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RKK-1

CALCULATION CHECKLIST

Project: **SR 1/I-95 Interchange** Comm. No.: **103-059-27U**

Title of Calculation Set: **Preconsolidation Stress Evaluation**

Project Manager: **EMK/JLT**

Calculations Prepared By: **SAB**

Calculation Checked By:

Computer Programs / Files:

Initial	Date	
		Subsurface Characterization approved by Project Manager
SAB	12/10/08	Calculations are neat, legible and understandable.
—	—	Table of Contents is provided.
SAB	12/10/08	Heading on each page filled out
SAB	12/10/08	The first page contains purpose of the calculation.
SAB	12/10/08	Symbols are defined.
SAB	12/10/08	References for data, methods, formulas and computer program names and version numbers are given.
SAB	12/10/08	Assumptions are listed and those that need to be verified later are Flagged.
SAB	12/10/08	Headings on front sheet of each set of computer input and output.
SAB	12/10/08	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JLT	1-2-09	All calculations checked and each calculation sheet initialed by checker.
JLT	1-2-09	Calculation set reviewed by Project Manager.
		Has this calculation been superseded? Reference new calculation, if applicable.

This sheet is to be prepared by the originator of the calculation and attached to the front of the calculation set.

Summary of All Cons. Testing.

SR 1/I-95 Interchange 103-059-27U

1/5/2009

SR 1/I-95 Interchange - Consolidation Soil Parameters - Stratum 2a																							
PointID	Sample	GS EL	GWL (ft)	Depth (ft)	Sample EL	γ_T (pcf)	NMC (%)	LL	PL	PI	LI	P_o (tsf)	$Pc_{Casagrande}$ (tsf)	$Pc_{Work\ Energy}$ (tsf)	OCR_c	$OCR_{W.E.}$	FINAL P_c (tsf)	FINAL OCR	e_o	c_c	c_r	$C_{v(Max)}$ (ft^2/d)	$C_{v(Min)}$ (ft^2/d)
IBR-52	U-1	57	11.5	16	41	126.9	29.8	43	23	20	0.34	0.88	1.10	3.75	1.3	4.3	3.75	4.3	0.678	0.18	0.07	0.22	0.02
IBR-60	U-1	86	11.4	18	68	133.3	20.5	30	19	11	0.14	0.94	1.97	1.83	2.1	2.0	1.97	2.1	0.521	0.13	0.03	2.10	0.01
IBR-60	U-2	86	11.4	46	40	132.3	24.2	36	21	15	0.21	1.90	1.23	2.00	0.6	1.1	2.00	1.1	0.602	0.16	0.04	1.11	0.01
IBR-61	U-1	84	24.0	14	70	123.6	30.7	34	21	13	0.75	0.87	2.91	1.85	3.4	2.1	2.91	3.4	0.748	0.24	0.05	2.64	0.03
IBR-61	U-2	84	24.0	59	25	123.3	33.3	46	24	22	0.42	2.55	0.69	2.50	0.3	1.0	2.50	1.0	0.839	0.22	0.06	0.56	0.01
IEB-15	U-1	83	52.0	12	71	129.5	26.7	49	26	23	0.03	0.78	3.53	6.00	4.5	7.7	3.53	4.5	0.669	0.19	0.05	3.17	0.02
IEB-15	U-2	83	52.0	31	52	132.8	22.6	36	20	16	0.16	2.02	5.29	1.91	2.6	0.9	5.29	2.6	0.527	0.17	0.05	1.10	0.01
IEB-15	U-3	83	52.0	56	27	132.8	25.5	47	25	22	0.02	3.56	2.40	4.05	0.7	1.1	4.05	1.1	0.582	0.20	0.06	1.70	0.01
URS-1	U-1	73	6.0	24	49	126.0	33.5	48	24	24	0.40	0.95	0.67	0.70	0.7	0.7	NV	NV	0.792	0.23	0.07	0.17	0.03
URS-3	U-1	82	6.0	35	47	132.3	26.1	40	22	18	0.23	1.33	2.59	2.40	1.9	1.8	2.59	1.9	0.614	0.20	0.07	1.92	0.02
URS-3	U-2	82	6.0	50	32	117.0	42.8	51	24	27	0.70	1.74	0.84	1.20	0.5	0.7	NV	NV	0.987	0.27	0.08	0.33	0.01
URS-4	U-1	77	14.0	22	55	123.9	34.7	53	28	25	0.27	1.12	1.78	3.10	1.6	2.8	3.1	2.8	0.851	0.25	0.09	2.50	0.01
URS-4	U-2	77	14.0	37	40	131.2	26.9	42	22	20	0.25	1.64	1.01	1.12	0.6	0.7	NV	NV	0.458	0.20	0.06	2.35	0.01
URS-5	U-1	63	4.0	35.5	27.5	121.5	34.5	55	29	26	0.21	1.24	2.01	1.60	1.6	1.3	2.01	1.6	0.786	0.23	0.09	1.61	0.01
IBR-04	T-1	65	2.0	18	47	115.5	12.6	22	17	5	-0.88	0.67	3.00	2.75	4.5	4.1	2.88	4.3	0.487	0.05	0.01	1.5	0
IBR-05	T-2	66	38.0	31.5	34.5	119.0	16.0	21	18	3	-0.67	1.17	4.75	2.70	4.1	2.3	NV	NV	0.661	0.15	0.02	1.0	
IBR-15	T-1	70	2.0	19.5	50.5	96.9	24.6	42	20	22	0.21	0.72	1.63	2.30	2.3	3.2	1.97	2.7	0.772	0.22	0.06	0.15	0.03
IBR-32	T-3	89		50	39	132.7	16.7	31	18	13	-0.10	2.11	3.00	3.38	1.4	1.6	3.19	1.5	0.519	0.16	0.05	0.02	
ICPT-15A	T-1	80.19	3.0	19	61.19	101.5	24.4	49	23	26	0.05	0.69	2.30	3.10	3.3	4.5	2.7	3.9	0.666	0.12	0.03	0.19	0.09
ICPT-15A	T-2	80.19	3.0	29	51.19	72.3	36.7	50	24	26	0.49	1.00	11.00	12.00	11.0	12.0	11.5	11.5	1.333	0.15	0.02	6.74	2.36
ICPT-15A	T-3	80.19	3.0	45	35.19	97.3	22.3	53	22	31	0.01	1.47	3.50	2.20	2.4	1.5	2.85	1.9	0.739	0.12	0.04	0.09	0.05
ICPT-16A	T-1	84.87	14.4	31	53.87	134.1	16.4	34	19	15	-0.17	1.90	3.90	5.00	2.1	2.6	4.45	2.3	0.474	0.07	0.01	2.27	0.29
ICPT-16A	T-2	84.87	14.4	45	39.87	134.1	16.7	41	18	23	-0.06	2.45	4.20	3.90	1.7	1.6	4.05	1.7	0.304	0.07	0.01	0.99	0.23
ICPT-16A	T-3	84.87	14.4	55	29.87	134.1	13.2	64	26	38	-0.34	3.39	5.00	5.40	1.5	1.6	5.20	1.5	0.872	0.19	0.04	1.08	0.08
IEB-13A	T-1	84	9.6	15	69	77.8	18.7	33	19	14	-0.02	0.82	2.95	3.30	3.6	4.0	3.13	3.8	0.554	0.12	0.02	0.23	
IEB-13B	T-2	81.64	7.0	33	48.64	115.9	16.1	28	17	11	-0.08	1.40	5.70	7.25	4.1	5.2	6.48	4.6	0.454	0.04	0.01	6.87	2.47
IEB-13B	T-3	81.64	7.0	39	42.64	116.9	15.5	27	14	13	0.12	1.63	10.00	7.25	6.1	4.5	8.63	5.3	0.447	0.05	0.03	4.99	1.59
IEB-13B	T-4	81.64	7.0	59	22.64	104.1	22.1	NP	NP	NP		2.13	8.00	9.60	3.8	4.5	8.8	4.1	0.505	0.04	0.01	1.76	0.34
IRW-09	T-2	59	DRY	35	24	110.9	17.5	23	18	5	-0.10	1.39	3.92	2.30	2.8	1.7	NV	NV	0.536	0.11	0.03	2.8	0.2
IRW-23	T-2	60	36.7	24.5	35.5	108.7	18.4	36	21	15	-0.17	0.81	4.96	3.63	6.1	4.5	4.29	5.3	0.522	0.13	0.03	0.38	0.06
IRW-32	T-1	79	13.4	25	54	114.2	19.5	39	19	20	0.03	1.24	6.50	4.60	5.3	3.7	NV	NV	0.545	0.14	0.04	0.24	0.05
IRW-33	T-1	79	DRY	27	52	100.5	26.1	47	22	25	0.16	1.30	1.12	1.40	0.9	1.1	1.26	1.0	0.801	0.20	0.07	0.16	0.02
IRW-33A	T-1	80	15.0	24	56	107.8	23.3	42	21	21	0.11	1.10	1.25	0.90	1.1	0.8	1.08	1.0	0.685	0.19	0.07	0.41	0.01
IRW-42	T-2	75	1.0	30	45	114.7	26.1	44	22	22	0.19	1.18	3.96	4.38	3.4	3.7	4.17	3.5	0.541	0.18	0.04	0.22	0.01
IRW-44	T-1	81	10.0	25	56	103.6	20.1	40	19	21	0.05	1.11	2.91	3.93	2.6	3.5	3.42	3.1	0.657	0.17	0.05	0.11	0
IRW-49	T-2	77	2.6	30	47	113.4	20.7	60	19	41	0.04	1.12	5.11	4.00	4.5	3.6	4.56	4.1	0.475	0.09	0.03	0.3	0.08
IRW-50	T-1	77.69	5.2	25	52.69	111.2	19.9	NP	NP	NP		1.02	8.28	5.25	8.1	5.2	NV	NV	0.563	0.19	0.03	1.0	0
IRW-51	T-1	80	10.7	25	55	105.8	21.6	38	19	19	0.14	1.17	1.94	2.75	1.7	2.4	2.35	2.0	0.64	0.23	0.09	0.2	0.03
IRW-52	T-2	88	15.2	35	53	108.3	22.3	44	19	25	0.13	1.63	2.56	2.60	1.6	1.6	2.58	1.6	0.628	0.16	0.05	0.47	0.24
IRW-53	T-1	63.39	18.5	15	48.39	107.6	19.9	39	17	22	0.13	0.96	1.96	4.00	2.0	4.2	NV	NV	0.539	0.15	0.04	0.32	0.04
																Average:	3.85	3.0	0.6393	0.16	0.05	1.3993	0.2292

NV: Consolidation Test Not Valid

RKK-2

OK 1-2-09

Summary:

SR 1/I-95 Interchange - Consolidation Soil Parameters - Stratum 2a																		
PointID	Sample	GS EL	GWL (ft)	Depth (ft)	Sample EL	γ_T (pcf)	P_0 (tsf)	$Pc_{Casagrande}$ (tsf)	$Pc_{Work\ Energy}$ (tsf)	OCR_C	$OCR_{W.E.}$	FINAL P_c (tsf)	FINAL OCR	e_0	C_c	C_r	$C_{v(Max)}$ (ft^2/d)	$C_{v(Min)}$ (ft^2/d)
IBR-52	U-1	57	11.5	16	41	126.9	0.88	1.10	3.75	1.3	4.3	3.75	4.3	0.678	0.18	0.07	0.22	0.02
IBR-60	U-1	86	11.4	18	68	133.3	0.94	1.97	1.83	2.1	2.0	1.97	2.1	0.521	0.13	0.03	2.10	0.01
IBR-60	U-2	86	11.4	46	40	132.3	1.90	1.23	2.00	0.6	1.1	2.00	1.1	0.602	0.16	0.04	1.11	0.01
IBR-61	U-1	84	24.0	14	70	123.6	0.87	2.91	1.85	3.4	2.1	2.91	3.4	0.748	0.24	0.05	2.64	0.03
IBR-61	U-2	84	24.0	59	25	123.3	2.55	0.69	2.50	0.3	1.0	2.50	1.0	0.839	0.22	0.06	0.56	0.01
IEB-15	U-1	83	52.0	12	71	129.5	0.78	3.53	6.00	4.5	7.7	3.53	4.5	0.669	0.19	0.05	3.17	0.02
IEB-15	U-2	83	52.0	31	52	132.8	2.02	5.29	1.91	2.6	0.9	5.29	2.6	0.527	0.17	0.05	1.10	0.01
IEB-15	U-3	83	52.0	56	27	132.8	3.56	2.40	4.05	0.7	1.1	4.05	1.1	0.582	0.20	0.06	1.70	0.01
URS-1	U-1	73	6.0	24	49	126.0	0.95	0.67	0.70	0.7	0.7	NV	NV	0.792	0.23	0.07	0.17	0.03
URS-3	U-1	82	6.0	35	47	132.3	1.33	2.59	2.40	1.9	1.8	2.59	1.9	0.614	0.20	0.07	1.92	0.02
URS-3	U-2	82	6.0	50	32	117.0	1.74	0.84	1.20	0.5	0.7	NV	NV	0.987	0.27	0.08	0.33	0.01
URS-4	U-1	77	14.0	22	55	123.9	1.12	1.78	3.10	1.6	2.8	3.1	2.8	0.851	0.25	0.09	2.50	0.01
URS-4	U-2	77	14.0	37	40	131.2	1.64	1.01	1.12	0.6	0.7	NV	NV	0.458	0.20	0.06	2.35	0.01
URS-5	U-1	63	4.0	35.5	27.5	121.5	1.24	2.01	1.60	1.6	1.3	2.01	1.6	0.786	0.23	0.09	1.61	0.01
											Average:	3.1	2.4	0.6896	0.21	0.06	1.5343	0.0150

NV: Consolidation Test Not Valid

Add I-95-09

Objective: To evaluate the new consolidation test results to determine the Preconsolidation Stress (P_c) and over-consolidation ratio (OCR) using the work energy method. This method will be compared with the Casagrande method & a final P_c & OCR value will be chosen. The final values will be chosen based on the best agreement with the consolidation test original stress-strain curve.

- Corrected overburden pressure on Consol test reports to actual pressure + not estimated.
- NV: Final P_c (or Final OCR) unable to be determined.

- 2 Work Energy graphs were constructed for each test. The first shows only the loading to the first unloading. This provides a "zoomed in" view of the x-axis. The second shows all of the loading cycles of the test. The graph most accurately depicting the consolidation test loading curve was used to determine the Preconsolidation pressure using the Work Energy method.

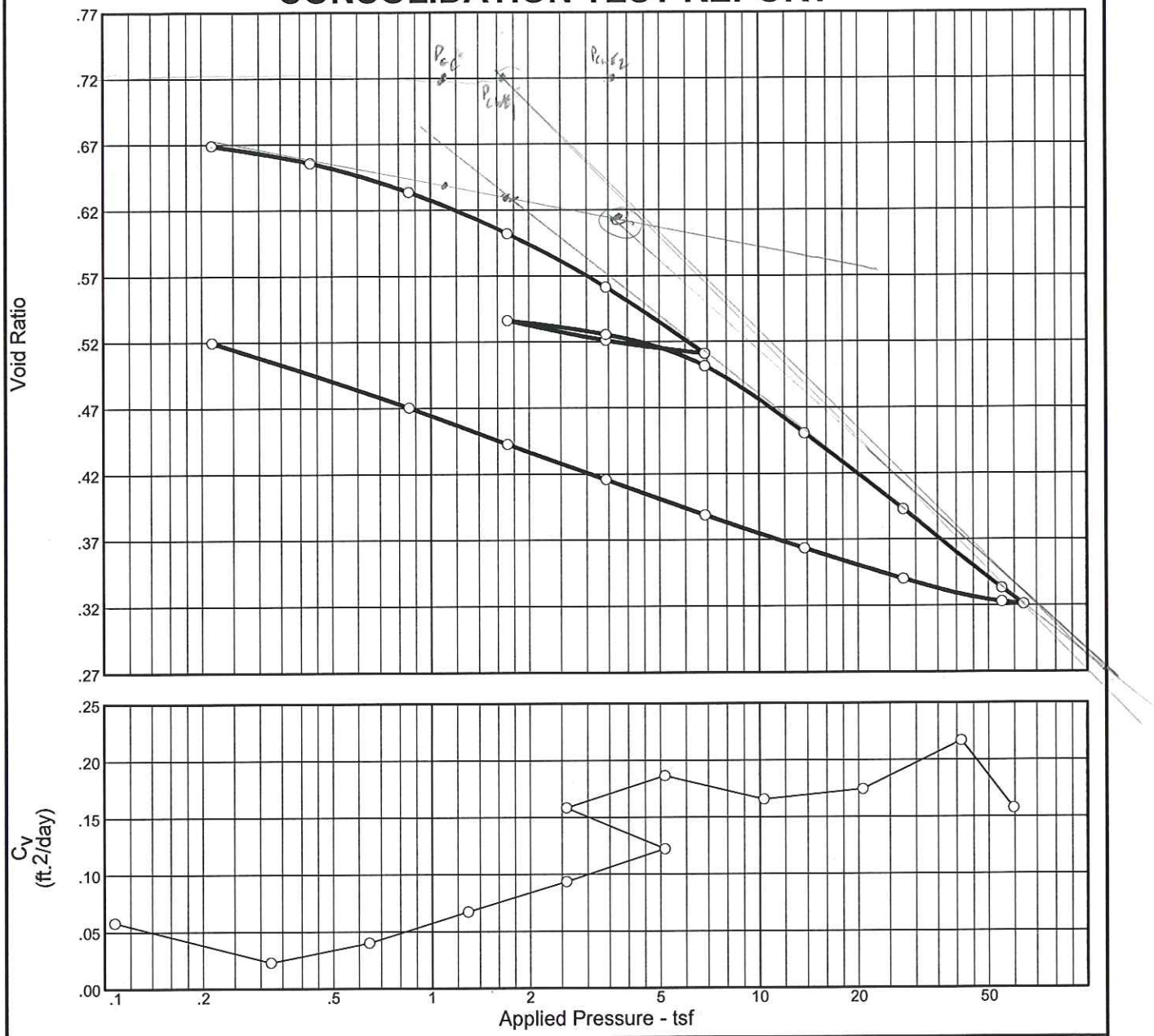
Legend
P_0 = Effective overburden stress
Pc_{cas} = Consolidation Test P_c
Pc_{WE} = Work Energy P_c
OCR_c = OCR from P_{cc}
OCR_{WE} = OCR from Pc_{WE}
Final P_c = P_c to use for design based on excel of P_{cc} + Pc_{WE}

RKK-3

JJT
1-2-09

RKK-4

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf)	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
115.7 %	29.8 %	97.8	43.1	19.7	2.628	0.99	1.10	0.18	0.07			0.678

MATERIAL DESCRIPTION	USCS	AASHTO
Saturated red and gray clay w/trace of fine to coarse sand.	CL	A-7-6(21

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

Source: IBR # 52 **Sample No.:** U-1 **Elev./Depth:** 16.0

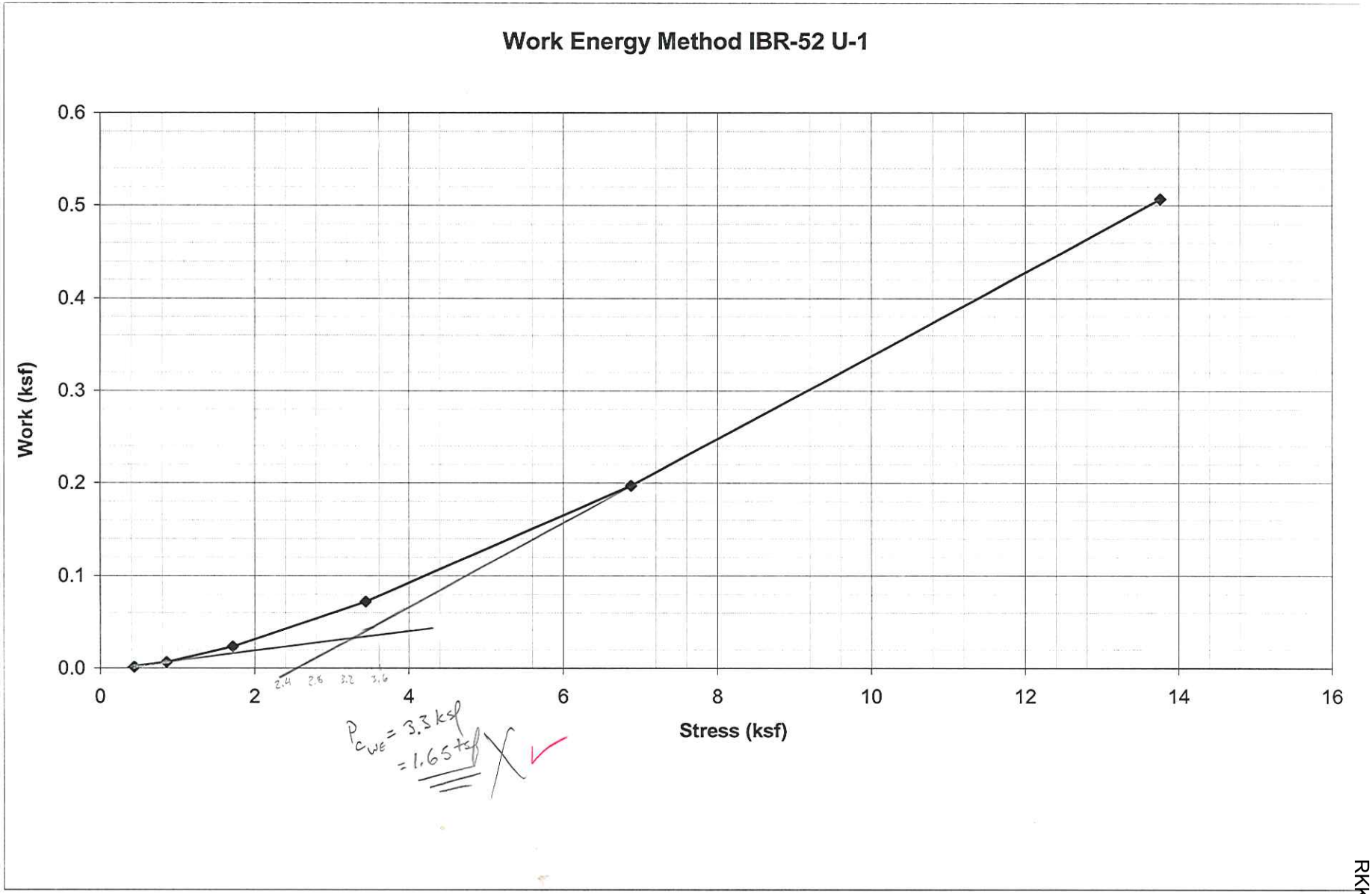
CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Remarks:

Figure

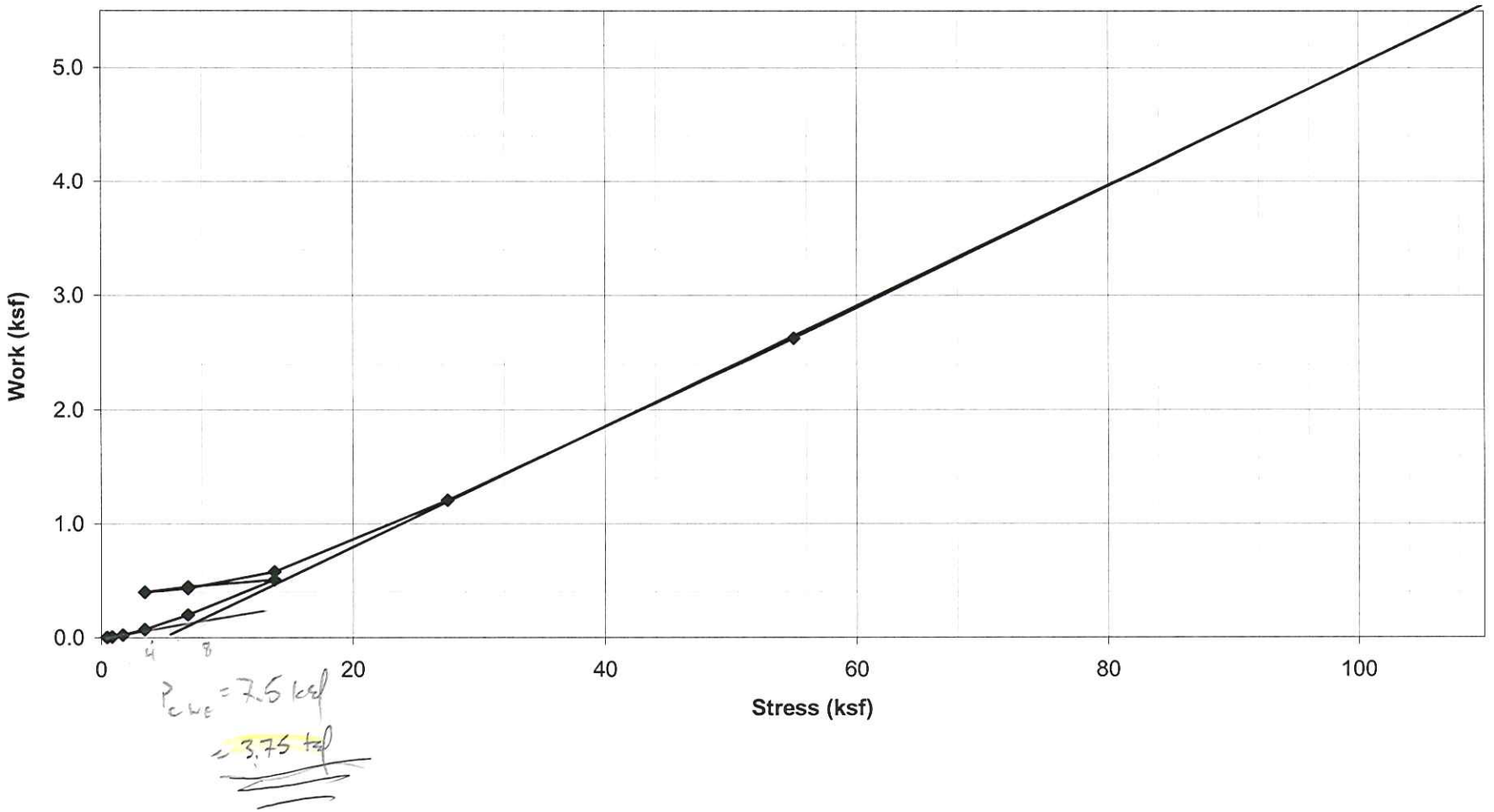
Delaware Turnpike Improvements
SR-1 Interchange



RKK-5

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy Final Design.xls

Work Energy Method IBR-52 U-1



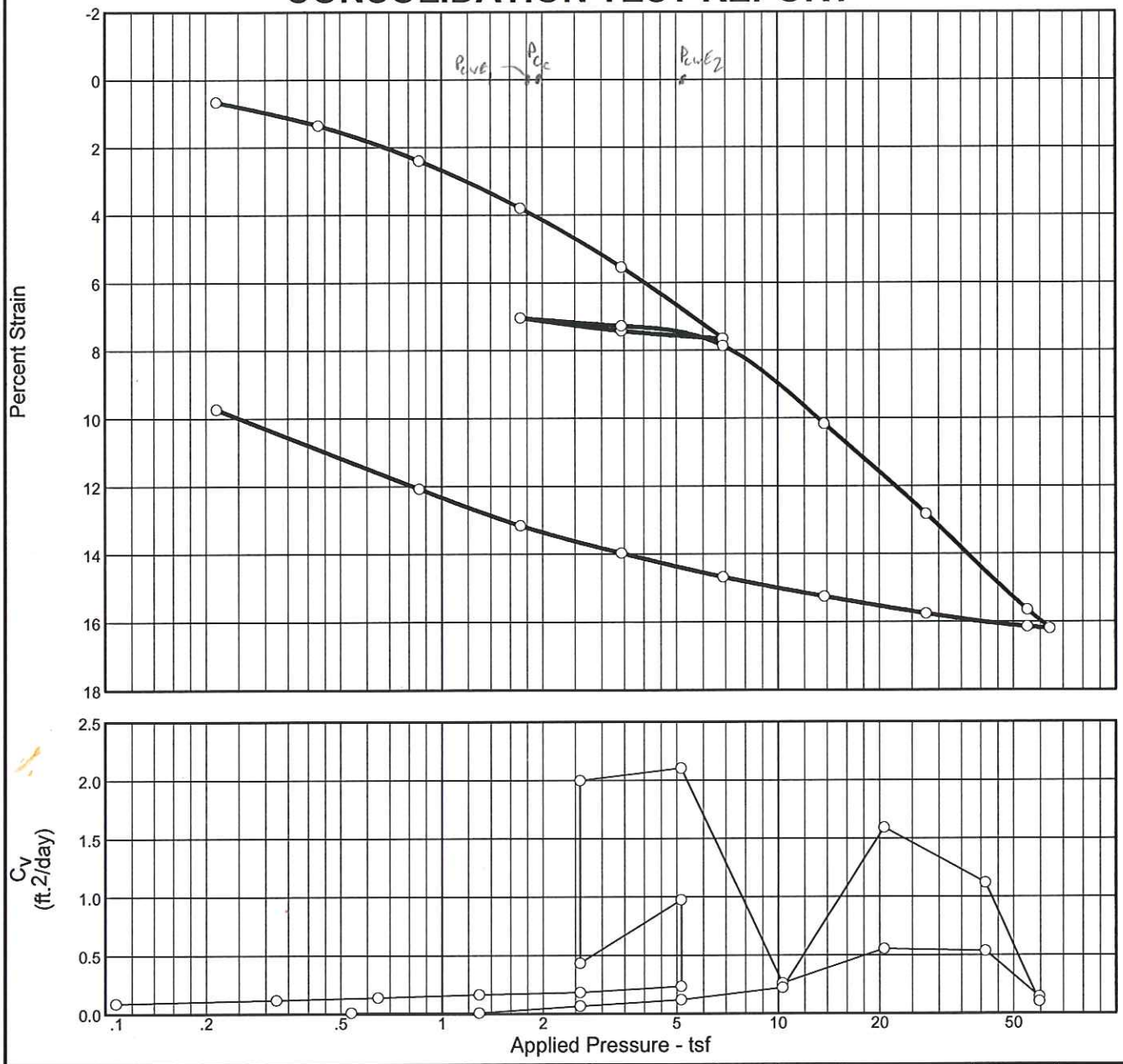
RKK-6

Apr 1-2-09

SBT
1-2-09

RKK-7

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf)	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
105.8 %	20.5 %	110.6	30.2	11.3	2.693	0.72	1.97	0.13	0.03			0.521

MATERIAL DESCRIPTION	USCS	AASHTO
Saturated gray fine sandy clay w/trace of coarse sand.	CL	A-6(8)

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

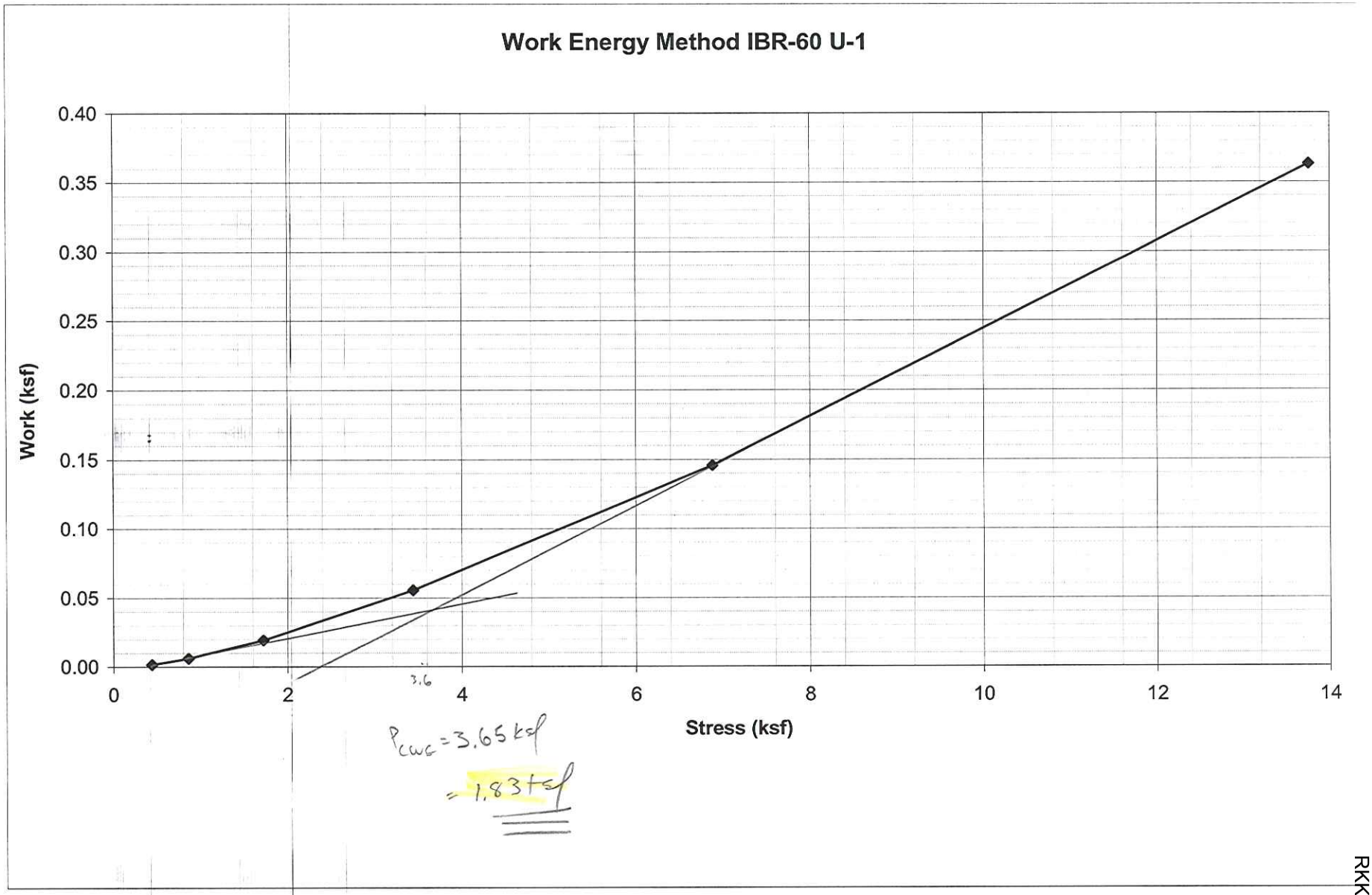
Source: IBR # 60 **Sample No.:** U-1 **Elev./Depth:** 18.0

CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

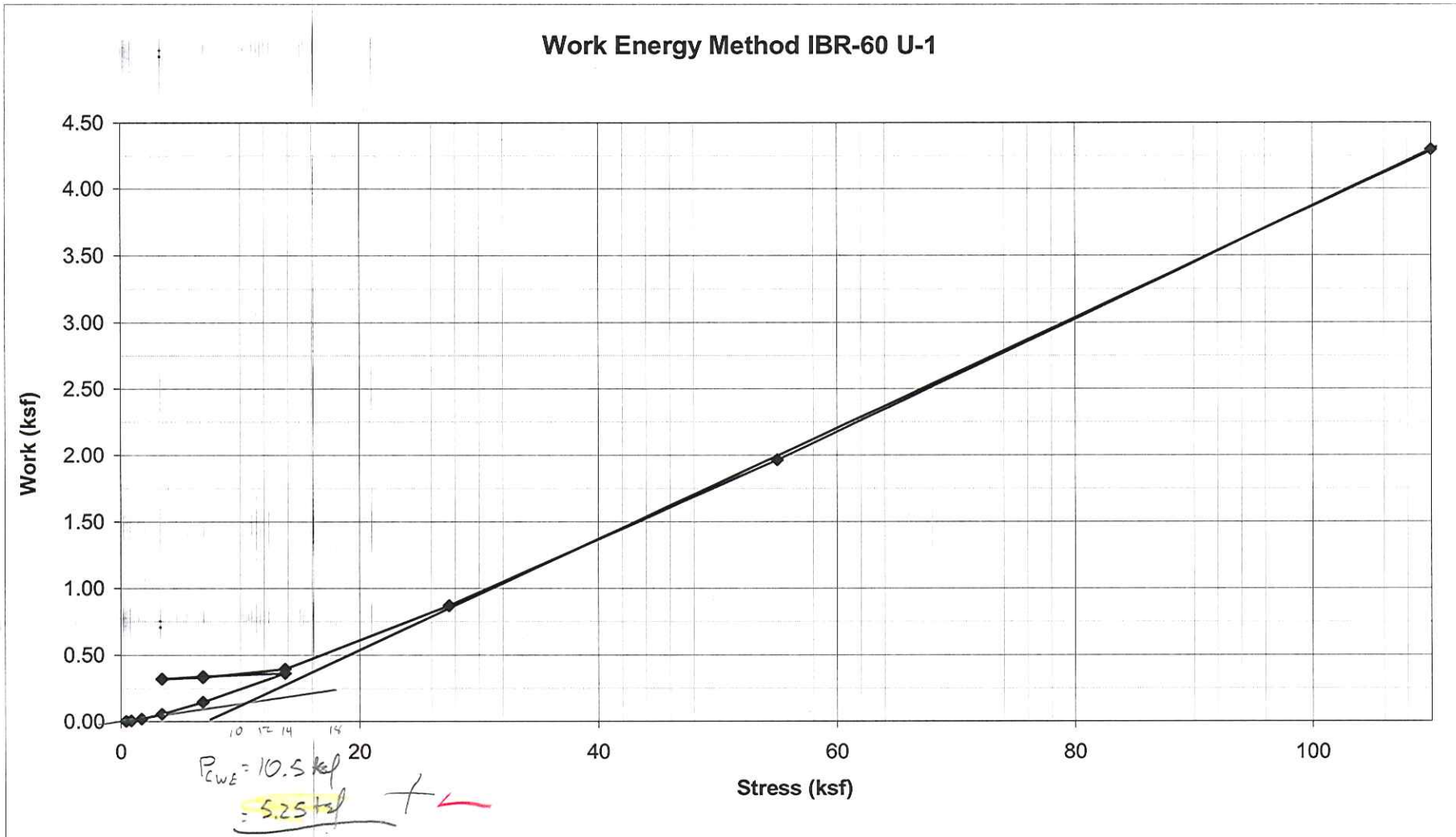
Remarks:

Figure



RKK-8

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy Final Design.xls

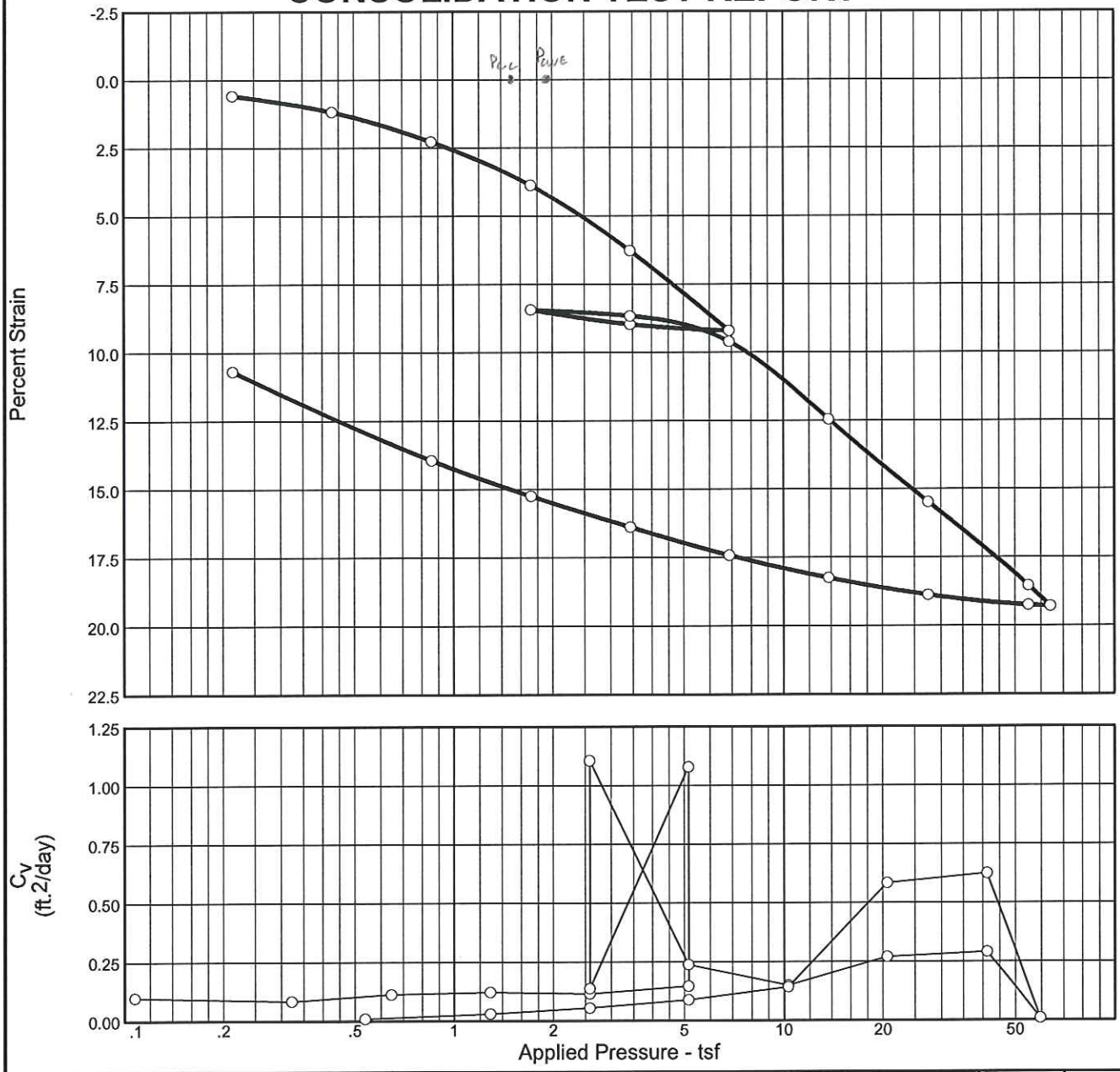

Work Energy Method IBR-60 U-1
Work (ksf)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
20
40
60
80
100
Stress (ksf)
10 12 14 16
P_{CWE} = 10.5 ksf
= 5.25 tsf

