	Strip Length, ft	Ratio of Strip Length to Exposed Height	*** is a flag for ratio<0.8
139+75	1	21.10	25.5	4.40	4.80	30.00	1.42	
139+75**	1	20.00	24.4	4.40	4.55	30.00	1.50	
140+00	1	25.50	29.5	4.00	6.38	34.00	1.33	
140+00**	1	24.20	28.2	4.00	6.05	34.00	1.40	
140+25	1	29.50	31.5	2.00	14.75	36.00	1.22	
140+25**	1	27.60	29.6	2.00	13.80	36.00	1.30	
140+75	1	29.60	34	4.40	6.73	38.00	1.28	
140+75**	1	28.00	32.4	4.40	6.36	38.00	1.36	
141+00	1	35.40	38	2.60	13.62	42.00	1.19	
141+00**	1	33.80	36.4	2.60	13.00	42.00	1.24	
141+10	1	36.50	40.5	4.00	9.13	44.00	1.21	
141+10**	1	36.20	40.2	4.00	9.05	44.00	1.22	
141+25	1	40.60	45	4.40	9.23	48.00	1.18	
141+25**	1	39.60	44	4.40	9.00	48.00	1.21	
142+75	**1**	**49.00**	**54**	**5.00**	**9.80**	**56.00**	**1.14**	
142+75**	1	48.60	53.6	5.00	9.72	56.00	1.15	
143+25	1	47.70	56.5	8.80	5.42	58.00	1.22	
143+25**	1	46.40	55.2	8.80	5.27	58.00	1.25	
143+50	1	43.30	51.5	8.20	5.28	54.00	1.25	
143+50**	1	43.60	51.8	8.20	5.32	54.00	1.24	
143+75	1	40.50	49.5	9.00	4.50	52.00	1.28	
143+75**	1	39.40	48.4	9.00	4.38	52.00	1.32	
145+50	1	42.20	47	4.80	8.79	50.00	1.18	
145+50**	1	42.60	47.4	4.80	8.88	50.00	1.17	
146+36	1	23.60	27	3.40	6.94	32.00	1.36	
146+36**	1	22.80	26.2	3.40	6.71	32.00	1.40	
146+50	1	21.10	23.5	2.40	8.79	28.00	1.33	
146+50**	1	20.40	22.8	2.40	8.50	28.00	1.37	
146+63	1	17.60	20	2.40	7.33	24.00	1.36	
146+63**	1	16.80	19.2	2.40	7.00	24.00	1.43	
147+00	1	12.80	17	4.20	3.05	20.00	1.56	
147+00**	1	11.80	16	4.20	2.81	20.00	1.69	
147+25	**1**	**12.50**	**13.5**	**1.00**	**12.50**	**16.00**	**1.28**	
147+25**	1	11.50	12.5	1.00	11.50	16.00	1.39	
147+50	1	8.90	11.5	2.60	3.42	14.00	1.57	
147+75	1	7.00	8	1.00	7.00	10.00	1.43	

Third Runway Project - South Wall Stability Analysis **J-4978-30**
30% Design
September 27, 2000

Summary of Stability Analysis Section/Station: 142+75
(HC 183+10)

COMPOUND STABILITY

#	Design Scenario	Target FS	Surface 1 (blk)	Surface 2 (blk)	Surface 3 (blk)	Surface 4 (cir)	Surface 5 (cir)	Surface 6 (cir)	Surface 7 (blk)
1	Steady state (Spencer)	1.5	**1.58**	**1.52**	**1.82 (Spencer) 1.58 (Bishop-Janbu)**	**1.33 (Spencer) 1.35 (Bishop-Janbu)**	**1.46 (Spencer) 1.46 (M-P)**	**1.57**	**1.52**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.21**	**1.16**	**1.14 (Bishop-Janbu)**	**0.97 (Bishop-Janbu)**	**1.06 (M-P)**	**1.10**	**1.13**
3	Liquefaction (Spencer)	1.1	**1.58**	**1.52**	**1.82**	**1.33**	**1.46**	**1.57**	**1.52**

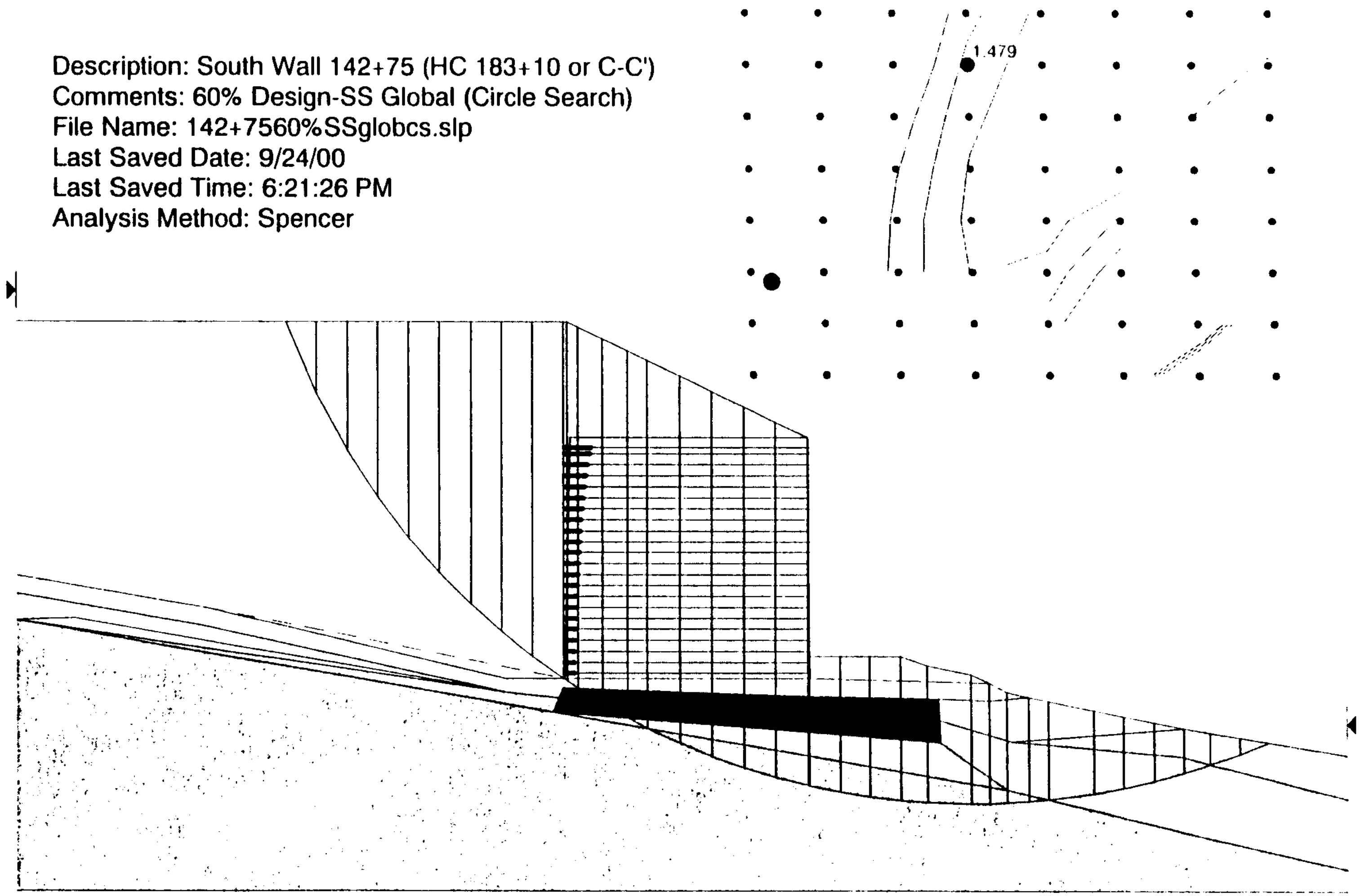
NOTES:
(1) Reinforced Fill: $\gamma = 140$ pcf, $\phi = 34°$; Embankment Fill: $\gamma = 135$ pcf; $\phi = 35°$
(2) Residual Shear Strength (cumulative mean to the 475-yr event) = 767 psf;
SD = 512 psf

GLOBAL STABILITY

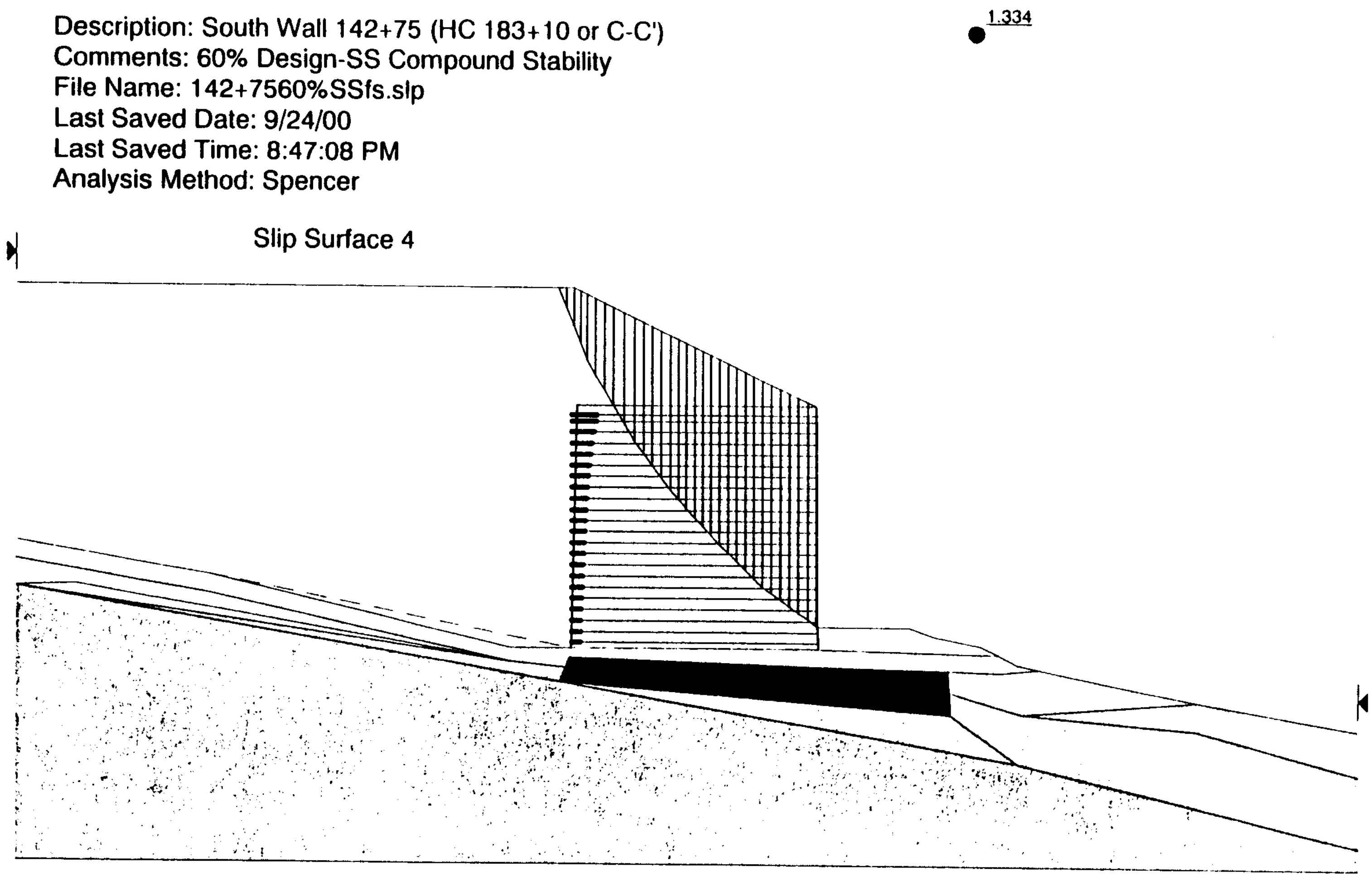
#	Design Scenario	Target FS	Circle Search	Block Search
1	Steady state (Spencer)	1.5	**1.48**	**1.57**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.10**	**1.17**
3	Liquefaction (Spencer)	1.1	**1.48**	**1.57**

DRAFT

Description: South Wall 142+75 (HC 183+10 or C-C')
Comments: 60% Design-SS Global (Circle Search)
File Name: 142+7560%SSglobcs.slp
Last Saved Date: 9/24/00
Last Saved Time: 6:21:26 PM
Analysis Method: Spencer



Description: South Wall 142+75 (HC 183+10 or C-C')
Comments: 60% Design-SS Compound Stability
File Name: 142+7560%SSfs.slp
Last Saved Date: 9/24/00
Last Saved Time: 8:47:08 PM
Analysis Method: Spencer



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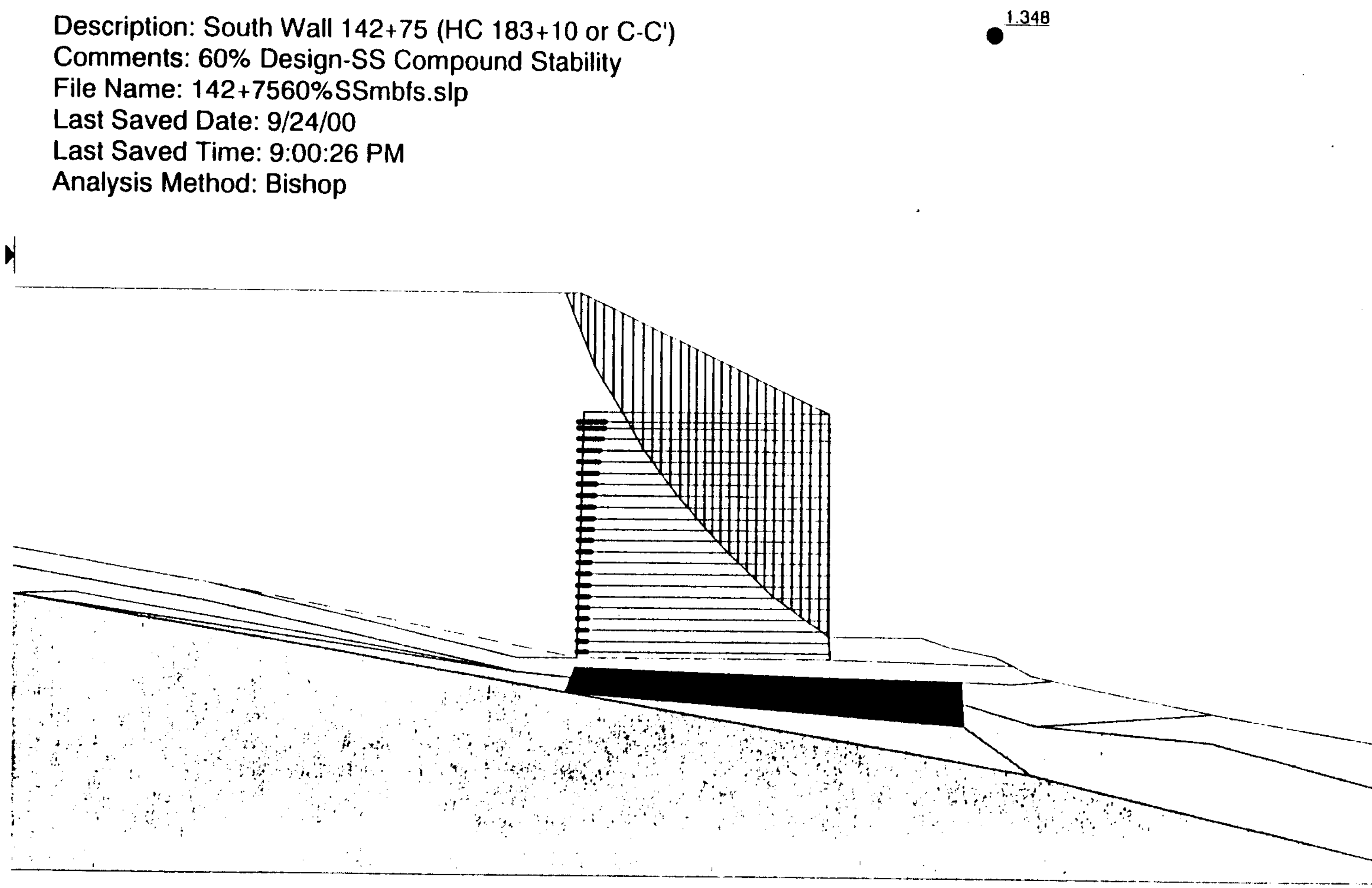
AR 046330