RKK-9

JDT
1-2-09

RKK-10

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf) 1.90	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
109.9 %	24.2 %	106.5	36.2	15.6	2.733	~~1.54~~	1.23	0.16	0.04			0.602

MATERIAL DESCRIPTION $P_{c.w.e} = 1.93$ tsf	USCS	AASHTO
Saturated red clay w/trace of fine sand.	CL	A-6(15)

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

Source: IBR # 60 **Sample No.:** U-2 **Elev./Depth:** 46.0

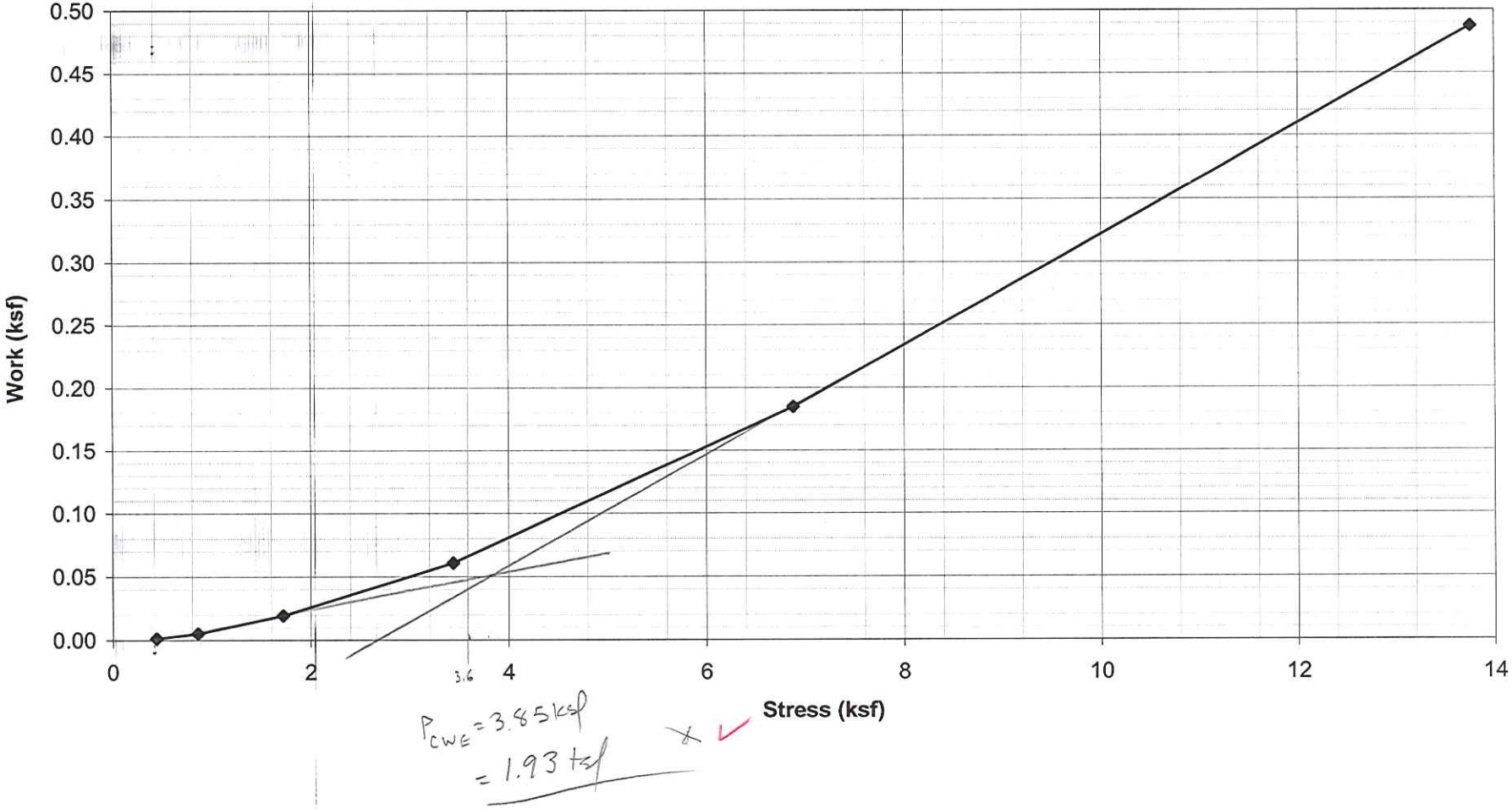
CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Remarks:

Figure

Work Energy Method IBR-60 U-2



RKK-11

1-2 09

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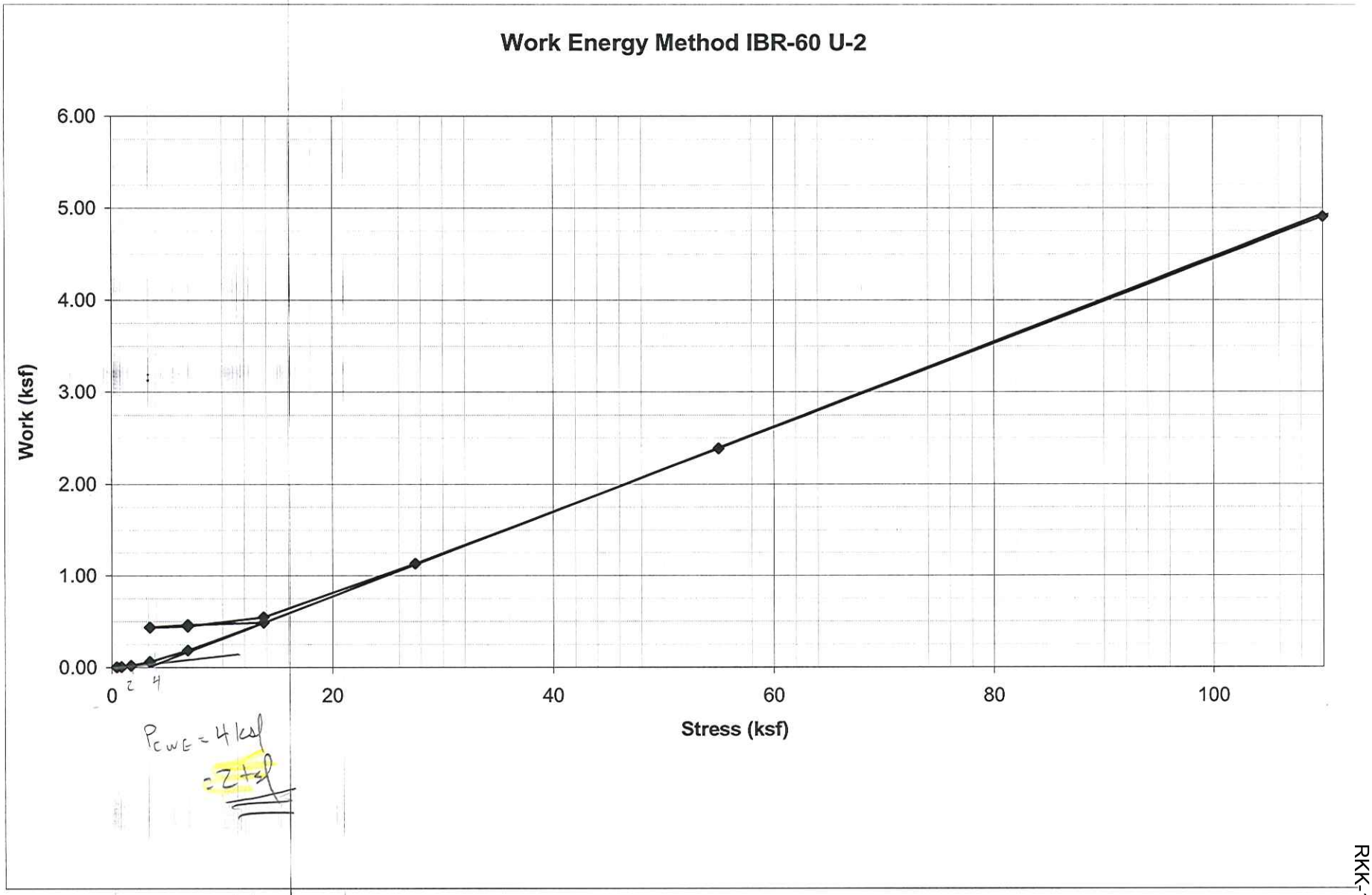

RKK-12

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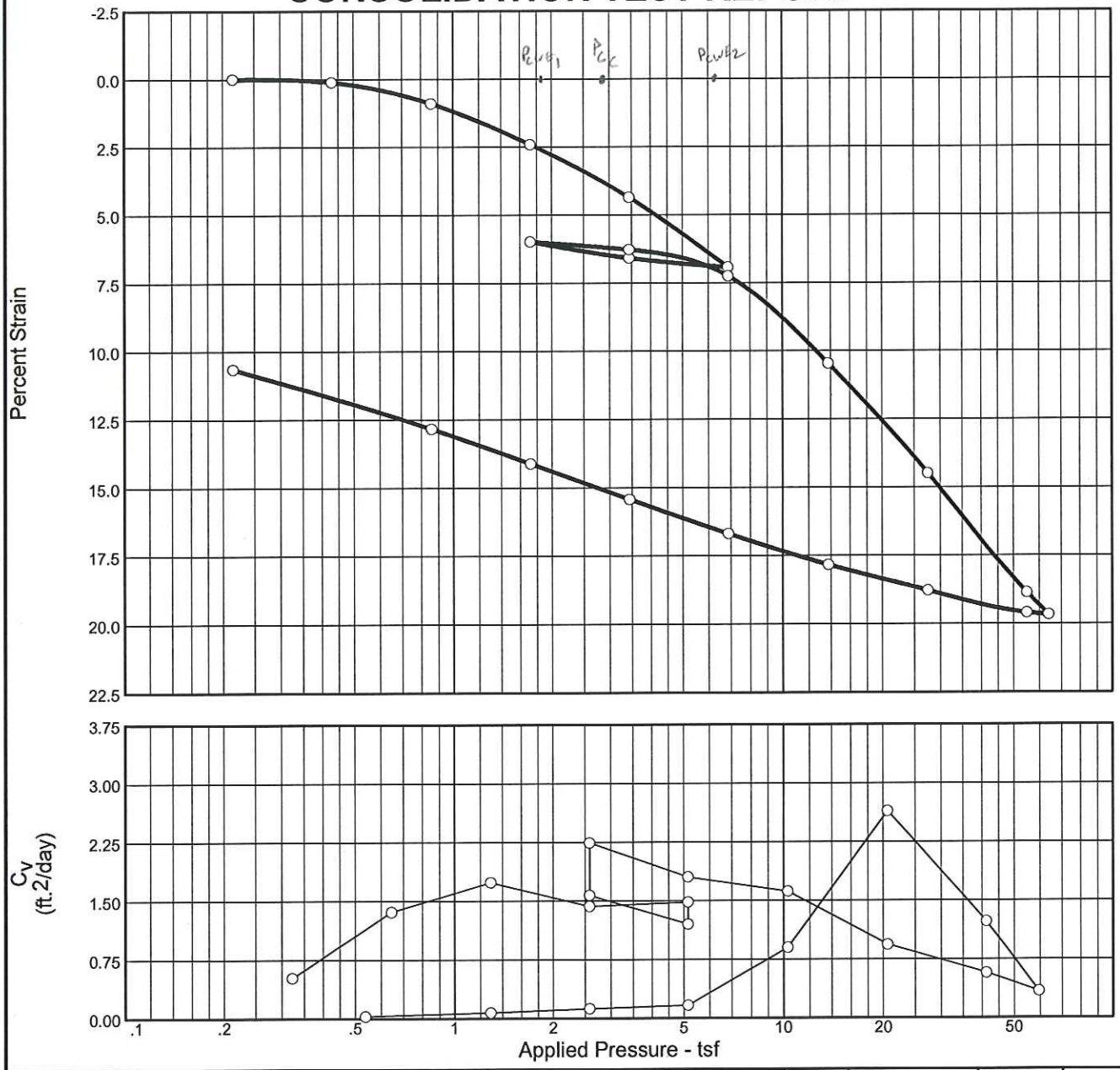
RKK-13

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf)	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
108.6 %	30.7 %	94.6	34.3	13.0	2.650	0.68	2.91	0.24	0.05			0.748

MATERIAL DESCRIPTION	USCS	AASHTO
Saturated gray clay w/trace of fine sand.	CL	A-6(13)

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

Source: IBR # 61 **Sample No.:** U-1 **Elev./Depth:** 14.0

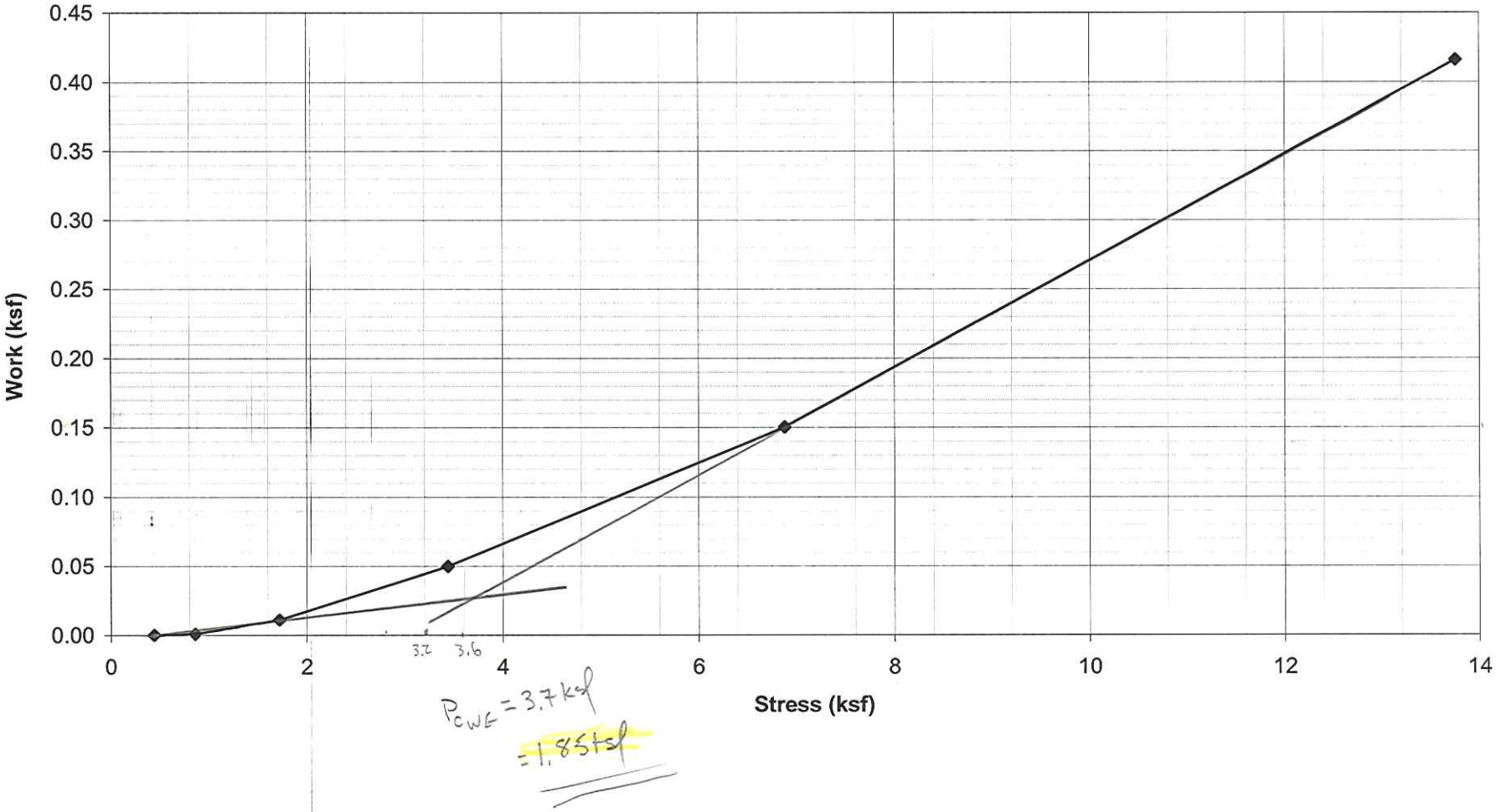
CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Remarks:

Figure

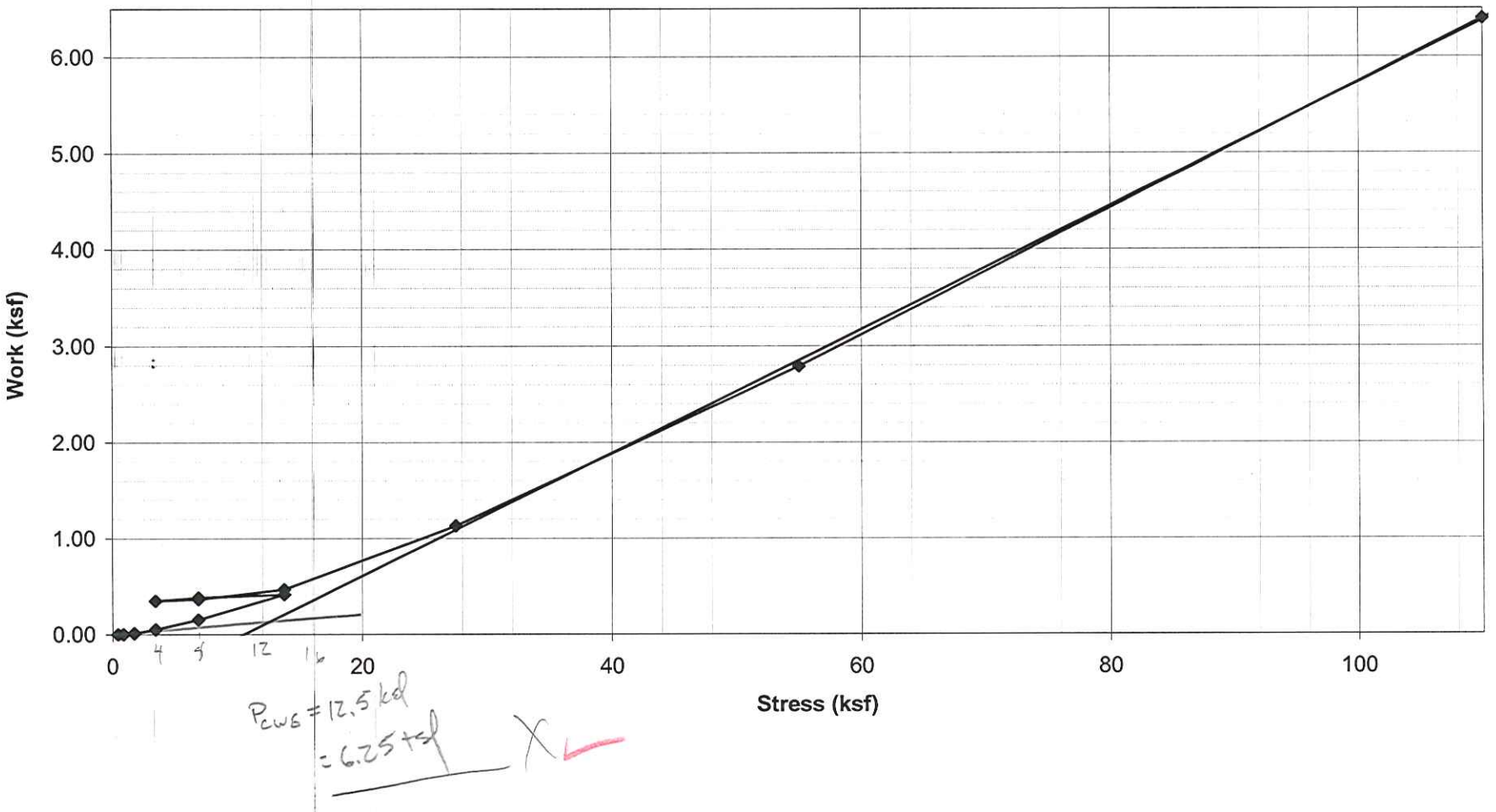
Work Energy Method IBR-61 U-1



RKK-14

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy Final Design.xls

Work Energy Method IBR-61 U-1



$P_{cwG} = 12.5$ ksf
$= 6.25$ tsf

RKK-15

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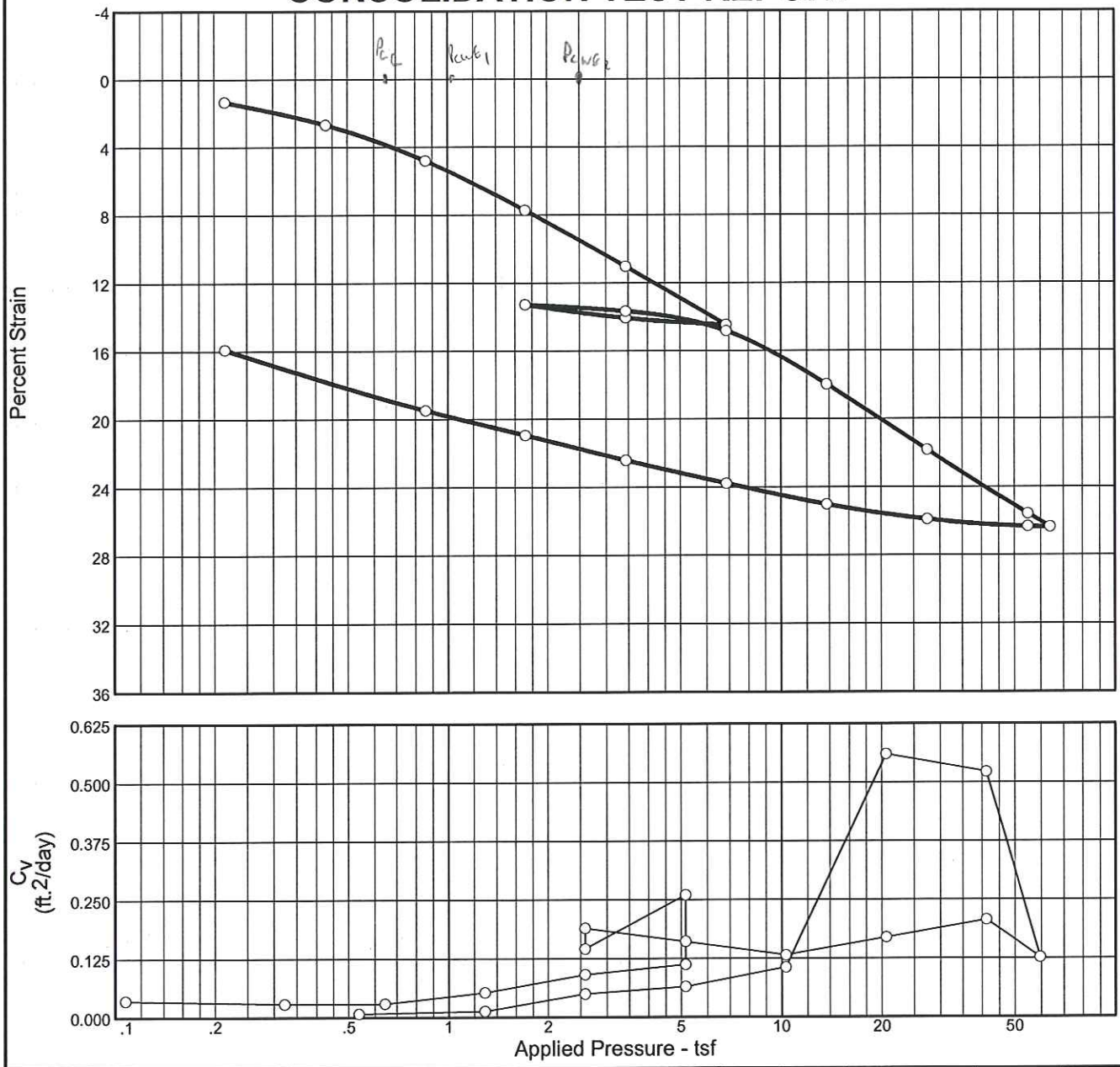
JPT 1-2-09

RKK-16

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf) 2.55	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
108.0 %	33.3 %	92.5	45.7	21.7	2.726	1.98	0.69	0.22	0.06			0.839

MATERIAL DESCRIPTION	USCS	AASHTO
Saturated reddish gray clay w/trace of fine to coarse sand and gravel.	CL	A-7-6(20

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

Source: IBR # 61 **Sample No.:** U-2 **Elev./Depth:** 59.0

CONSOLIDATION TEST REPORT

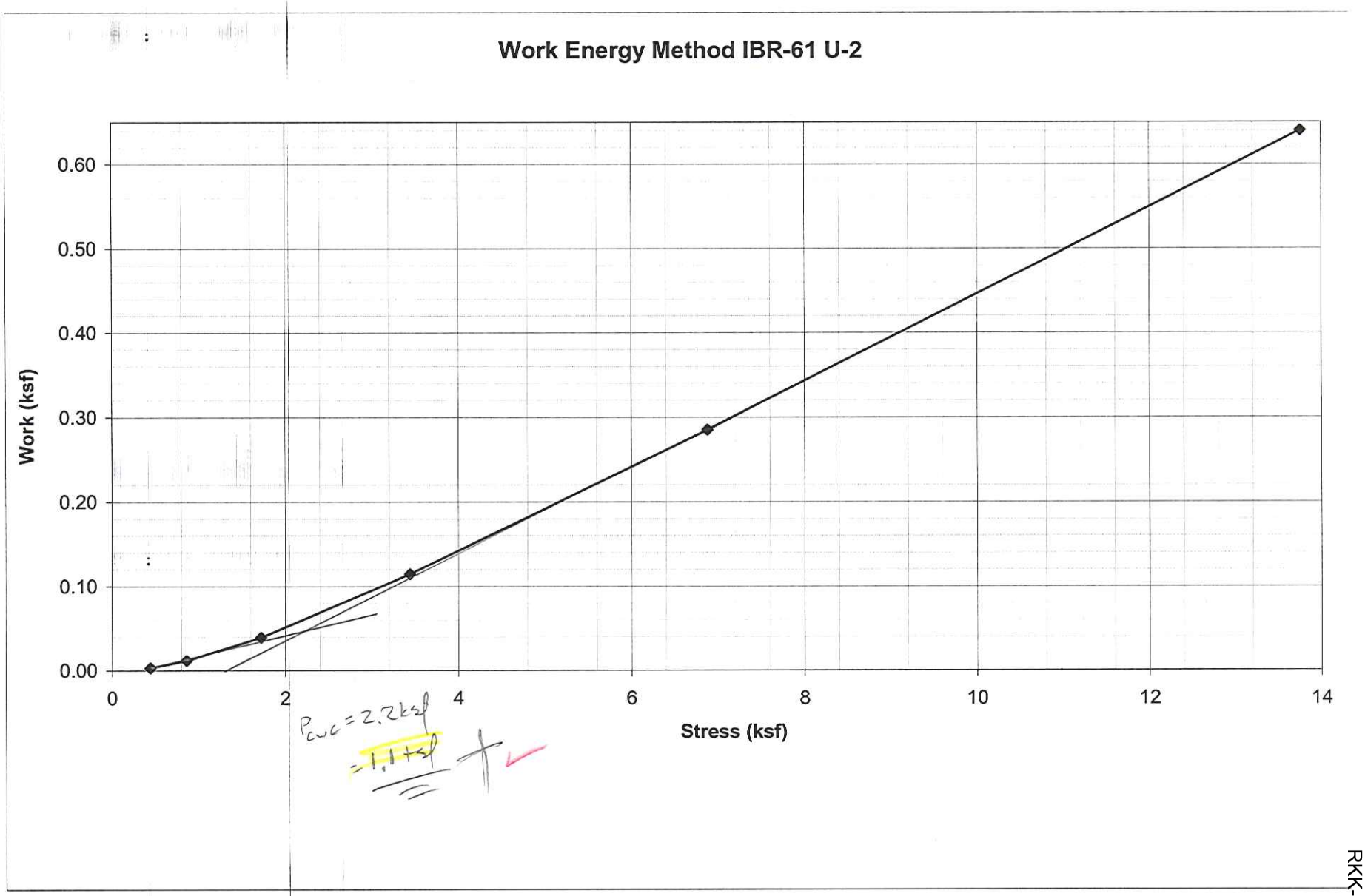
Delaware Department of Transportation
Materials and Research Laboratory

Remarks:

Figure

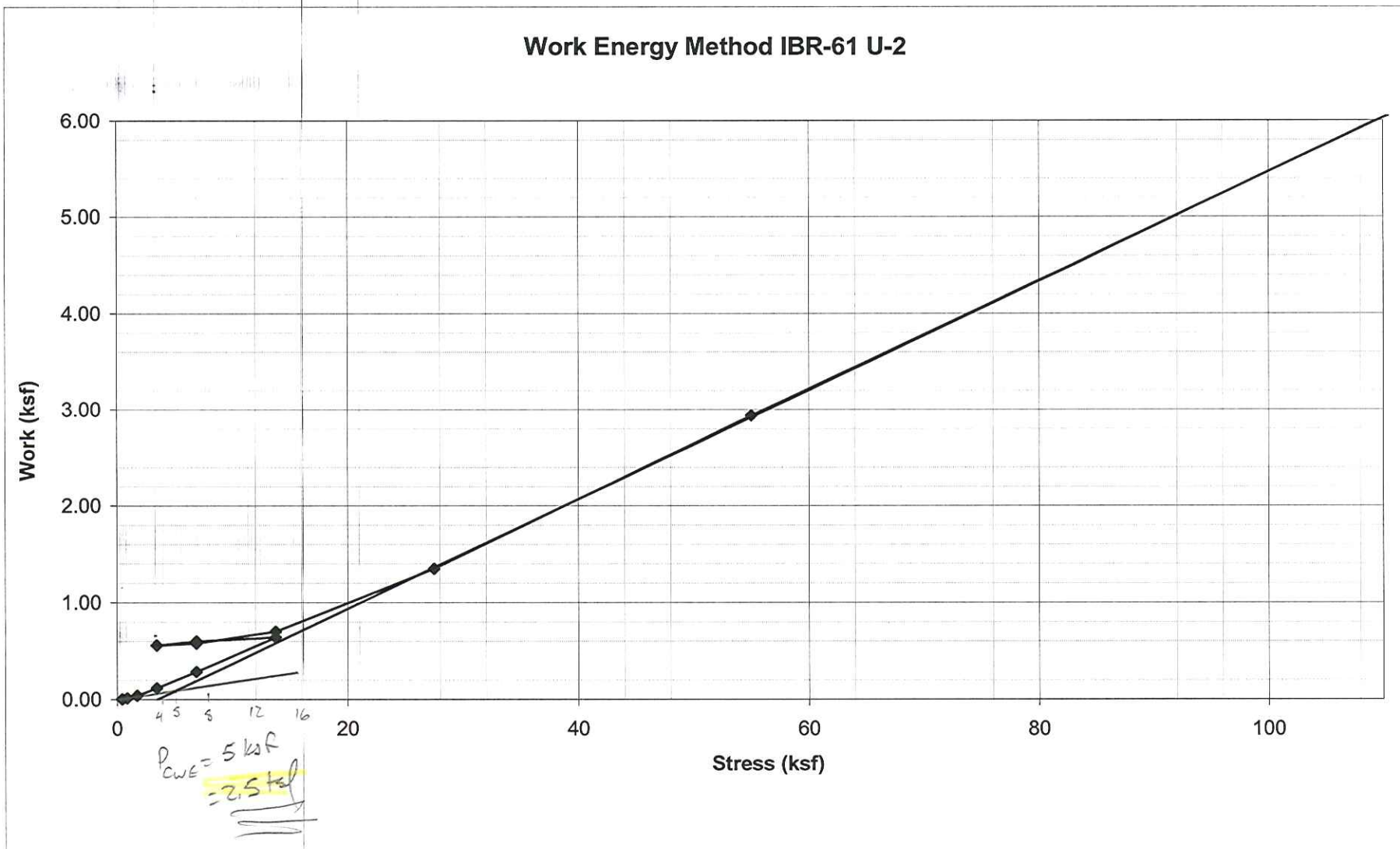
103-059-27U

SR1 / I-95 Interchange



RKK-17

1-2-09


Work Energy Method IBR-61 U-2
Work (ksf)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
20
40
60
80
100
Stress (ksf)
4 5 8 12 16
P_{CWE} = 5 ksf
= 2.5 tsf

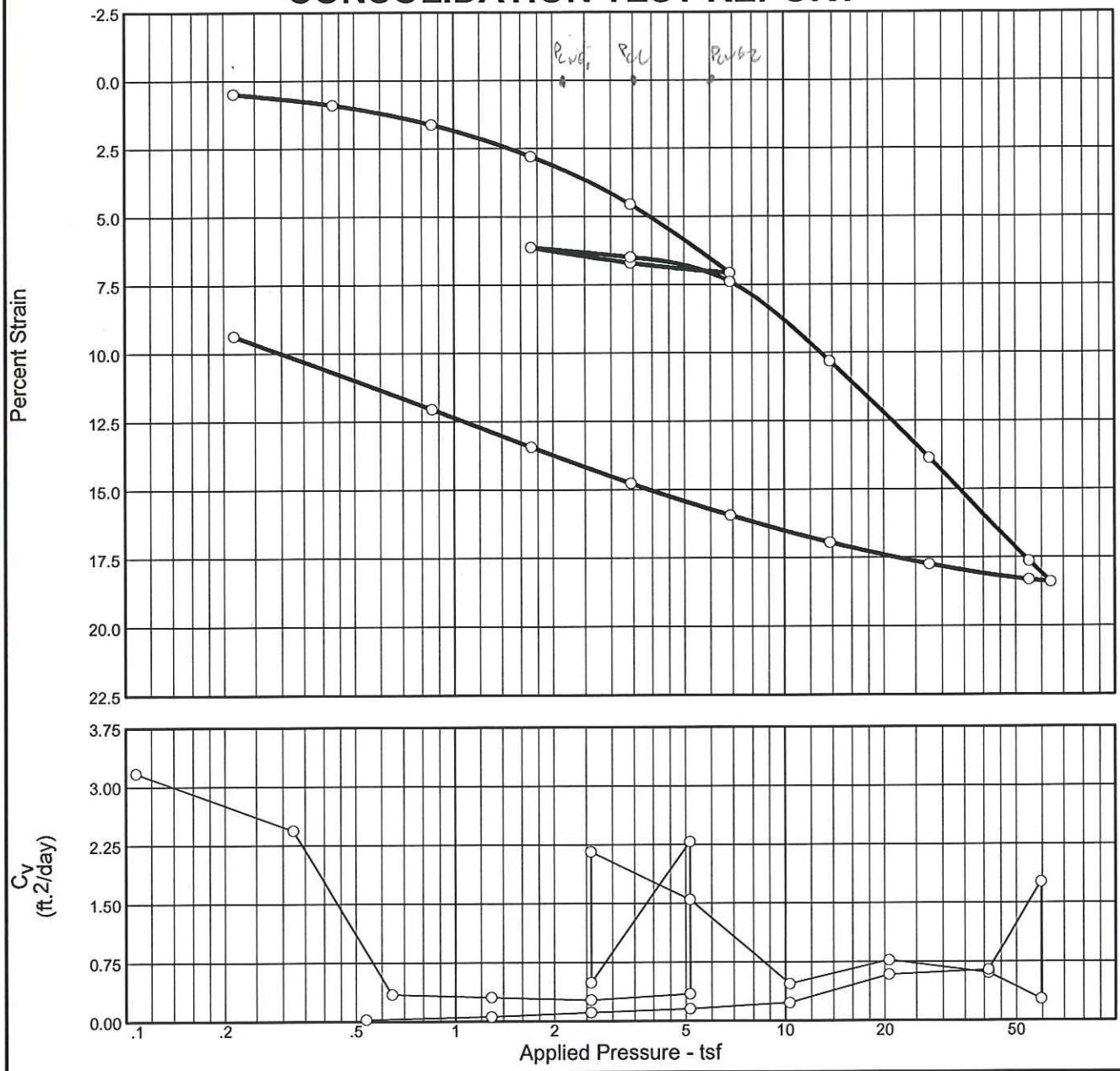
RKK-18

1-2-07

SPT 1-2-09

RKK-19

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf) 0.73	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
109.1 %	26.7 %	102.2	48.8	22.7	2.733	0.75	3.53	0.19	0.05	—		0.669

MATERIAL DESCRIPTION P_{CWE} = 2.2 tsf / 6 tsf	USCS	AASHTO
Saturated red clay w/trace of fine sand.	CL	A-7-6(27

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

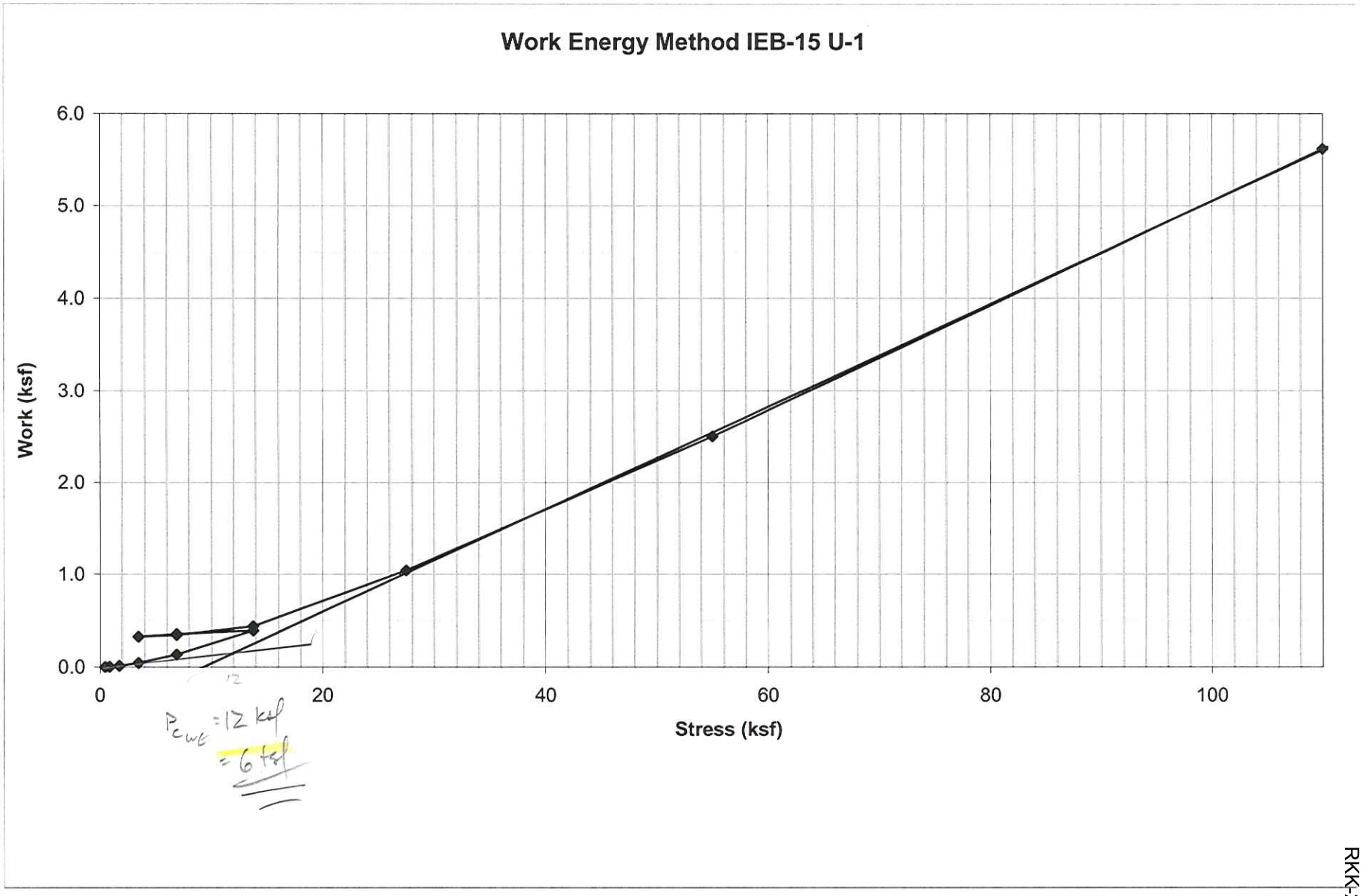
Source: IEB # 15 **Sample No.:** U-1 **Elev./Depth:** 12.0

CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

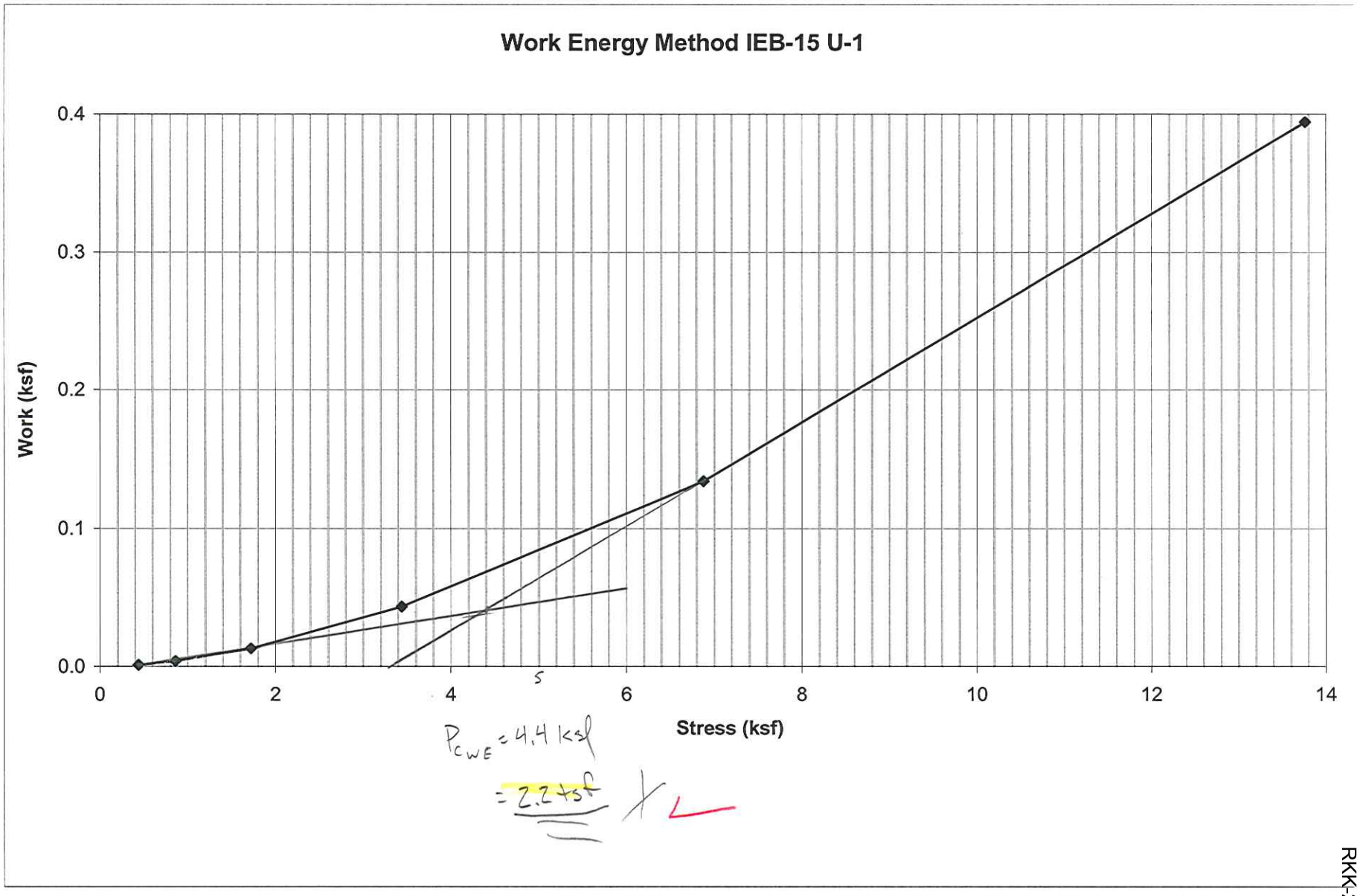
Remarks:

Figure



RKK-20

POT 1-2-09



RKK-21

OUT 1-2-09

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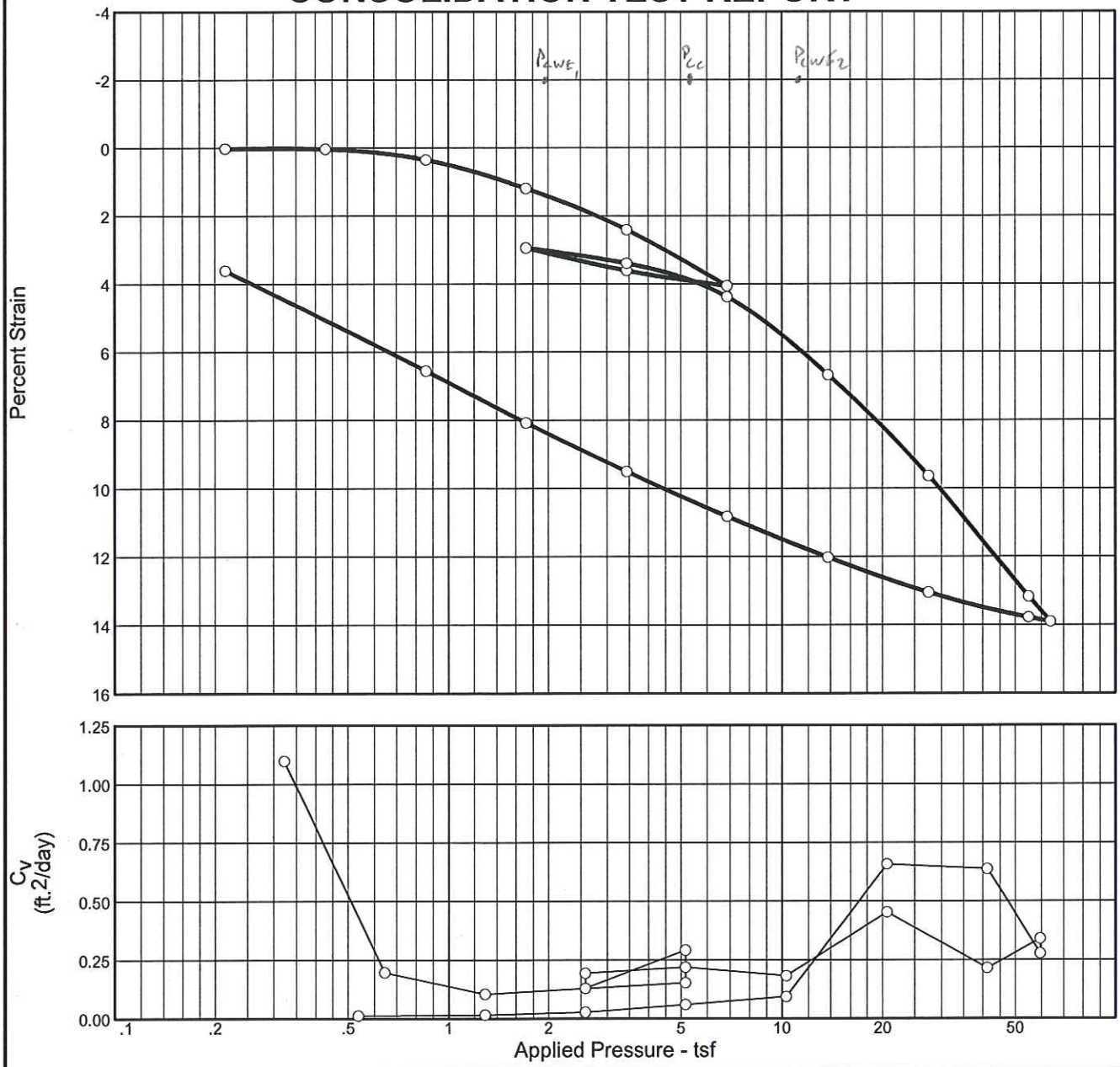
JPT 1-2-09

RKK-22

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf)	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
113.8 %	22.6 %	108.3	35.8	16.2	2.649	1.89	5.29	0.17	0.05			0.527

2.02

MATERIAL DESCRIPTION	USCS	AASHTO
Saturated gray clay w/trace of fine to coarse sand.	CL	A-6(16)

$P_{c\,WE} = 1.9$ tsf / 11.25 tsf

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

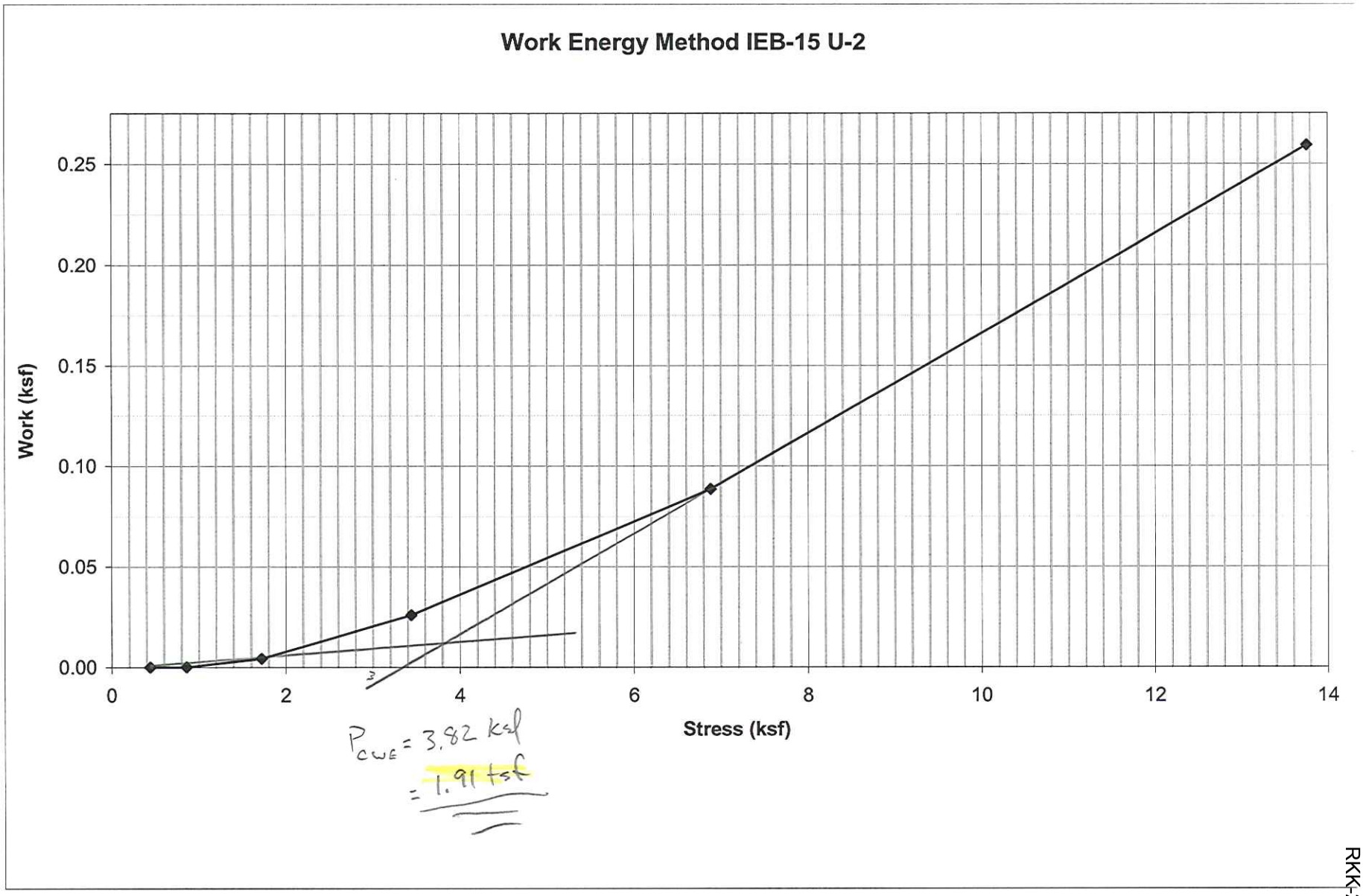
Source: IEB # 15 **Sample No.:** U-2 **Elev./Depth:** 31.0

CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

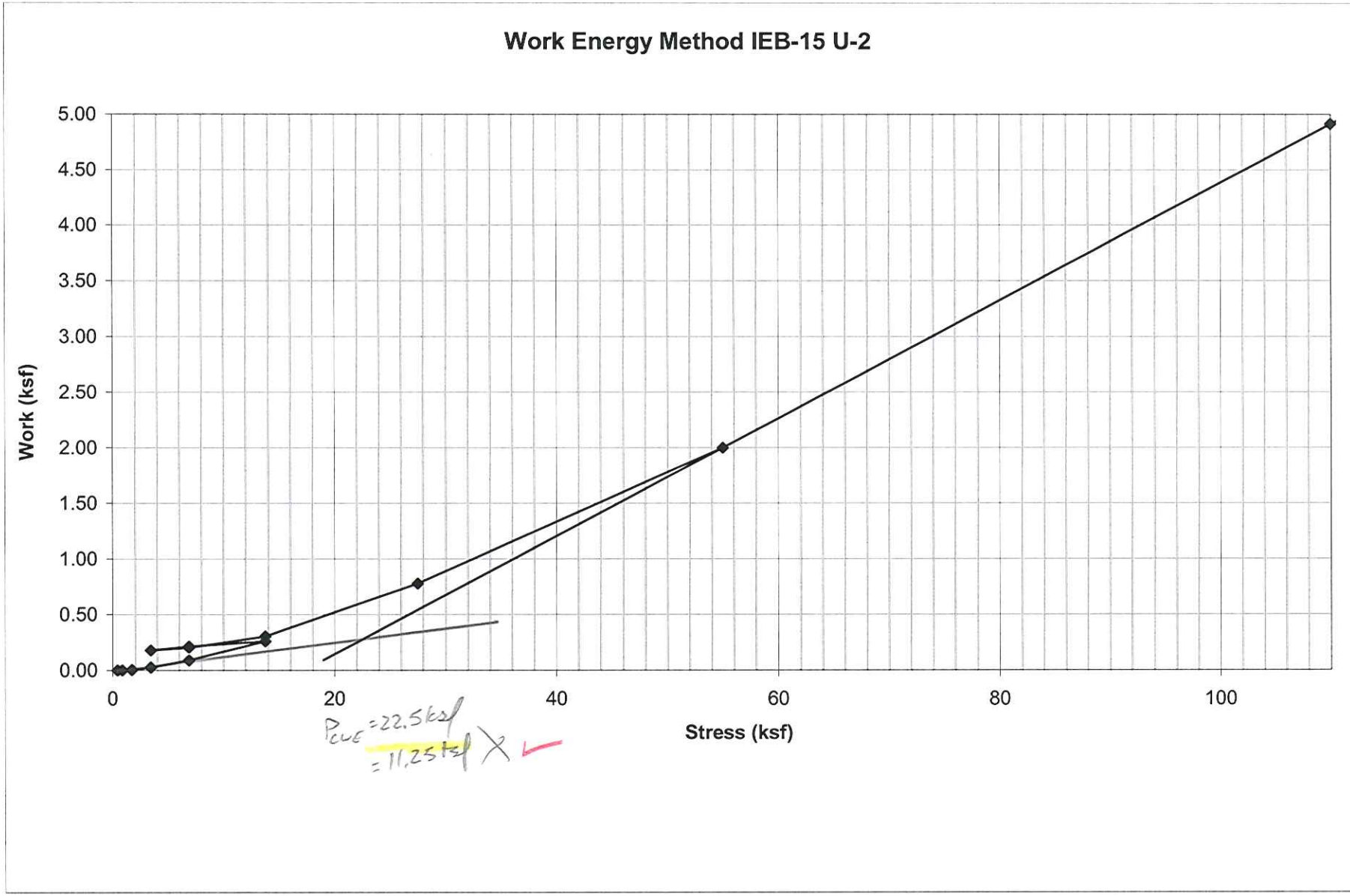
Remarks:

Figure



RKK-23

JVT 1-2-07

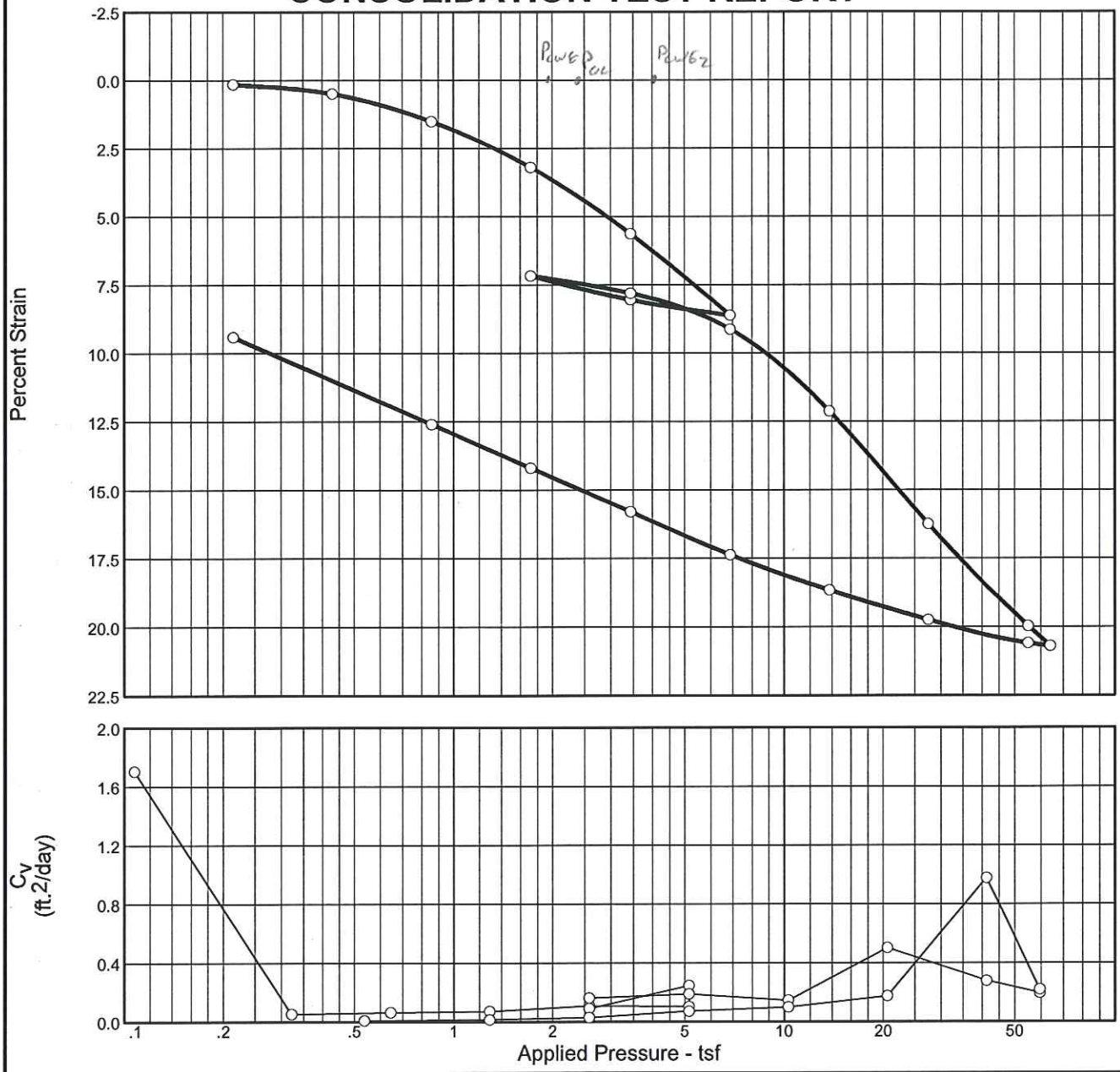

Work Energy Method IEB-15 U-2
Work (ksf)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
20
40
60
80
100
Stress (ksf)
P_{ave} = 22.5 ksf
= 11.25 tsf

RKK-24

SPT 1-2-09

RKK-25

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf) 3.56	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
117.6 %	25.5 %	105.8	47.2	22.3	2.682	3.42	2.40	0.20	0.06			0.582

MATERIAL DESCRIPTION	USCS	AASHTO
$P_{c/E}$ = 1.8 tsf @ 4.05 Ft Saturated red and gray clay w/trace of fine sand.	CL	A-7-6(25

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

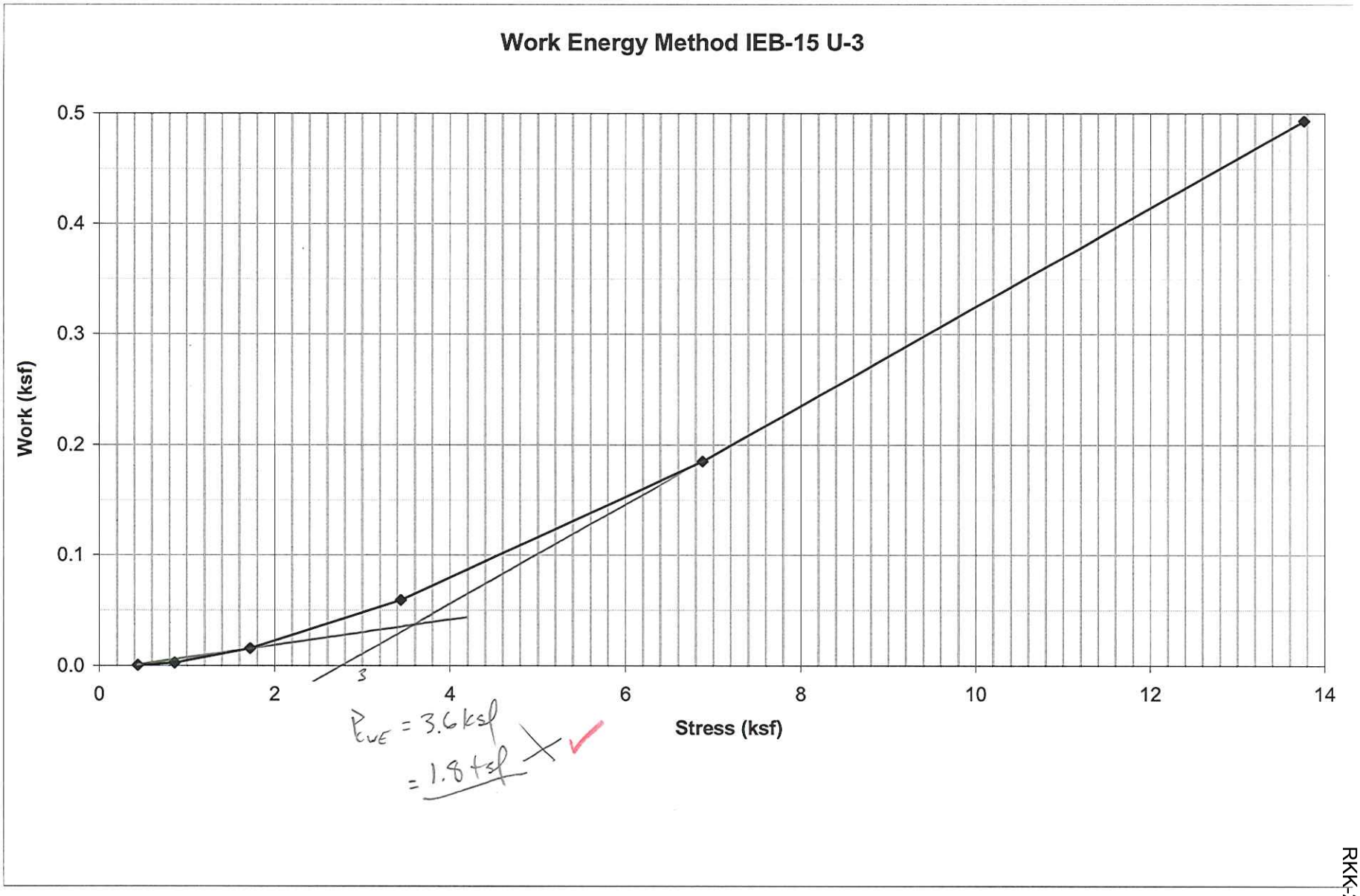
Source: IEB # 15 **Sample No.:** U-3 **Elev./Depth:** 56.0

CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Remarks:

Figure



RKK-26

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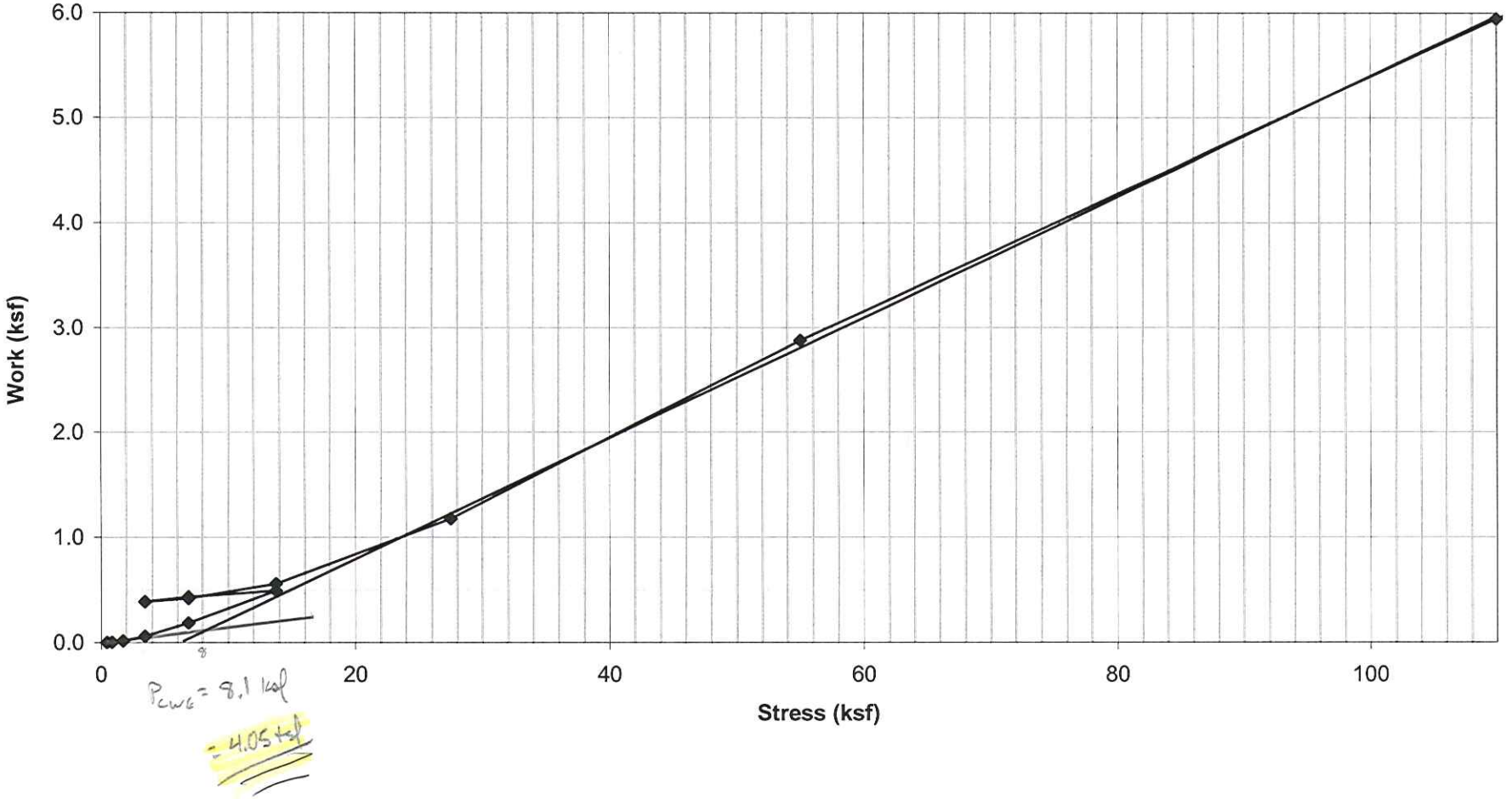
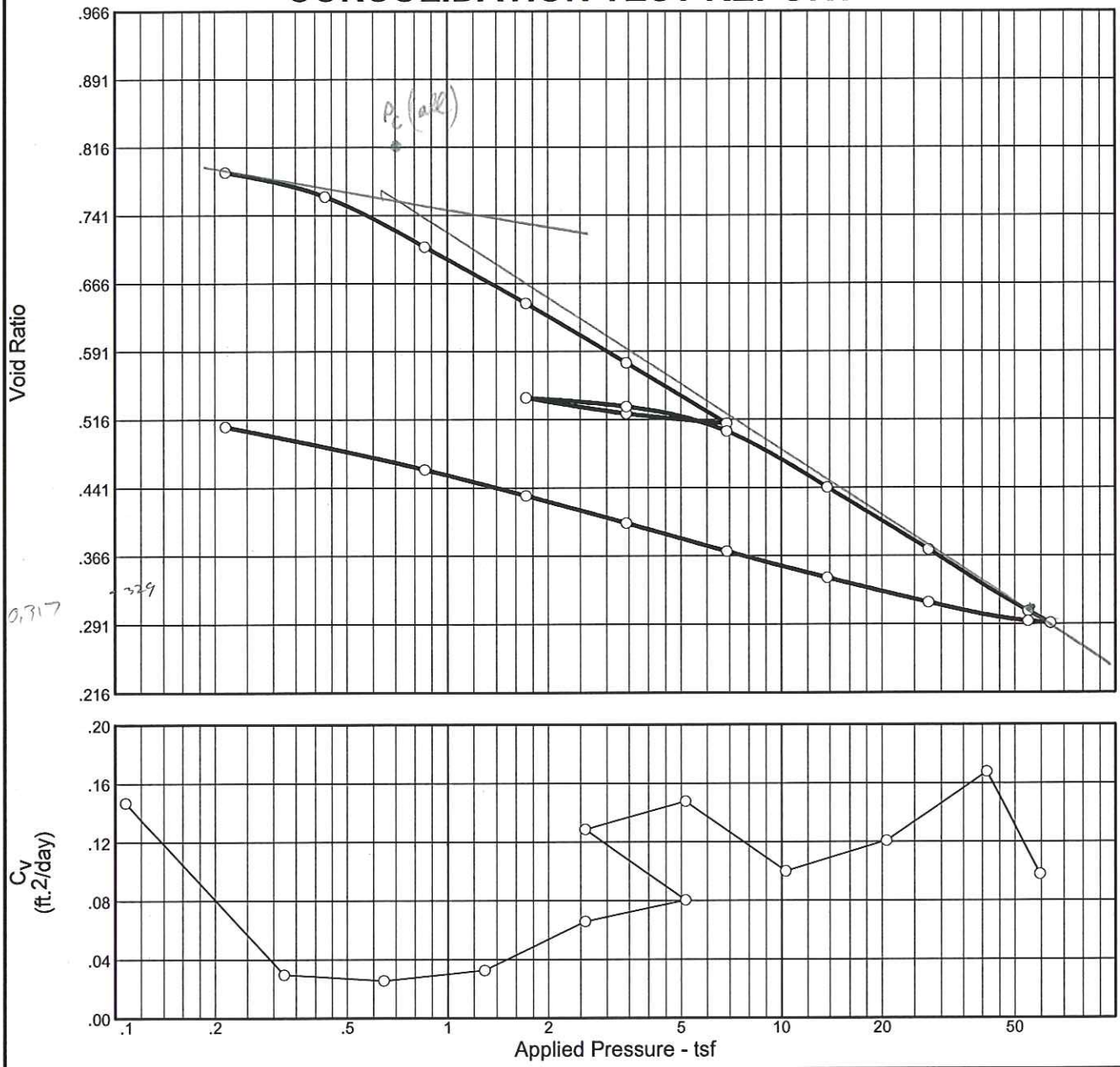
Work Energy Method IEB-15 U-3



RKK-27

RKK-28

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf)	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
114.4 %	33.5 %	94.4	47.8	23.5	2.709	1.22	0.67	0.23	0.07			0.792

MATERIAL DESCRIPTION	USCS	AASHTO
Saturated light gray clay w/trace of fine to coarse sand.	CL	A-7-6(23

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

Source: URS # 1 **Sample No.:** U-1 **Elev./Depth:** 24.0

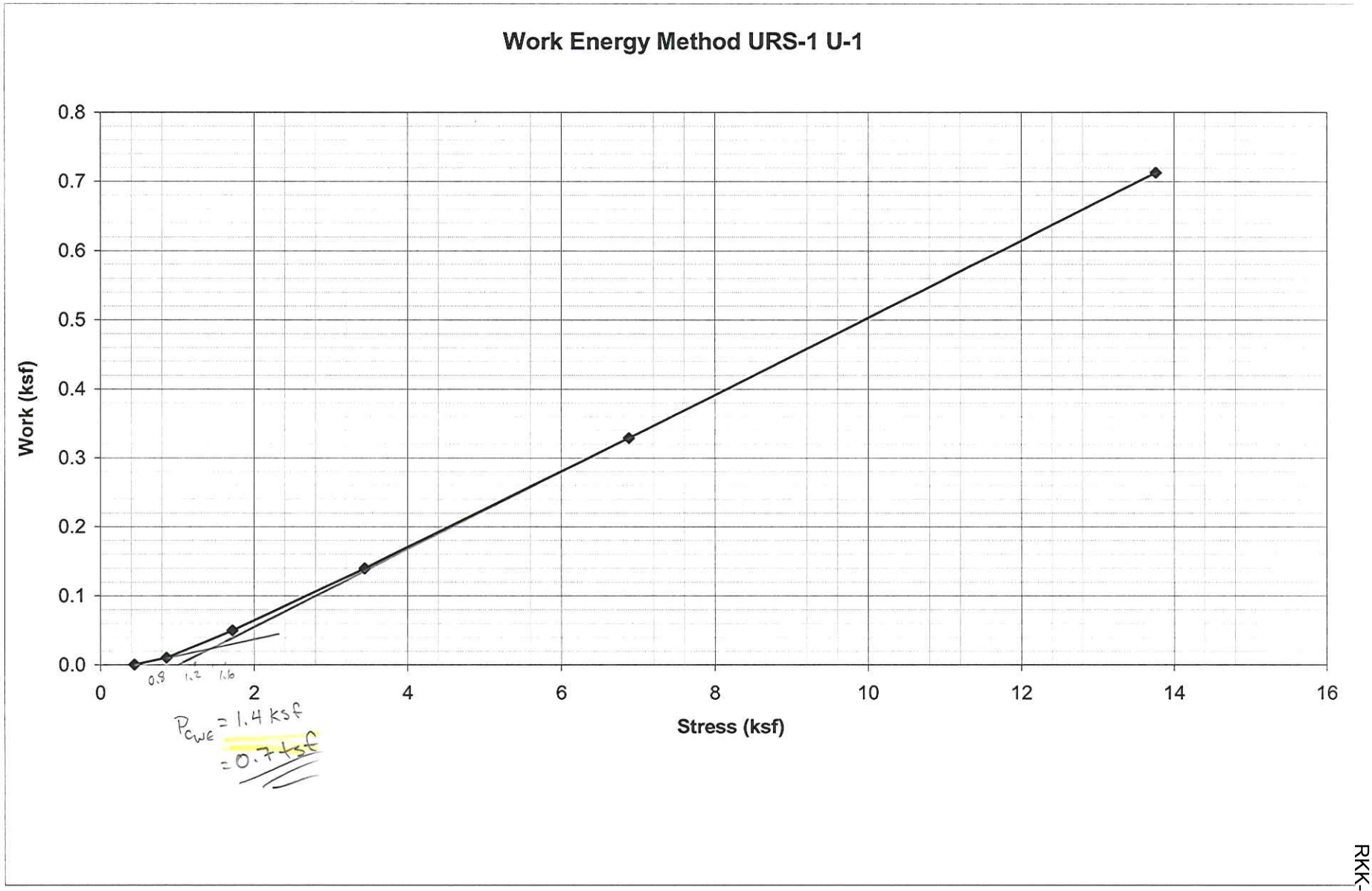
CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Remarks:

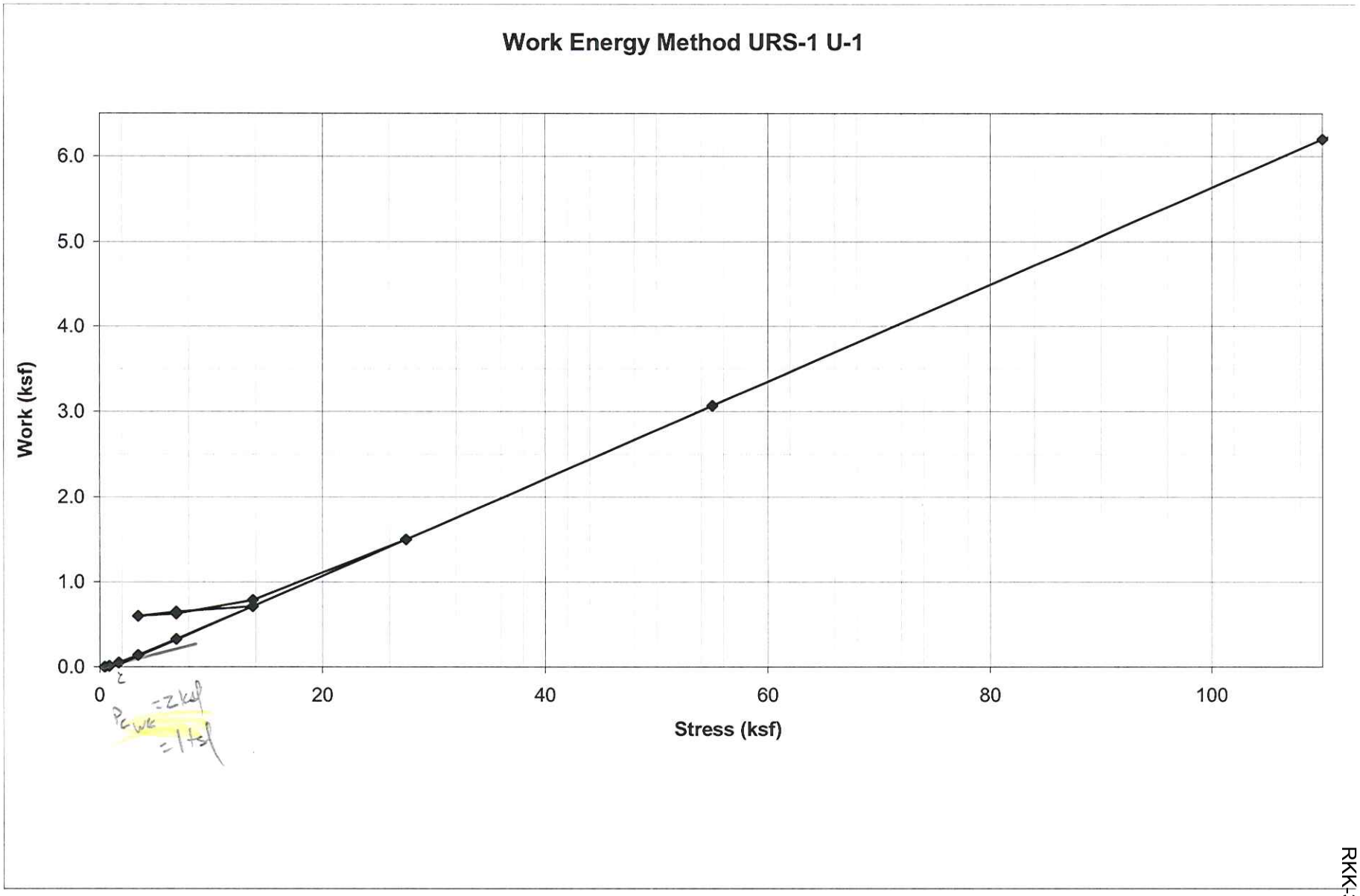
Figure

Delaware Turnpike Improvements
SR-1 Interchange



RKK-29

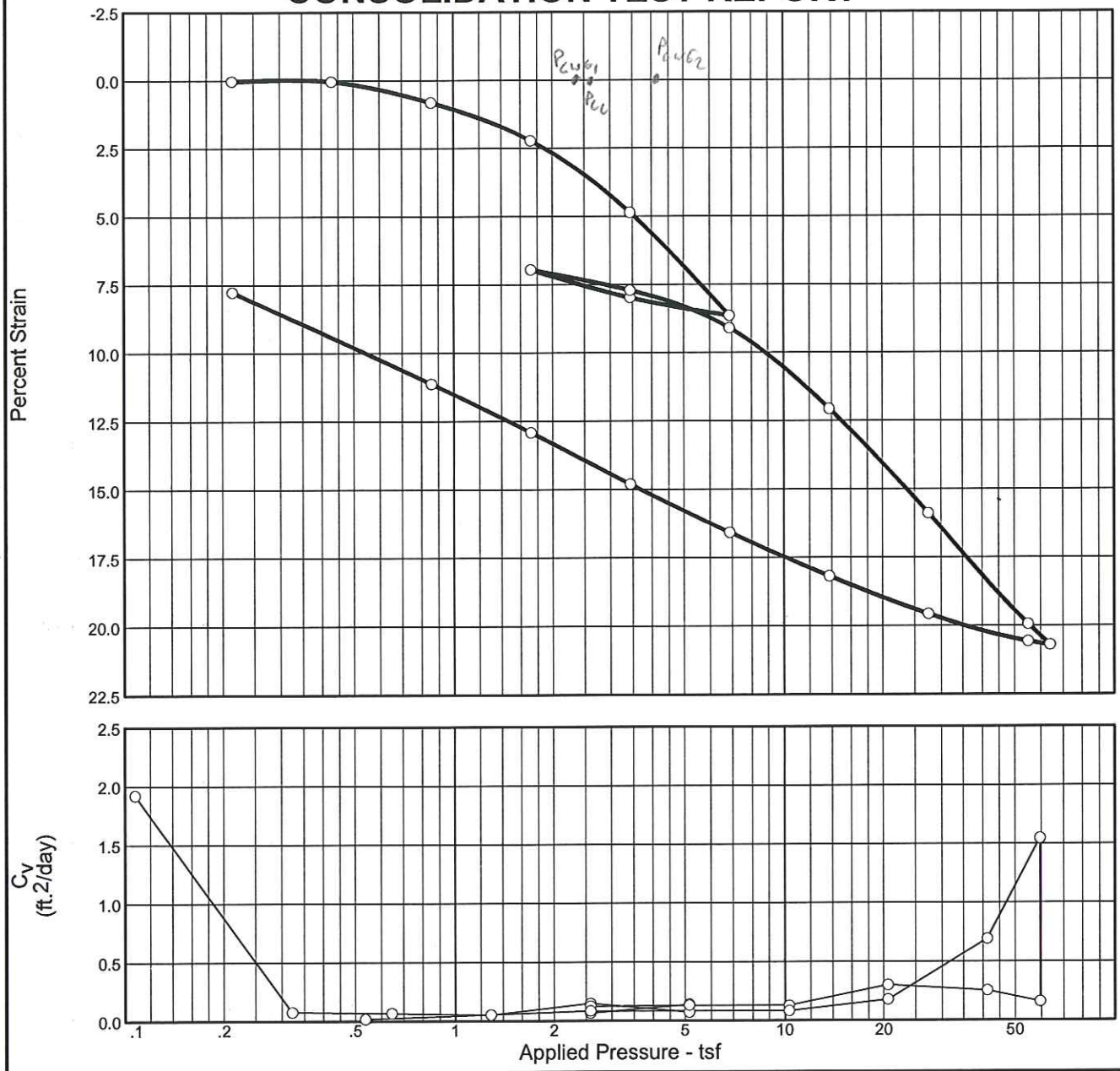
M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy Final Design.xls