Description: South Wall 142+75 (HC 183+10 or C-C')
Comments: 60% Design-SS Compound Stability
File Name: 142+7560%SSmbfs.slp
Last Saved Date: 9/24/00
Last Saved Time: 9:00:26 PM
Analysis Method: Bishop



DRAFT

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DRAFT

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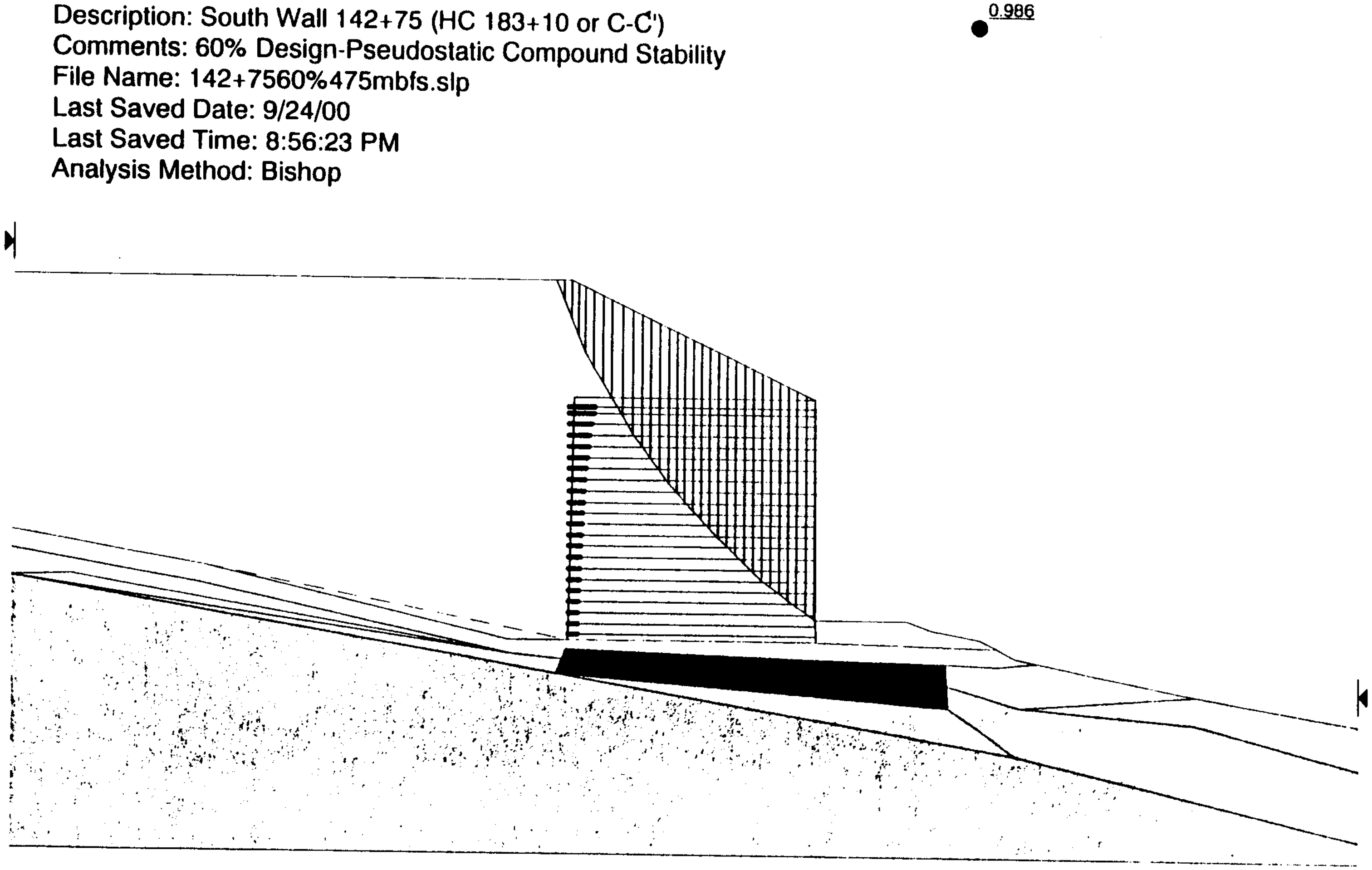
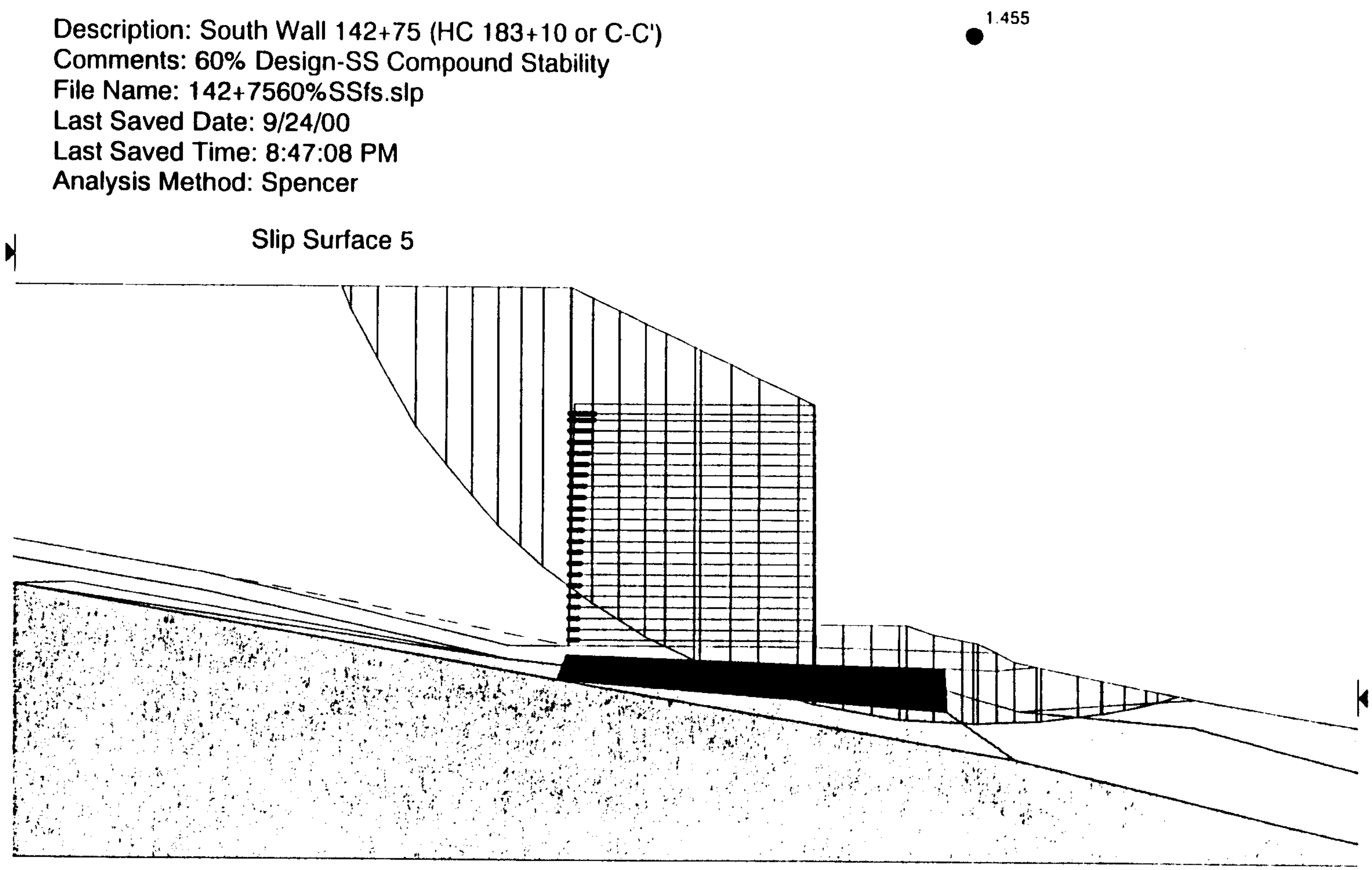
Description: South Wall 142+75 (HC 183+10 or C-C')
Comments: 60% Design-Pseudostatic Compound Stability
File Name: 142+7560%475mbfs.slp
Last Saved Date: 9/24/00
Last Saved Time: 8:56:23 PM
Analysis Method: Bishop



Description: South Wall 142+75 (HC 183+10 or C-C')
Comments: 60% Design-SS Compound Stability
File Name: 142+7560%SSfs.slp
Last Saved Date: 9/24/00
Last Saved Time: 8:47:08 PM
Analysis Method: Spencer

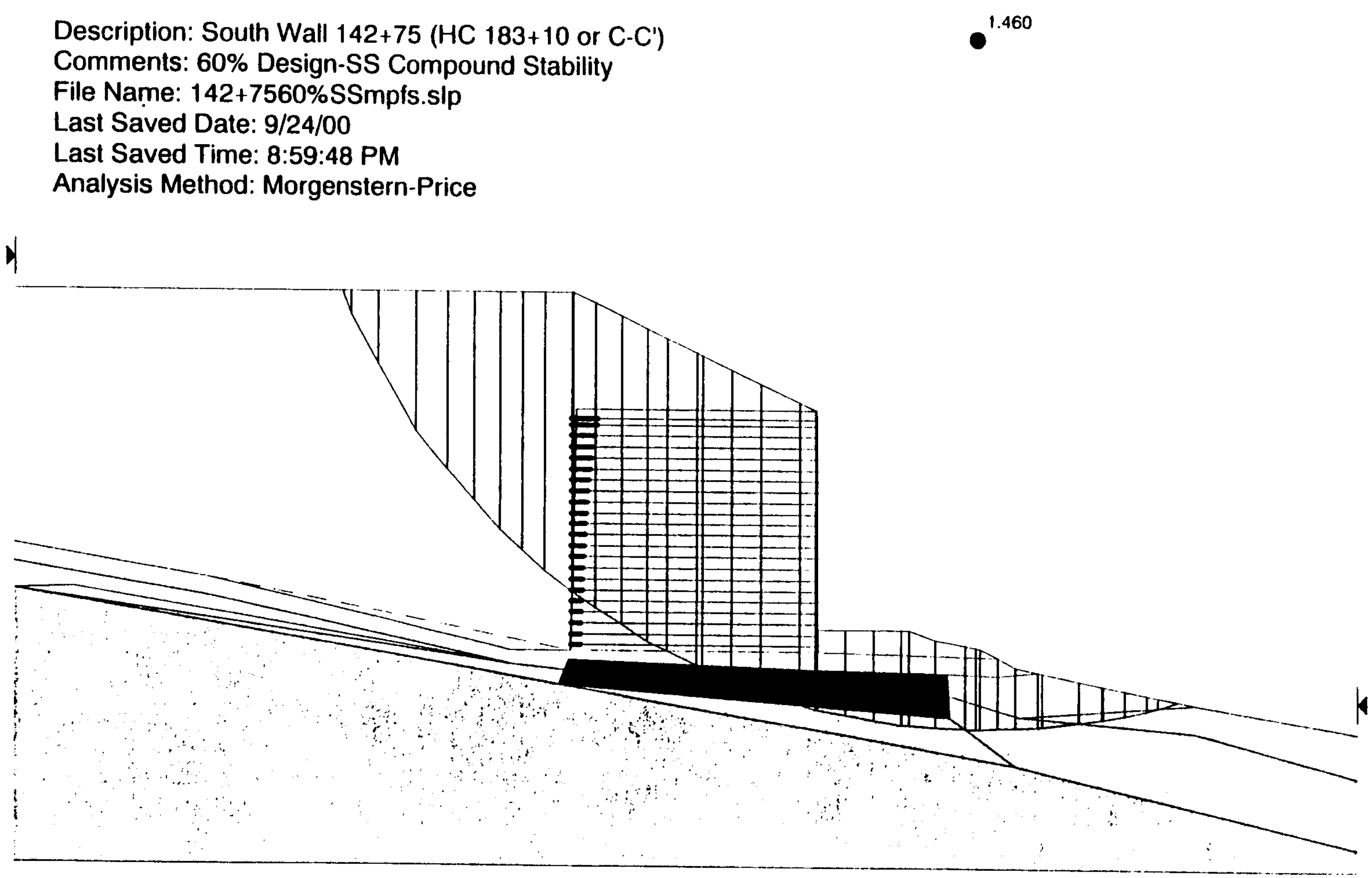


DRAFT

25

DRAFT

Description: South Wall 142+75 (HC 183+10 or C-C')
Comments: 60% Design-SS Compound Stability
File Name: 142+7560%SSmpfs.slp
Last Saved Date: 9/24/00
Last Saved Time: 8:59:48 PM
Analysis Method: Morgenstern-Price

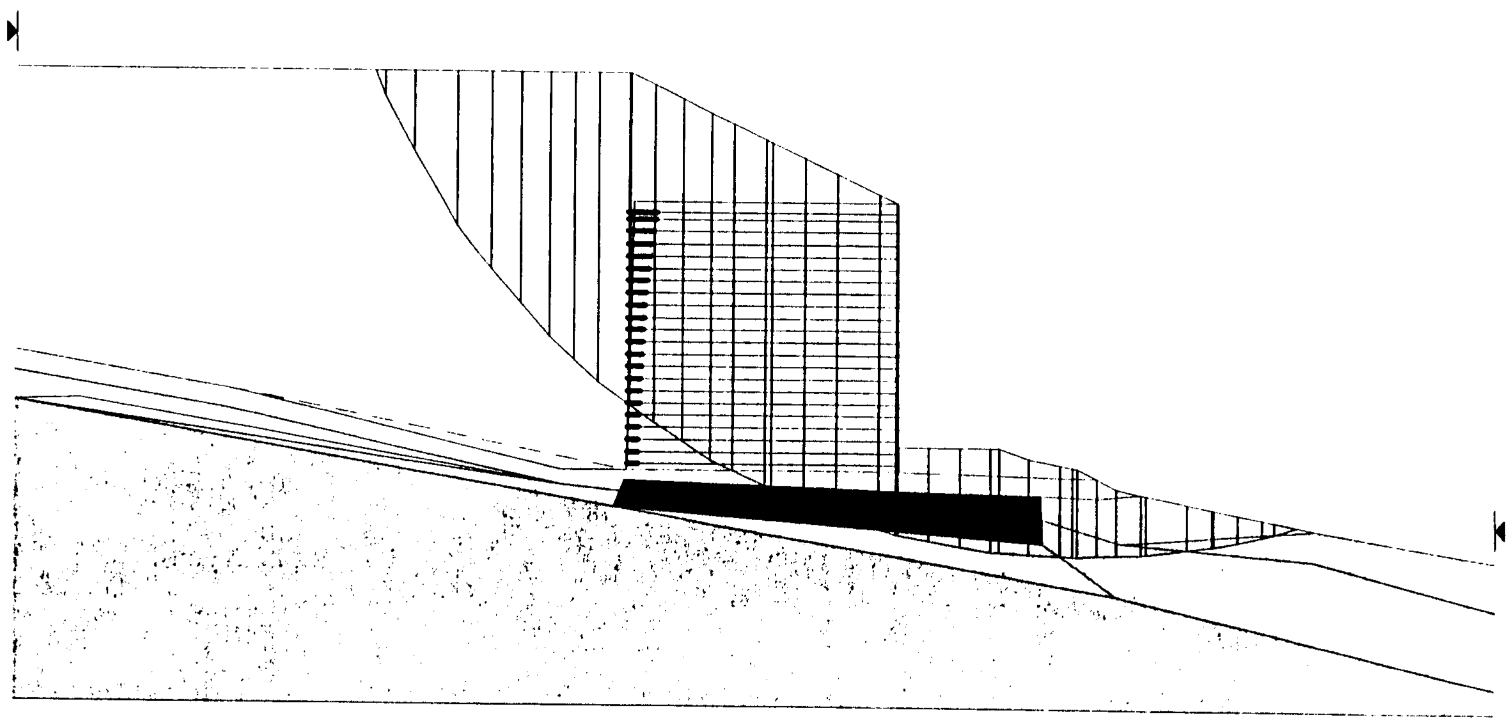


DRAFT

27

Description: South Wall 142+75 (HC 183+10 or C-C')
Comments: 60% Design-Pseudostatic Compound Stability
File Name: 142+7560%475mpfs.slp
Last Saved Date: 9/24/00
Last Saved Time: 8:55:31 PM
Analysis Method: Morgenstern-Price

1.058



Third Runway Project - South Wall Stability Analysis **J-4978-30**
September 26, 2000

Summary of Stability Analysis Section/Station: 147+25
(HC 147+50 or F-F')