Work Energy Method URS-1 U-1
Work (ksf)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
20
40
60
80
100
Stress (ksf)
RKK-30

JDT 1-2-09

RKK-31

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf)	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
115.4 %	26.1 %	104.9	40.4	18.0	2.711	1.19	2.59	0.20	0.07			0.614

MATERIAL DESCRIPTION	USCS	AASHTO
Saturated gray and red clay w/trace of fine sand.	CL	A-6(20)

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

Source: URS # 3 **Sample No.:** U-1 **Elev./Depth:** 35.0

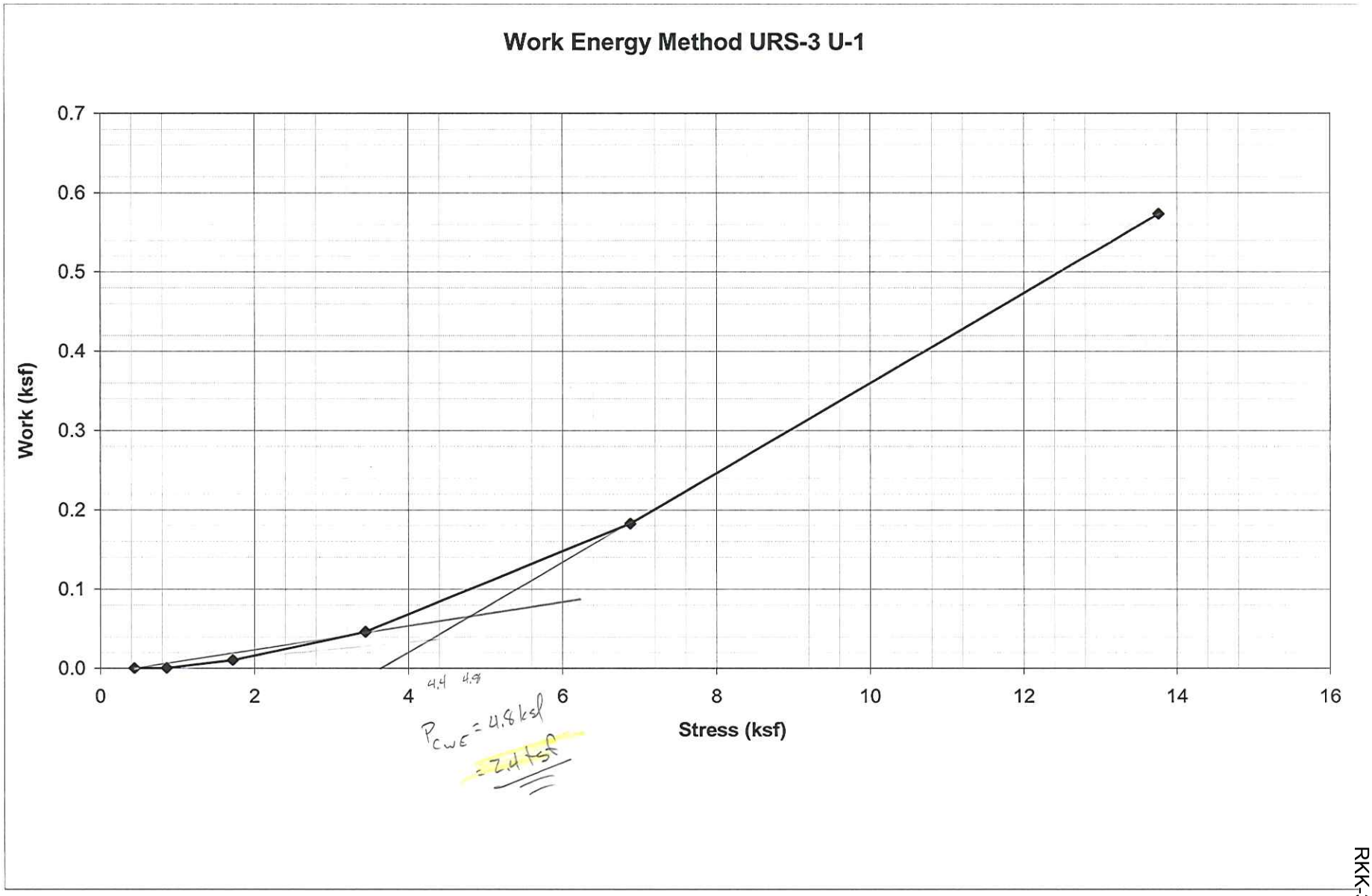
CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Remarks:

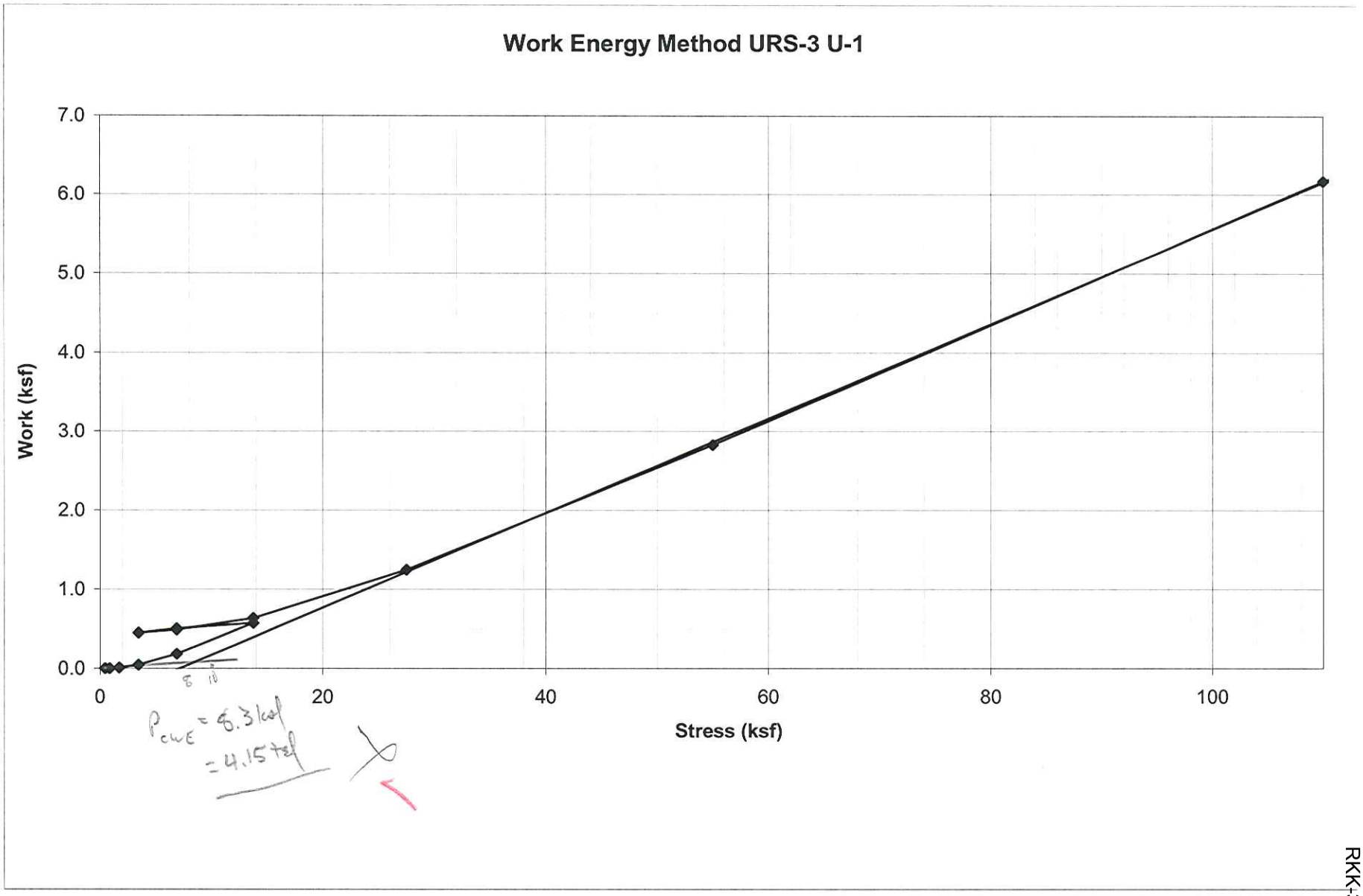
Figure

Delaware Turnpike Improvements
SR-1 Interchange



RKK-32

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy Final Design.xls



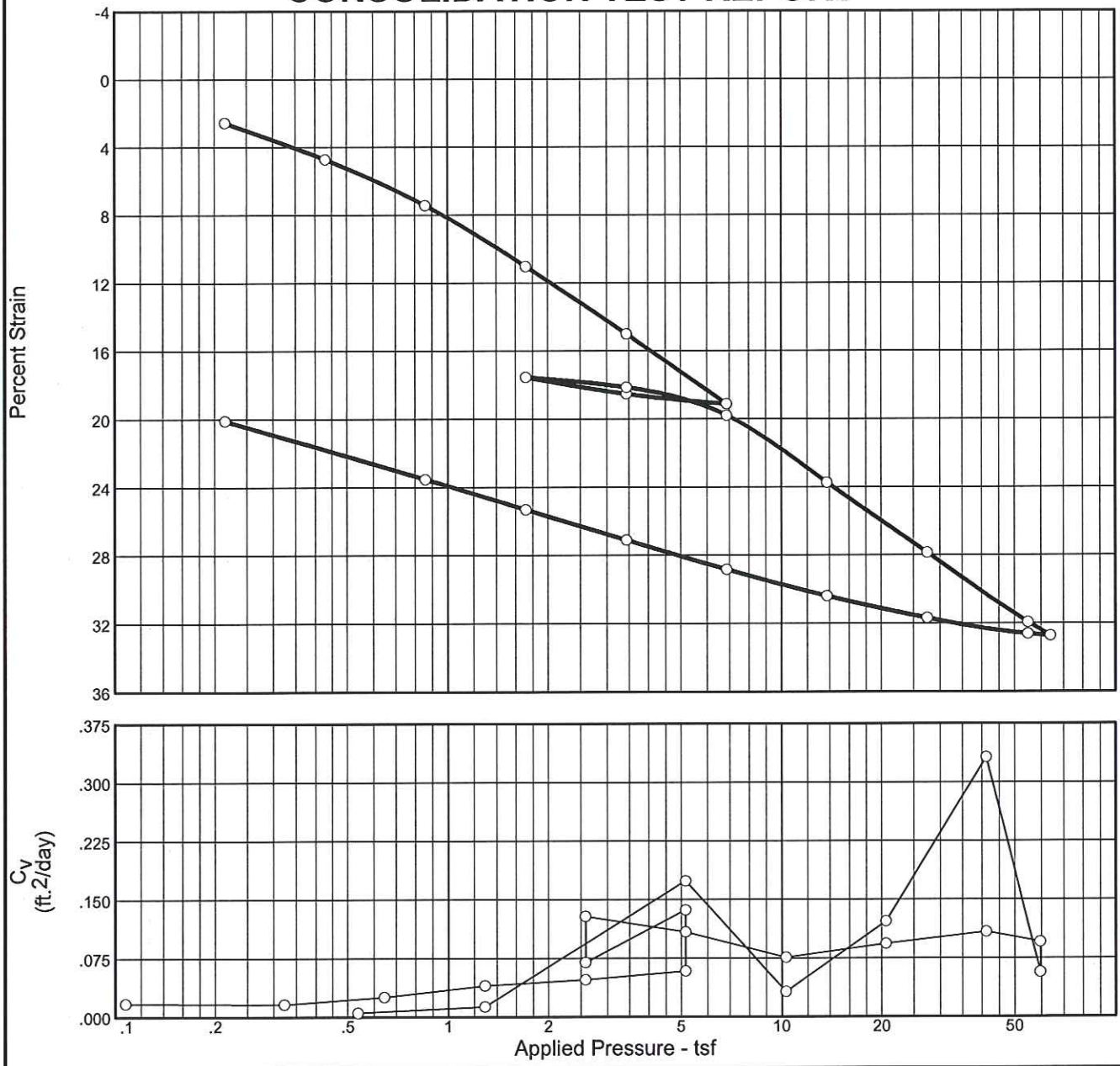
RKK-33

QPT 1-2-09

RKT
1-2-09

RKK-34

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf)	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
113.1 %	42.8 %	81.9	51.2	27.2	2.608	1.64 1.79	0.84 NV	0.27	0.08			0.987

MATERIAL DESCRIPTION	USCS	AASHTO
Saturated gray clay w/trace of fine sand. P_{swell} = 1.2 tsf NV (0.1 tsf)	CH	A-7-6(30)

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

Source: URS # 3 **Sample No.:** U-2 **Elev./Depth:** 50.0

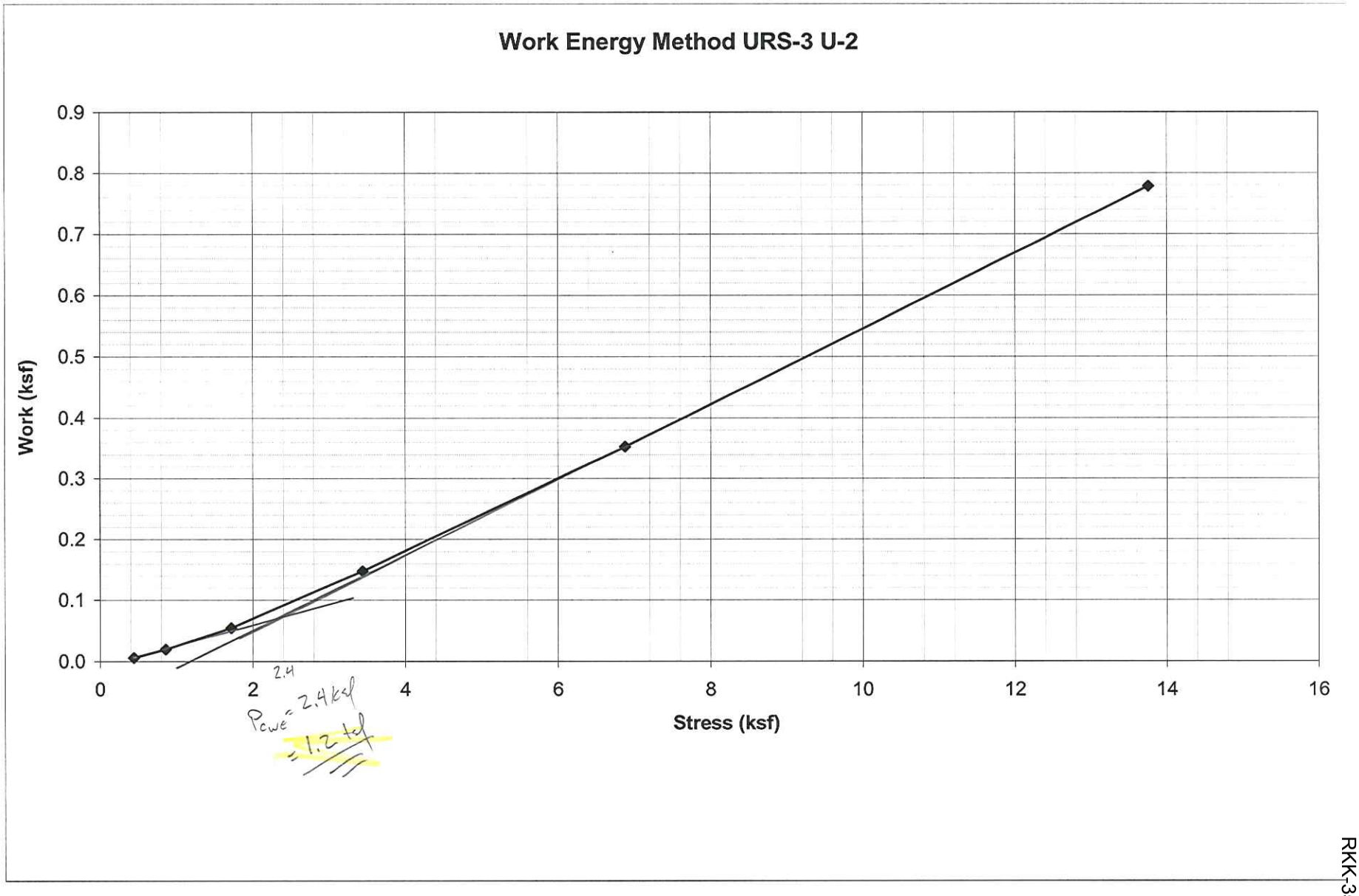
CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Remarks:

Figure

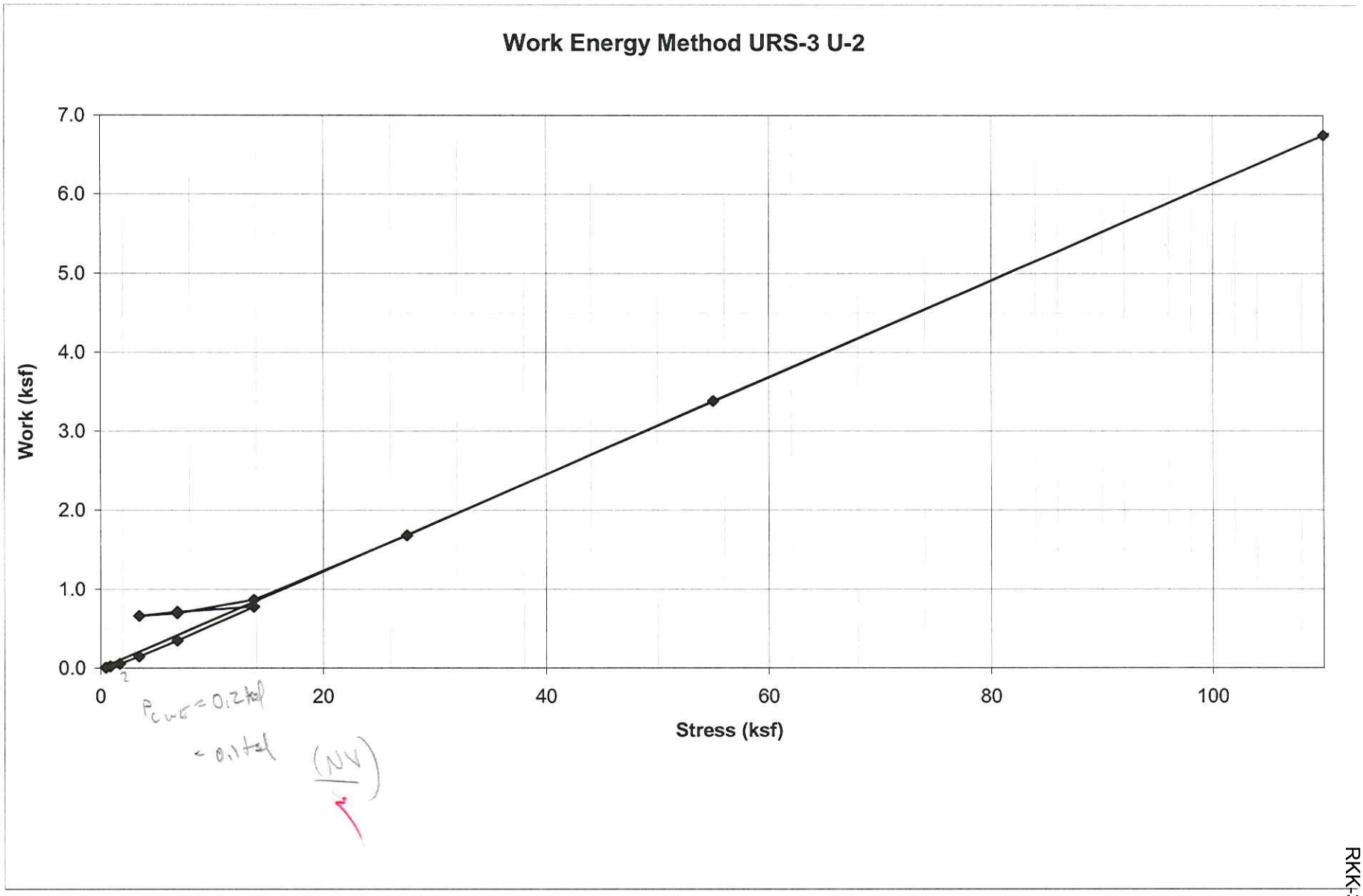
Delaware Turnpike Improvements
SR-1 Interchange



RKK-35

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy Final Design.xls

RTT 1-2-09

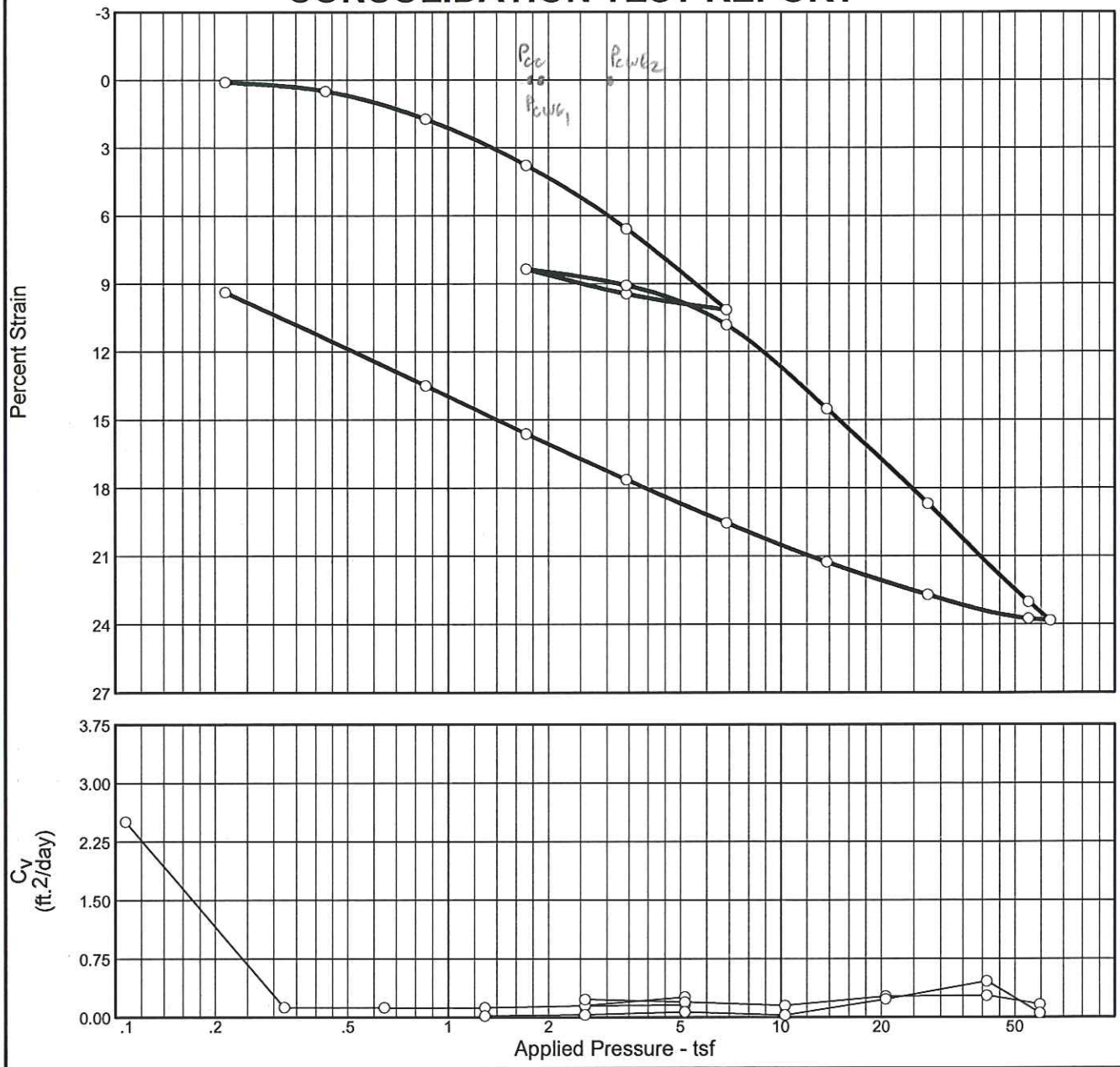

Work Energy Method URS-3 U-2
Work (ksf)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
20
40
60
80
100
Stress (ksf)

RKK-36

SST 1-2-09

RKK-37

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf)	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
111.3 %	34.7 %	92.0	53.4	25.3	2.729	1.01	1.78	0.25	0.09			0.851

MATERIAL DESCRIPTION	USCS	AASHTO
Saturated red and gray clay.	CH	A-7-6(30

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

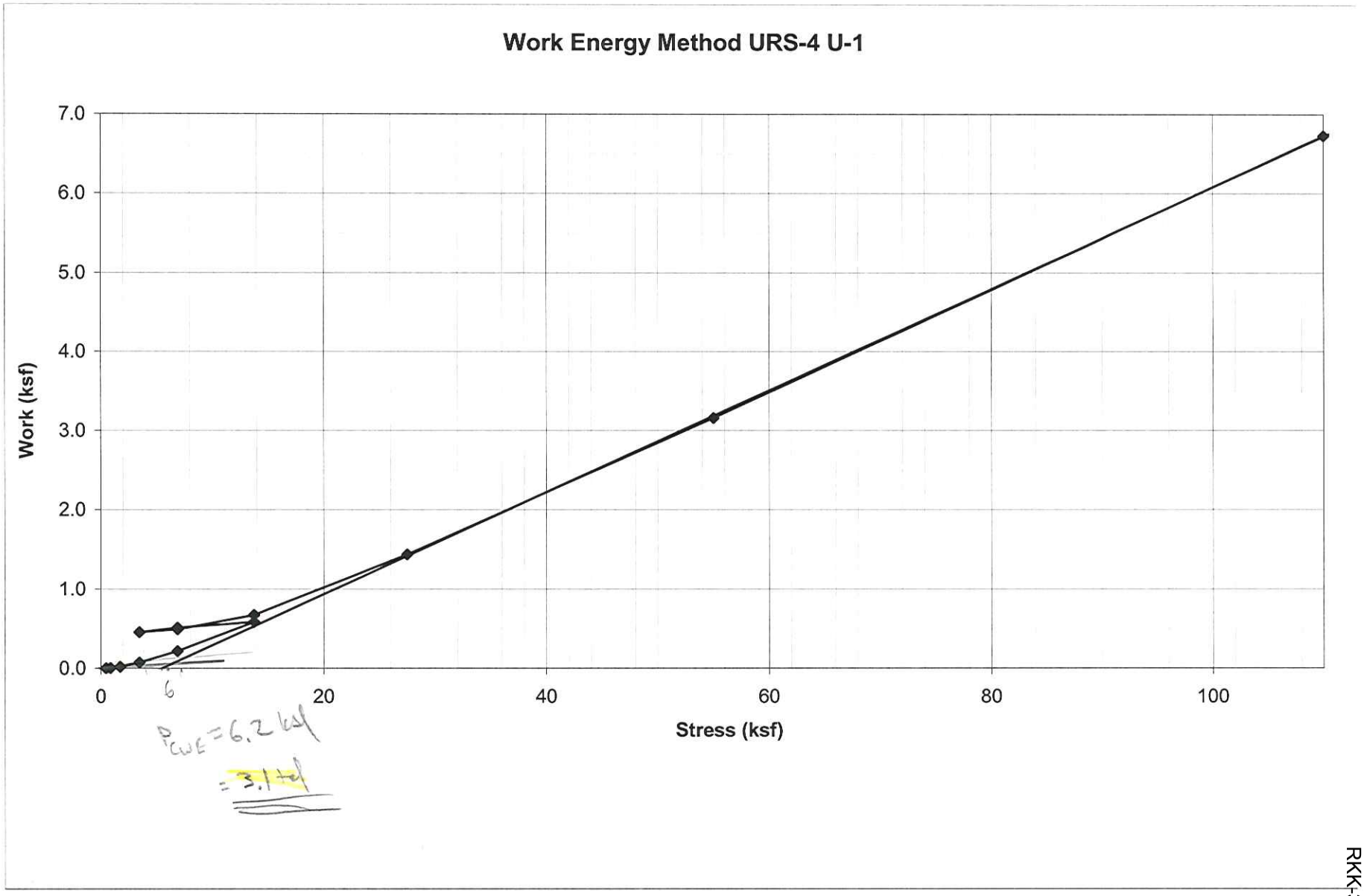
Source: URS # 4 **Sample No.:** U-1 **Elev./Depth:** 22.0

CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Remarks:

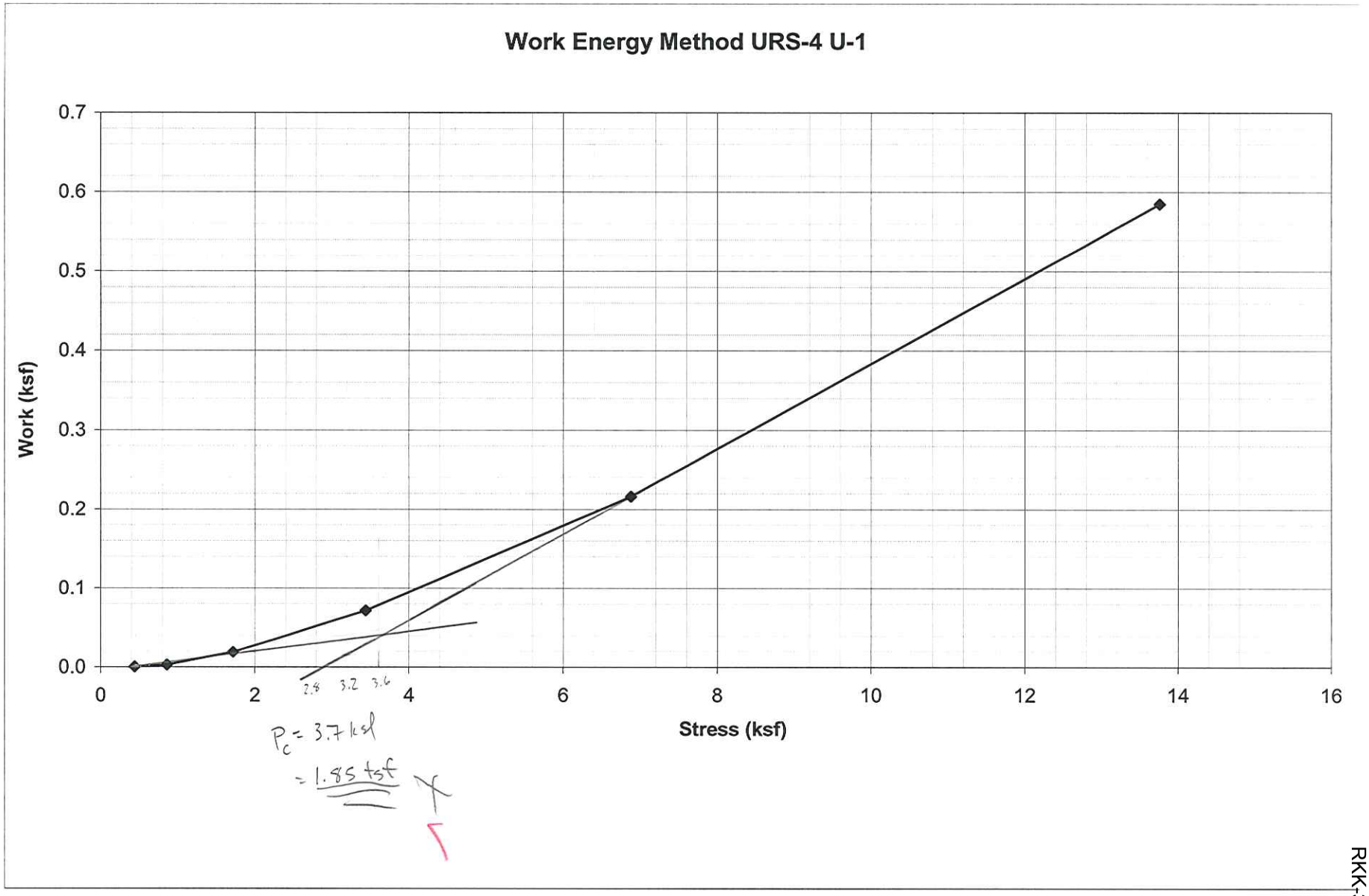
Figure



RKK-38

DOT 1-2-09

Delaware Turnpike Improvements
SR-1 Interchange



RKK-39

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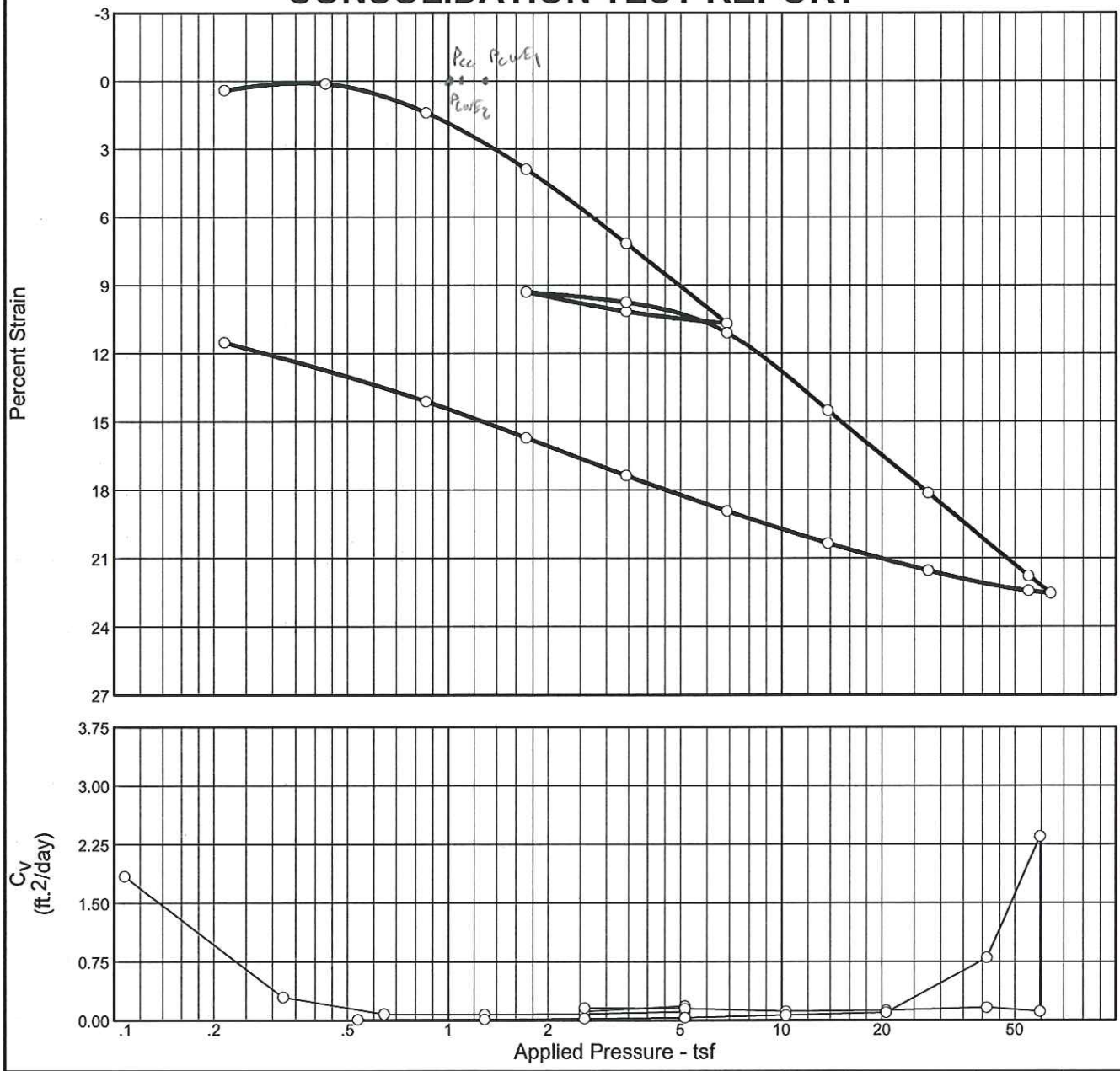
JPT
1-7-09

RKK-40

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf) 1.69	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
113.4 %	26.9 %	103.4	42.1	19.8	2.729	1.42	1.01	0.20	0.06			0.648

MATERIAL DESCRIPTION $P_{cwε}$ = 1.25 tsf // 1.12 ksf	USCS	AASHTO
Saturated gray clay w/some fine sand. Test NV	CL	A-7-6(19

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

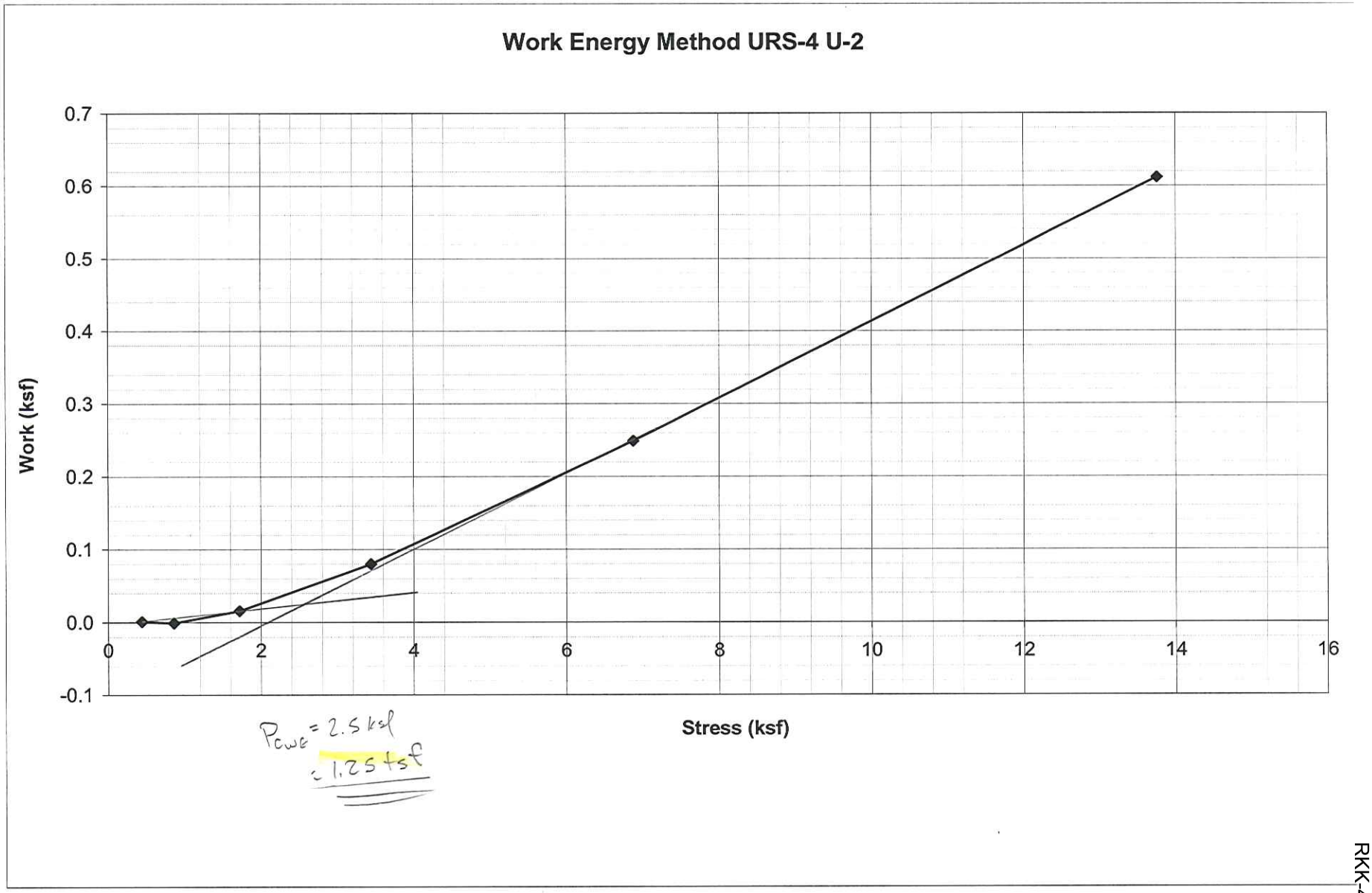
Source: URS # 4 **Sample No.:** U-2 **Elev./Depth:** 37.0