COMPOUND STABILITY

#	Design Scenario	Target FS	Surface 1 (cir)	Surface 2 (cir)	Surface 3 (blk)	Surface 4 (blk)	Surface 5 (blk)	Surface 6 (cir)
1	Steady state (Spencer)	1.5	**1.37**	**1.47**	**1.39**	**1.53**	**1.50**	**1.49**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**0.95**	**1.01**	**1.01**	**1.16**	**1.09**	**1.03**

NOTES:

(1) Reinforced Fill: $\gamma = 140$ pcf, $\phi = 34°$; Embankment Fill: $\gamma = 135$ pcf; $\phi = 35°$
(2) Residual Shear Strength (cumulative mean to the 475-yr event) = 767 psf;
SD = 512 psf

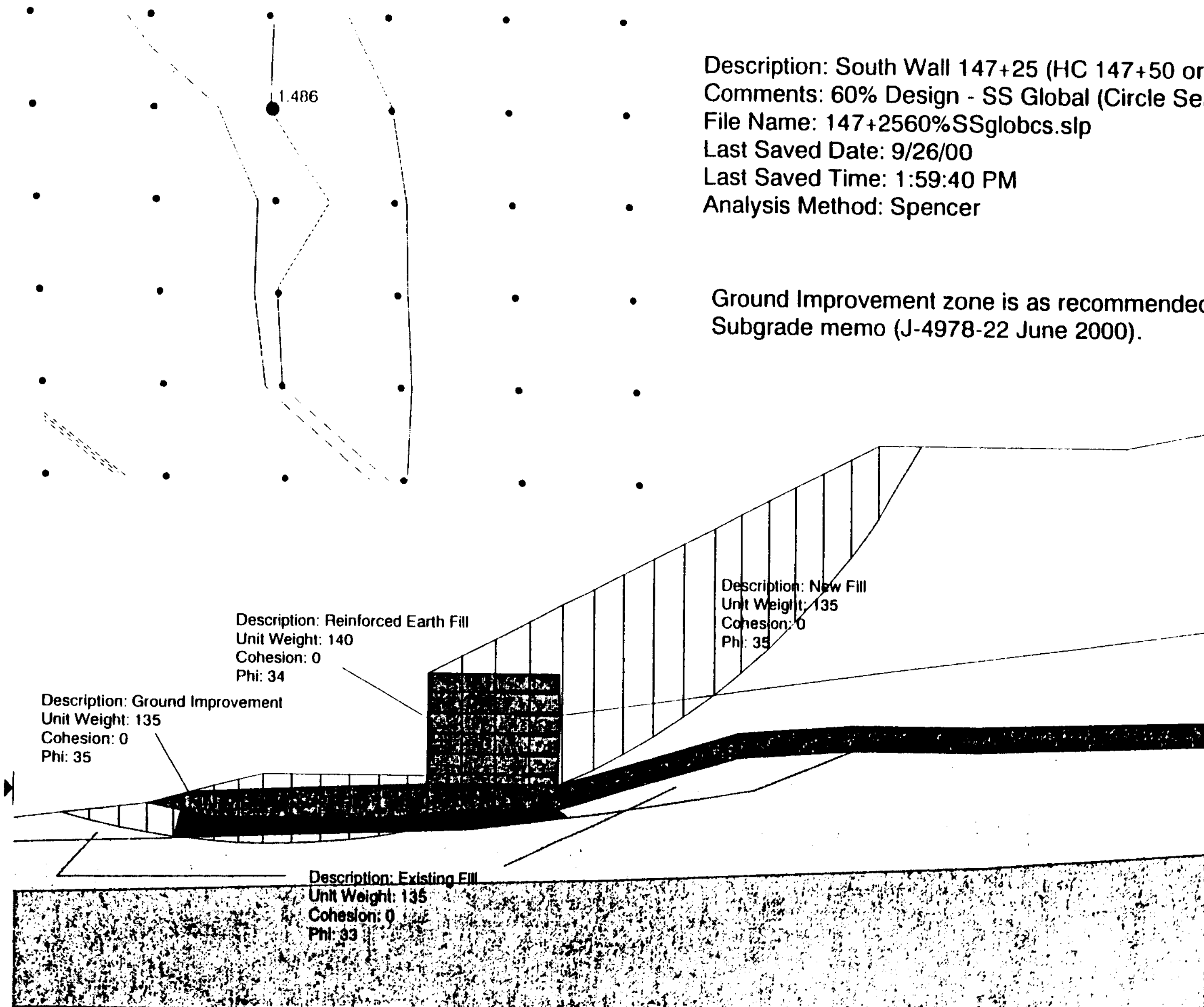
GLOBAL STABILITY

#	Design Scenario	Target FS	Circle Search	Block Search
1	Steady state (Spencer)	1.5	**1.49**	**1.67**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.04**	**1.26**

DRAFT

Description: South Wall 147+25 (HC 147+50 or F-F')
Comments: 60% Design - SS Global (Circle Search)
File Name: 147+2560%SSglobcs.slp
Last Saved Date: 9/26/00
Last Saved Time: 1:59:40 PM
Analysis Method: Spencer

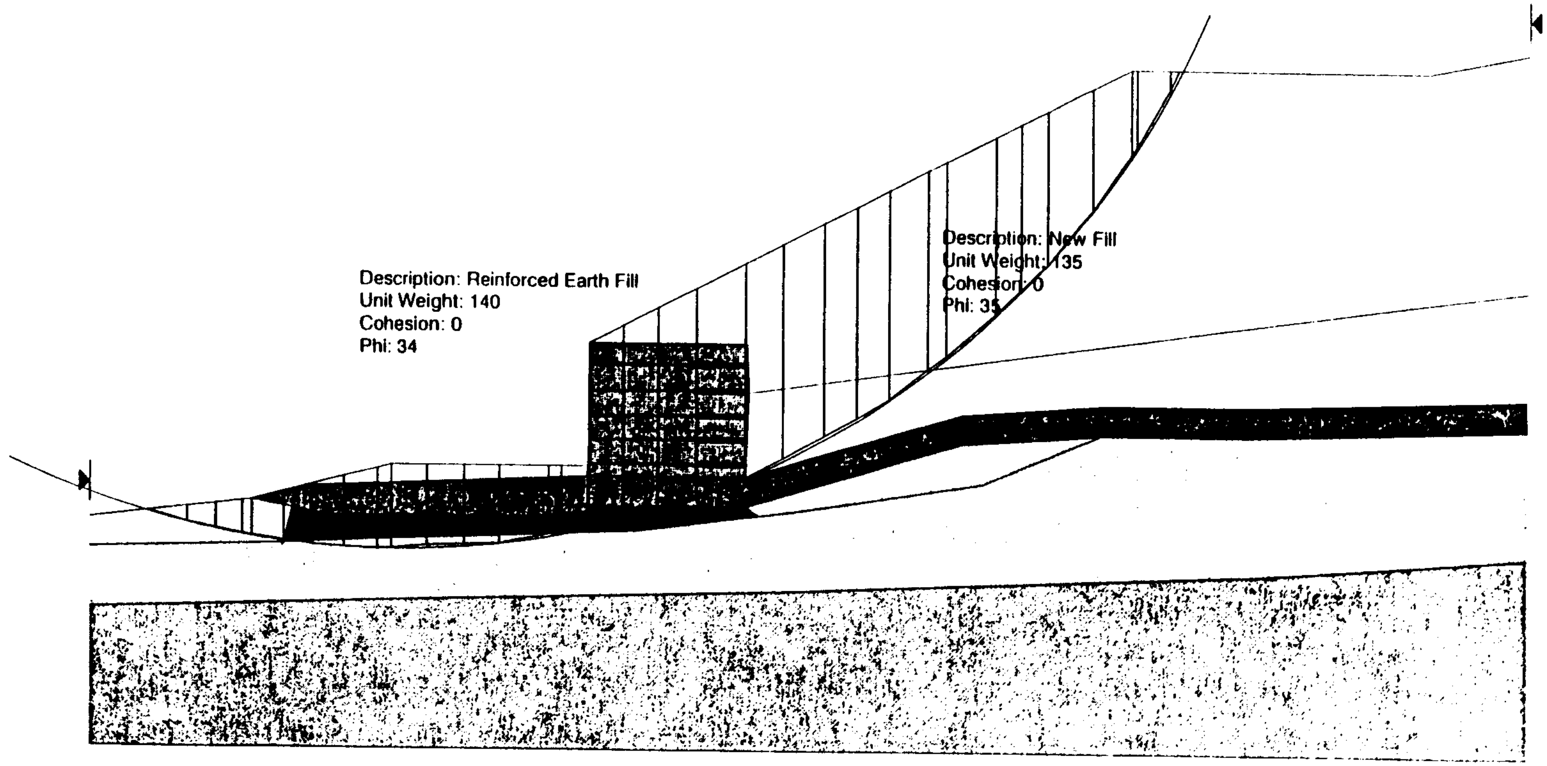
Ground Improvement zone is as recommended in Subgrade memo (J-4978-22 June 2000).



DRAFT

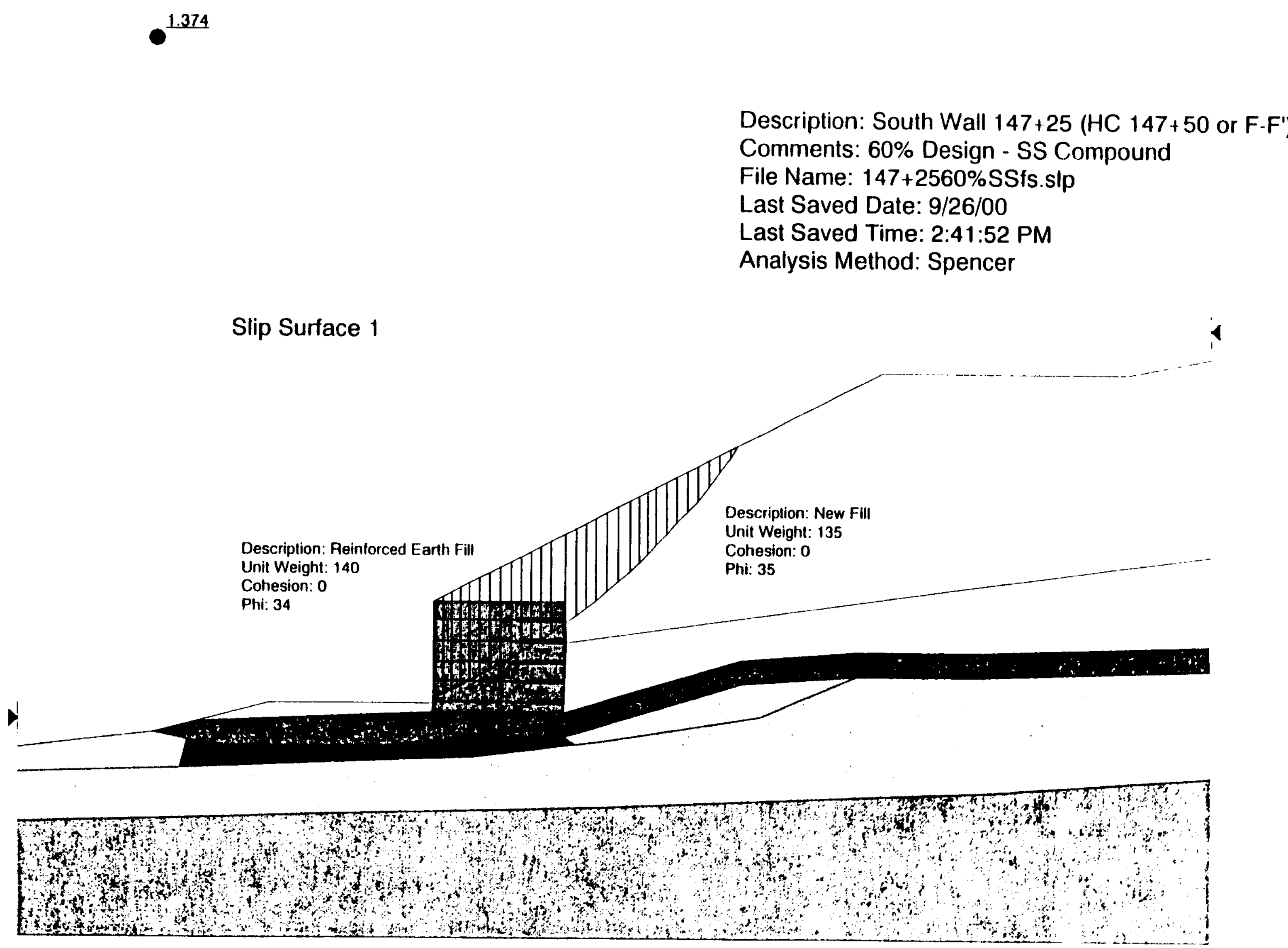
Description: South Wall 147+25 (HC 147+50 or F-F')
Comments: 60% Design - Pseudostatic Global (Circl
File Name: 147+2560%475globc.slp
Last Saved Date: 9/26/00
Last Saved Time: 1:35:42 PM
Analysis Method: Spencer

1.038



DRAFT

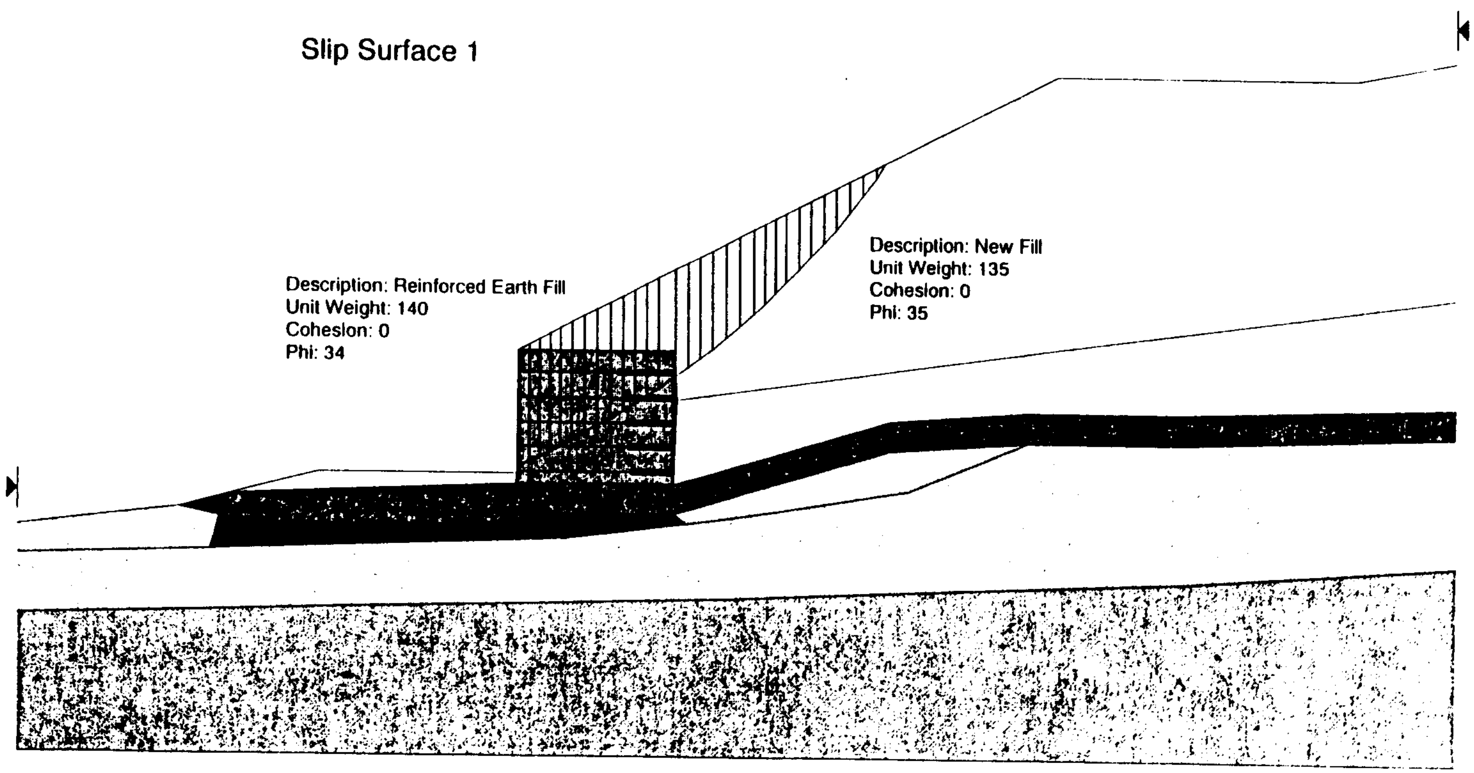
31



1.374
Description: South Wall 147+25 (HC 147+50 or F-F')
Comments: 60% Design - SS Compound
File Name: 147+2560%SSfs.slp
Last Saved Date: 9/26/00
Last Saved Time: 2:41:52 PM
Analysis Method: Spencer
Slip Surface 1
Description: Reinforced Earth Fill
Unit Weight: 140
Cohesion: 0
Phi: 34
Description: New Fill
Unit Weight: 135
Cohesion: 0
Phi: 35

0.950

Description: South Wall 147+25 (HC 147+50 or F-F')
Comments: 60% Design - Pseudostatic Compound
File Name: 147+2560%475fs.slp
Last Saved Date: 9/26/00
Last Saved Time: 2:44:32 PM
Analysis Method: Spencer



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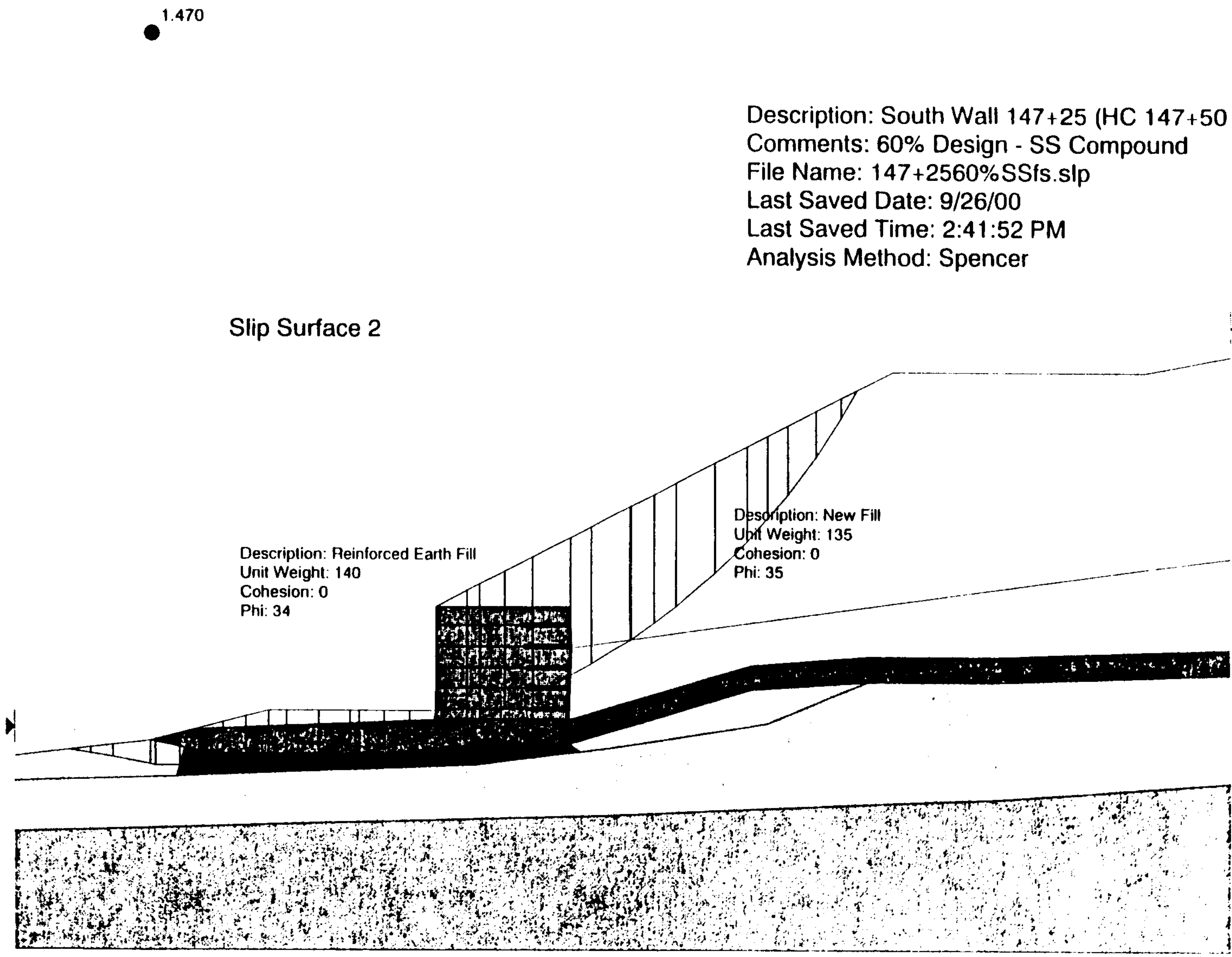
AR 046340

DRAFT

Description: South Wall 147+25 (HC 147+50 or F-F')
Comments: 60% Design - SS Compound
File Name: 147+2560%SSfs.slp
Last Saved Date: 9/26/00
Last Saved Time: 2:41:52 PM
Analysis Method: Spencer

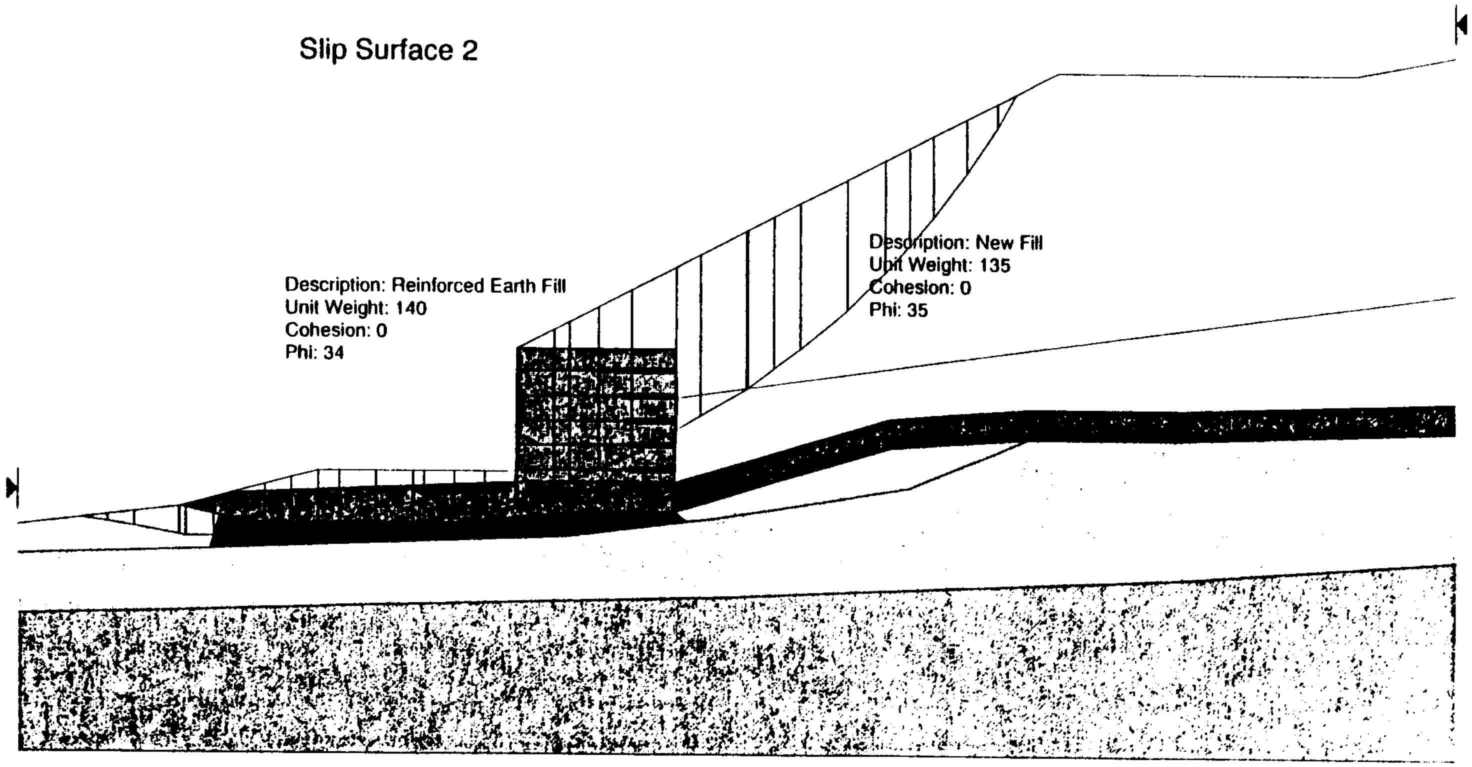


DRAFT

34

1.008

Description: South Wall 147+25 (HC 147+50 or F-F')
Comments: 60% Design - Pseudostatic Compound
File Name: 147+2560%475fs.slp
Last Saved Date: 9/26/00
Last Saved Time: 2:44:32 PM
Analysis Method: Spencer



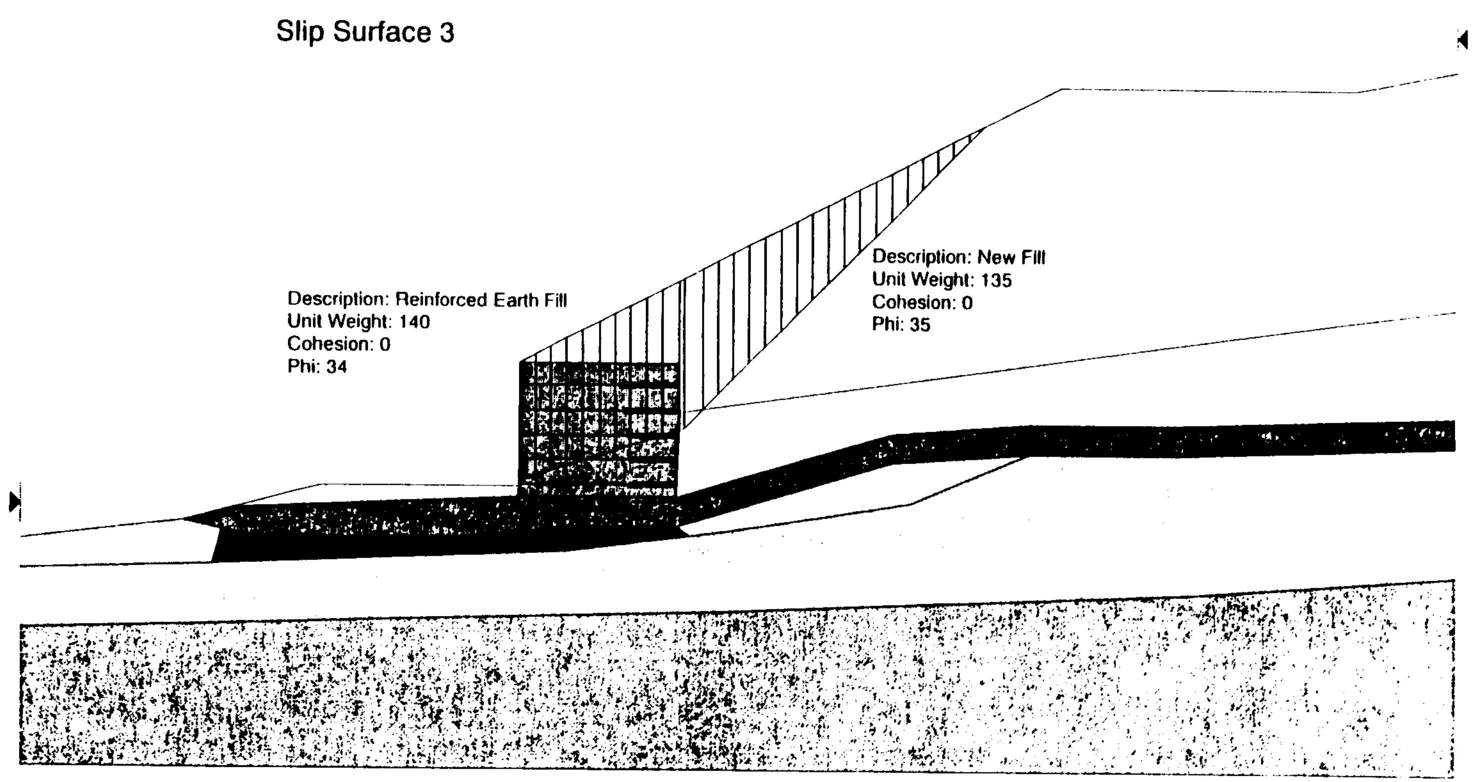
AR 046342

DRAFT

35

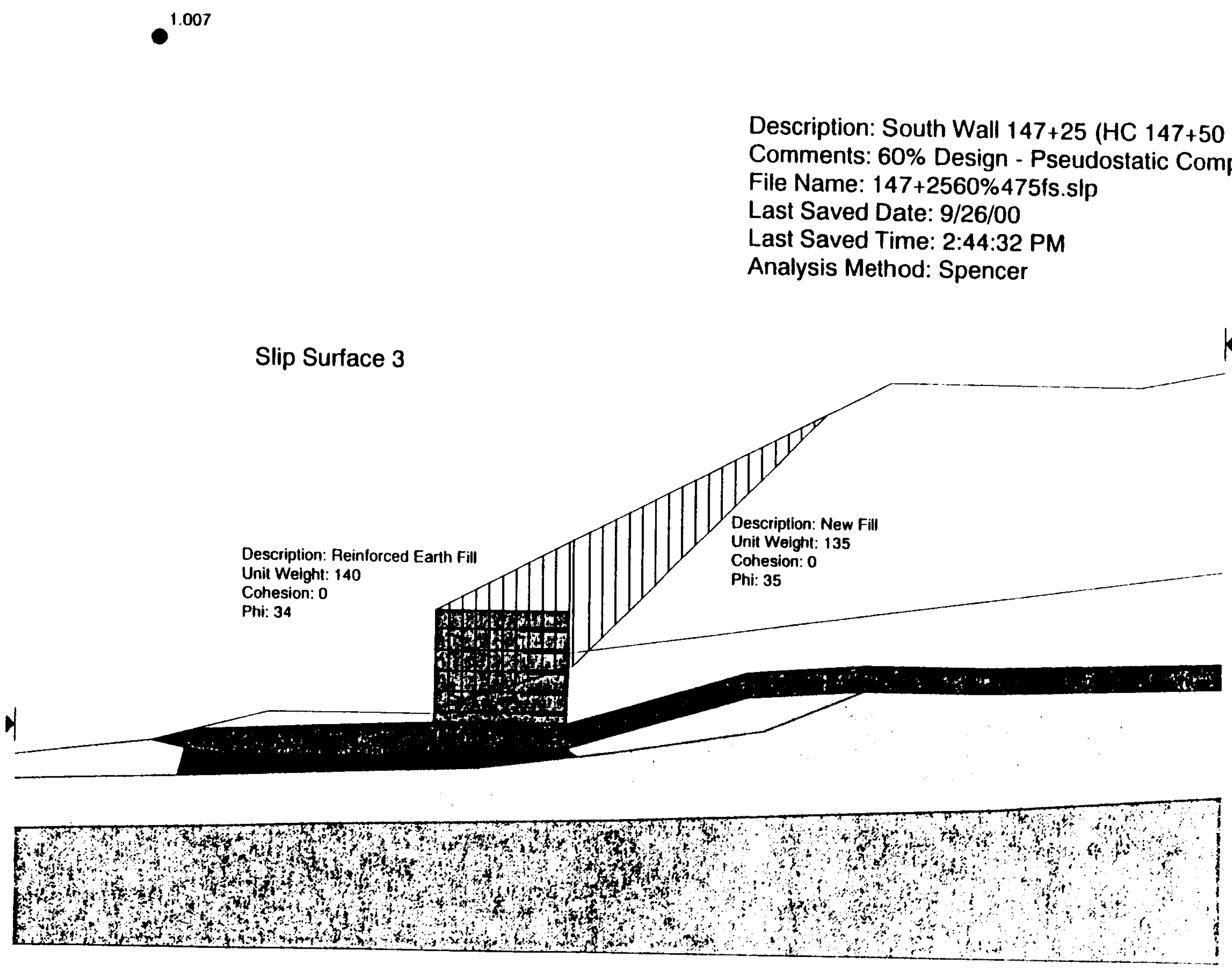
1.385

Description: South Wall 147+25 (HC 147+50 or F-F')
Comments: 60% Design - SS Compound
File Name: 147+2560%SSfs.slp
Last Saved Date: 9/26/00
Last Saved Time: 2:41:52 PM
Analysis Method: Spencer