CONSOLIDATION TEST REPORT

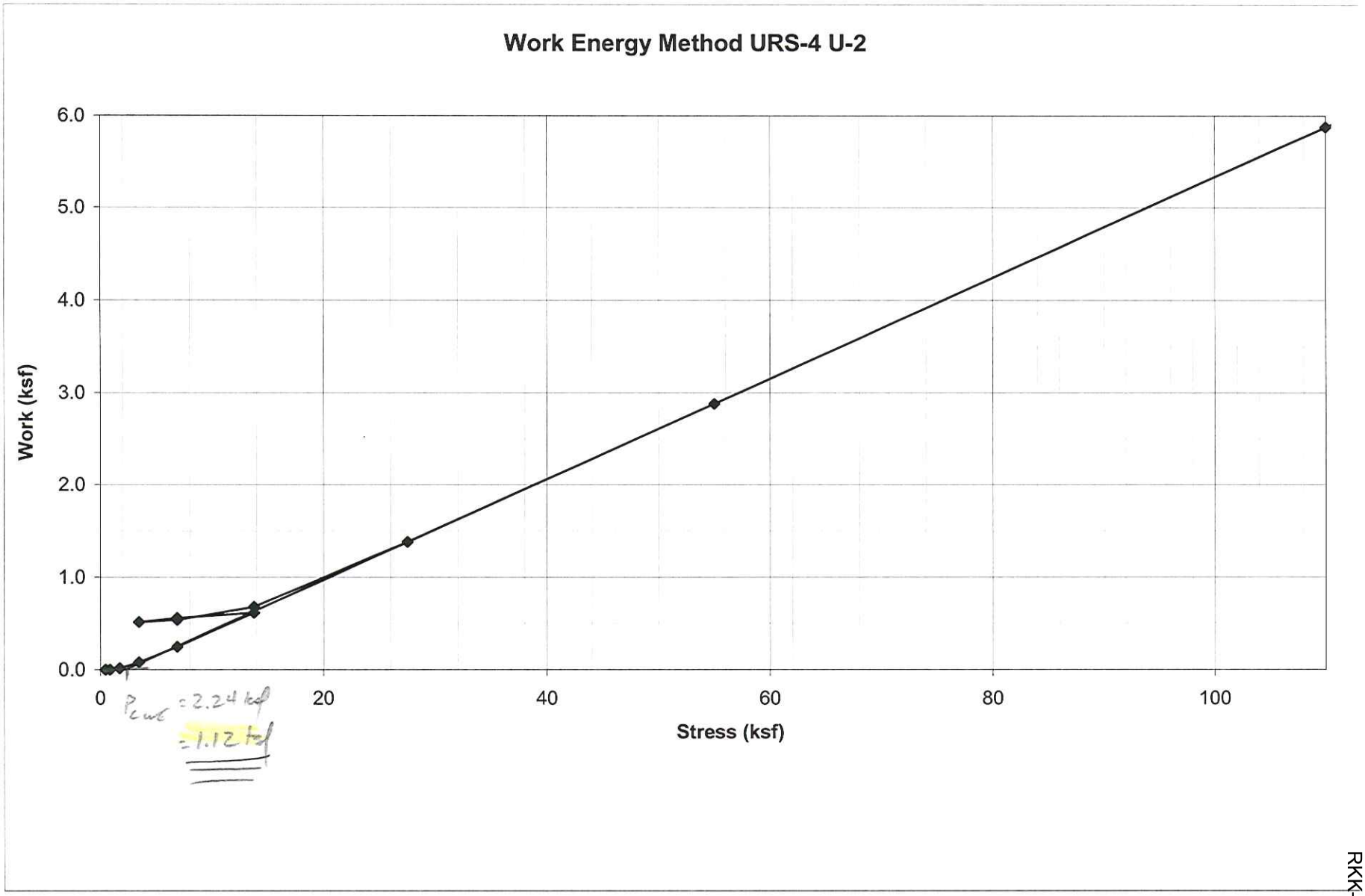
Delaware Department of Transportation
Materials and Research Laboratory

Remarks:

Figure


Work Energy Method URS-4 U-2
Work (ksf)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
0
2
4
6
8
10
12
14
16
Stress (ksf)
P_{cwe} = 2.5 ksf
= 1.25 tsf

RKK-41



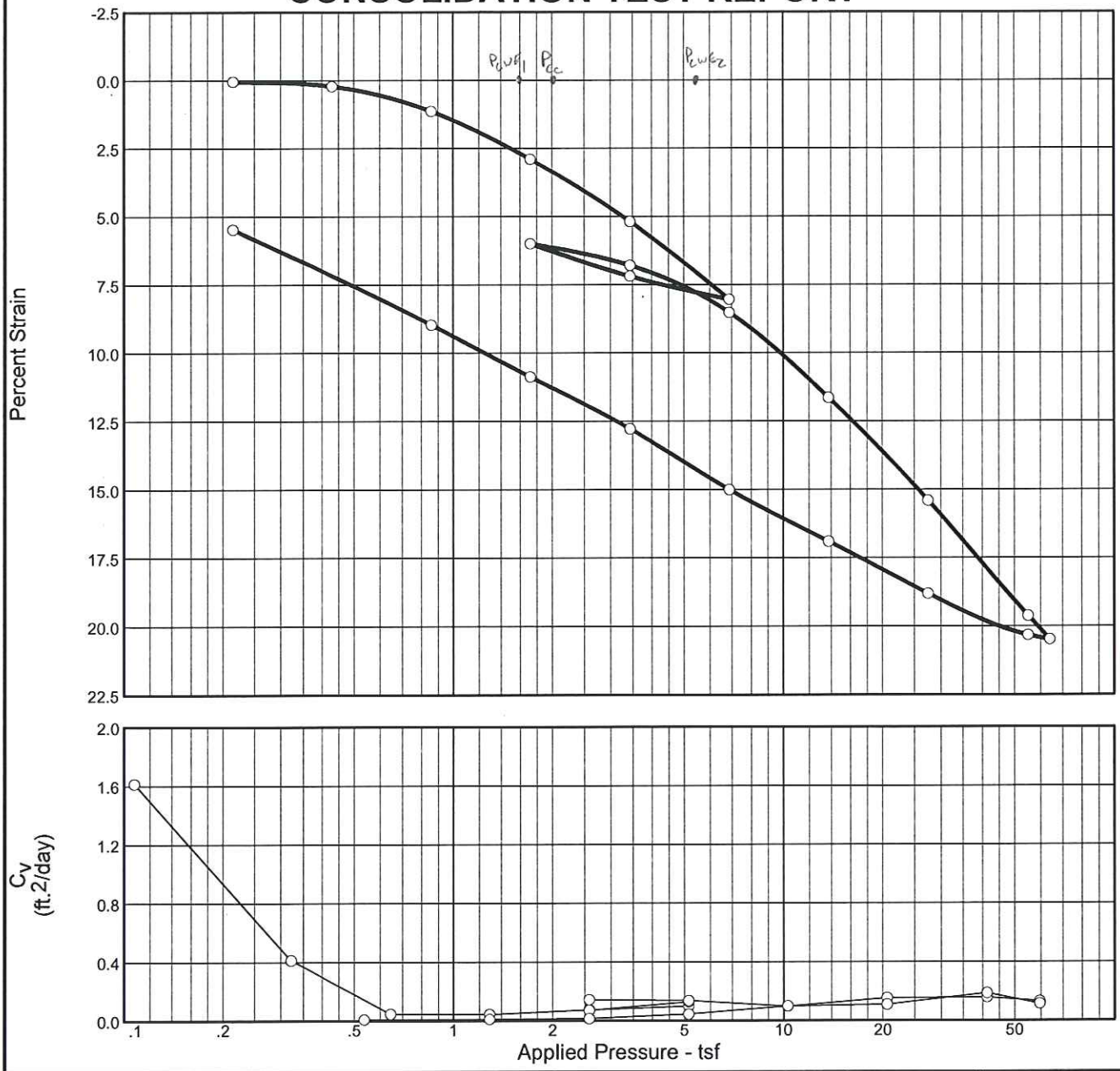
RKK-42

JDT 1-2-09

SUT 1-2-09

RKK-43

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf)	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Swell %	e_o
113.4 %	34.5 %	90.3	55.2	25.6	2.582	1.27	2.01	0.23	0.09			0.786

MATERIAL DESCRIPTION	USCS	AASHTO
Saturated gray and red clay w/trace of fine to coarse sand.	MH	A-7-5(29

Project No. 28-090-03 **Client:**

Project: S.R. 1/I-95 Interchange

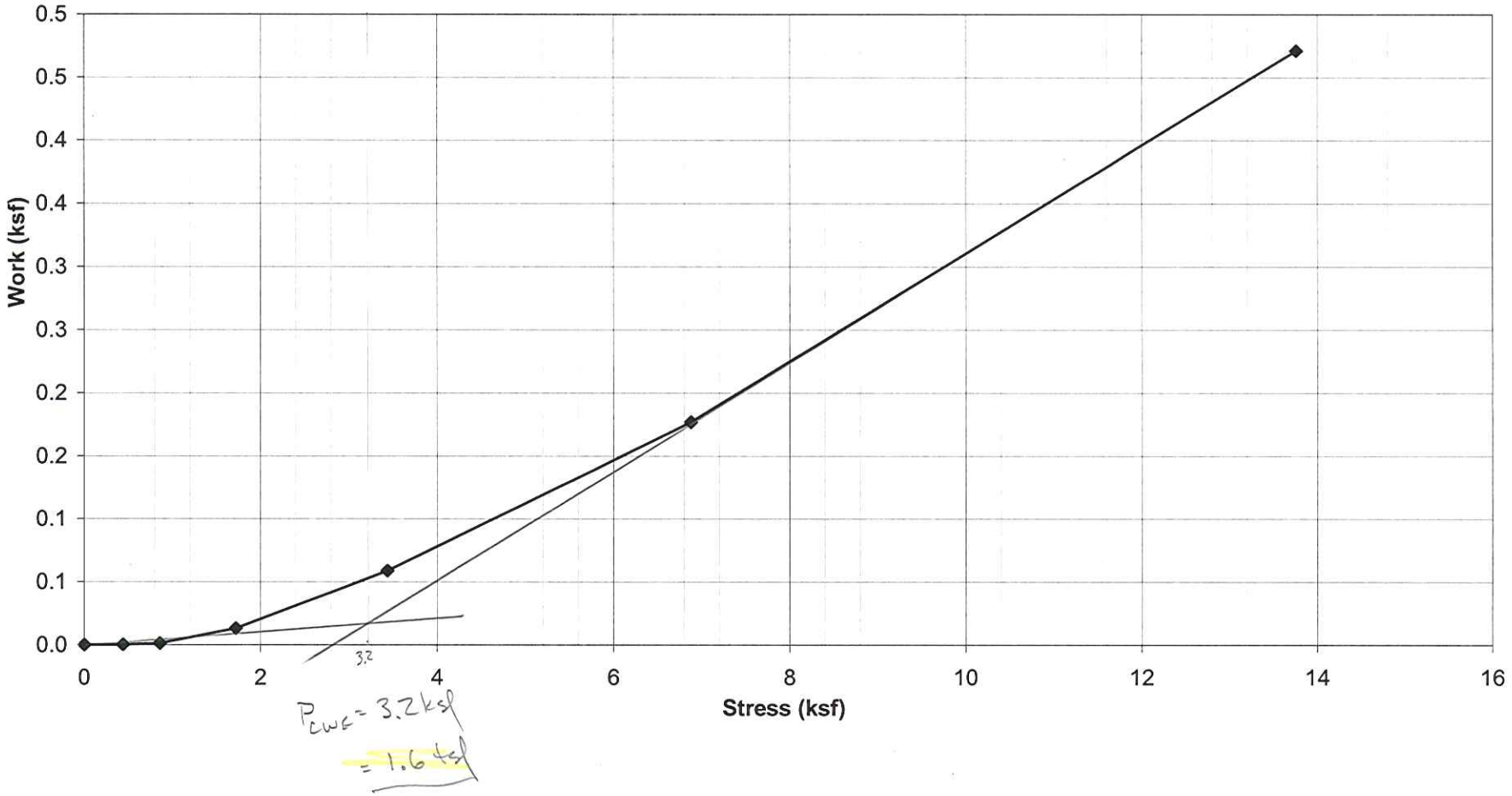
Source: URS # 5 **Sample No.:** U-1 **Elev./Depth:** 35.5

CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Remarks:

Figure



RKK-44

JCT 1-2-09

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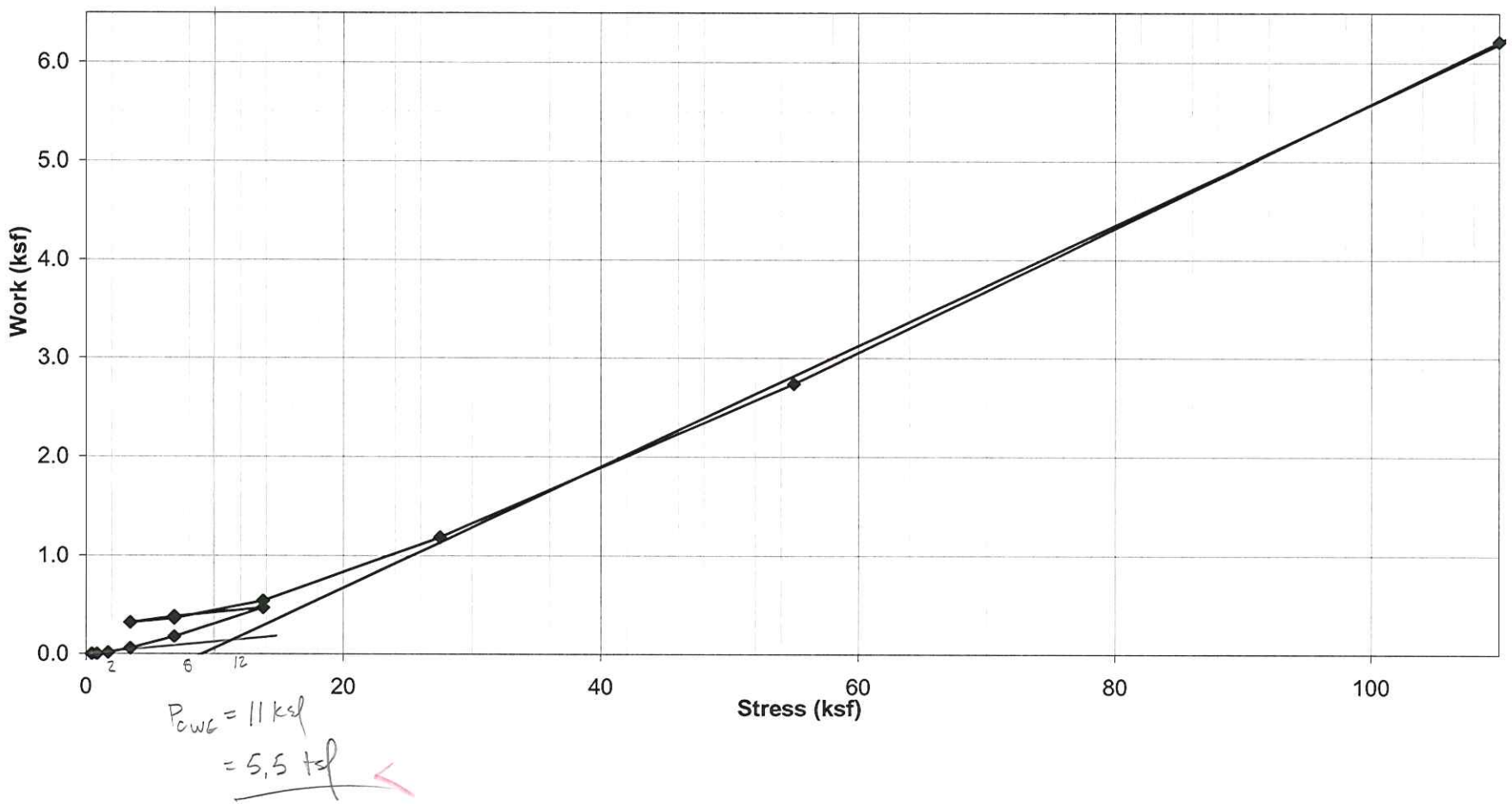


$P_{cwG} = 11$ ksf

$= 5.5$ tsf

RKK-45

RKK-46

CALCULATION CHECKLIST

Project: **I-95/SR 1 Interchange** Comm. No.: **103-059-27U**

Title of Calculation Set: **Preconsolidation Stress/OCR Calculations**

Project Manager: **EMK/JLT**

Calculations Prepared By: **SAB**

Calculation Checked By:

Computer Programs / Files: **Excel**

Initial	Date	
		Subsurface Characterization approved by Project Manager
SAB	9/22/08	Calculations are neat, legible and understandable.
SAB	9/22/08	Table of Contents is provided.
SAB	9/22/08	Heading on each page filled out
SAB	9/22/08	The first page contains purpose of the calculation.
SAB	9/22/08	Symbols are defined.
SAB	9/22/08	References for data, methods, formulas and computer program names and version numbers are given.
SAB	9/22/08	Assumptions are listed and those that need to be verified later are Flagged.
SAB	9/22/08	Headings on front sheet of each set of computer input and output.
SAB	9/22/08	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JLT	9-30-08	All calculations checked and each calculation sheet initialed by checker.
JLT	9-30-08	Calculation set reviewed by Project Manager.
		Has this calculation been superseded? Reference new calculation, if applicable.

This sheet is to be prepared by the originator of the calculation and attached to the front of the calculation set.

I-95/SR1 Interchange 103-059-27U 9/22/08

Preconsolidation Stress/OCR Calculations

Casagrande Method

SUMMARY

I-95/SR 1 Interchange Improvements - Preconsolidation Stress and OCR from Consolidation Testing													
PointID	Sample	GS EL	GWL (ft)	Depth (ft)	Sample EL	UW (pcf)	Po (tsf)	Pc (tsf)	$Pc_{Work\ Energy}$ (tsf)	OCR	$OCR_{work\ energy}$	FINAL Pc (tsf)	FINAL OCR
IBR-04	T-1	65	2.0	18	47	115.5	0.67	~~3.0~~ 3.3	2.75 ✓	~~4.5~~ 4.1	4.1	~~NV~~ 2.88	~~NV~~ 4.2
IBR-05	T-2	66	38.0	31.5	34.5	119	1.17	~~1.74~~ 1.75	~~3.38~~ 2.7	4.1	2.3	NV	NV
IBR-15	T-1	70	2.0	19.5	50.5	96.9	0.72	1.63	2.30	2.3	3.2	1.97	2.7
IBR-32	T-3	89		50	39	132.7	2.11	3.00	3.38 ✓	1.4	1.6	3.19	1.5
ICPT-15A	T-1	80.19	3.0	19	61.19	101.5	0.69	2.30	3.10	3.3	4.5	2.7	3.9
ICPT-15A	T-2	80.19	3.0	29	51.19	72.3	1.00	11.00	12.00	11.0	12.0	11.5	11.5
ICPT-15A	T-3	80.19	3.0	45	35.19	97.3	1.47	3.50	~~3.50~~ 2.2	~~2.4~~ 2.4	~~2.4~~ 1.5	2.85	1.9
ICPT-16A	T-1	84.87	14.4	31	53.87	134.1	1.90	3.90	5.00	2.1	2.6	4.45	2.3
ICPT-16A	T-2	84.87	14.4	45	39.87	134.1	2.45	4.20	3.90	1.7	1.6	4.05	1.7
ICPT-16A	T-3	84.87	14.4	55	29.87	134.1	3.39	5.00	5.40	1.5	1.6	5.20	1.53
IEB-13A	T-1	84	9.6	15	69	77.8	0.82	2.95	3.30 ✓	3.6	4.0	3.13	3.8
IEB-13B	T-2	81.64	7.0	33	48.64	115.9	1.40	5.70	7.25	4.1	5.2	6.48	4.6
IEB-13B	T-3	81.64	7.0	39	42.64	116.9	1.63	10.00	7.25	6.1	4.5	8.63	5.3
IEB-13B	T-4	81.64	7.0	59	22.64	104.1	2.13	8.00	9.60	3.8	4.5	8.8	4.1
IRW-09	T-2	59	DRY	35	24	110.9	1.39	3.92	2.30 ✓	2.8	1.7	NV	NV
IRW-23	T-2	60	36.7	24.5	35.5	108.7	0.81	4.96	3.63 ✓	6.1	4.5	4.29	5.3
IRW-32	T-1	79	13.4	25	54	114.2	1.24	~~3.34~~ 6.5	4.60	5.2	3.7	NV	NV
IRW-33	T-1	79	DRY	27	52	100.5	1.30	1.12	1.40 ✓	0.9	1.1	1.26	1.0
IRW-33A	T-1	80	15.0	24	56	107.8	1.10	1.25	0.90	1.1	0.8	1.08	1.0
IRW-42	T-2	75	1.0	30	45	114.7	1.18	3.96	4.38	3.4	3.7	4.17	3.5
IRW-44	T-1	81	10.0	25	56	103.6	1.11	2.91	3.93	2.6	3.5	3.42	3.1
IRW-49	T-2	77	2.6	30	47	113.4	1.12	5.11	4.00	4.5	3.6	4.56	4.1
IRW-50	T-1	77.69	5.2	25	52.69	111.2	1.02	8.28	5.25	8.1	5.2	NV	NV
IRW-51	T-1	80	10.7	25	55	105.8	1.17	1.94	2.75	1.7	2.4	2.35	2.0
IRW-52	T-2	88	15.2	35	53	108.3	1.63	2.56	2.60	1.6	1.6	2.58	1.6
IRW-53	T-1	63.39	18.5	15	48.39	107.6	0.96	1.96	4.00	2.0	4.2	NV	NV

NV: Consolidation Test Not Valid

Objective: To estimate the preconsolidation stress and over-consolidation ratio (OCR) from the laboratory consolidation test results and using work energy Method.

CALCULATIONS: 1) Work Energy Method Packet 1

2) Consolidation Test Graphs with Casagrande P_c, Work Energy P_c, and Final P_c Packet 2

* For Design use Final Pc + Final OCR.
* Pc/OCR Table to be updated w/ results of Supplemental Lab. Testing.

RKK-47

SCPT 9-30-08

Ref: FHWA Geotechnical Engineering Circular 5: "Evaluation of Soil and Rock Properties."

RKK-48

JFT 9-30-08

Table 25. Strain-energy method to evaluate σ_p'.

1. Compute the change in work per unit volume for each strain increment according to:

$$\Delta W = \frac{(\sigma_i' + \sigma_f')}{2} * (\varepsilon_f - \varepsilon_i) \qquad \text{(Equation 37)}$$

where: ΔW = change in work (kPa/m^3) per unit volume

σ_i = stress at beginning of strain increment (kPa)

σ_f = stress at end of strain increment (kPa)

ε_i = strain at beginning of increment (dimensionless)

ε_f = strain at end of increment (dimensionless)

2. Plot stress versus summation of work for each respective stress increment. For plotting purposes, it is assumed that the stress value corresponding to the summation of work is the stress at the end of the strain increment.

3. A noticeable change in slope should be evident when data are plotted. A curve connecting the data should have a sharp transition from a flatter slope in the recompression range (slope 1) to a steeper slope (slope 2) in the virgin compression range. Construct a trend line through the data that represent a line with slope 1. Construct a second line through the data that represent a line with slope 2.

4. The stress where these two trend lines intersect is the preconsolidation stress. The strain-energy method is illustrated in figure 50.

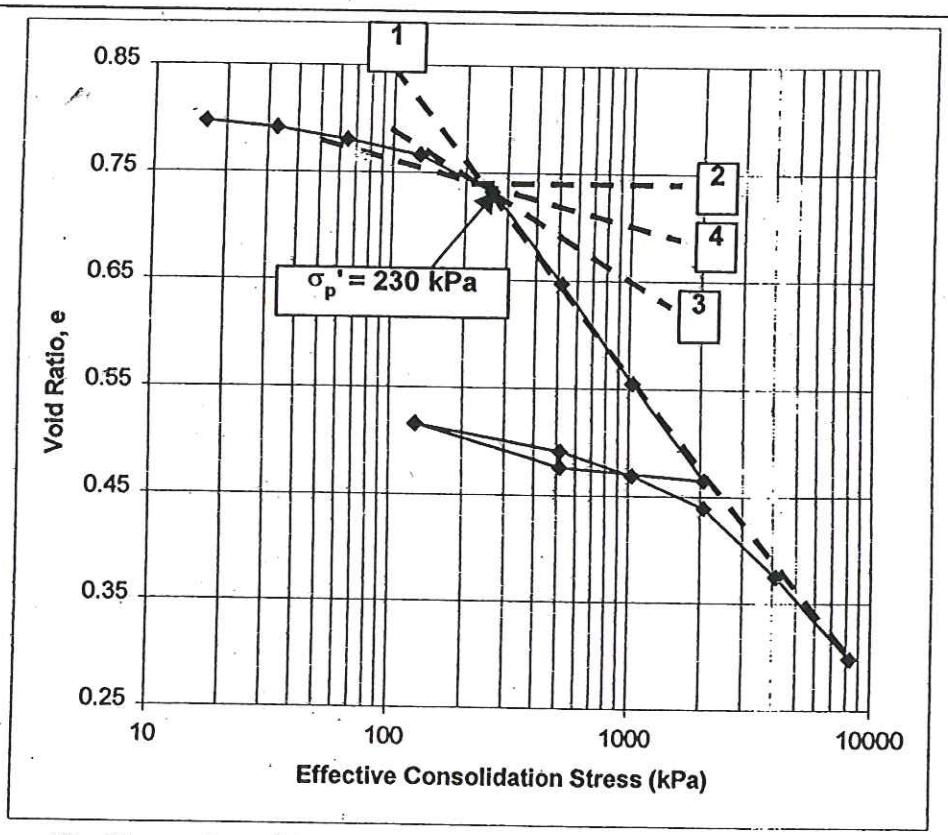
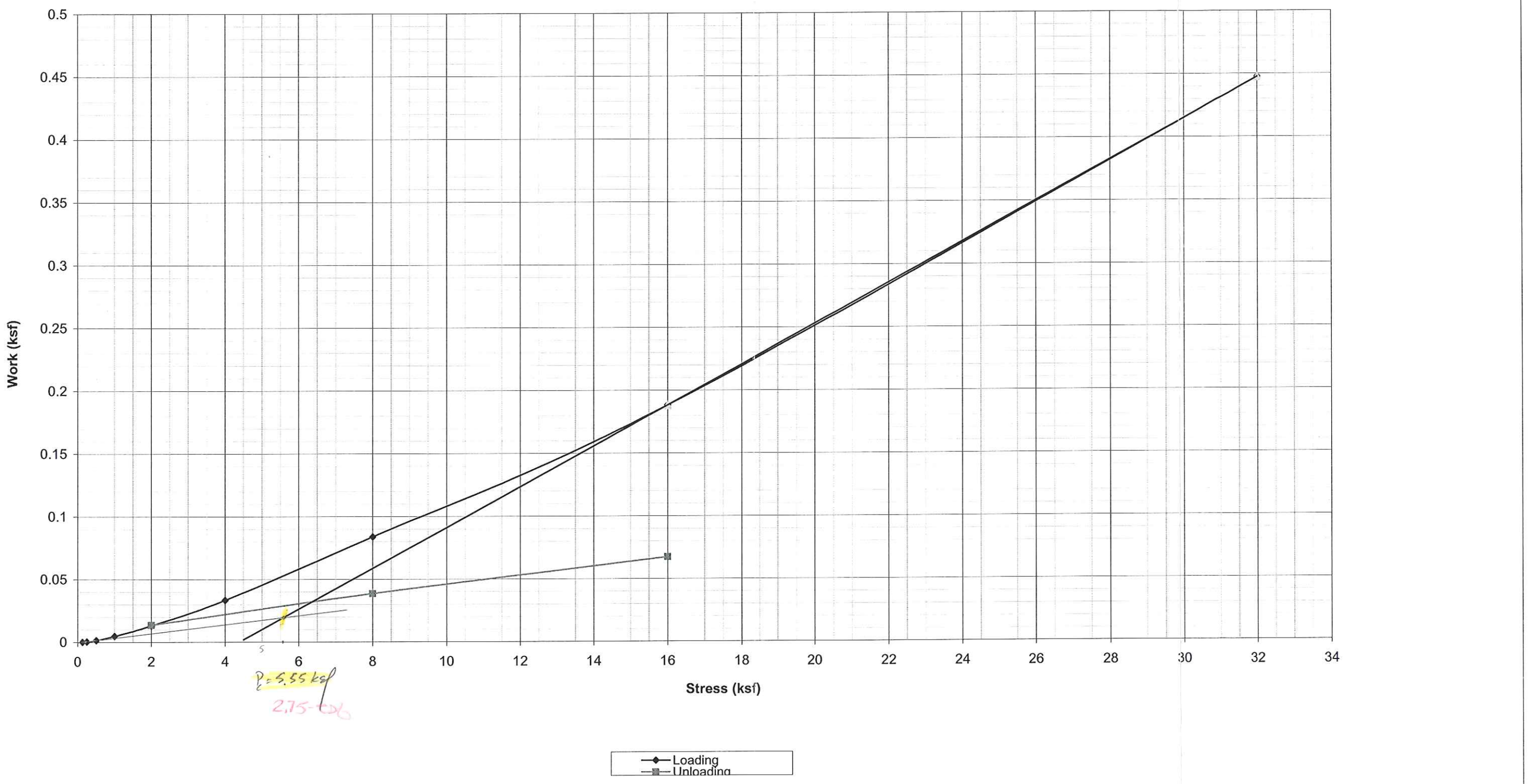


Figure 49. Illustration of Casagrande method to evaluate preconsolidation stress.

JJT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange

Work Energy Method IBR-4 T1



RKK-49

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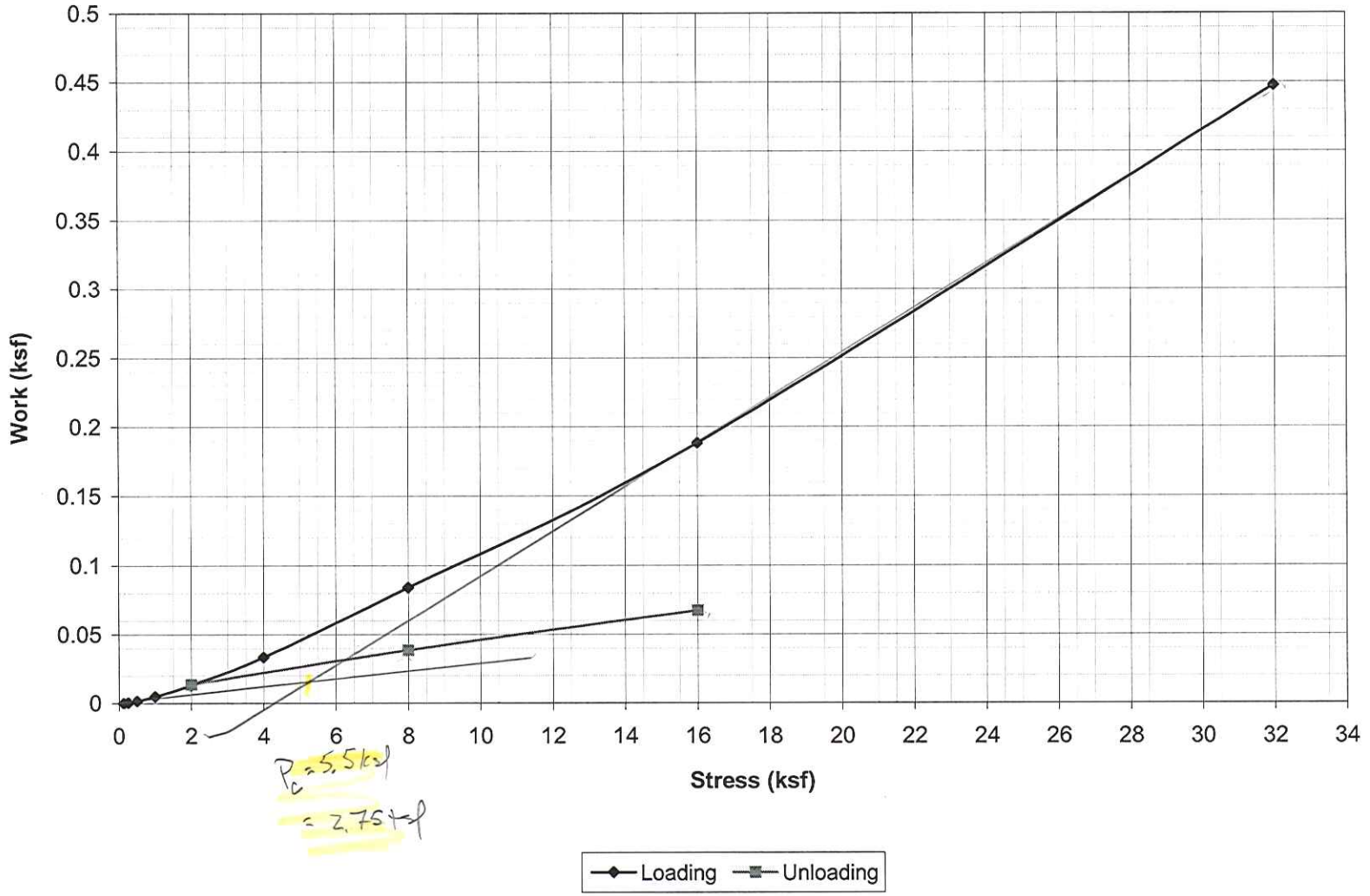

JLT 9-30-05

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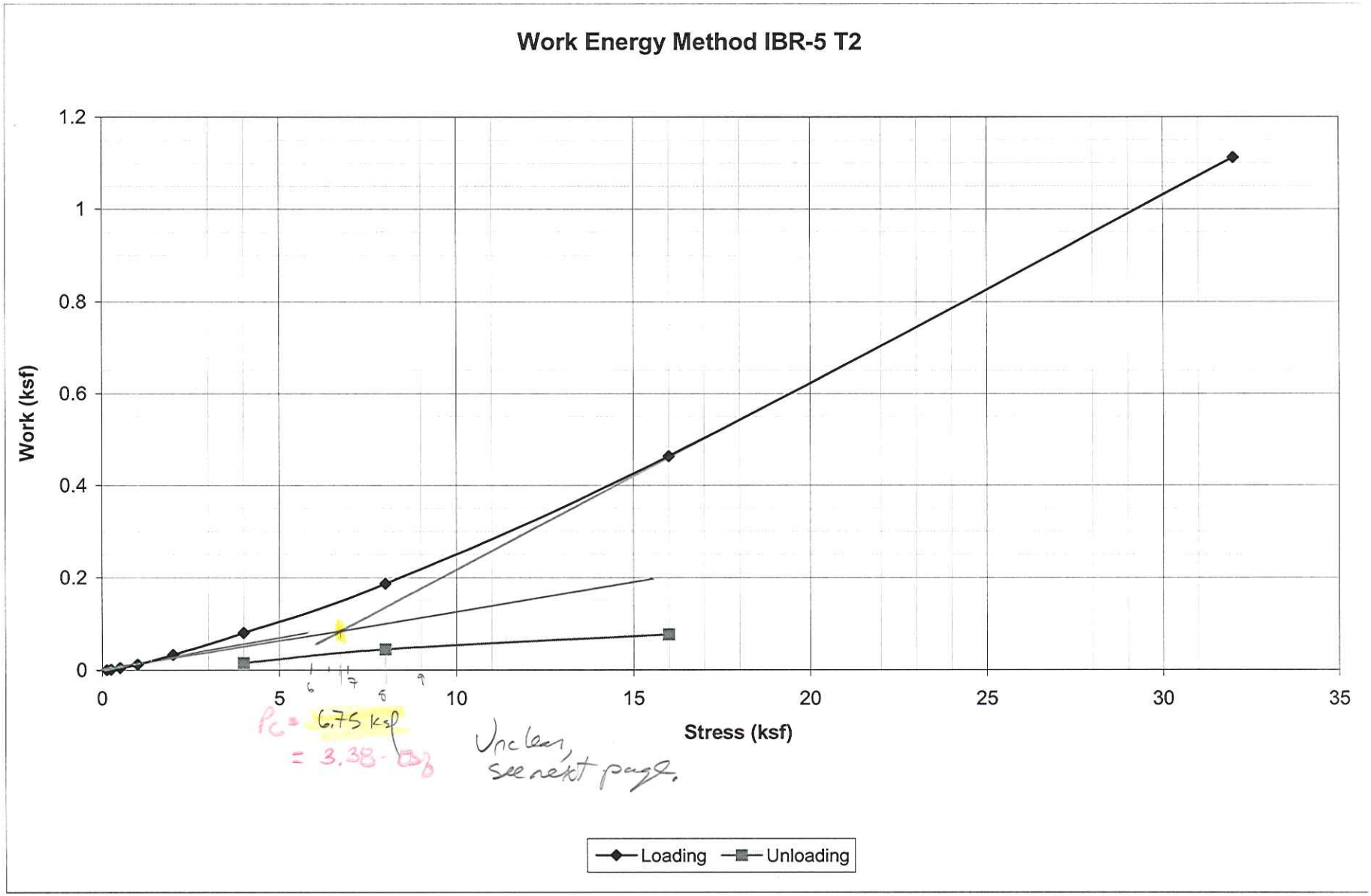
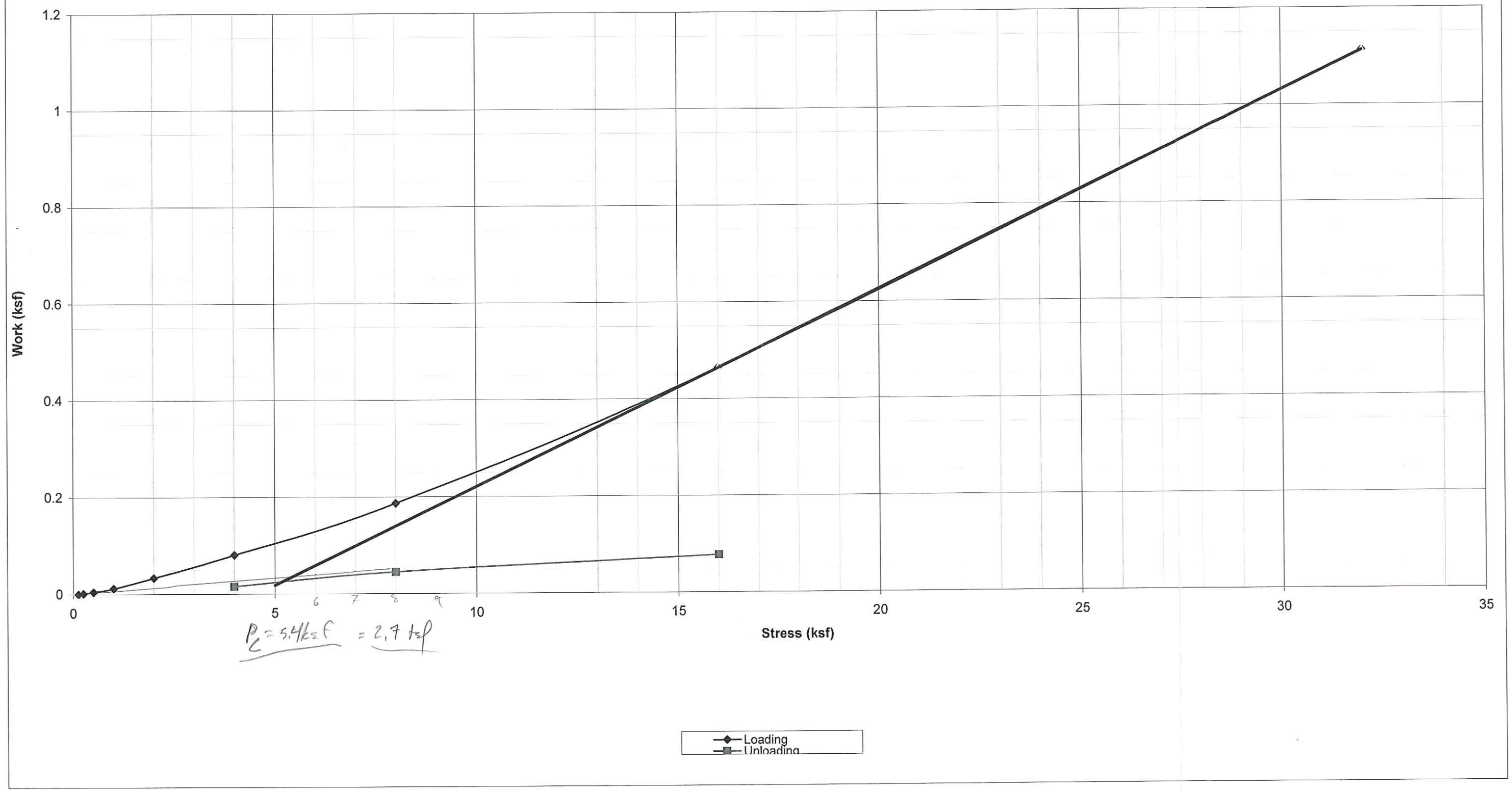

Work Energy Method IBR-5 T2
Work (ksf)
1.2
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
Stress (ksf)
Pc = 6.75 ksf
= 3.38 - 0.0
Unclear, see next page.
Loading
Unloading