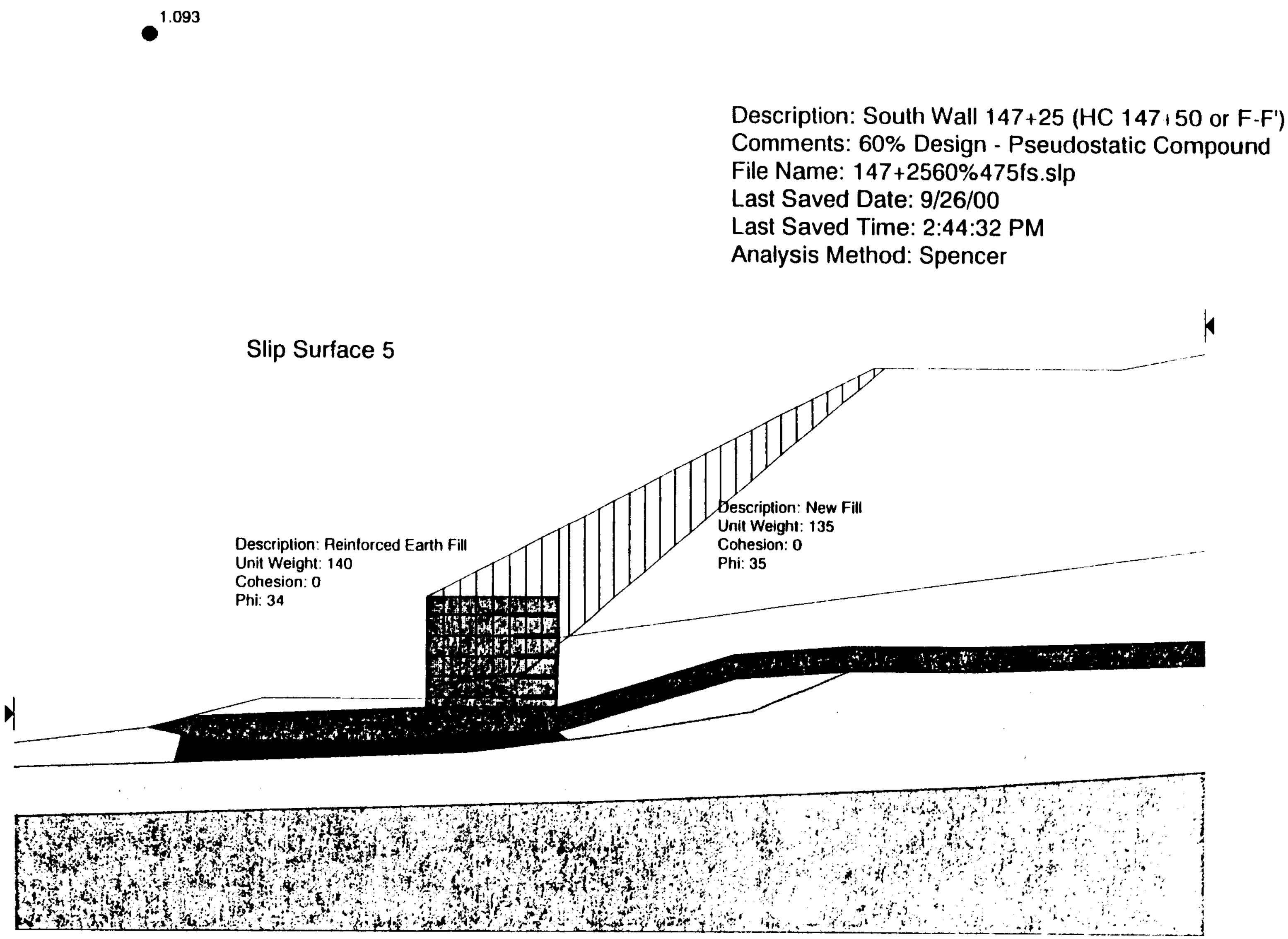


DRAFT

Description: South Wall 147+25 (HC 147+50 or F-F')
Comments: 60% Design - Pseudostatic Compound
File Name: 147+2560%475fs.slp
Last Saved Date: 9/26/00
Last Saved Time: 2:44:32 PM
Analysis Method: Spencer



AR 046344


1.093
Description: South Wall 147+25 (HC 147+50 or F-F')
Comments: 60% Design - Pseudostatic Compound
File Name: 147+2560%475fs.slp
Last Saved Date: 9/26/00
Last Saved Time: 2:44:32 PM
Analysis Method: Spencer
Slip Surface 5
Description: Reinforced Earth Fill
Unit Weight: 140
Cohesion: 0
Phi: 34
Description: New Fill
Unit Weight: 135
Cohesion: 0
Phi: 35

DRAFT

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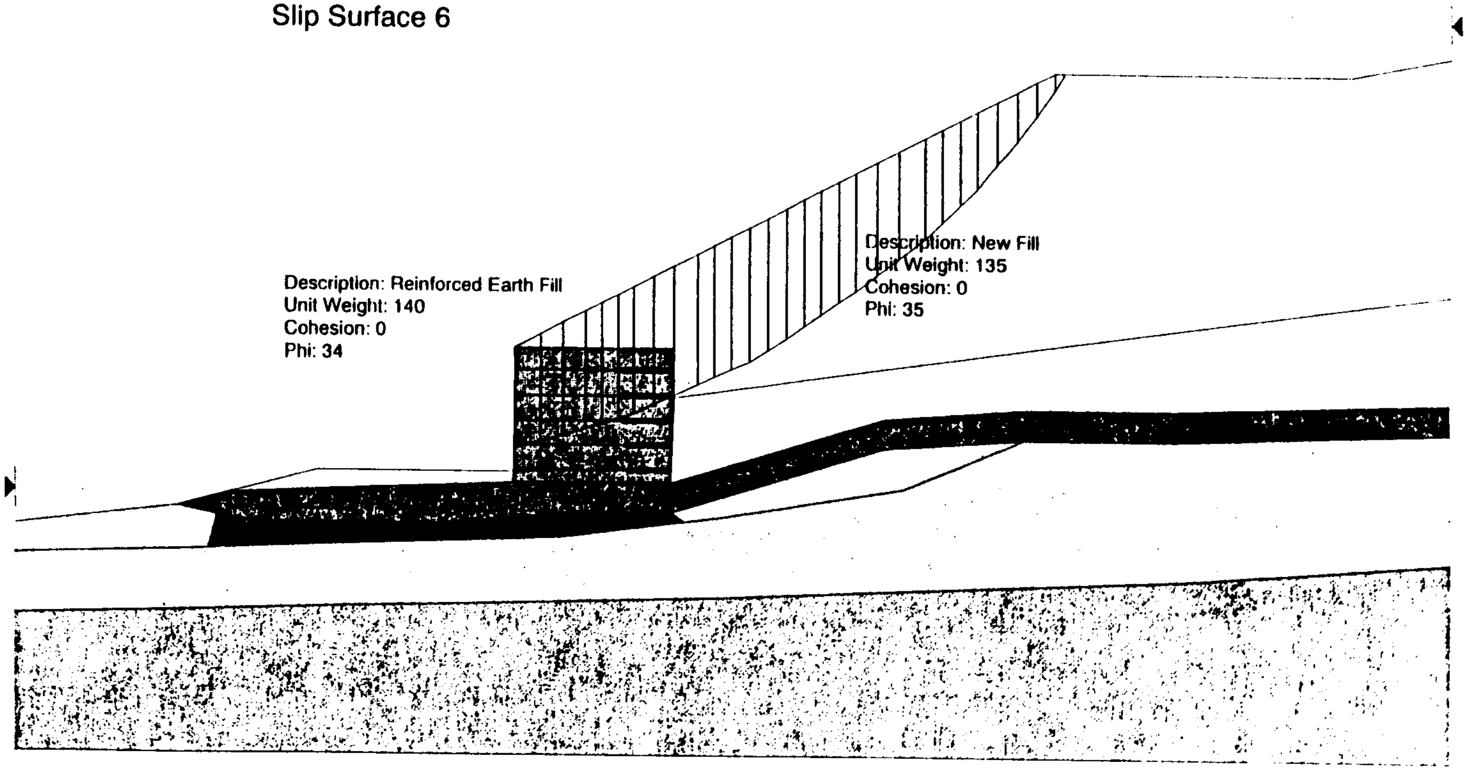
DRAFT

1.491

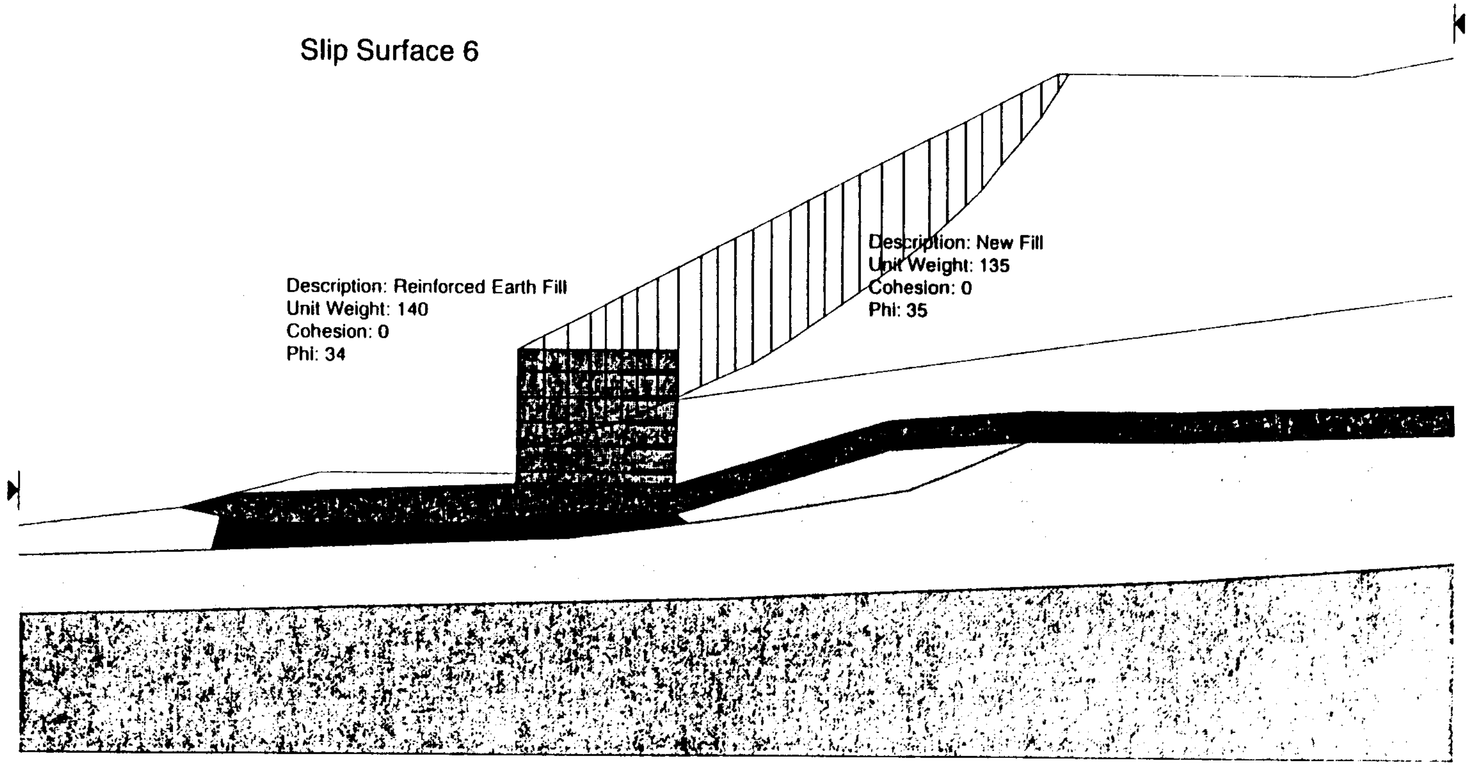
Description: South Wall 147+25 (HC 147+50 or F-F')
Comments: 60% Design - SS Compound
File Name: 147+2560%SSfs.slp
Last Saved Date: 9/26/00
Last Saved Time: 2:41:52 PM
Analysis Method: Spencer

Slip Surface 6



1.027

Description: South Wall 147+25 (HC 147+50 or F-F')
Comments: 60% Design - Pseudostatic Compound
File Name: 147+2560%475fs.slp
Last Saved Date: 9/26/00
Last Saved Time: 2:44:32 PM
Analysis Method: Spencer



DRAFT

Third Runway Project - West Wall Stability Analysis **J-4978-30**
30% Design
September 27, 2000

Summary of Stability Analysis Section/Station: 186+00

COMPOUND STABILITY

#	Design Scenario	Target FS	Surface 1 (cir)	Surface 2 (blk)	Surface 3 (blk)	Surface 4 (blk)	Surface 5 (cir)	Surface 6 (cir)
1	Steady state (Spencer)	1.5	**1.73**	**1.50**	**1.51**	**1.65**	**1.54**	**1.57**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.18**	**1.13**	**1.03**	**1.09**	**1.09**	**1.12**
2a	Pseudostatic, 475-yr event (Spencer) with 50x6mm steel	1.1			**1.89**			

NOTES:

[1] Reinforced Fill: γ = 140 pcf, ϕ = 37°; Embankment Fill: γ = 135 pcf; ϕ = 35°
[2] Residual Shear Strength (cumulative mean to the 475-yr event) = 779 psf; SD = 426 psf

GLOBAL STABILITY

#	Design Scenario	Target FS	Circle Search	Block Search
1	Steady state (Spencer)	1.5	**1.60**	**1.57**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.15**	**1.31**

Third Runway Project - South Wall Stability Analysis **J-4978-30**
30% Design
September 27, 2000

Summary of Stability Analysis Section/Station: 142+75
(HC 183+10)

COMPOUND STABILITY

#	Design Scenario	Target FS	Surface 1 (blk)	Surface 2 (blk)	Surface 3 (blk)	Surface 4 (cir)	Surface 5 (cir)	Surface 6 (cir)	Surface 7 (blk)
1	Steady state (Spencer)	1.5	**1.58**	**1.52**	**1.82 (Spencer) 1.58 (Bishop-Janbu)**	**1.33 (Spencer) 1.35 (Bishop-Janbu)**	**1.46 (Spencer) 1.46 (M-P)**	**1.57**	**1.52**
1a	Steady state (Spencer) W/50x6mm steel	1.5				**3.22 (Bishop-Janbu)**	**1.57 (Spencer)**		
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.21**	**1.16**	**1.14 (Bishop-Janbu)**	**0.97 (Bishop-Janbu)**	**1.06 (M-P)**	**1.10**	**1.13**
2a	Pseudostatic, 475-yr event (Spencer) W/50x6mm steel	1.1				**2.08 (Bishop-Janbu)**	**1.14 (Spencer)**		
3	Liquefaction (Spencer)	1.1	**1.58**	**1.52**	**1.82**	**1.33**	**1.46**	**1.57**	**1.52**

NOTES:

(1) Reinforced Fill: γ = 140 pcf, ϕ = 34°; Embankment Fill: γ = 135 pcf; ϕ = 35°

(2) Residual Shear Strength (cumulative mean to the 475-yr event) = 767 psf; SD = 512psf

GLOBAL STABILITY

#	Design Scenario	Target FS	Circle Search	Block Search
1	Steady state (Spencer)	1.5	**1.48**	**1.57**
1a	Steady state (Spencer) w/ 50x6mm steel	1.5	**1.48**	
1b	Steady state (Spencer) w/ 50x6mm steel & incr. Strip length by 2 ft	1.5	**1.50**	
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.10**	**1.17**
3	Liquefaction (Spencer)	1.1	**1.48**	**1.57**

Third Runway Project - South Wall Stability Analysis **J-4978-30**
September 26, 2000

Summary of Stability Analysis Section/Station: 147+25
(HC 147+50 or F-F')

COMPOUND STABILITY

#	Design Scenario	Target FS	Surface 1 (cir)	Surface 2 (cir)	Surface 3 (blk)	Surface 4 (blk)	Surface 5 (blk)	Surface 6 (cir)
1	Steady state (Spencer)	1.5	**1.37**	**1.47**	**1.39**	**1.53**	**1.50**	**1.49**
1a	Steady state (Spencer) w/ 50x6mm steel	1.5	**1.71**	**1.54**	**1.53**			**1.65**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**0.95**	**1.01**	**1.01**	**1.16**	**1.09**	**1.03**
2a	Pseudostatic, 475-yr event (Spencer) w/ 50x6mm steel	1.1	**1.14**	**1.05 (see below)**	**1.09**		**1.17**	**1.12**

NOTES:

(1) Reinforced Fill: γ = 140 pcf, ϕ = 34°; Embankment Fill: γ = 135 pcf; ϕ = 35°
(2) Residual Shear Strength (cumulative mean to the 475-yr event) = 767 psf;
SD = 512 psf

GLOBAL STABILITY

#	Design Scenario	Target FS	Circle Search	Block Search
1	Steady state (Spencer)	1.5	**1.49**	**1.67**
2	Pseudostatic, 475-yr event (Spencer)	1.1	**1.04**	**1.26**

COMPOUND - SURFACE 2 (STEEL INCREASED TO 50x6 mm)

Embedment (feet)	Strip length (feet)	Pseudostatic FS (Spencer)
1	16 (design)	1.054
2	16	1.06
1	17	1.067
2	17	1.072
1	18	1.077
2	18	**1.083**

GLOBAL – CIRCULAR FAILURE (STEEL INCREASED TO 50x6mm)

Embedment (feet)	Strip length (feet)	Steady-State FS	Pseudostatic FS
1	16 (design)	**1.51**	1.06
1	17	1.54	1.08
2	18	1.63	**1.20**

JOB TITLE : J-4978-30 Third Runway Embankment - File: 3rw20r.dat

FLAC (Version 4.00)

LEGEND

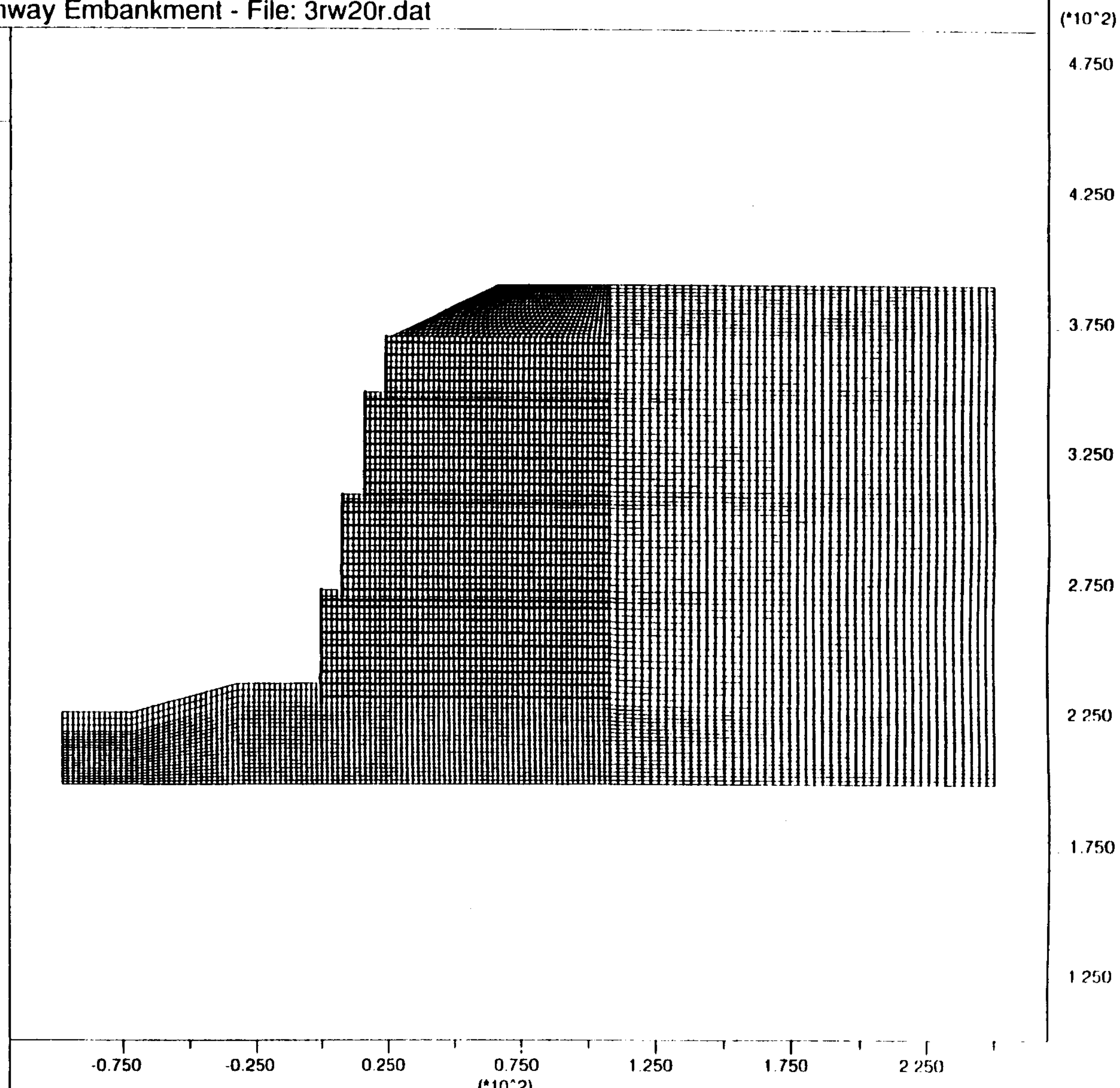
16-Oct-00 22:51
step 213115
-1.173E+02 <x< 2.693E+02
1.023E+02 <y< 4.890E+02

Grid plot

0 1E 2

Beam plot
Cable plot

Hart Crowser, Inc.
Seattle, WA USA



JOB TITLE : J-4978-30 Third Runway Embankment - File: 3rw20r.dat

FLAC (Version 4.00)

LEGEND

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step 213115
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1.023E+02 <y< 4.890E+02

X-displacement contours
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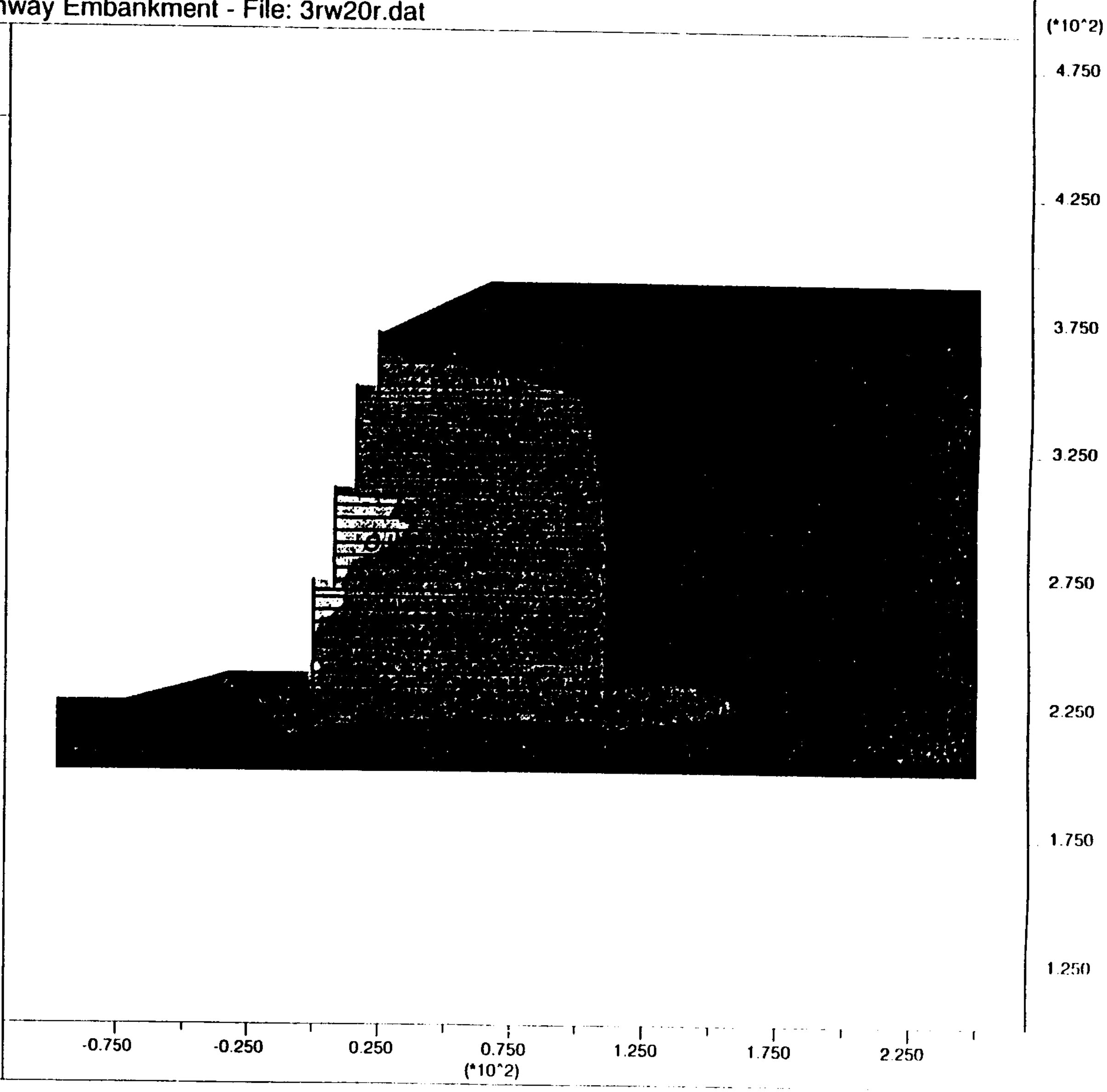
-8.00E-01
-6.00E-01
-4.00E-01
-2.00E-01
0.00E+00

Contour interval= 2.00E-01
Beam plot
Cable plot

Hart Crowser, Inc.
Seattle, WA USA



AR 046352

JOB TITLE : J-4978-30 Third Runway Embankment - File: 3rw20r.dat

FLAC (Version 4.00)

LEGEND

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step 213115
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Y-displacement contours
-1.75E+00
-1.50E+00
-1.25E+00
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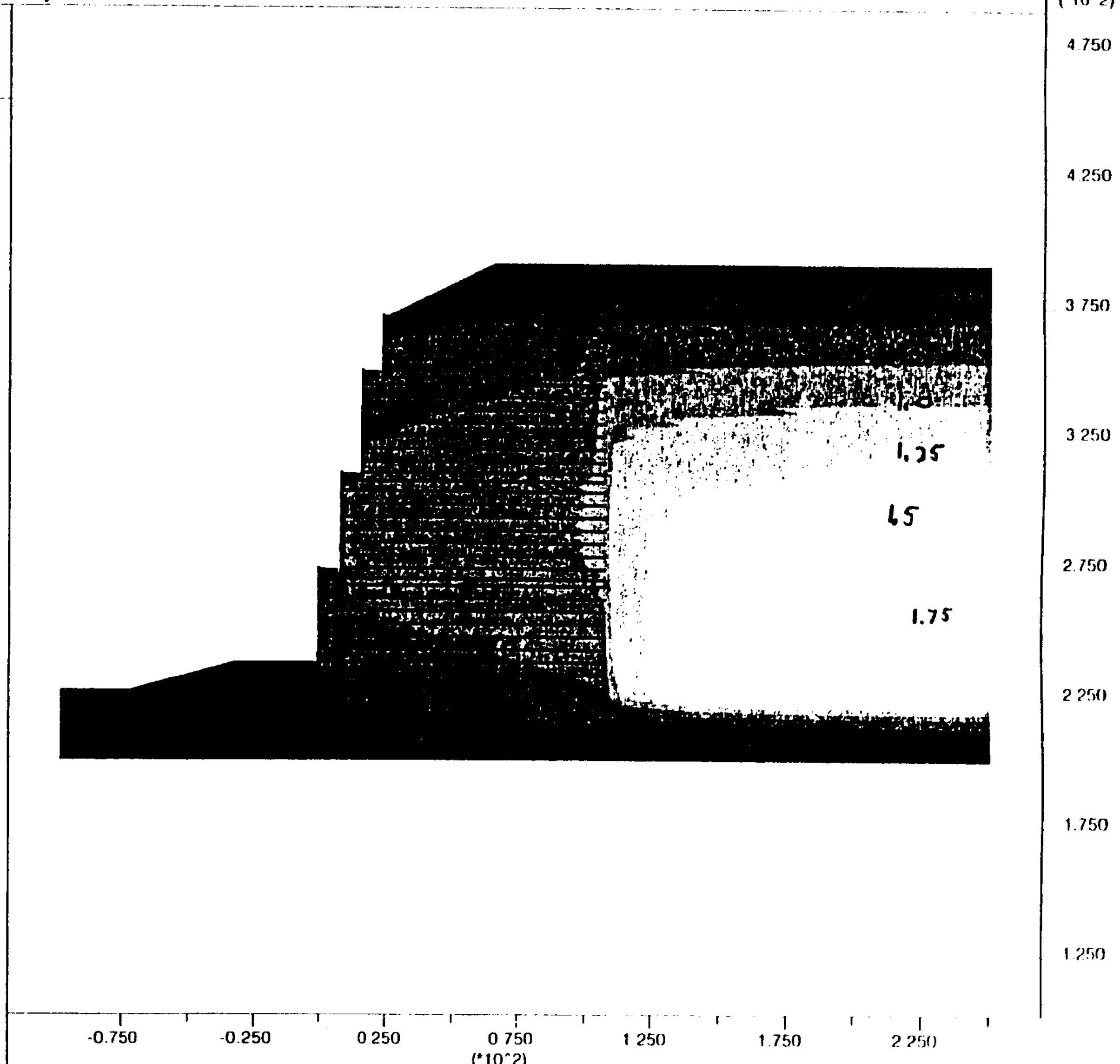
-7.50E-01
-5.00E-01
-2.50E-01
0.00E+00

Contour interval= 2.50E-01
Beam plot
Cable plot

Hart Crowser, Inc.
Seattle, WA USA



AR 046353

JOB TITLE : J-4978-30 Third Runway Embankment - File: 3rw30ad.dat (475-year event)

FLAC (Version 4.00)

LEGEND

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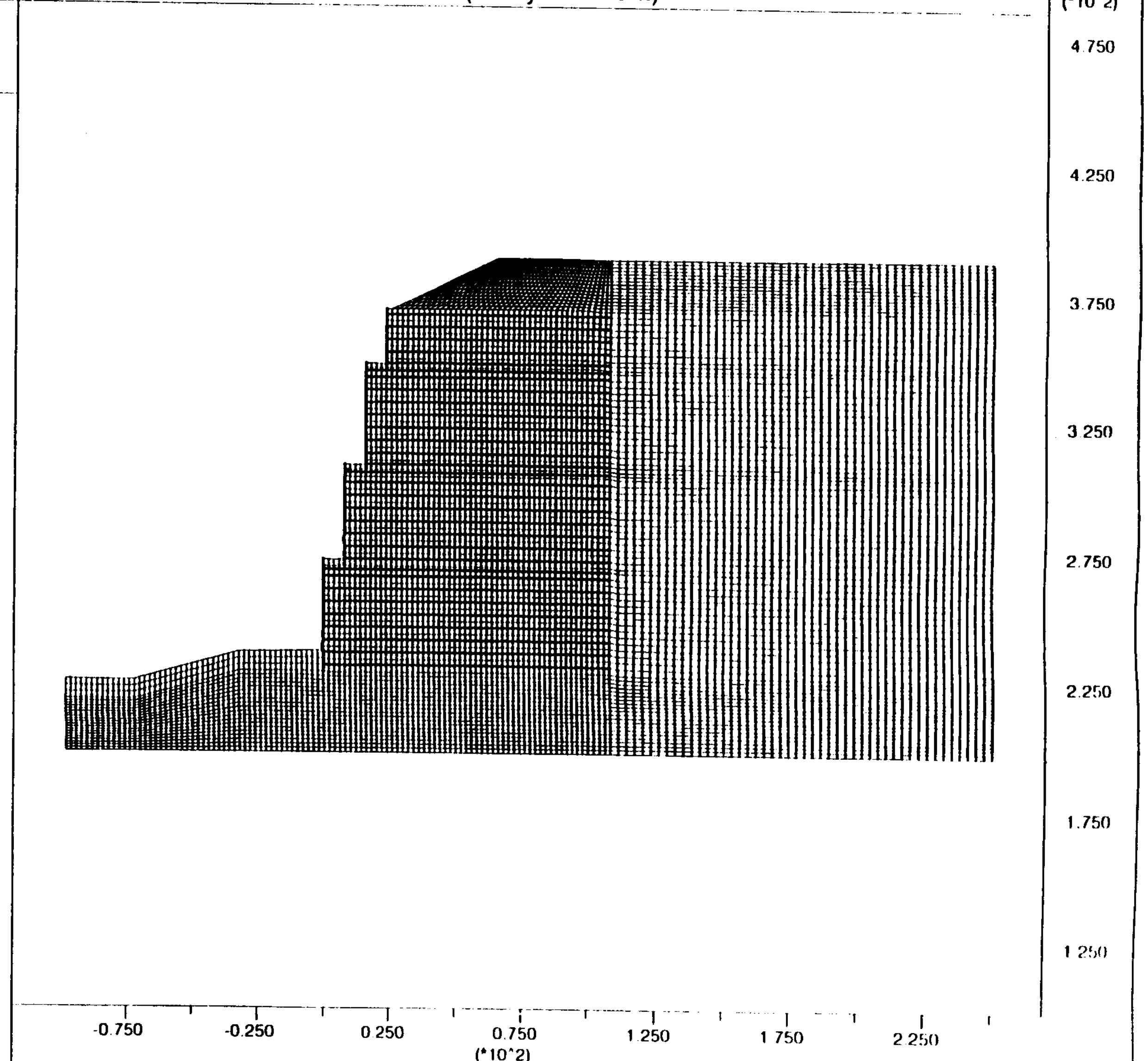
1.020E+02 <y< 4.890E+02