JST 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange

Work Energy Method IBR-5 T2



$P_c = 5.4 ksf = 2.7 tsf$

RKK-52

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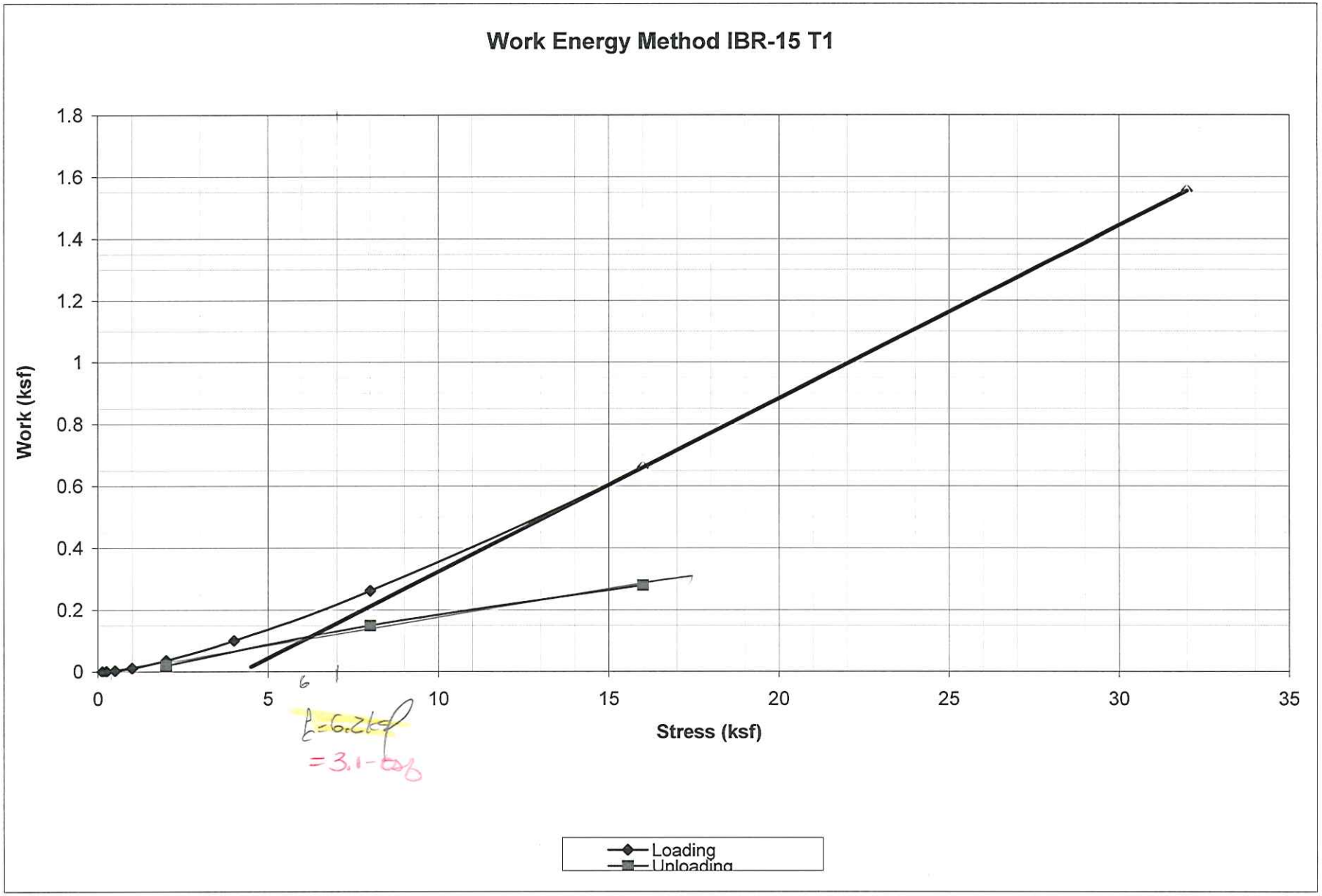
Delaware Turnpike Improvements
SR-1 Interchange



RKK-53

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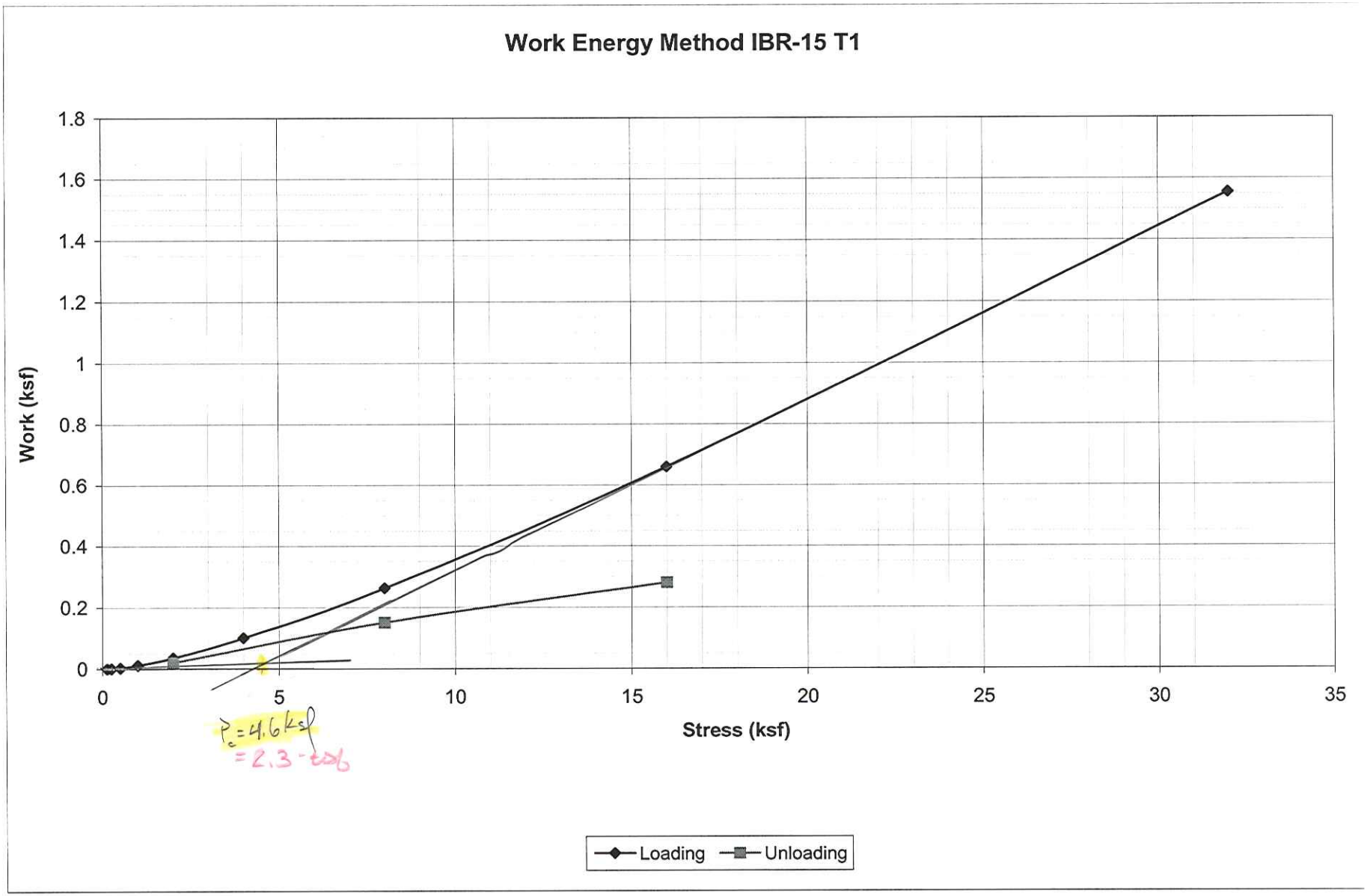
Delaware Turnpike Improvements
SR-1 Interchange



DGT 9-30-08

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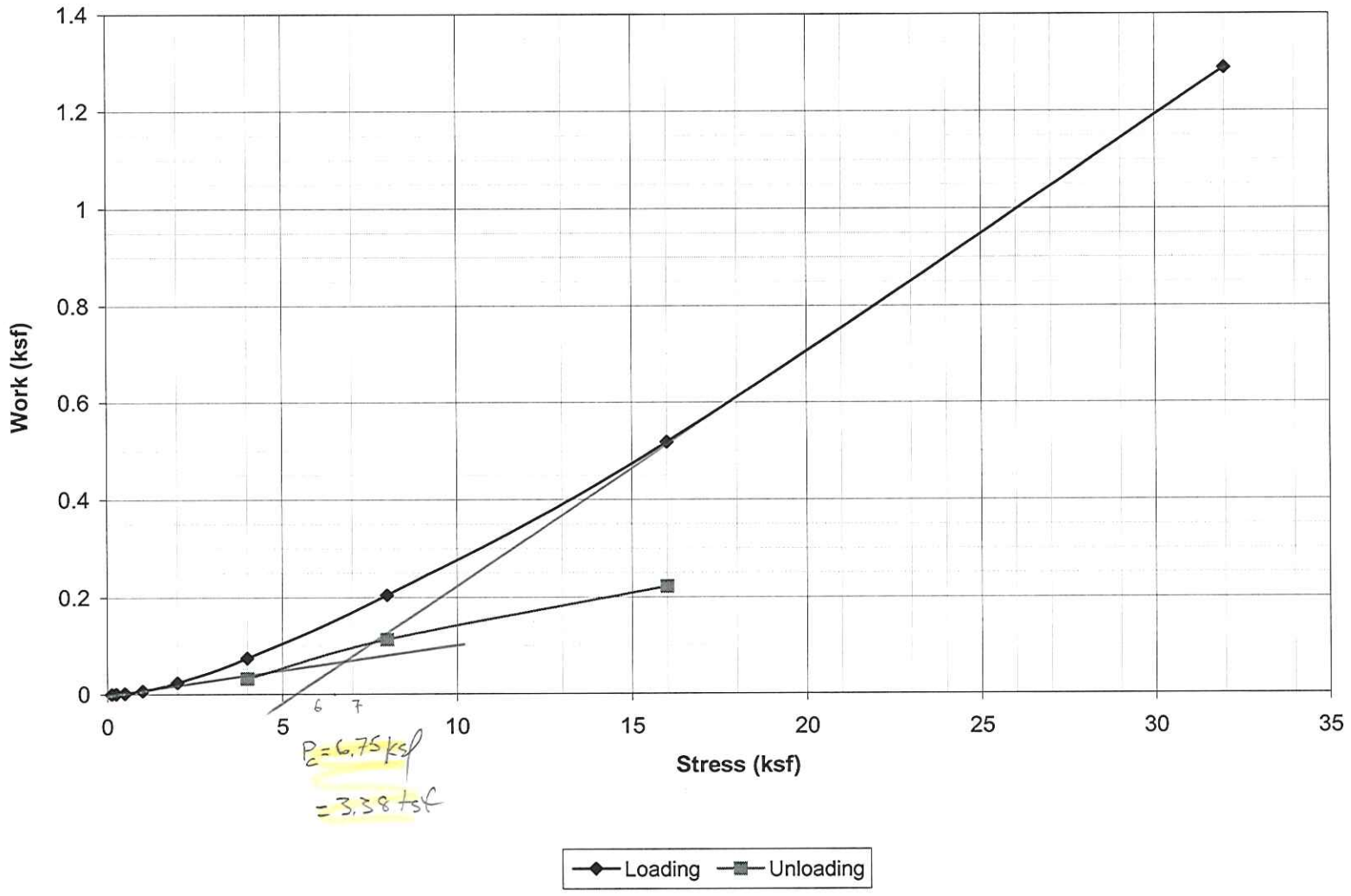
Delaware Turnpike Improvements
SR-1 Interchange



JCP 9-30-08

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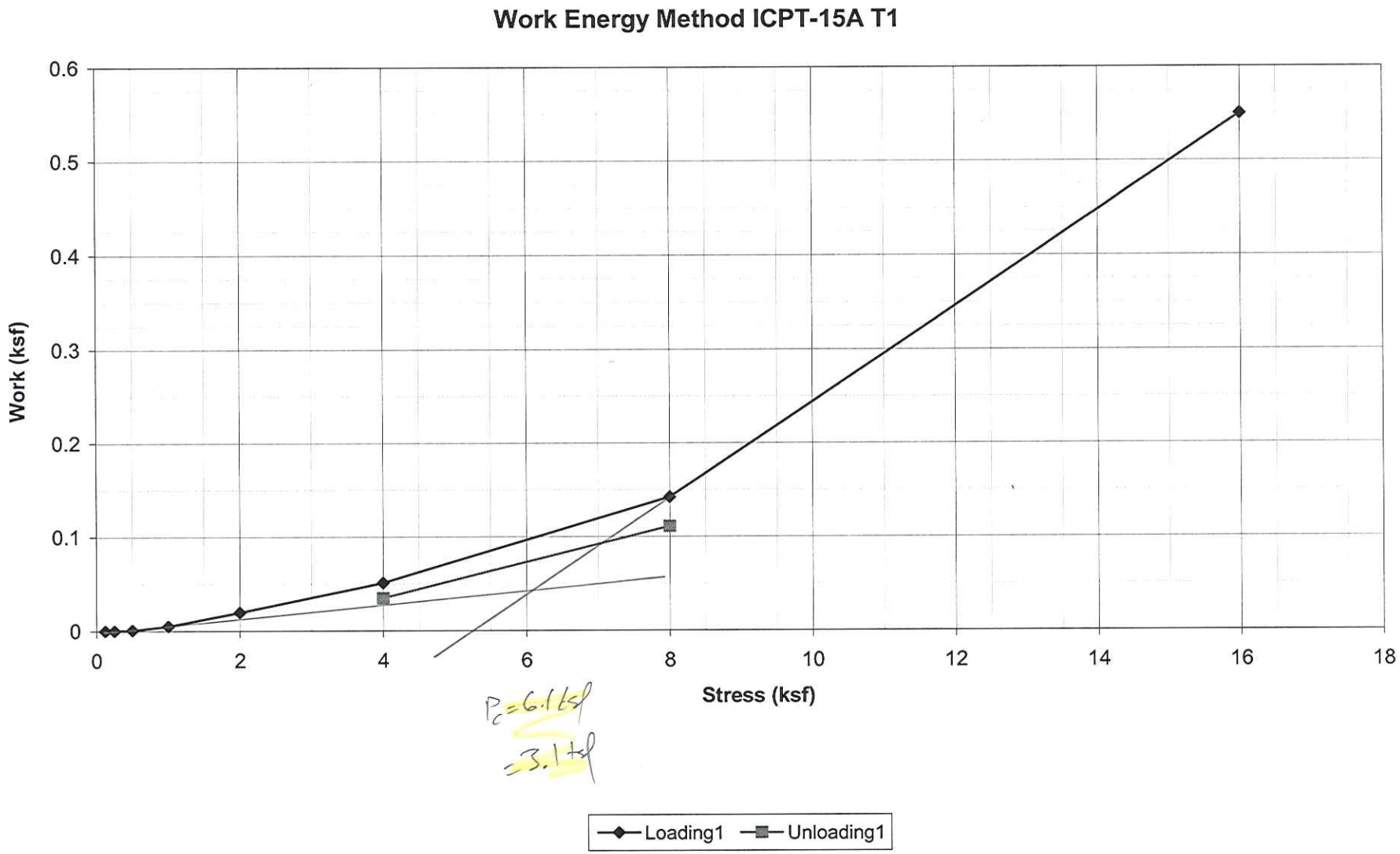
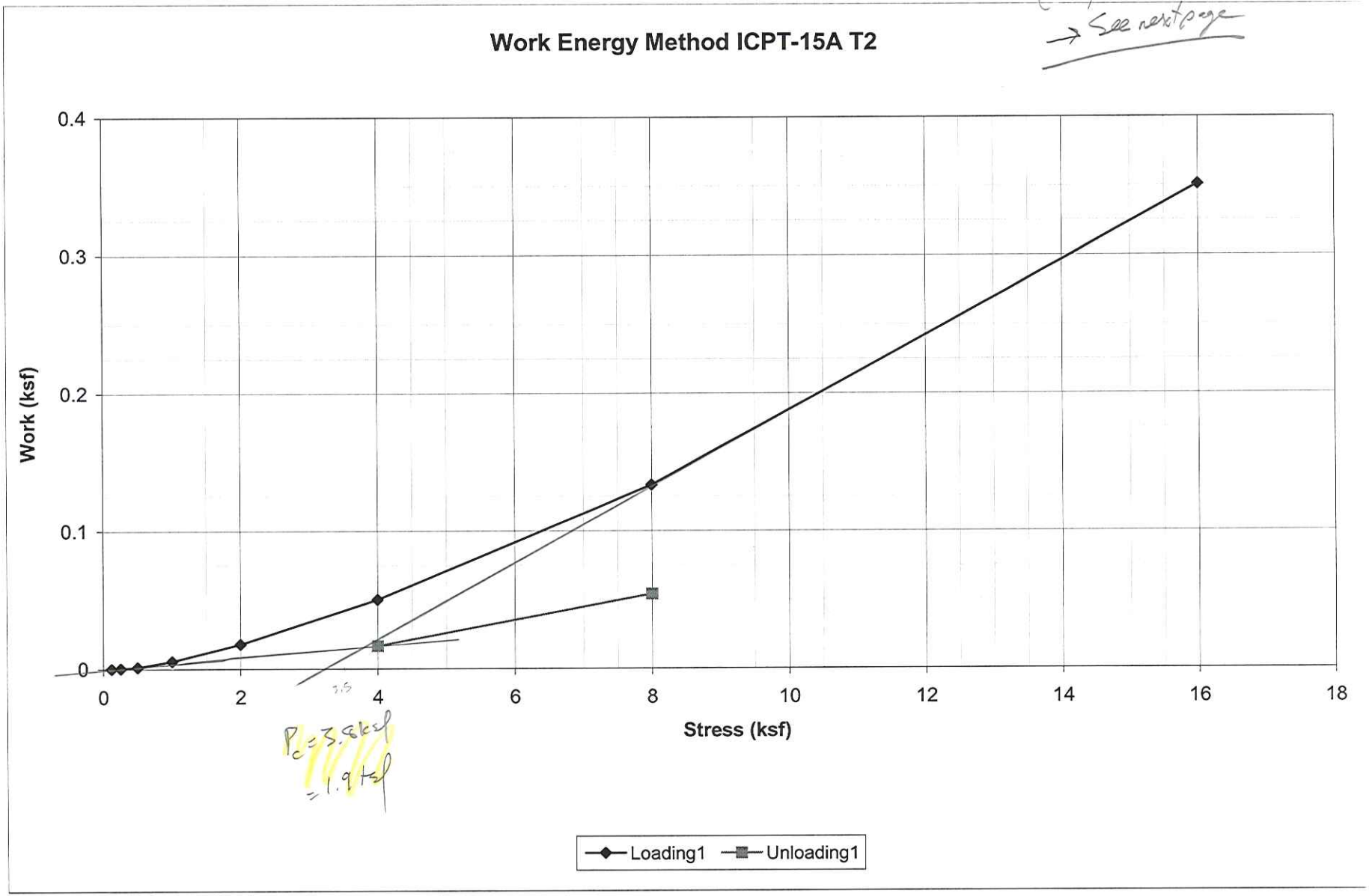


P_c = 6.1 tsf
= 3.1 tsf

ICPT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange

May be more accurate to graph 2nd loading too (Virgin curve is more apparent)
→ See next page



P_c = 3.6 ksf
= 1.9 tsf

JBT 9-30-08

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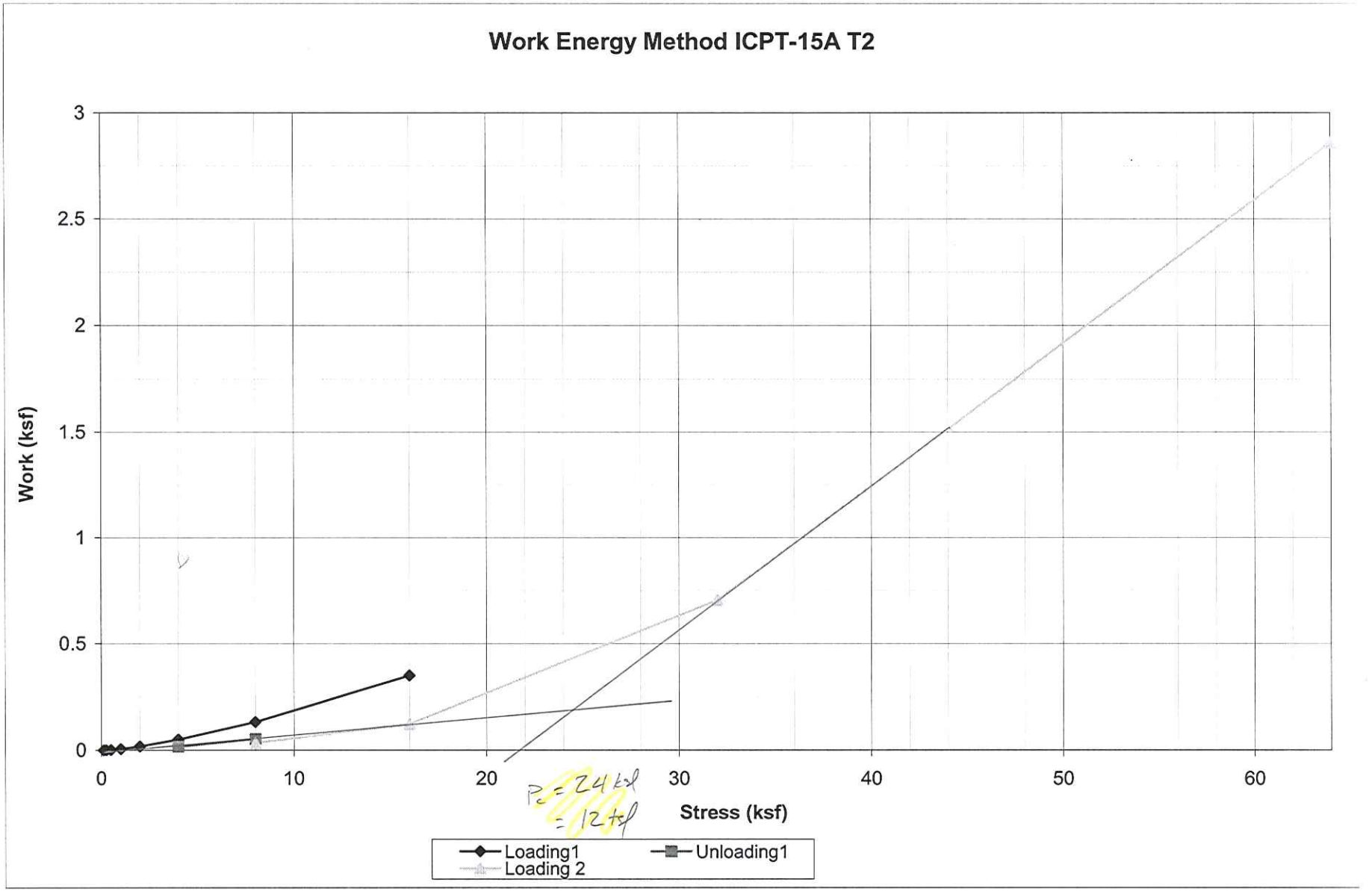
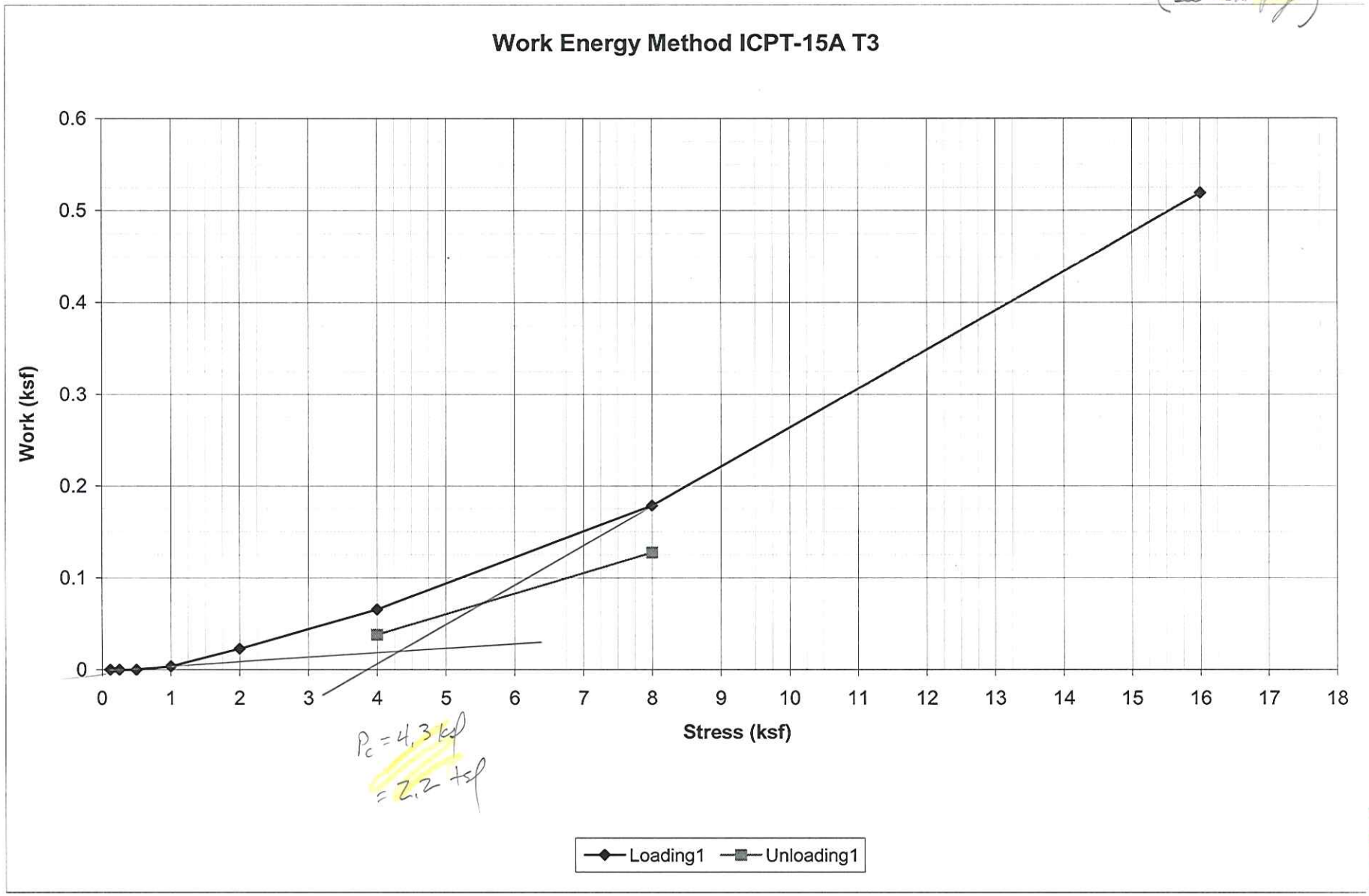

Work Energy Method ICPT-15A T2
Work (ksf)
Stress (ksf)
0
0.5
1
1.5
2
2.5
3
0
10
20
30
40
50
60
Pc = 24 ksf
= 12 tsf
Loading1
Unloading1
Loading 2

RKK-58

9-30-08

Graph 2nd Loading to get more accurate P_c (See next page)

Delaware Turnpike Improvements
SR-1 Interchange



RPT 9.30-08

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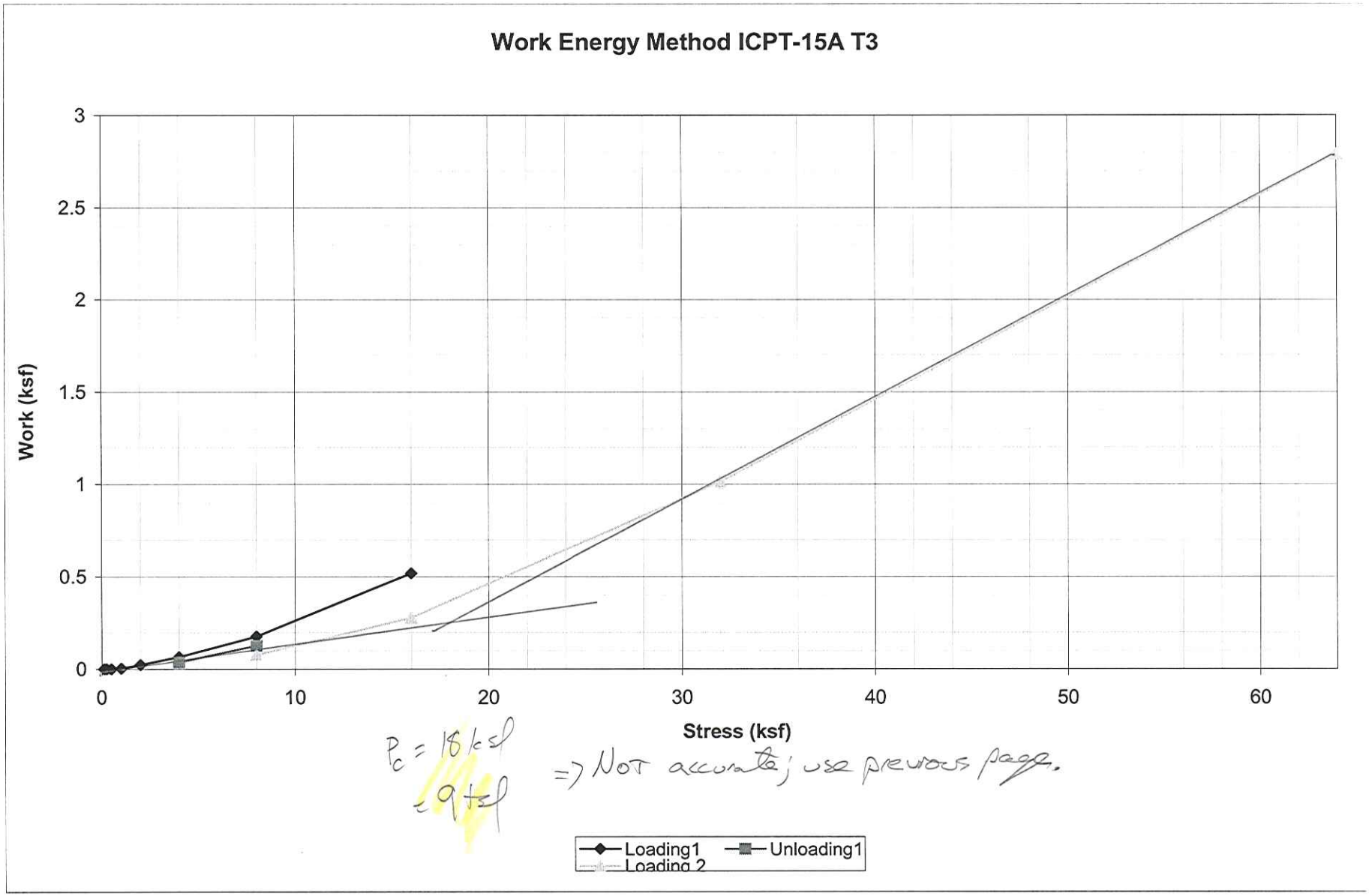
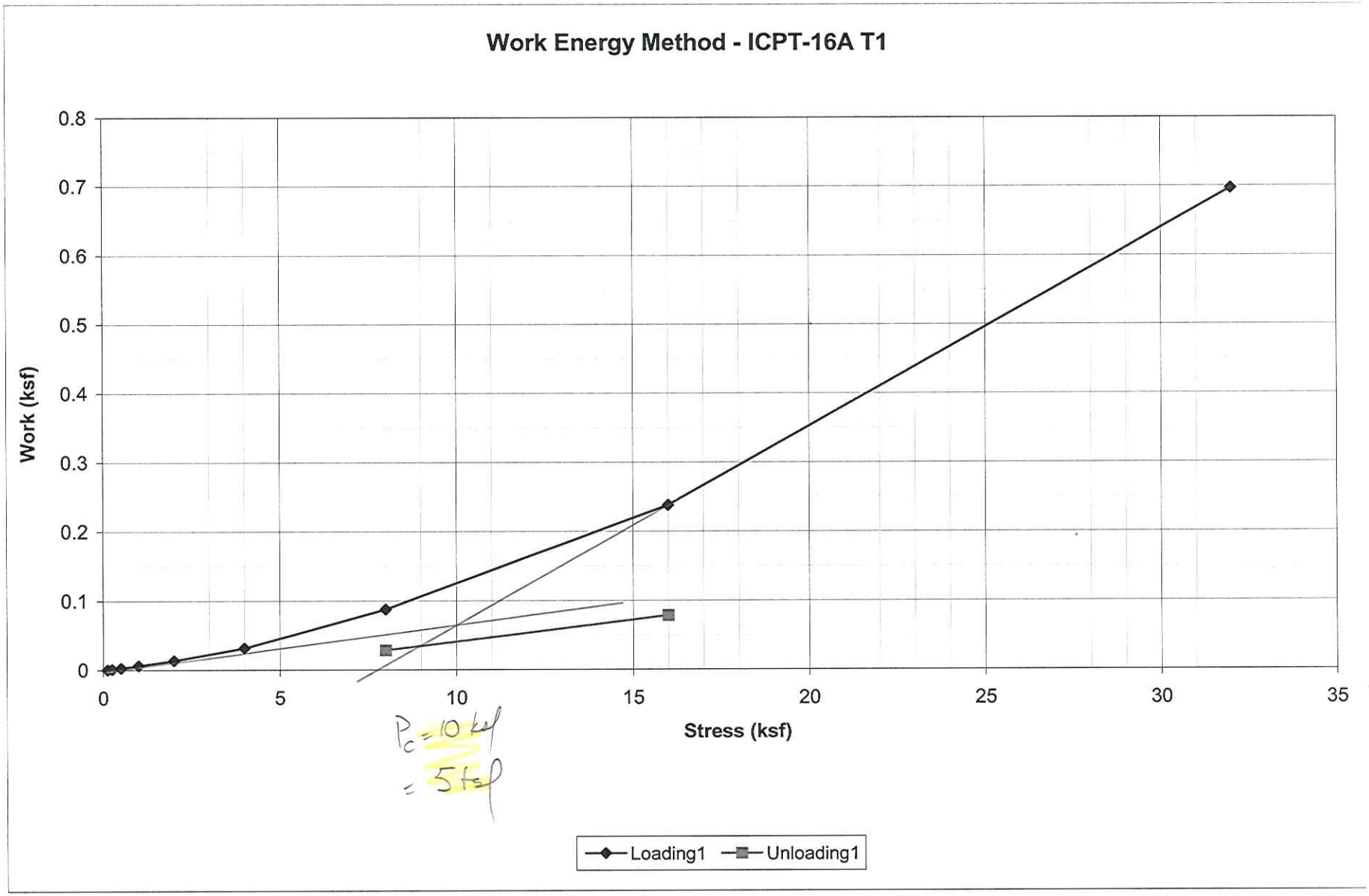


$P_c = 18$ ksf
≈ 9 tsf

=> Not accurate; use previous page.

JPT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-61

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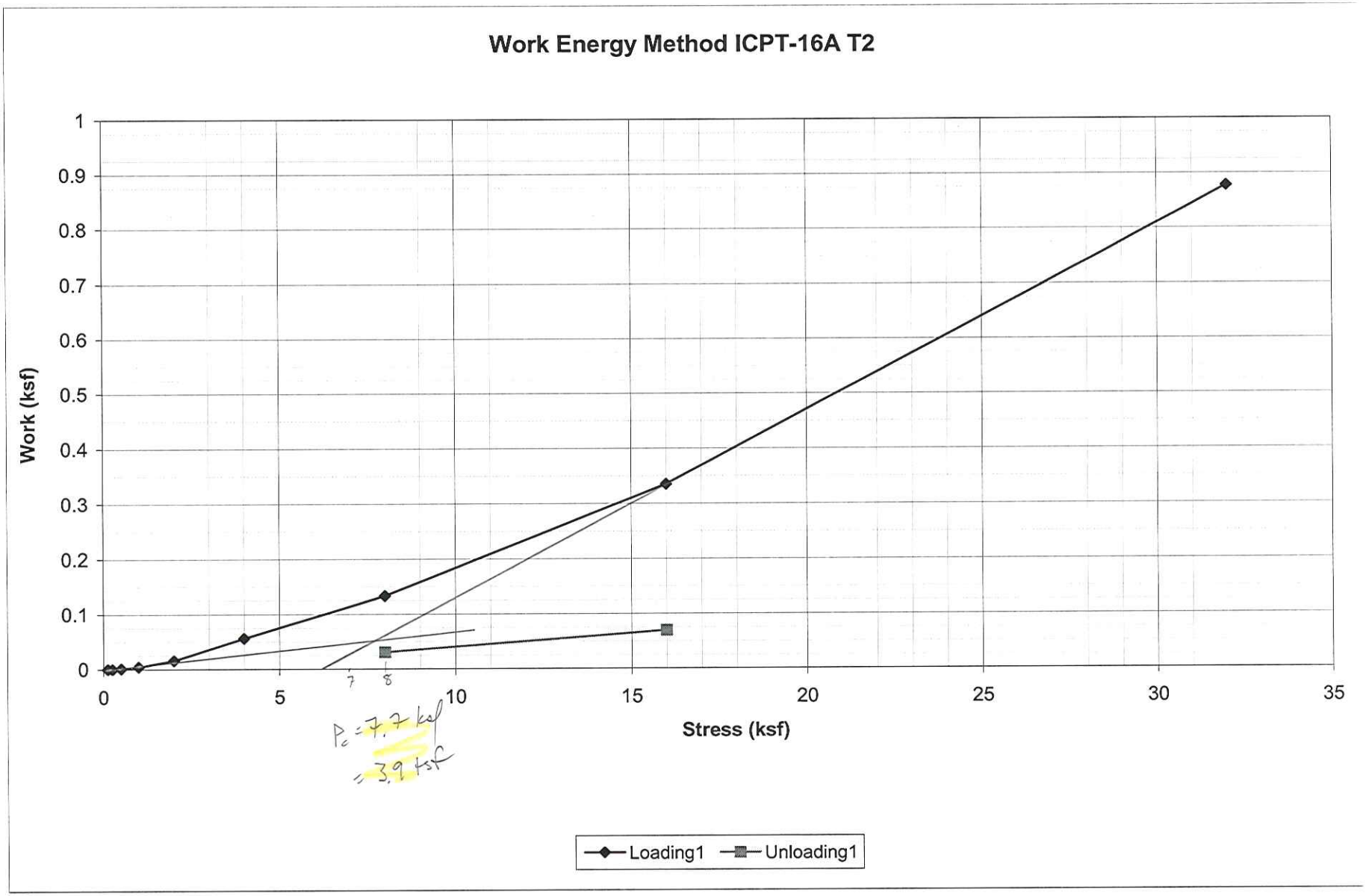
Delaware Turnpike Improvements
SR-1 Interchange



RKK-62

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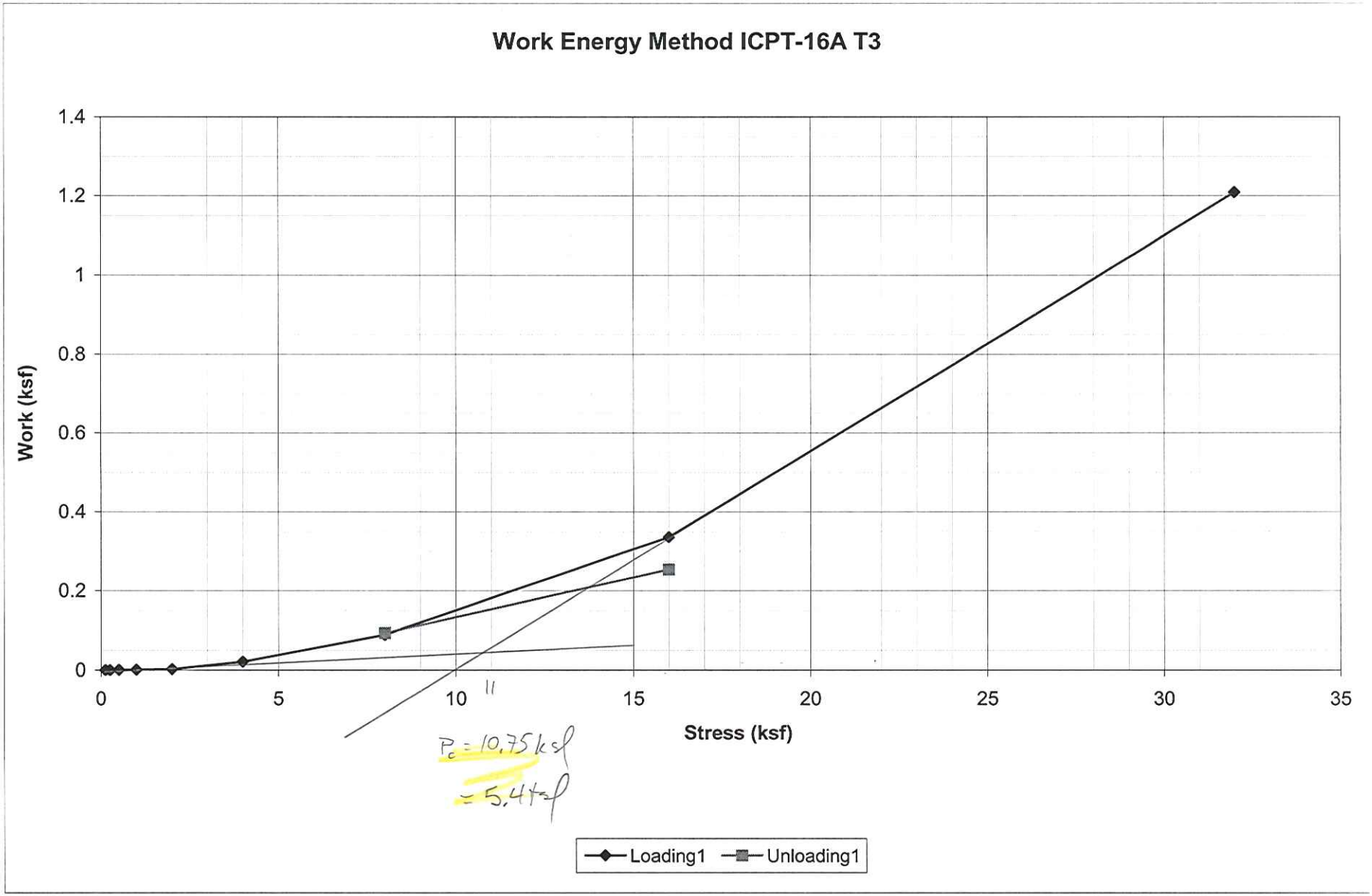
9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-63

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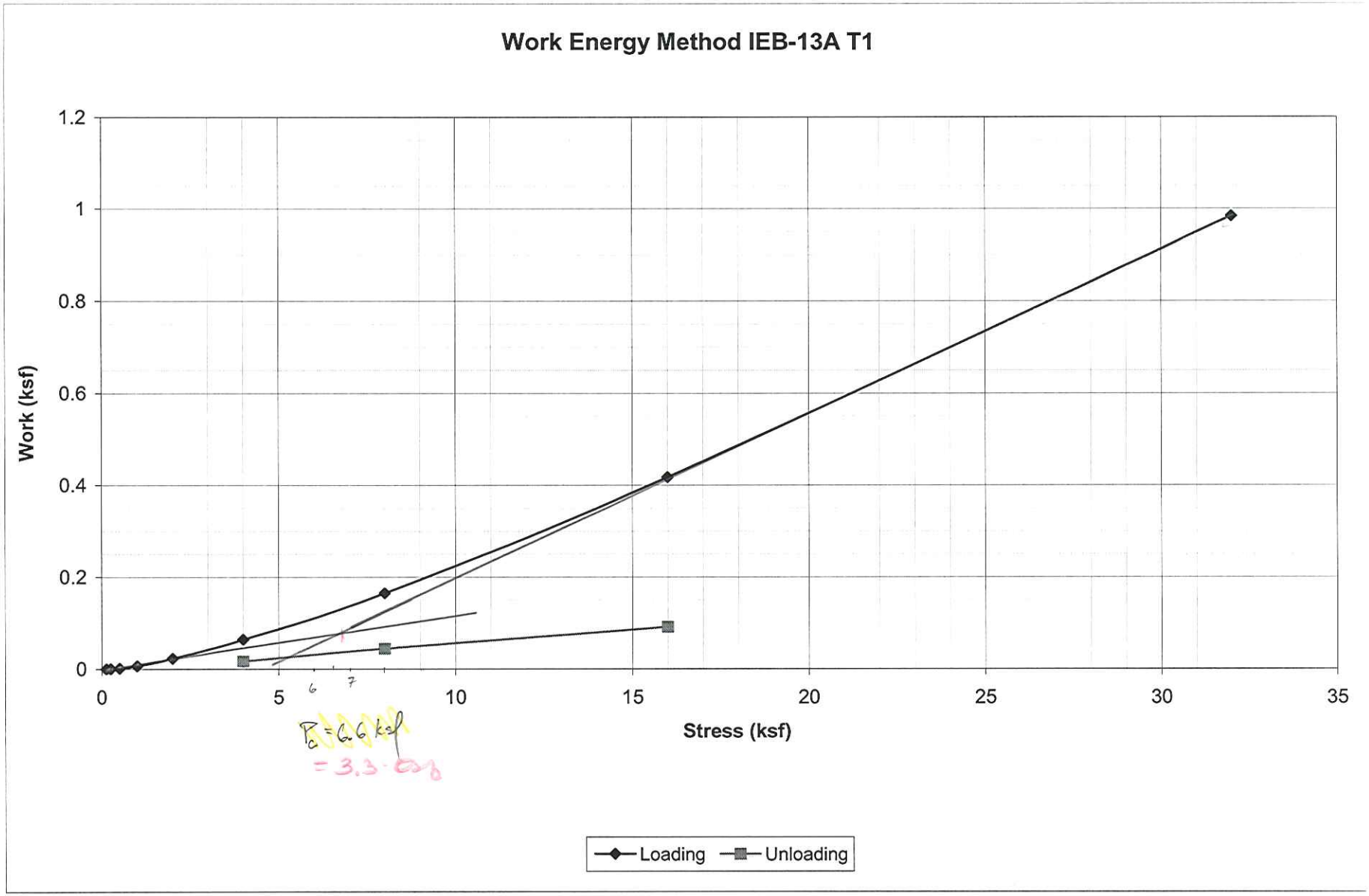
9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



$P_c = 6.6$ ksf
$= 3.3 \cdot 2$

RKK-64

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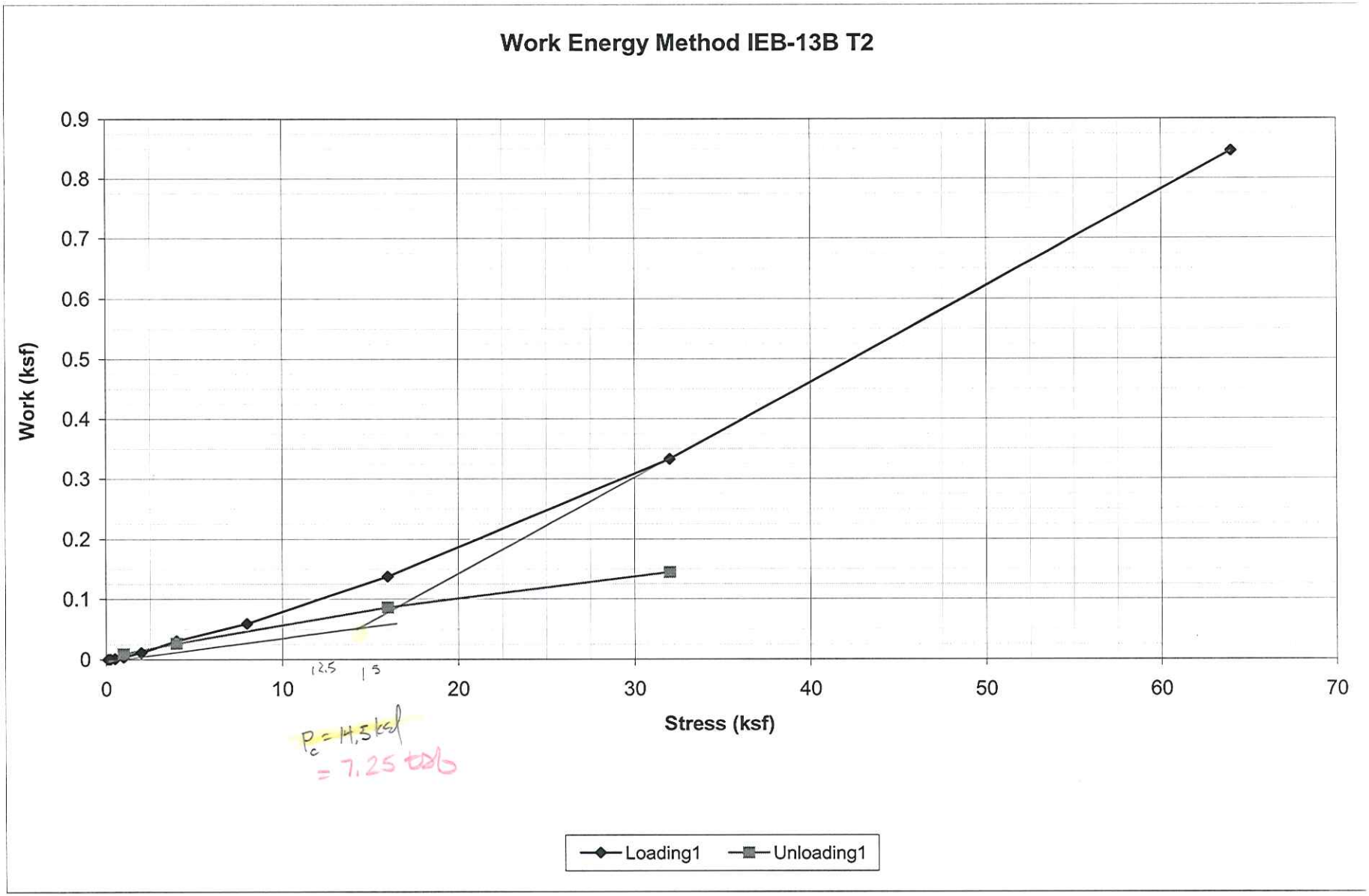
9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-65

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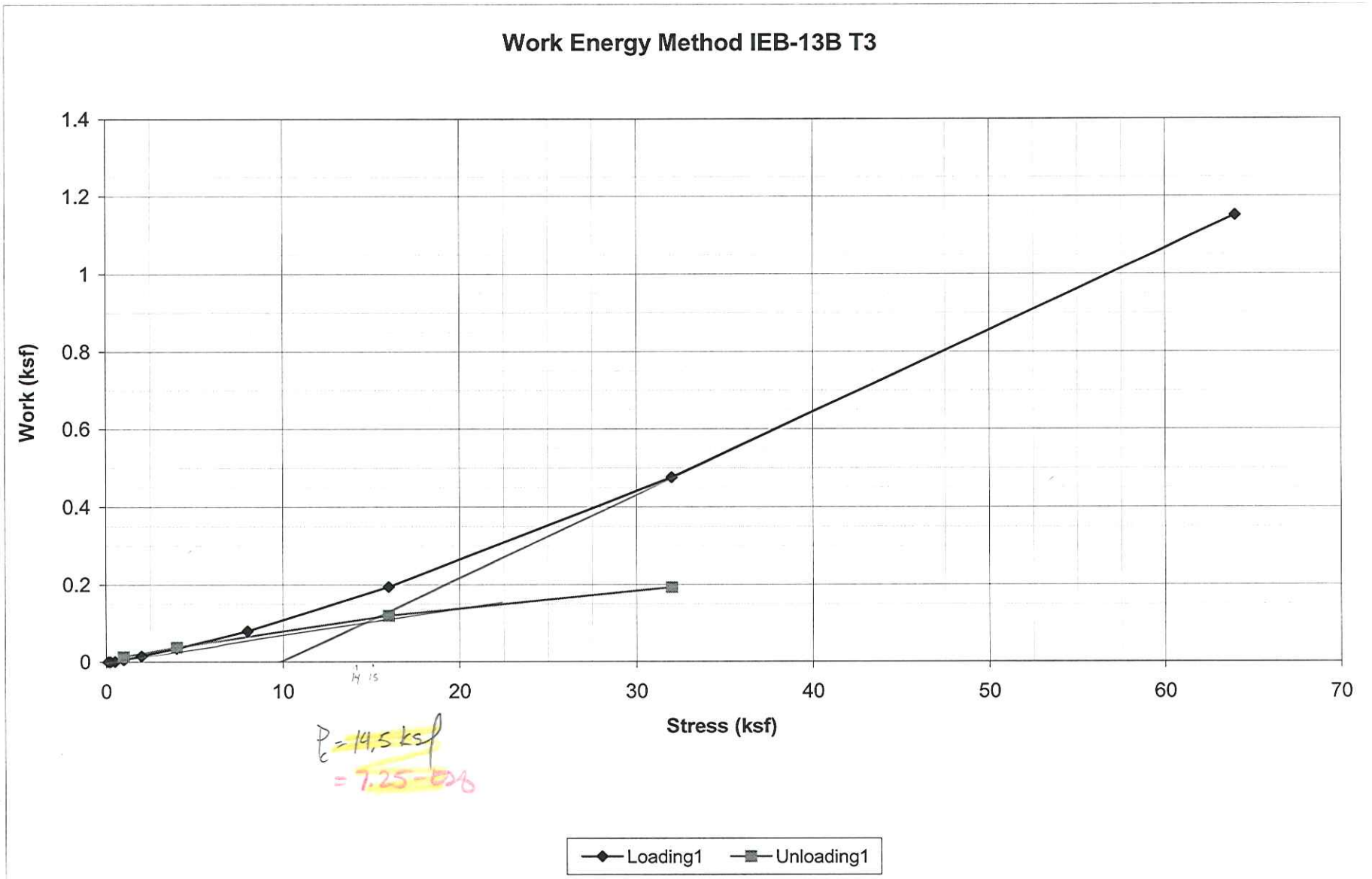
RPT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange

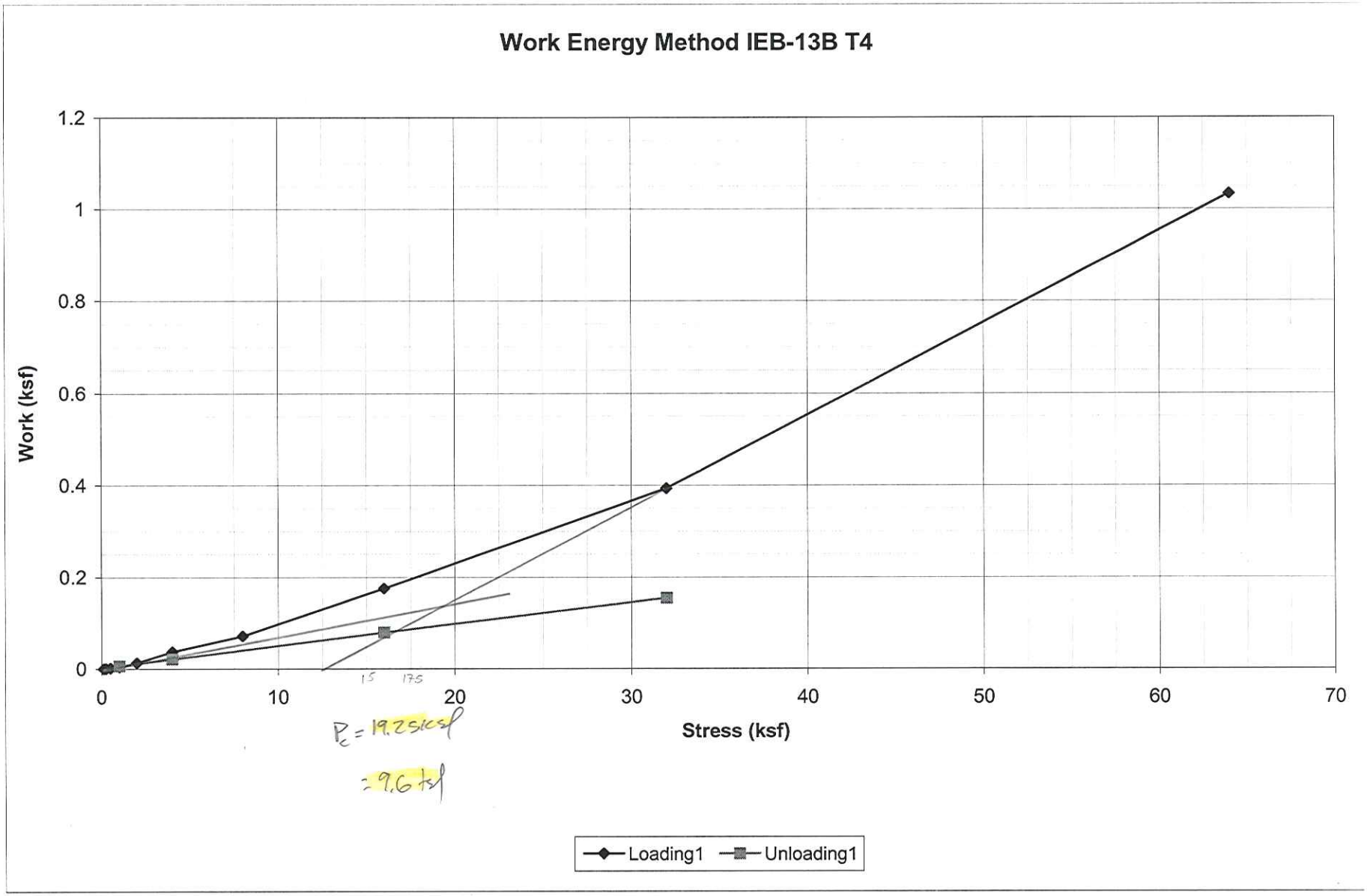


P_c = 14.5 ksf
= 7.25 - 0%

RKK-66
M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy.xls

9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



JDT 9-30-08

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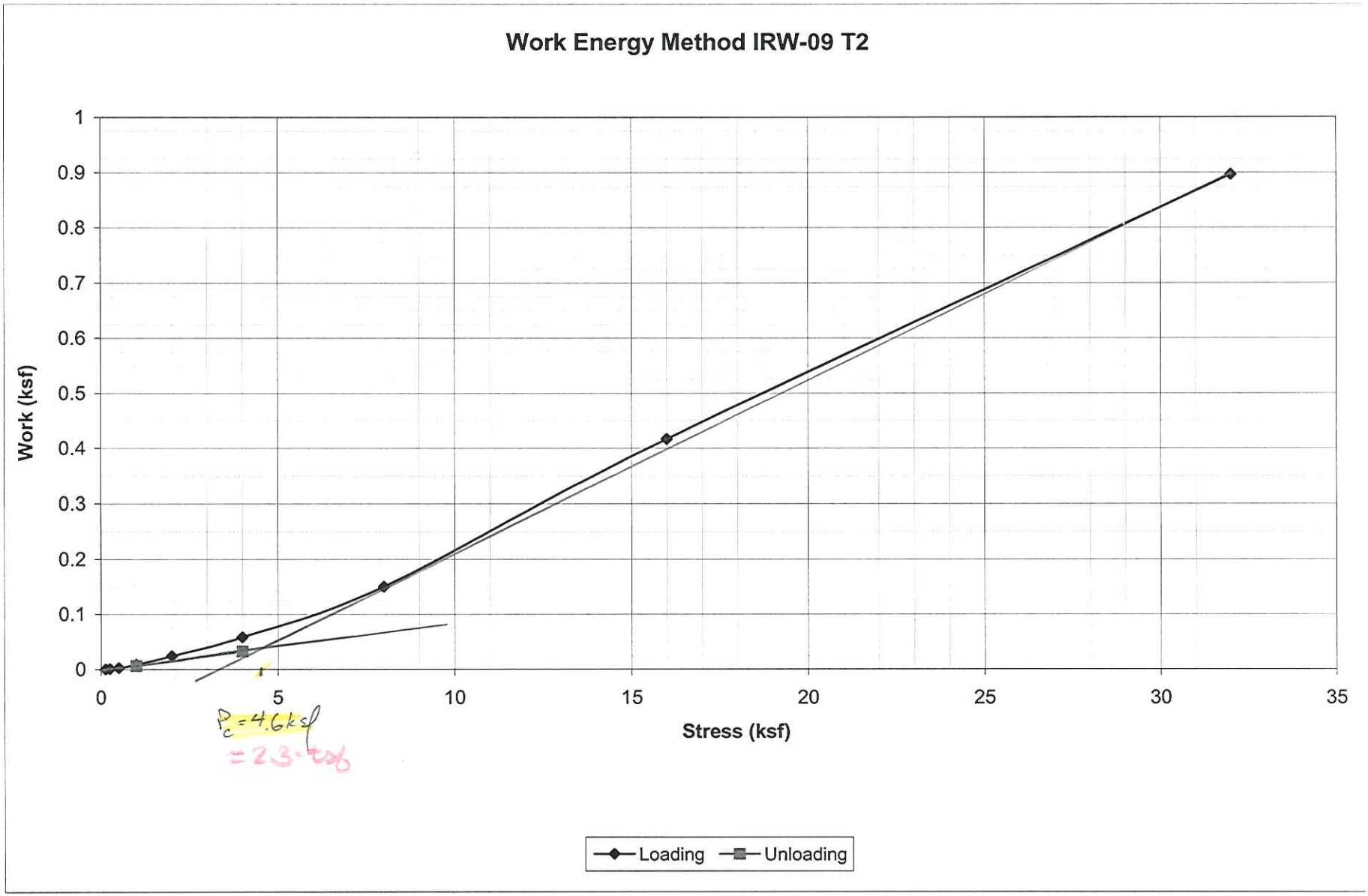
Delaware Turnpike Improvements
SR-1 Interchange



App I
9-30-08

RKK-68

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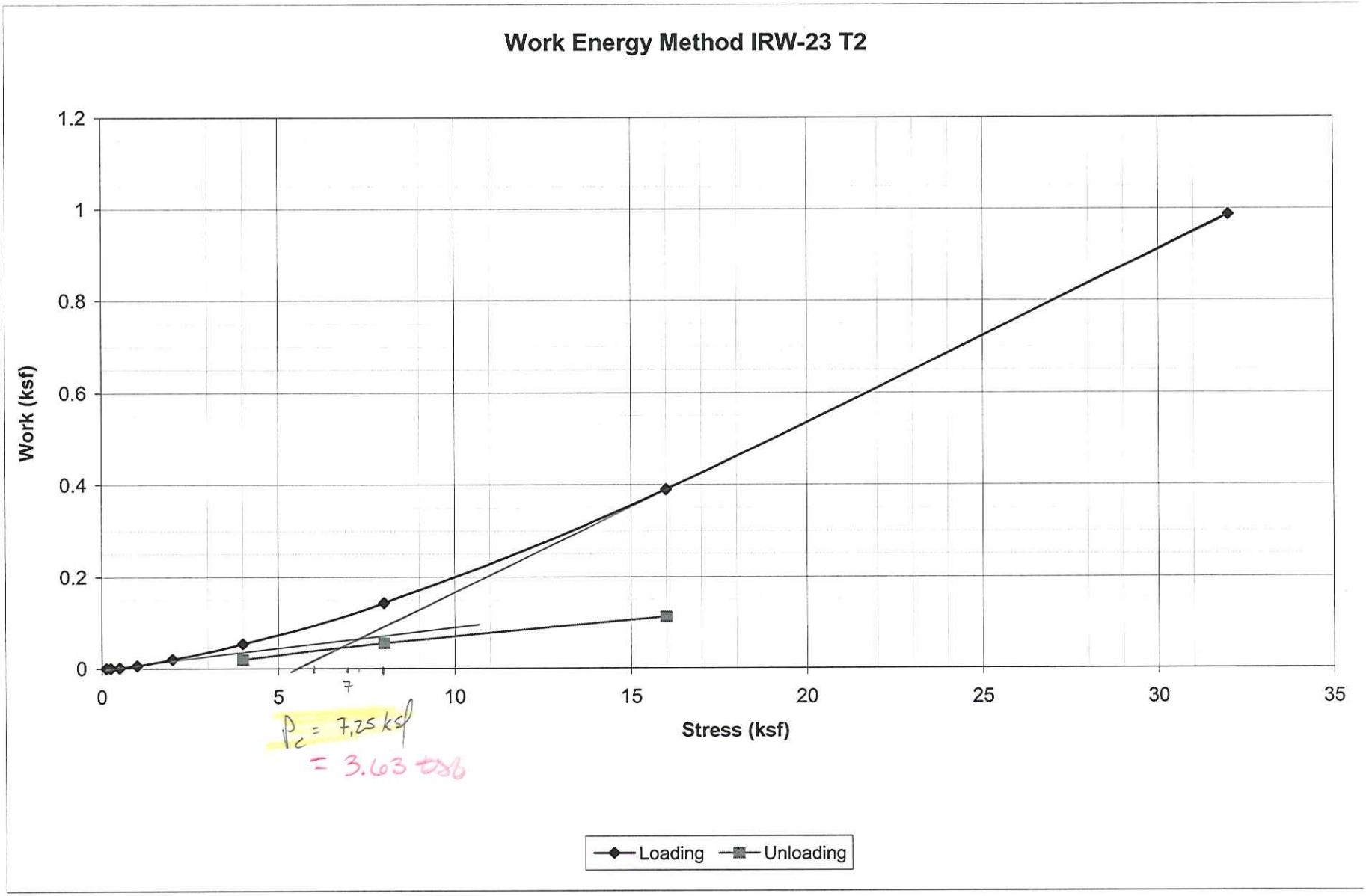
Delaware Turnpike Improvements
SR-1 Interchange

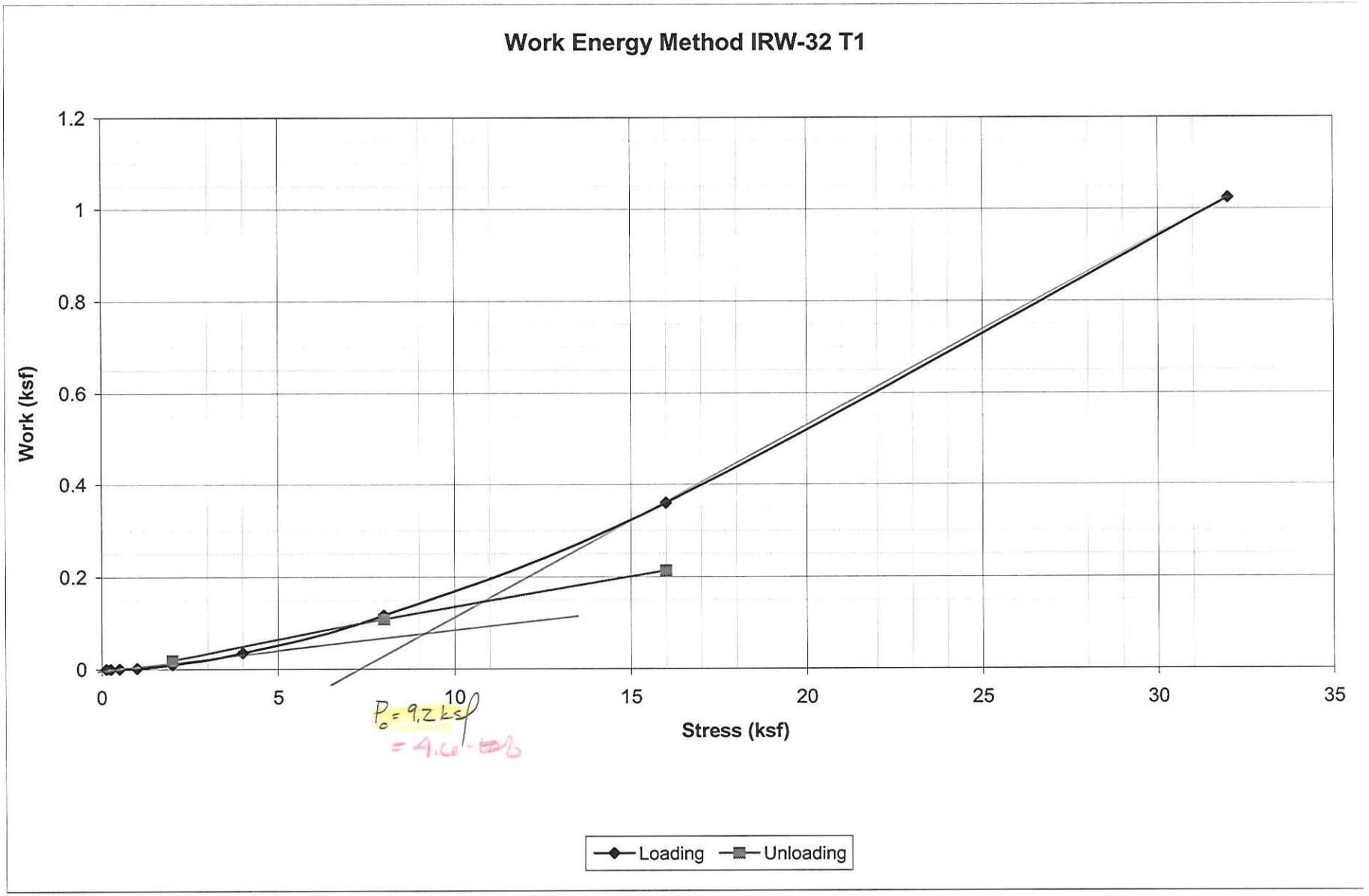


RKK-69

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy.xls

DDT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-70

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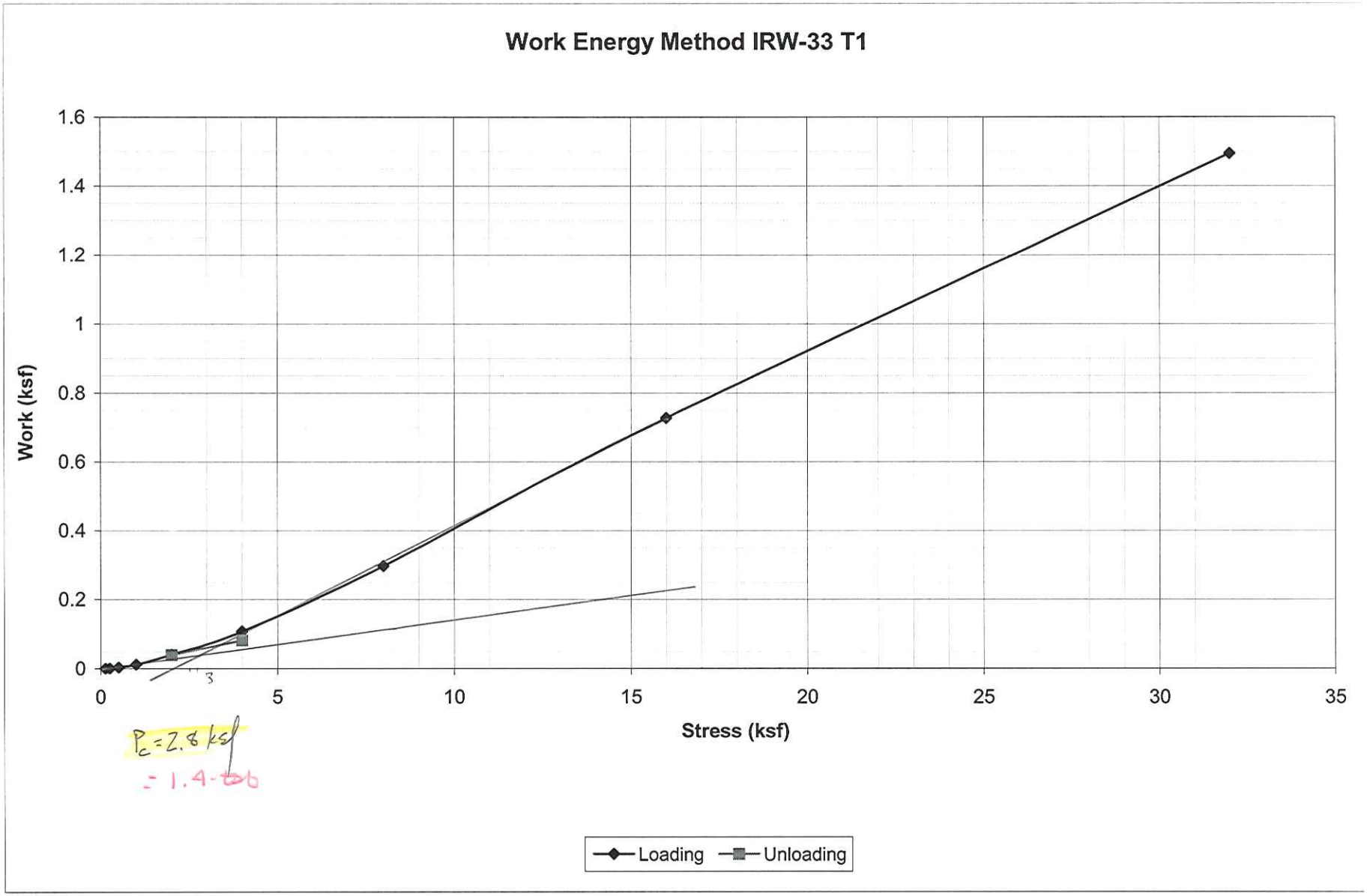
9-30-08

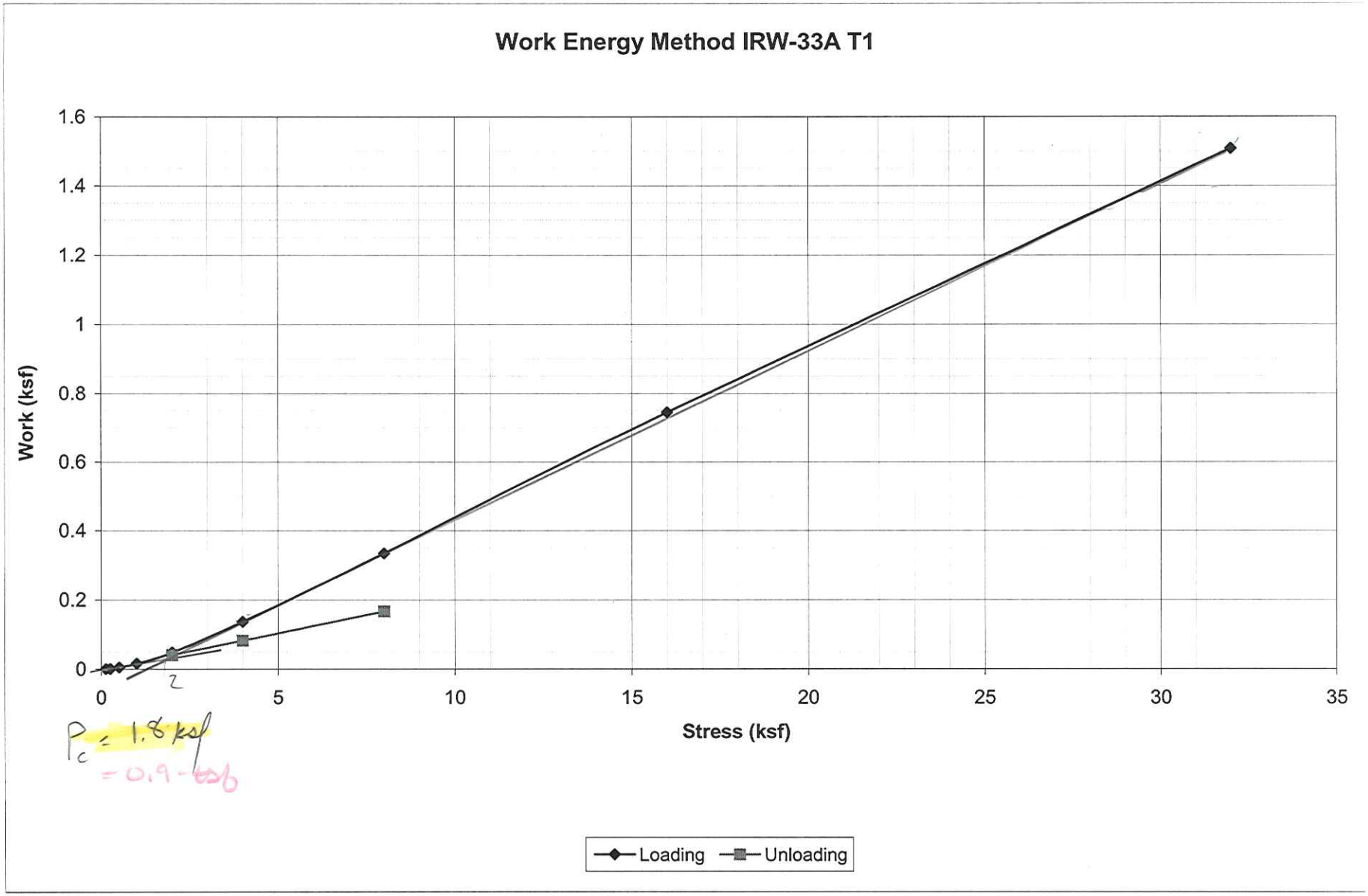
Delaware Turnpike Improvements
SR-1 Interchange



RKK-71

9-30-08

Delaware Turnpike Improvements
SR-1 Interchange

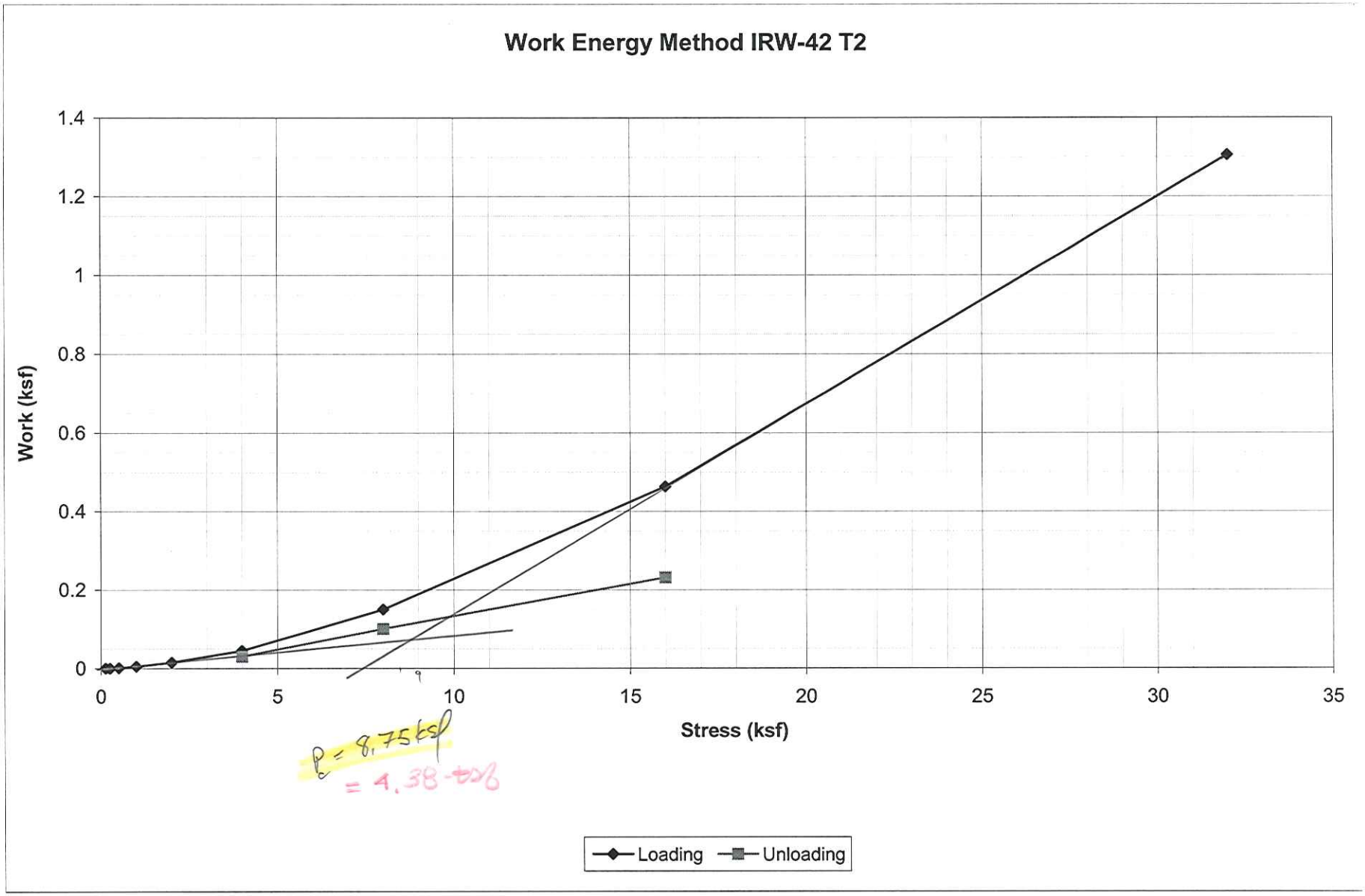


P_c = 1.8 ksf
= 0.9 tsf

RKK-72

9-30-04

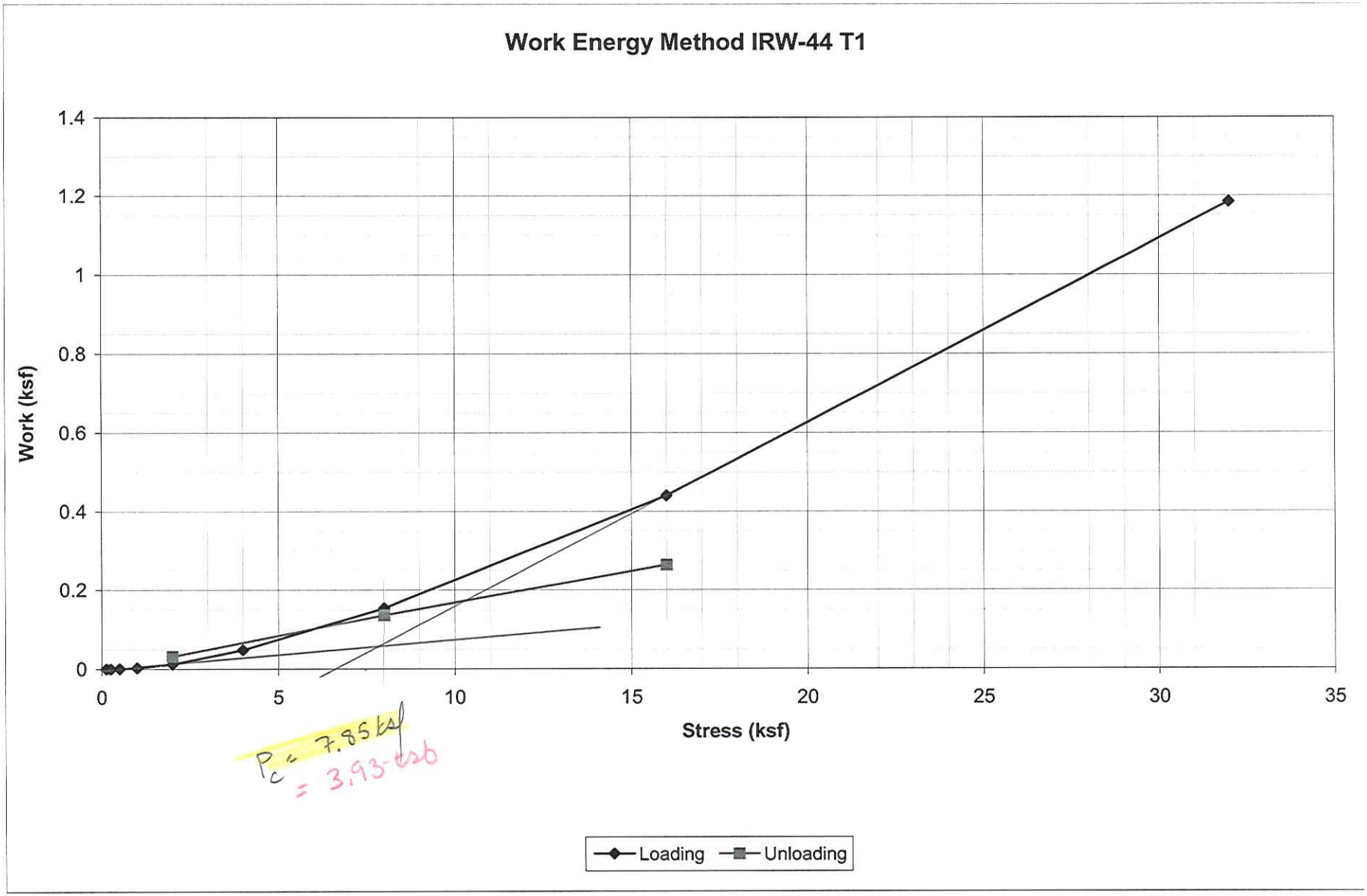
Delaware Turnpike Improvements
SR-1 Interchange