Grid plot

0 1E 2

Beam plot
Cable plot



Hart Crowser, Inc.
Seattle, WA USA

AR 046354

JOB TITLE : J-4978-30 Third Runway Embankment - File: 3rw30ad.dat (475-year event)

FLAC (Version 4.00)

LEGEND

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step 738912
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1.020E+02 <y< 4.890E+02

X-displacement contours
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-8.00E-01
-7.00E-01
-6.00E-01
-5.00E-01
-4.00E-01
-3.00E-01
-2.00E-01
-1.00E-01
0.00E+00

Contour interval= 1.00E-01
Beam plot
Cable plot

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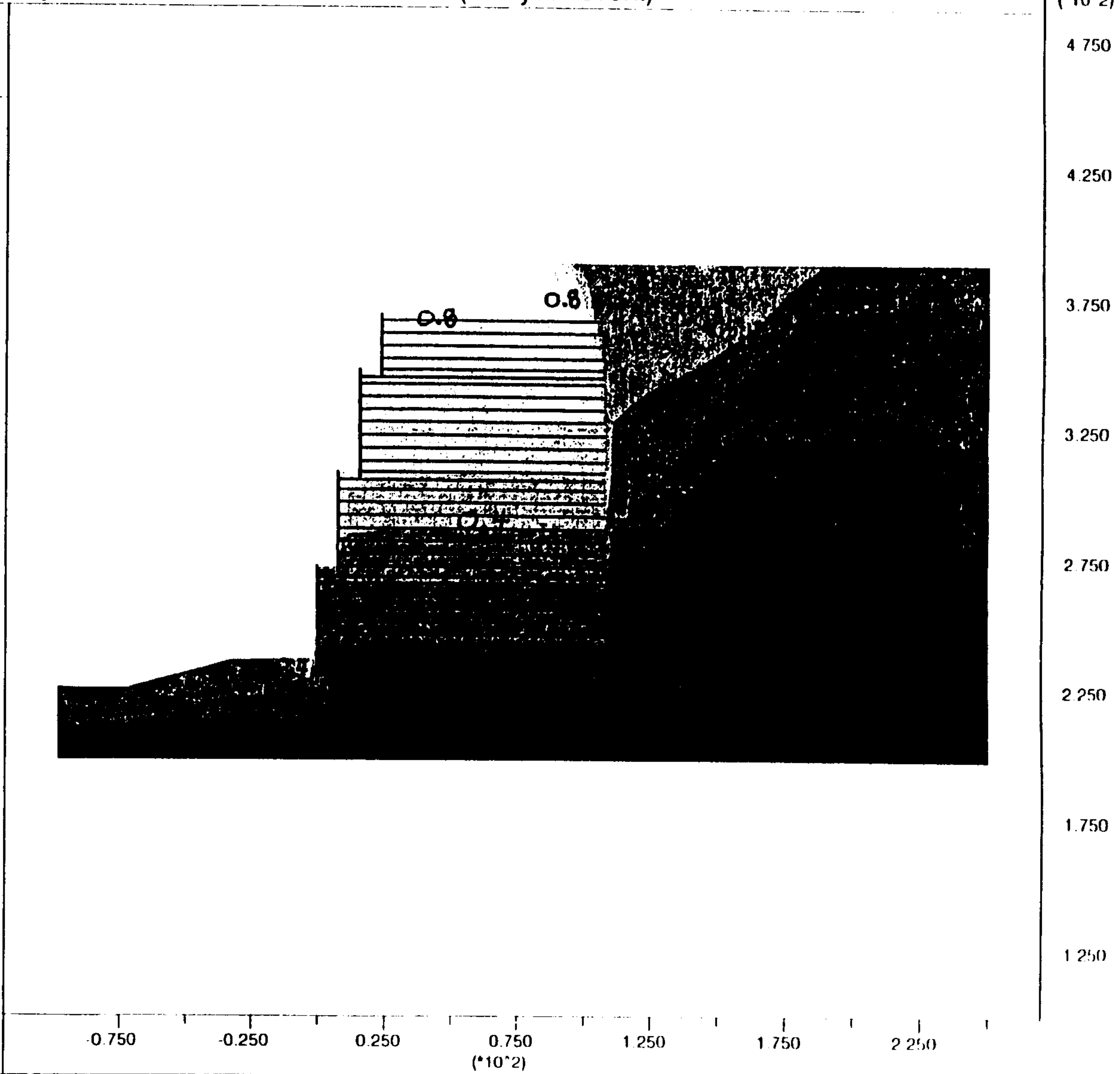
Seattle, WA USA



4-7

JOB TITLE : J-4978-30 Third Runway Embankment - File: 3rw30ad.dat (475-year event)

FLAC (Version 4.00)

LEGEND

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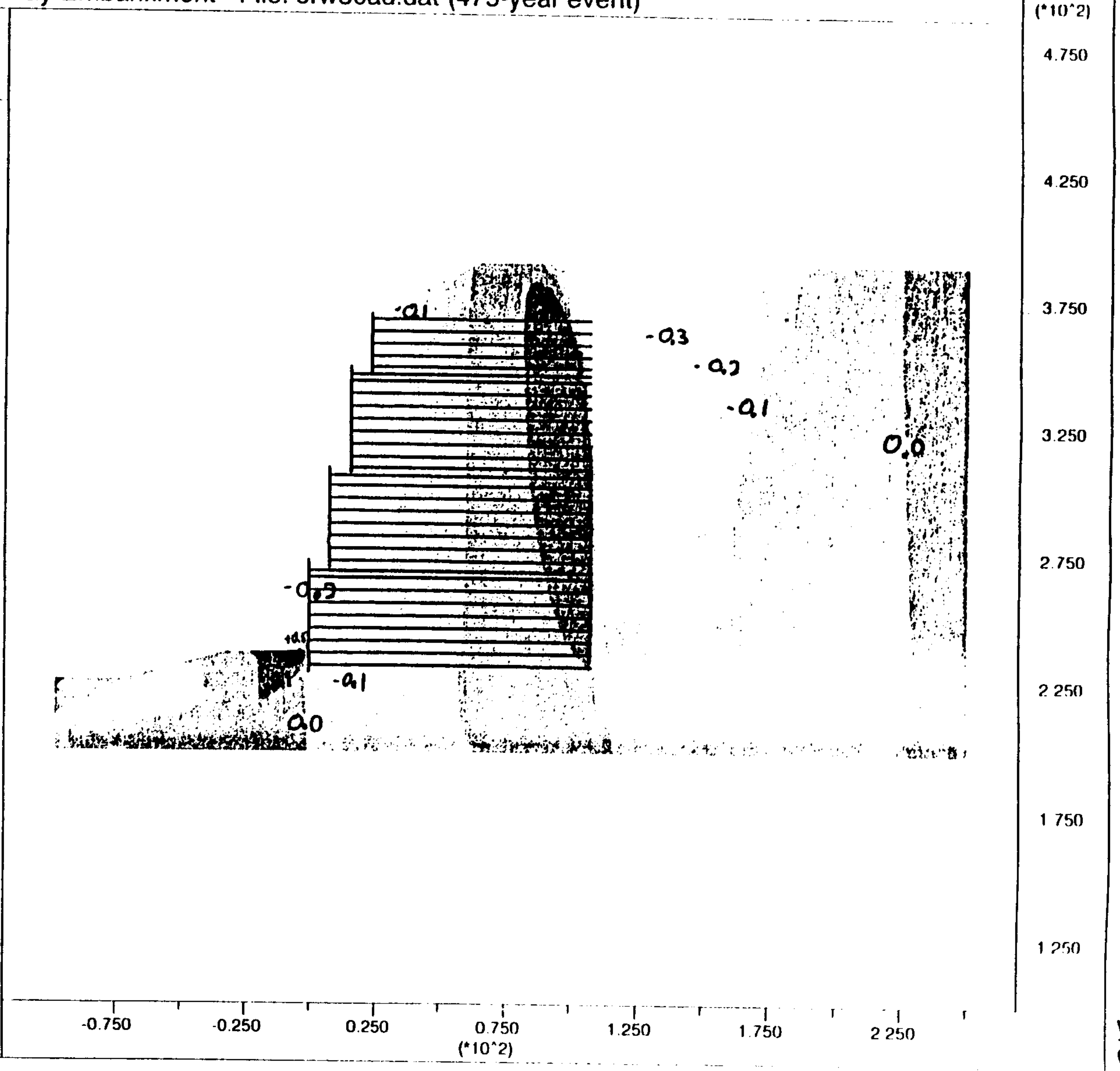
step 738912
-1.176E+02 <x< 2.693E+02
1.020E+02 <y< 4.890E+02

Y-displacement contours
-3.00E-01
-2.00E-01
-1.00E-01
0.00E+00
1.00E-01
2.00E-01
3.00E-01
4.00E-01
5.00E-01

Contour interval= 1.00E-01
Beam plot
Cable plot

Hart Crowser, Inc.
Seattle, WA USA



AR 046356

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HARTCROWSER

Calculations

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Project	Third Runway - South MSE Wall Analysis	**Job. No.**	J-4978-30
	Station 147+25	**Made by**	D. D. Lindquist
Calculations for	Documentation of FLAC Analysis	**Date**	November 3, 2000
		Checked by	
		Date	

Introduction

This file documents the input properties and grid used in the displacement-based FLAC analyses for Station 147+25 (formerly Hart Crowser Section F-F') at Third Runway South Wall in SeaTac, Washington. The analyses include static construction of the mechanically stabilized earth (MSE) wall and a dynamic analysis consisting of a design level earthquake (time history of velocity or acceleration) applied to the base of the FLAC model. The file names for the static and dynamic analyses are 3rs10a.dat and 3rs10ad.dat, respectively. They are included at the end of this document.

The following sections are included in this write-up:

- Introduction
- Model Geometry
- Soil Properties
- Structural Properties
- Dynamic Parameters
- Results
- Conclusions
- References

Model Geometry

The Reinforced Earth Company (RECo) Station 147+25 was used in this analysis. The subsurface profile was obtained from the Hart Crowser slope stability analysis (Section F-F') adjacent to Station 147+25. The grid used in the FLAC analysis is shown in Figure 1. Few notable features include:

- Model length 150 feet (50 feet left of wall, 100 feet right of wall);
- Model height 25 feet on the left, 65 feet on the right;
- Wall height 12.5 feet with and additional 2.5 feet embedded; and
- 2H:1V slope height of 25.8 feet above top of wall.

As a check of the slope stability analyses, which indicated low stability under a seismic event, the FLAC analyses were set up to model the recommended changes that bring the seismic slope stability up to a higher level of stability. Changes to the RECo design were as follows:

1. Increase the wall embedment 2 feet;
2. Add one layer of reinforcement below the wall;
3. Increase all reinforcement lengths from 16 feet to 18 feet; and
4. Change reinforcement thickness from 4mm to 6mm.

The FLAC grid consisted of 75 horizontal elements and 38 vertical elements for a total of 2850 elements. The LHS of the grid was defined to be at x = 0. The y-coordinates reflect the project elevation. The LHS of the grid (i = 1) and RHS of the grid (i = 76) were fixed in the x-direction. The base of the grid (j = 1) was fixed in x- and y-directions and was defined to be at El. 300.

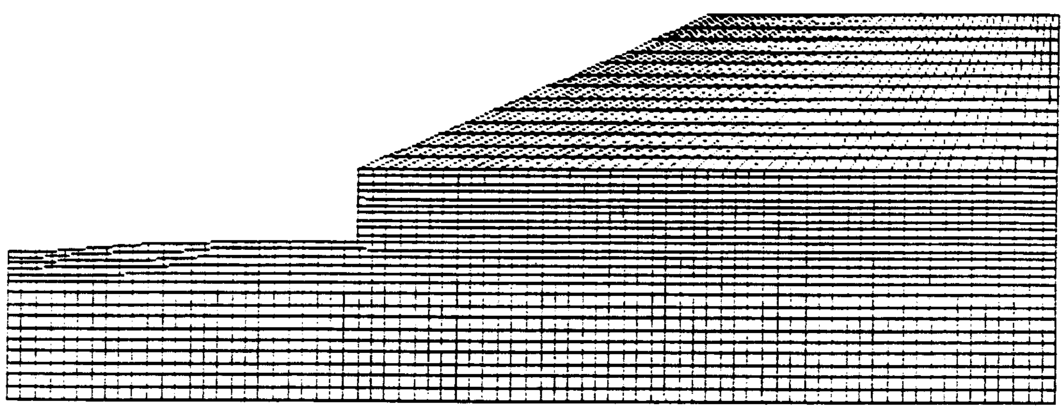

Figure 1. FLAC Grid

Soil Properties

The soil profile, shear strength and unit weight were based on what was used in the slope stability analyses. The soil moduli were based on the results of pressuremeter tests that were performed in the area (Hart Crowser, 2000b). The subsurface soil in the vicinity of the MSE wall can be characterized as existing fill over dense to very dense sand over glacial till. The soil profile is shown in Figure 2 with soil descriptions in Table 1. The groundwater table was defined to be at elevation 320, which is 20 feet above the base of the model. Effective stresses are used in shear strength calculations within FLAC.

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Project	Third Runway - South MSE Wall Analusis	**Job. No.**	J-4978-30
	Station 147+25	**Made by**	D. D. Lindquist
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		Checked by	
		Date	

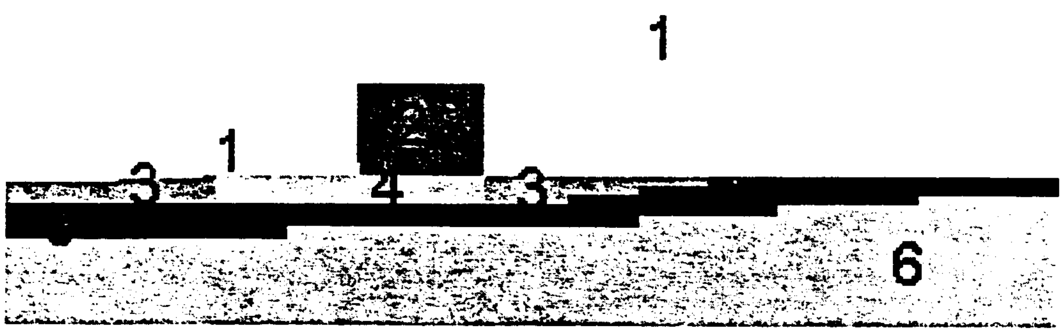

Figure 2. FLAC Soil Profile

Table 1. FLAC Soil Properties

Soil Strata and Engineering Properties	Assumed Value	FLAC Input
Soil Unit 1 – Embankment Fill (Unreinforced)		
Unit weight	135 pcf	dens = 4.19 slugs/ft^3
Elastic modulus	11 ksi	bu = 1.32e6 psf
Poisson's ratio	0.3	sh = 6.09e5 psf
Friction angle	35°	fr = 35°
Cohesion	0 psf	coh = 0 psf
Dilation angle	14°	dil = 14°
Tension	0 psf	tens = 0 psf
Soil Unit 2 – Embankment Fill (Reinforced)		
Unit weight	140 pcf	dens = 4.35 slugs/ft^3
Elastic modulus	10 ksi	bu = 1.20e6 psf
Poisson's ratio	0.3	sh = 5.54e5 psf
Friction angle	34°	fr = 34°
Cohesion	0 psf	coh = 0 psf
Dilation angle	13°	dil = 13°
Tension	0 psf	tens = 0 psf

Table 1. FLAC Soil Properties Cont.

Soil Strata and Engineering Properties	Assumed Value	FLAC Input
Soil Unit 3 - Existing Fill		
Unit weight	135 pcf	dens = 4.19 slugs/ft^3
Elastic modulus	7 ksi	bu = 8.40e5 psf
Poisson's ratio	0.3	sh = 3.88e5 psf
Friction angle	33°	fr = 33 °
Cohesion	0 psf	coh = 0 psf
Dilation angle	8°	dil = 8 °
Tension	0 psf	tens = 0 psf
Soil Unit 4 - Subgrade Improvement		
Unit weight	135 pcf	dens = 4.19 slugs/ft^3
Elastic modulus	10 ksi	bu = 1.20e6 psf
Poisson's ratio	0.3	sh = 5.54e5 psf
Friction angle	35°	fr = 35 °
Cohesion	0 psf	coh = 0 psf
Dilation angle	13.1°	dil = 13.1 °
Tension	0 psf	tens = 0 psf
Soil Unit 5 - Dense to very dense SAND		
Unit weight	135 pcf	dens = 4.19 slugs/ft^3
Elastic modulus	13 ksi	bu = 1.56e6 psf
Poisson's ratio	0.3	sh = 7.20e5 psf
Friction angle	38°	fr = 38 °
Cohesion	0 psf	coh = 0 psf
Dilation angle	15°	dil = 15 °
Tension	0 psf	tens = 0 psf
Soil Unit 6 - Very dense, silty, gravelly SAND (Glacial Till)		
Unit weight	140 pcf	dens = 4.35 slugs/ft^3
Elastic modulus	25 ksi	bu = 3.00e6 psf
Poisson's ratio	0.3	sh = 1.38e6 psf
Friction angle	40°	fr = 40 °
Cohesion	0 psf	coh = 0 psf
Dilation angle	16°	dil = 16 °
Tension	0 psf	tens = 0 psf

dens = unit weight/gravity = unit weight/32.2
Bulk Modulus, bu = K = E/[3(1-2v)]
Shear Modulus, sh = G = E/[2(1+v)]

HARTCROWSER **Calculations**

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Project	Third Runway - South MSE Wall Analysis	Job. No.	J-4978-30
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		Checked by	
		Date	

Structural Properties

The RECo wall design included concrete facing panels and steel reinforcement strips connecting from the back of the concrete panel some length into the soil mass. The concrete panels are typically 4.92 feet tall and 5 1/2 to 7 inches thick. For the analyses presented here the 7-inch thick panels were modeled. (Typically the 7-inch panels are used only where wall stresses are greater or equal to 2.55 ksf.) This section was modeled with three 5-foot tall facing panels with pin joints between beam panels. Six layers of reinforcement (2 layers per facing panel) were modeled to extend from the facing panels 18 feet into the soils mass. This geometry includes some changes form the RECo design as described previously in Model Geometry. The steel reinforcement was 50mm wide and 6mm thick. However, 1.008 mm reduction per side was made to the steel thickness to account for corrosion during the 100-year design life span per AASHTO recommendations. (RECo believes this reduction is very/overly conservative.) The structural properties for the facing and the reinforcement were obtained from Melissa Berkebile from RECo. Table 2 presents the concrete facing properties and Table 3 presents the steel reinforcement properties based on two steel strips placed every 5 feet (into the page) in each row.

Table 2. FLAC Beam (concrete facing) Properties

PROPERTIES	VALUE	FLAC INPUT
Area	0.583 ft^2	a = 0.583 ft^2 [7/12 * 1]
Elastic Modulus (Fy=4000 psi concrete)	3.6 x 10^6 psi	e = 5.18e8 psf [3.6e6 * 144]
Bending (plastic) Moment	4.9 k-ft/ft	pmom = 996 lb-ft
Moment of Inertia	343 in^4/ft	i = 0.01654 ft^4
Density	150 pcf	dens=4.66 slugs/ft^3

Table 3. FLAC Cable (two 50mm x 6mm steel reinforcement with corrosion loss) Properties

PROPERTIES	VALUE	FLAC INPUT
Area	2*50x(6-2*1.008) mm^2	a = 0.0043 ft^2
Perimeter	2*(50x2+(6-2*1.008)x2)/5 mm/ft	peri = 0.144 ft/ft
Elastic Modulus	29 x 10^9 psi	e = 8.49e8 psf [3.6e6 * 144]
Yield Strength	65 ksi	yield = 4500 lb/ft [0.6 Fy]
Compressive Strength	65 ksi	ycom = 4500 lb/ft [0.6 Fy]
Soil/Reinforcement Adhesion	0 psf	sbond = 0 psf
Soil/Reinforcement Friction	34°	sfric = 34°
Soil/Reinforcement Stiffness	14000 psf/ft	kbond = 14000 psf/ft

Dynamic Parameters

The 10% probability of exceedance in 50 years (475-year return period) seismic event was selected as the seismic basis of design by the owner and HNTB after review of Hart Crowser recommendations (Hart Crowser, 2000a). Hart Crowser developed a response spectrum for this level of event based on the results of the site-specific probabilistic seismic hazard analysis (Hart Crowser, 1999). Professor Steven L. Kramer was retained to develop a synthetic seismic time history (earthquake record) for the FLAC analyses. This time history was used as input into the 1-D ground response analysis program ProShake as an outcrop motion at an equivalent bedrock depth of 250 feet. The dynamic site response was evaluated at the base of the FLAC model for input into dynamic FLAC analyses. The input time history, shown in Figure 3, had a peak acceleration of 0.32g and was 42 seconds in duration.

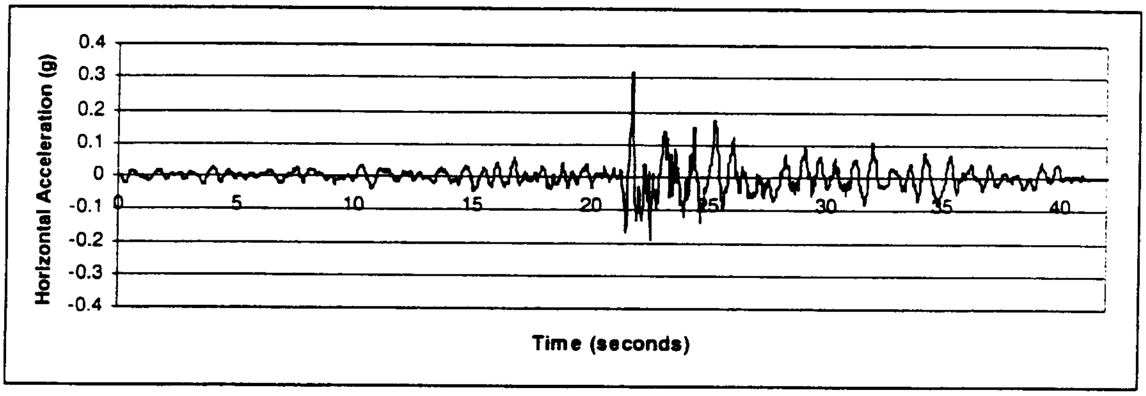

Figure 3. Input Motion Applied at the Base of the FLAC Model

The LHS and RHS boundary conditions for the dynamic analyses were set to free field conditions to model an infinite extent in both horizontal directions. The time history of acceleration was applied horizontally to the base of the FLAC model. Five percent Rayleigh material damping was used with a predominant frequency of 20 Hertz.

Results

Static Results

The maximum static horizontal displacement was just less than 0.4 inches at the face of the wall approximately mid-height. Figure 3 illustrates the distribution of horizontal displacements throughout the model. The maximum static vertical displacement was just more than 0.6 inches in the backfill beneath the highest portion of the embankment. Figure 4 illustrates the distribution of vertical displacements throughout the model. The maximum stress in the reinforcement was calculated to be in the third layer of reinforcement at the wall face. Stresses in the reinforcement at the end of construction are shown in Table 4.

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Calculations

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		Checked by	
		Date	

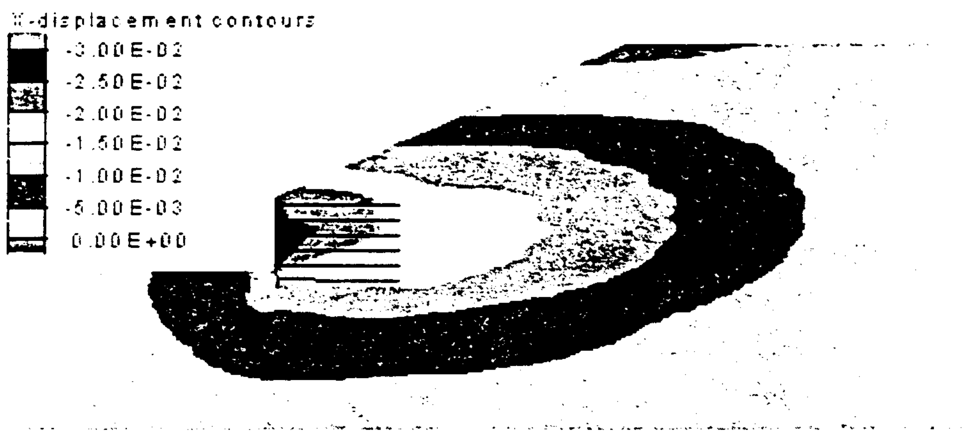

Figure 3. Static horizontal displacement contours in feet

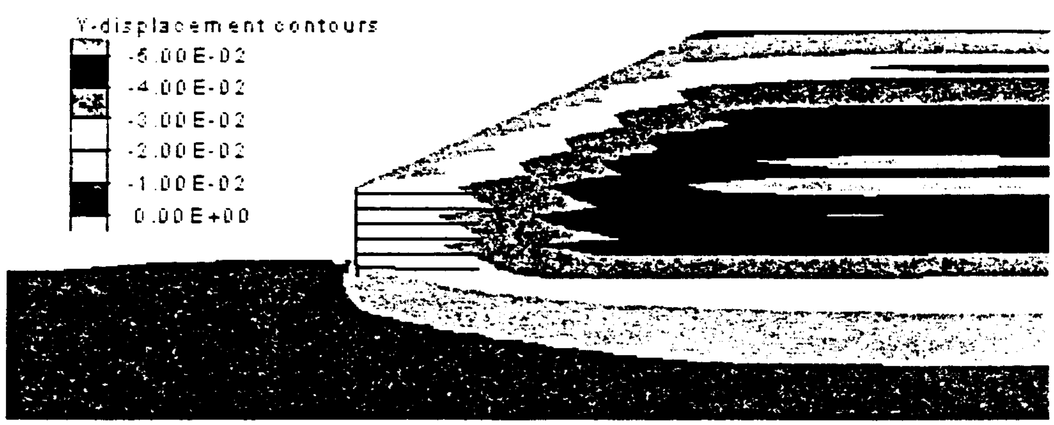

Figure 4. Static vertical displacement contours in feet

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Calculations

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		Date	

Table 4. Stress in the reinforcement at the end of construction (yield stress = 65 ksi * 0.6 = 39 ksi)

Reinforcing Layer	Stress in the Reinforcement in ksi at Various Distances Behind the Wall Face				
	3 feet	6 feet	9 feet	12 feet	15 feet
6 (top layer)	3	3	2	2	1
5	6	5	4	3	2
4	7	7	5	4	2
3	10	9	7	5	2
2	8	7	5	3	2
1 (base layer)	1	1	0	0	0

Seismic Results

After static construction of the model it was subjected to a synthetic earthquake motion. The maximum seismic (end of shaking) horizontal displacement was just less than 14 inches just above the top of the wall on the toe of the 2H:1V slope. Figure 5 illustrates the distribution of seismic horizontal displacements throughout the model. The maximum seismic (end of shaking) downward vertical displacement was just less than 5 inches at the top of the 2H:1V slope above the wall. There was upward vertical displacement at the toe of the wall of just more than 9 inches. Figure 6 illustrates the distribution of seismic vertical displacements throughout the model. The maximum stresses in the reinforcement were monitored throughout the earthquake and are shown in Table 5. The maximum stress in the reinforcement was calculated to be in the base layer of reinforcement at the wall face. In general, the maximum seismic stresses were much larger than the static stresses in the reinforcement. However, the yield strength was not reached in the analysis.

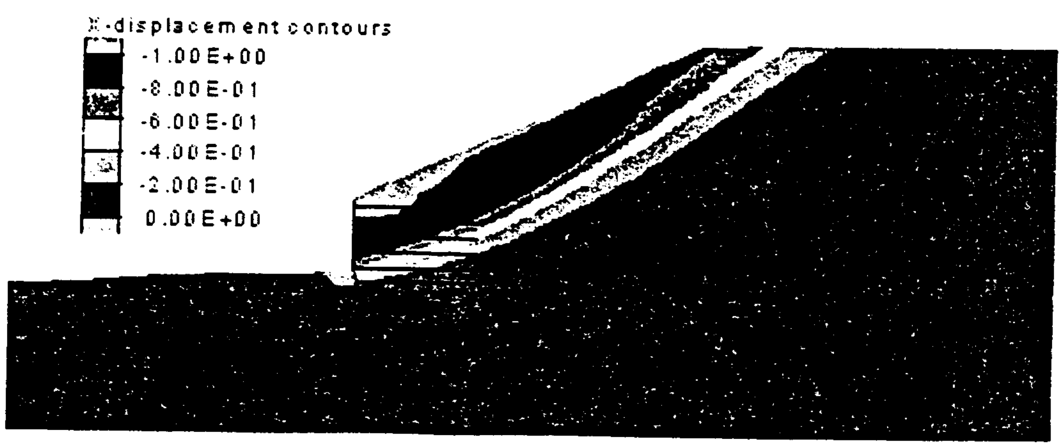

Figure 5. Seismic horizontal displacement contours in feet

Project Third Runway - South MSE Wall Analysis
Station 147+25

Job. No. J-4975-30

Made by D. D. Lindquist

Calculations for Documentation of FLAC Analysis

Date November 3, 2000

Checked by

Date

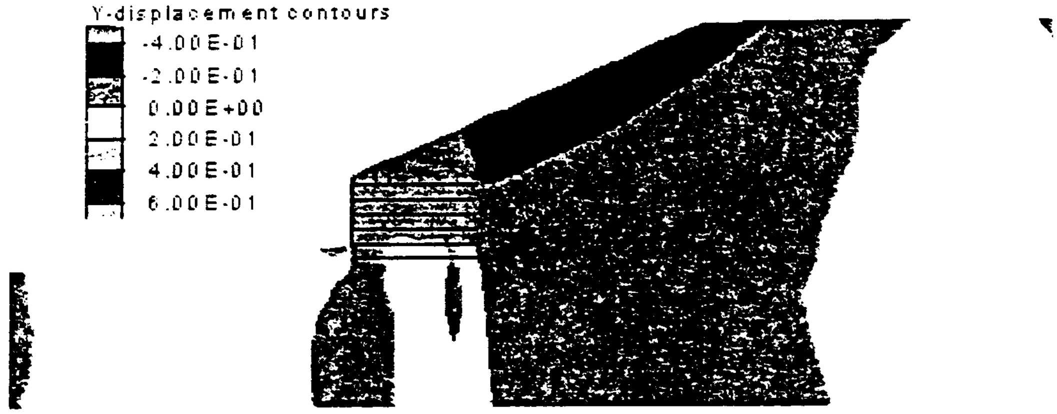

Figure 6. Seismic vertical displacement contours in feet

Table 5. Maximum stress in the reinforcement during the seismic analysis (yield stress = 65 ksi * 0.6 = 39 ksi)

Reinforcing Layer	Stress in the Reinforcement in ksi at Various Distances Behind the Wall Face				
	3 feet	6 feet	9 feet	12 feet	15 feet
6 (top layer)	10	9	7	5	3
5	13	12	10	7	4
4	16	15	12	8	4
3	22	18	14	9	5
2	27	21	16	11	5
1 (base layer)	29	23	17	12	6

References

Hart Crowser, 1999. Draft Memorandum: Sea-Tac Airport Third Runway, Probabilistic Seismic Hazard Analysis Results, SeaTac, Washington, October 8, 1999.

Hart Crowser, 2000a. Draft Memorandum: Seismic Basis of Design, Third Runway Project, SeaTac, Washington, April 10, 2000.

Hart Crowser, 2000b. Draft Memorandum: Use of Advanced Testing Data, Sea-Tac Third Runway Project, SeaTac, Washington, August 28, 2000.