RKK-73

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy.xls

Delaware Turnpike Improvements
SR-1 Interchange

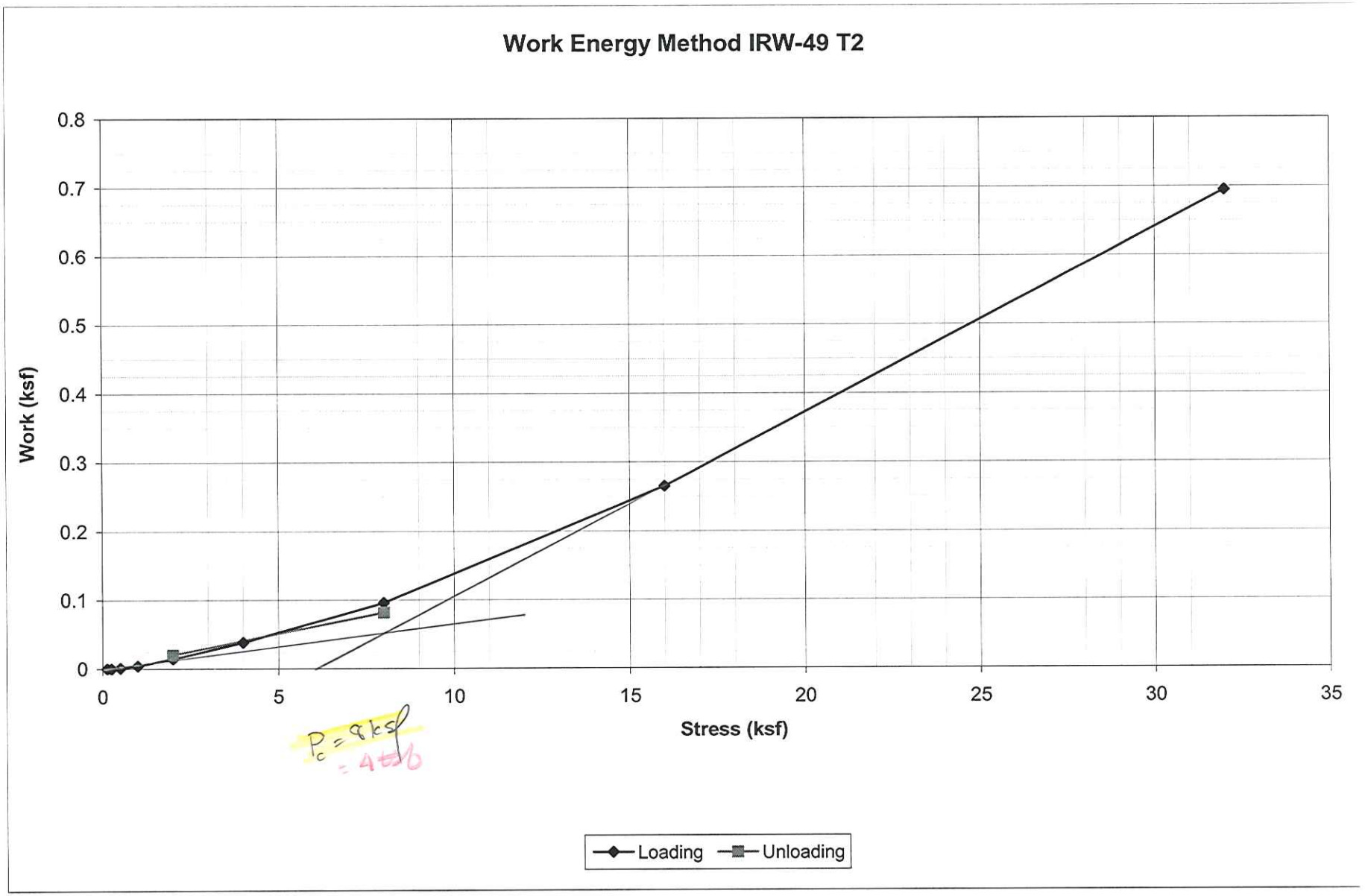


RKK-74

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy.xls

AJT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange

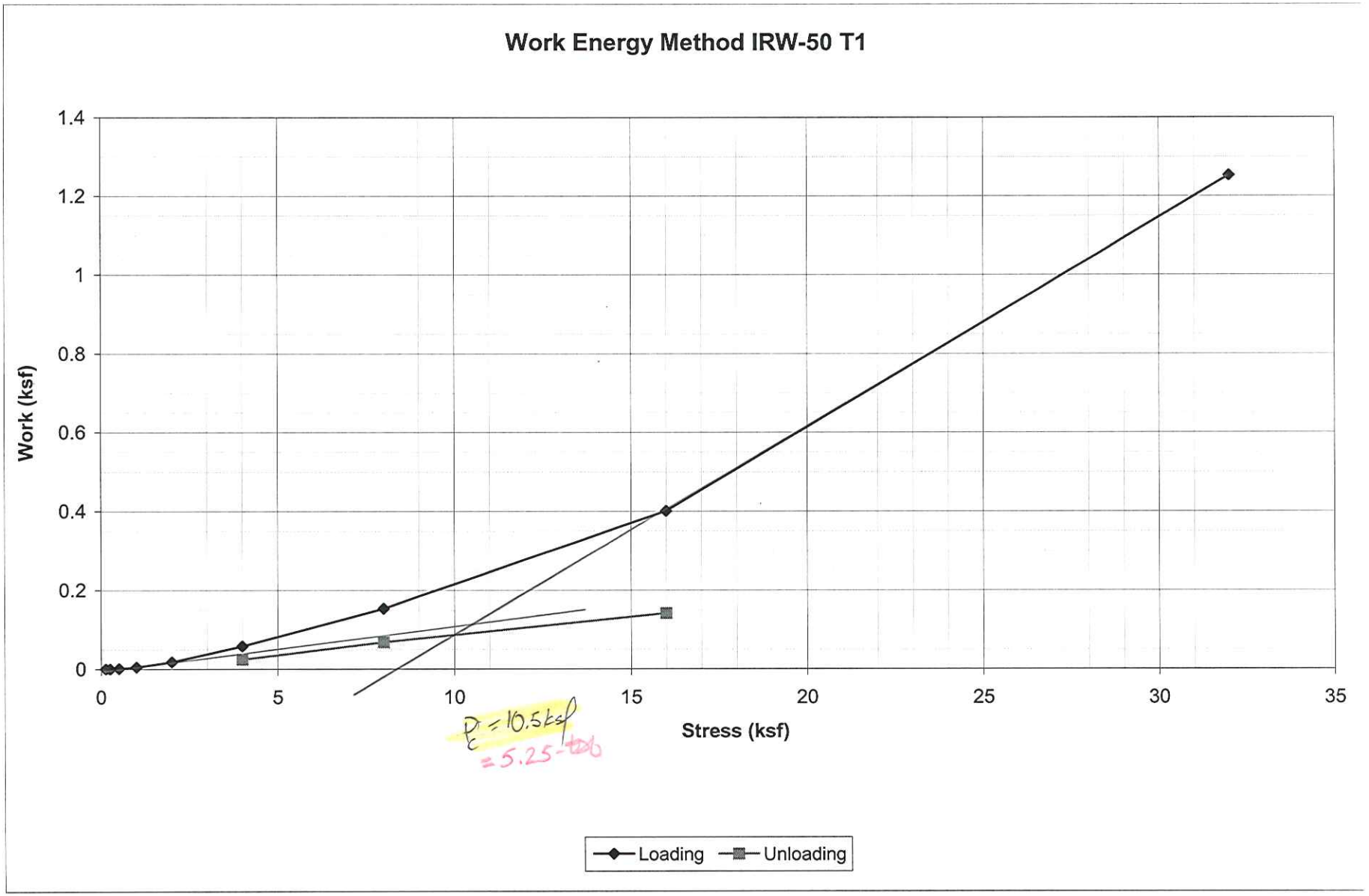


RKK-75

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy.xls

RKT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange

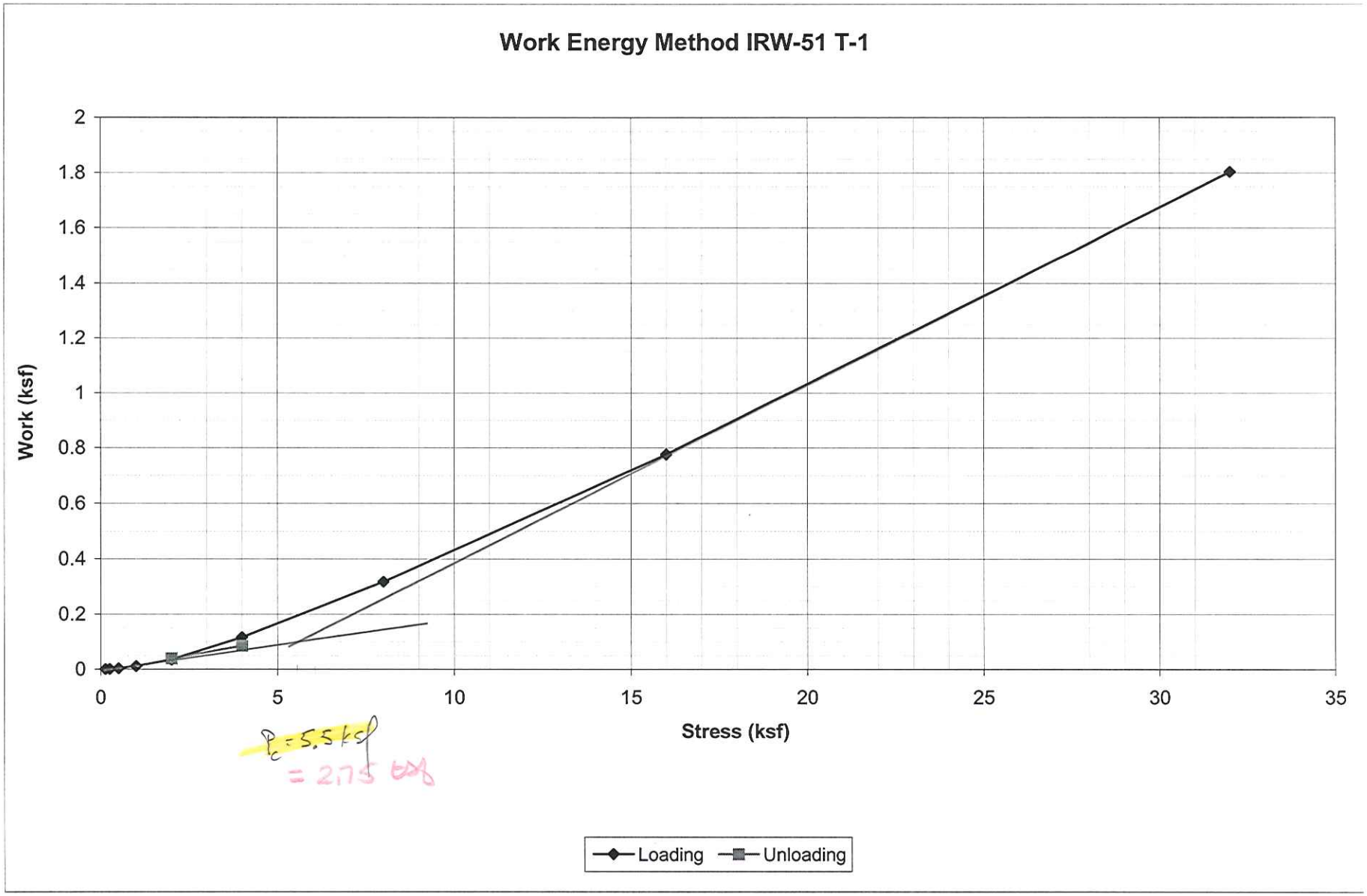


RKK-76

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy.xls

JCH 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange

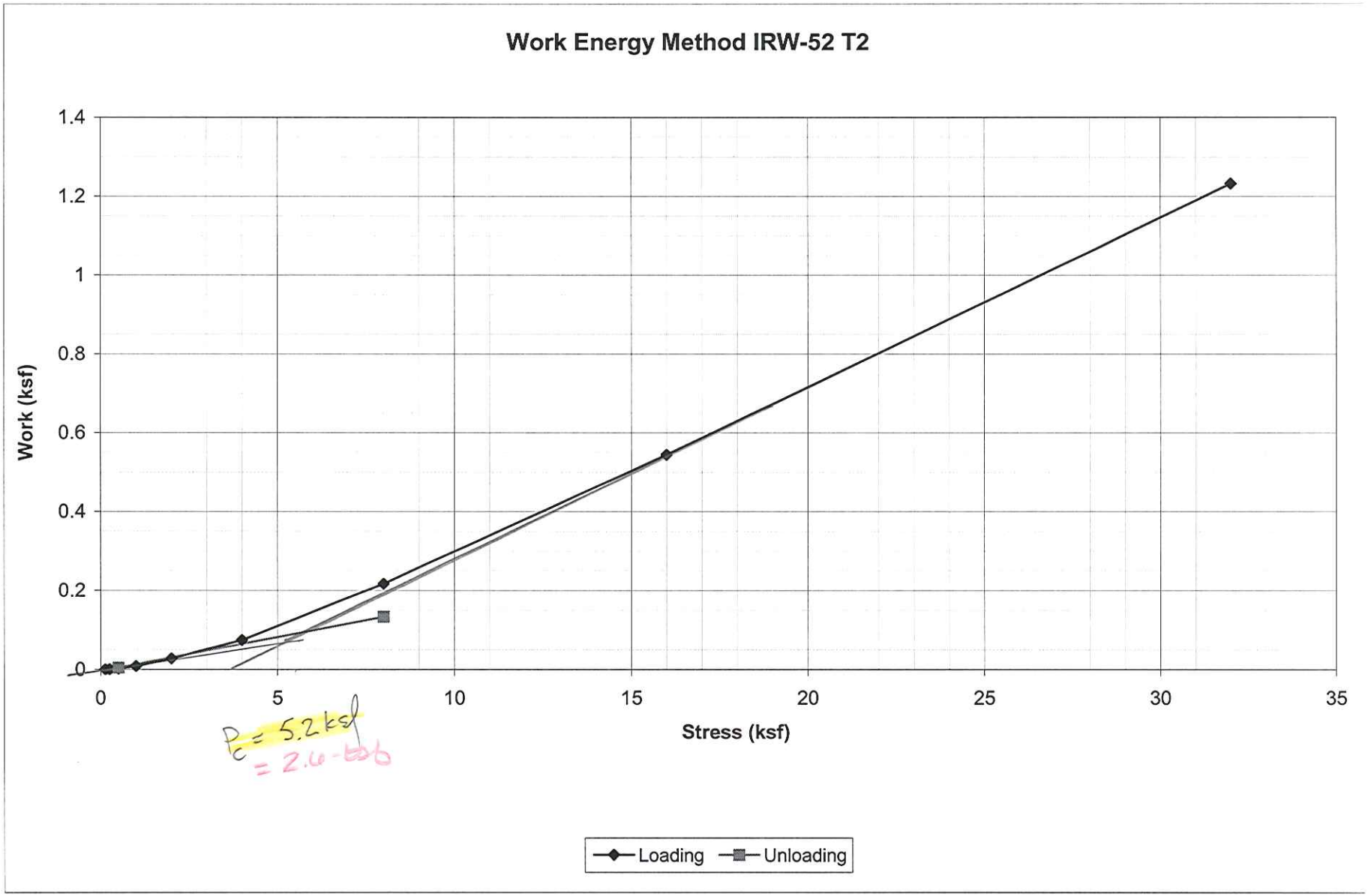


$P_c = 5.5$ ksf
$= 2.75$ tsf

RKK-77
M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy.xls

JDT 9-30-08

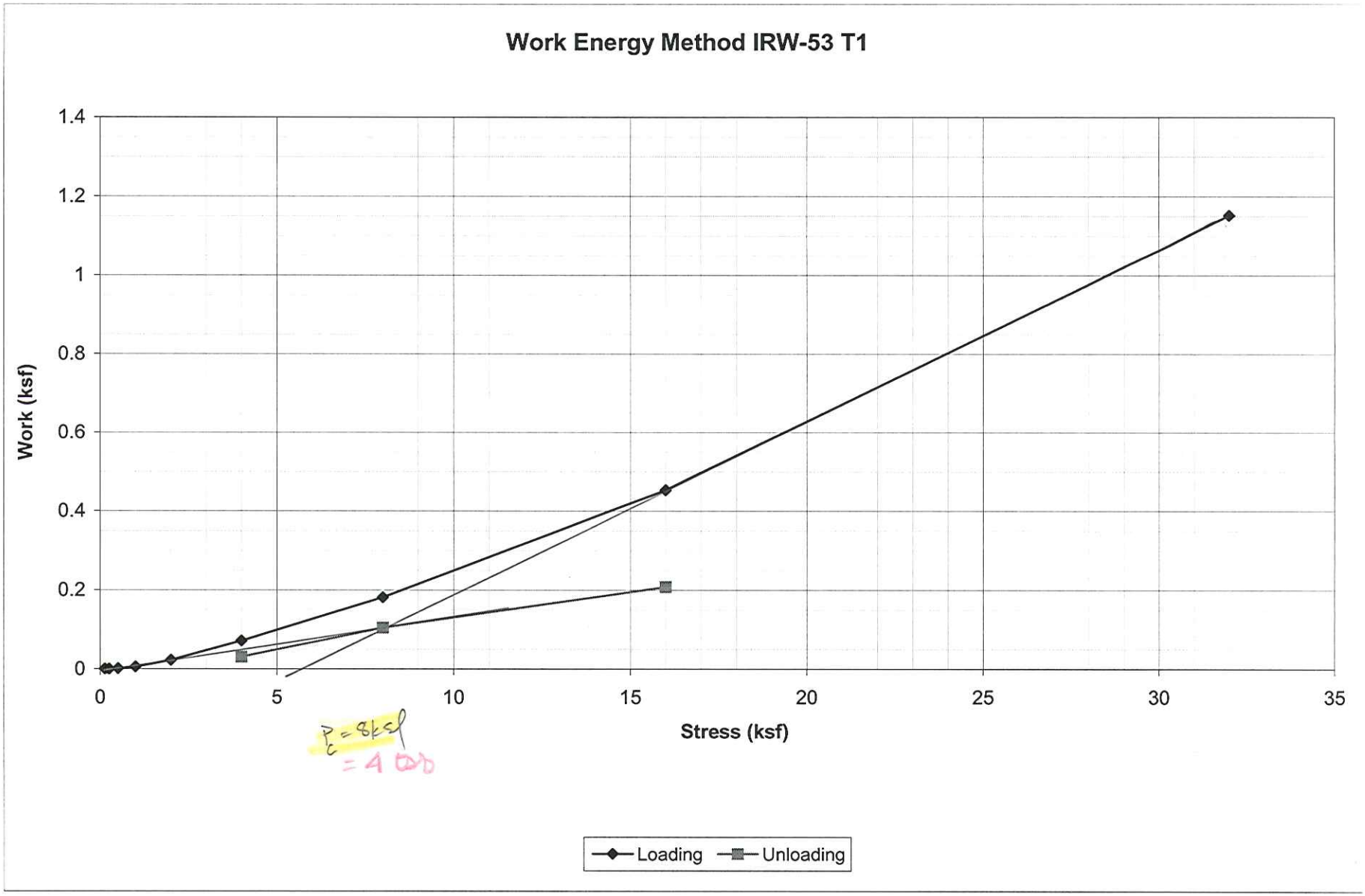
Delaware Turnpike Improvements
SR-1 Interchange



RKK-78
M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy.xls

DDT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



P_c = 8 ksf
= 4 OCD

RKK-79

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Work Energy.xls

On the following pages, the preconsolidation stress (P_c) from the work energy method (P_{cWE}) is plotted on the line of zero strain. The P_c from the Casagrande method is also verified and plotted. Both values are then evaluated in relation to the consolidation curve, and the most realistic P_c value is chosen, or an average of the values is chosen to represent the sample.

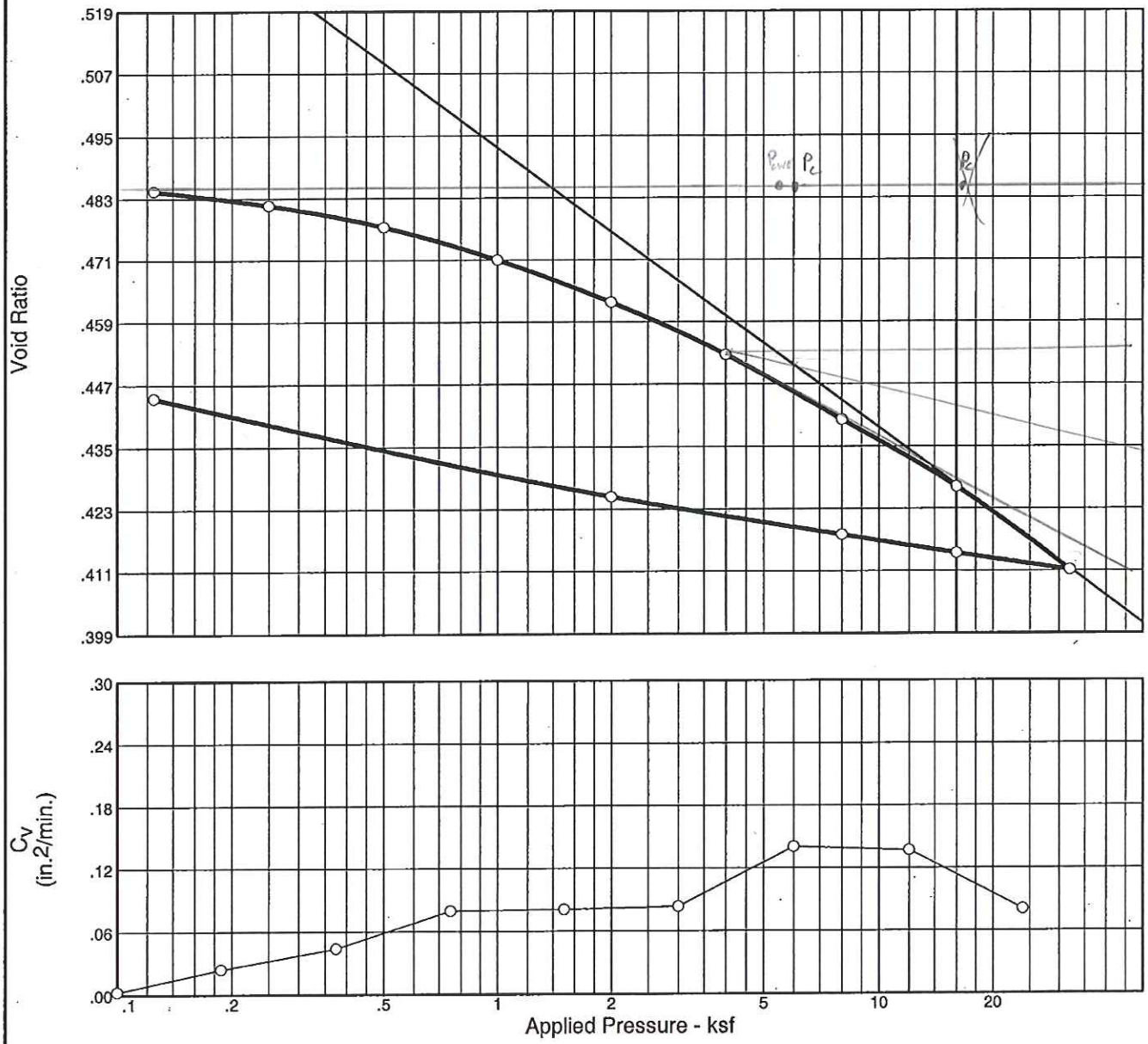
The most realistic P_c is indicated as Final P_c in the Summary Table. The Final OCR was estimated by Final P_c / P_o.

* Final P_c + OCR to be updated w/ results of Supplemental Lab Testing.

JJT 9-30-08

RKK-81

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf)		C_c	C_r	Initial Void Ratio
Saturation	Moisture										
80.3 %	14.2 %	115.5	22	5	2.75		~~16.52~~	5.5	0.05	0.01	0.487

MATERIAL DESCRIPTION	USCS	AASHTO
Mottled Yellwish Brown & Gray SANDY SILTY CLAY. Final Pc 5.75 ksf	CL-ML	

Project No. 14678 **Client:** RUMMEL, KLEPPER AND KAHL

Project: DELAWARE TURNPIKE IMPROVEMENTS - INTERCHANGE (103-059)

Location: IBR-4, T-1 @ 18.0'-20.0'

Remarks: Undisturbed Specimen

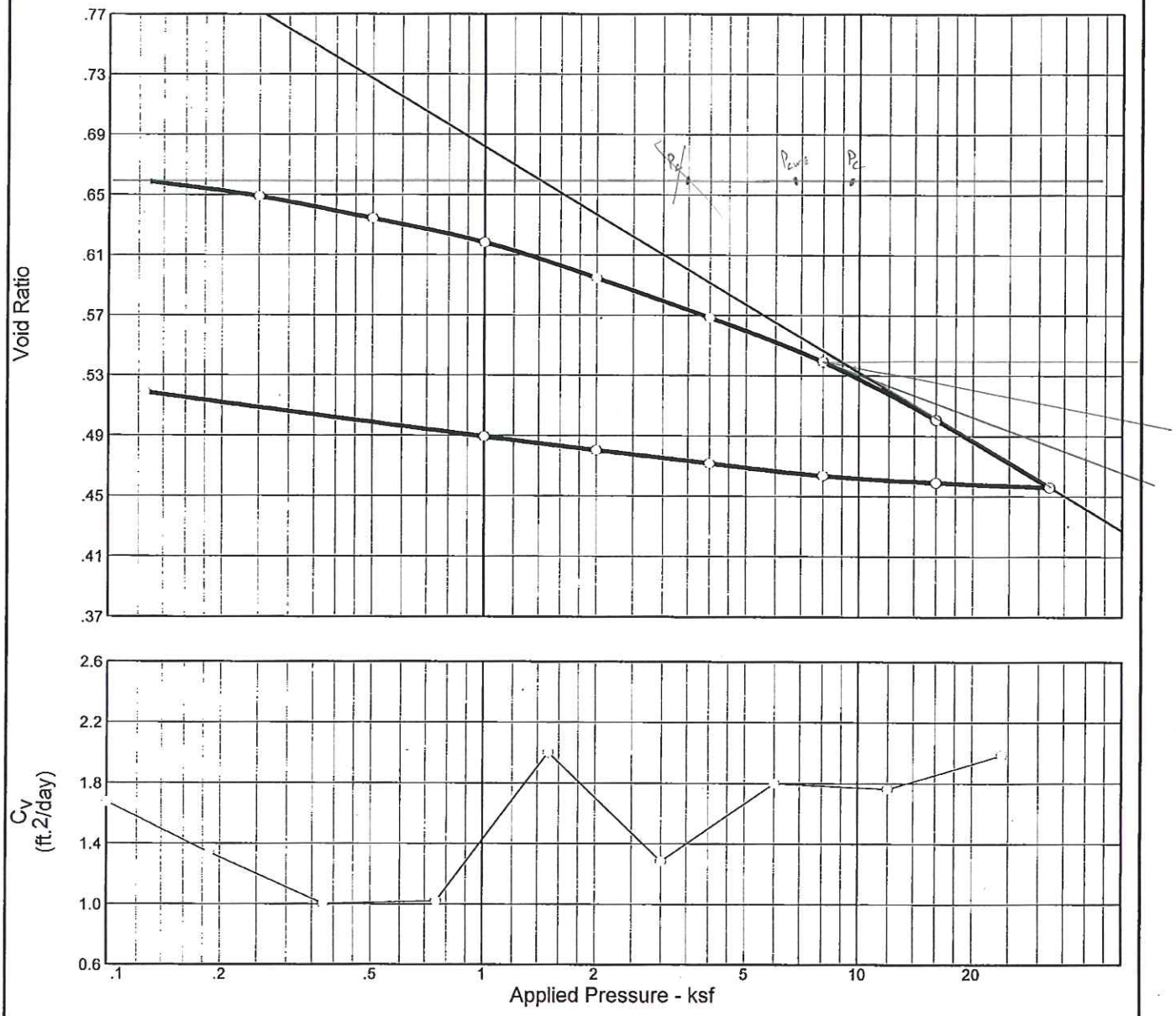
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 9-30-08

RKK-82

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf)	C_c	C_r	Initial Void Ratio
Saturation	Moisture						3.47 / 6.75 Pcwe			
70.9 %	17.4 %	101.4	21	3	2.696		9.5 5.4	0.15	0.02	0.661

MATERIAL DESCRIPTION	USCS	AASHTO
Mottled Red & Gray SANDY SILT. Final Pc NV	ML	

Project No. 14678 **Client:** RUMMELL,KLEPPER & KAHL. LLC

Project: DELAWARE TURNPIKE IMPROVEMENTS -Interchange
RK & K Job No. 103-059

Location: IBR-5, T-2@31.5'-33.5'

Remarks:
Undisturbed Sample

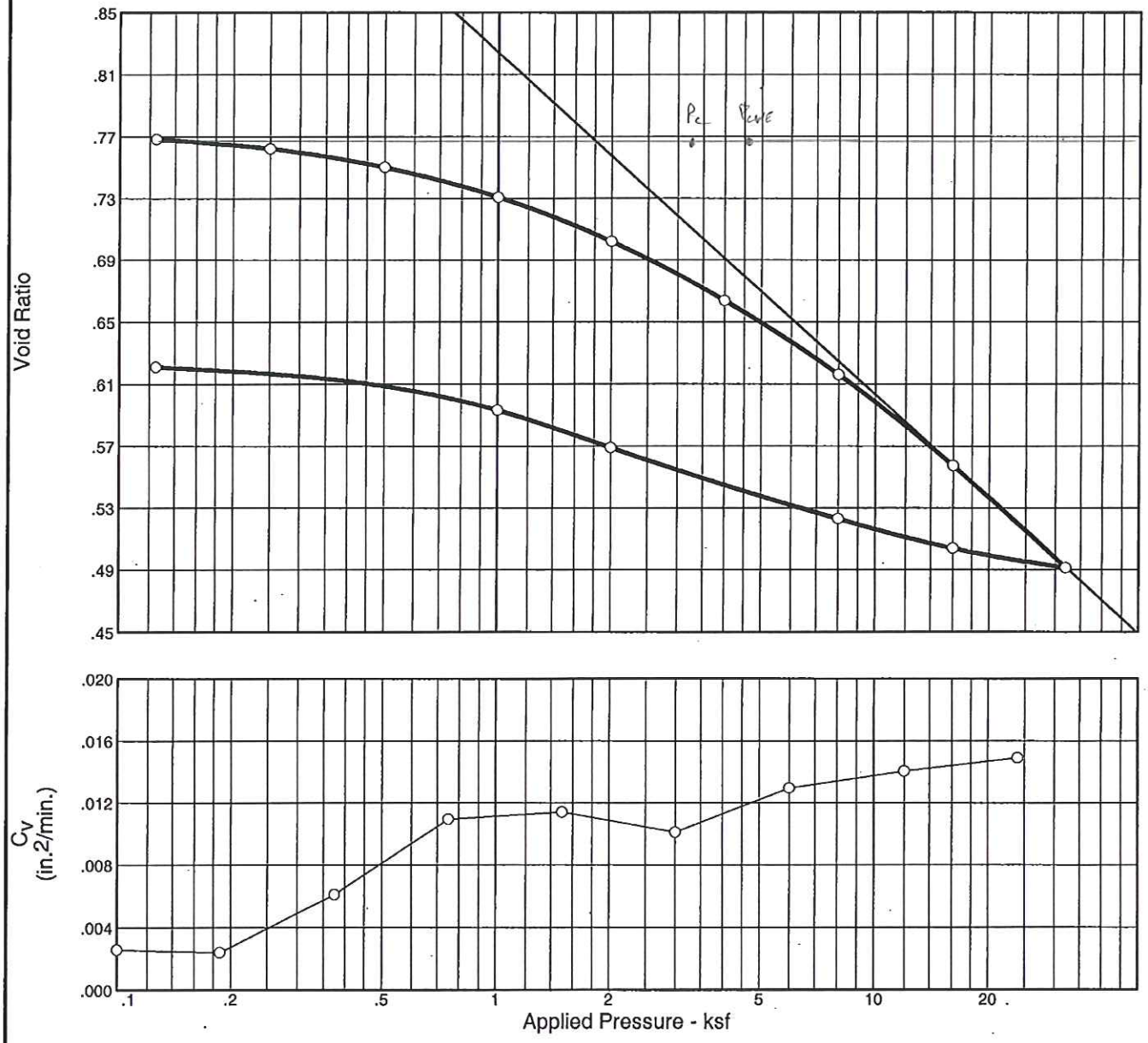
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JSP 9-30-08

RKK-83

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf)	C_c	C_r	Initial Void Ratio
Saturation	Moisture									
98.0 %	27.5 %	96.9	42	22	2.75		3.26 / 4.6	0.22	0.06	0.772

MATERIAL DESCRIPTION	USCS	AASHTO
Final P_c => 3.93 ksf		
Dark Red LEAN CLAY.	CL	

Project No. 14678 **Client:** RUMMEL, KLEPPER AND KAHL

Project: DELAWARE TURNPIKE IMPROVEMENTS - INTERCHANGE (103-059)

Location: IBR-15 T-1 @ 19.5'-21.5'

Remarks:
Remolded Sample

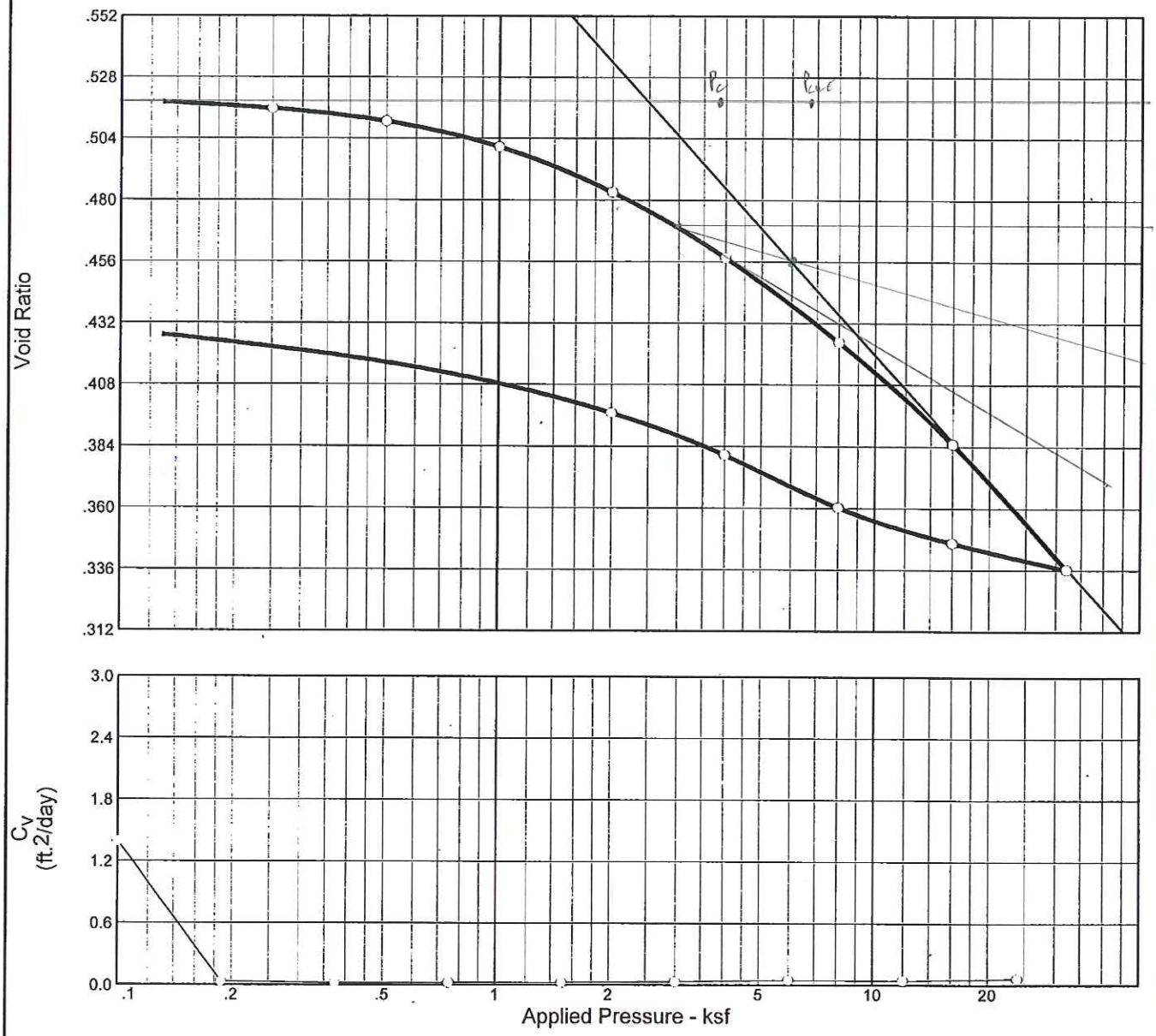
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JST 9-30-08

RKK-84

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf) Pc we	C_c	C_r	Initial Void Ratio
88.9 %	16.7 %	113.7	31	13	2.766		3.84 / 6.75 (6 kg) ⇒ 6.38 (Final Pc)	0.16	0.05	0.519

MATERIAL DESCRIPTION	USCS	AASHTO
Mottled Brown & Tan LEAN CLAY.	CL	

Project No. 14678 **Client:** RUMMELL,KLEPPER & KAHL. LLC

Project: DELAWARE TURNPIKE IMPROVEMENTS -Interchange
RK & K Job No. 103-059

Location: IBR-32,T-3@50.0'-52.0'

Remarks:
Undisturbed Sample

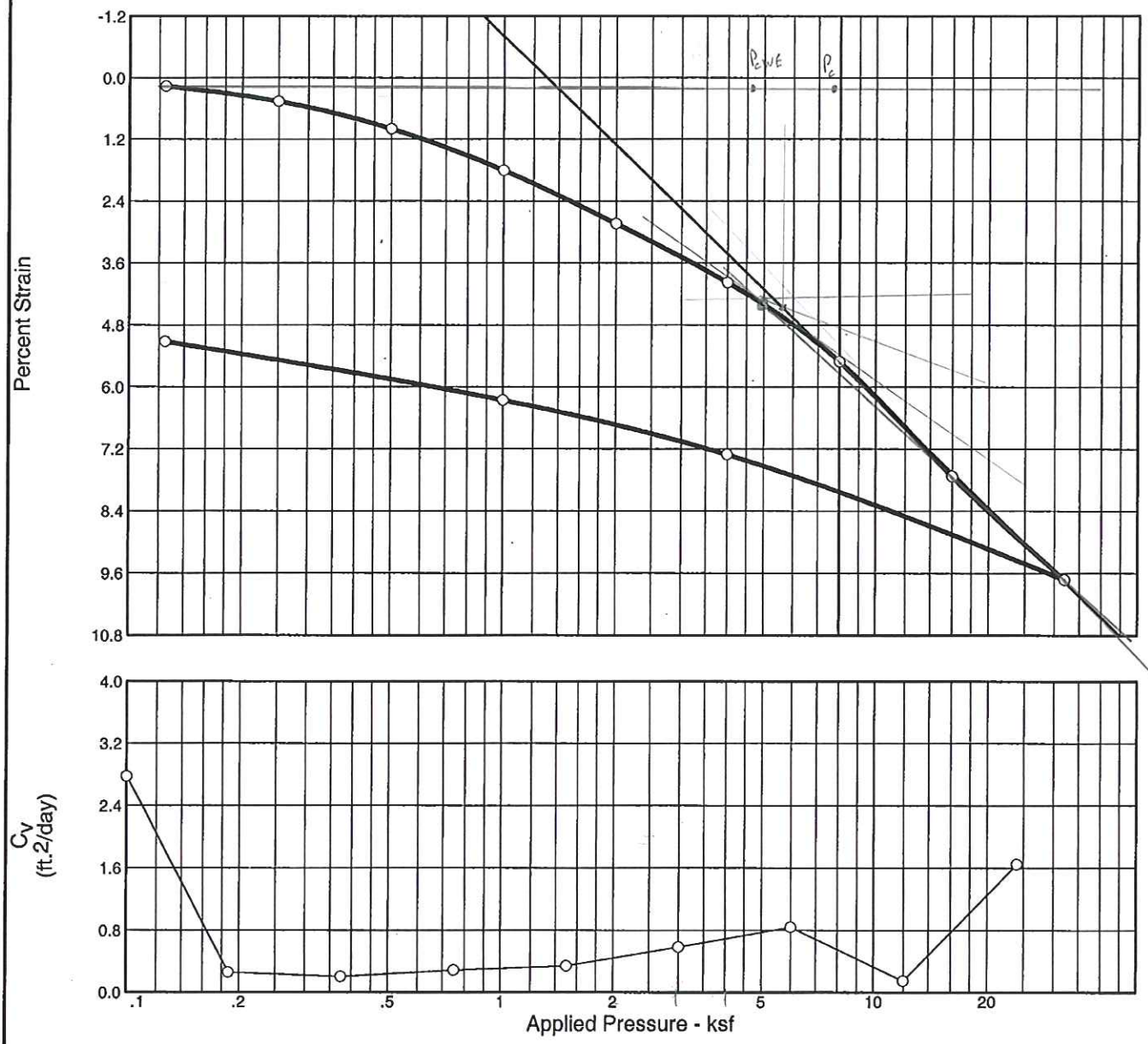
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JST 9-30-08

RKK-85

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	Pc (ksf) Pc WE	Cc	Cr	Initial Void Ratio
86.3 %	17.5 %	110.9	23	18	2.65	4.68	7.83/7.6	0.11	0.03	0.536

MATERIAL DESCRIPTION	USCS	AASHTO
Gray SANDY ORGANIC CLAY.	OL	

Fine Pc NV

Project No. 14678 **Client:** RUMMELL,KLEPPER & KAHL. LLC

Project: DELAWARE TURNPIKE IMPROVEMENTS -Interchange
RK & K Job No. 103-059

Location: IRW-9,T-2@35.0-37.0

Remarks:
Undisturbed Sample

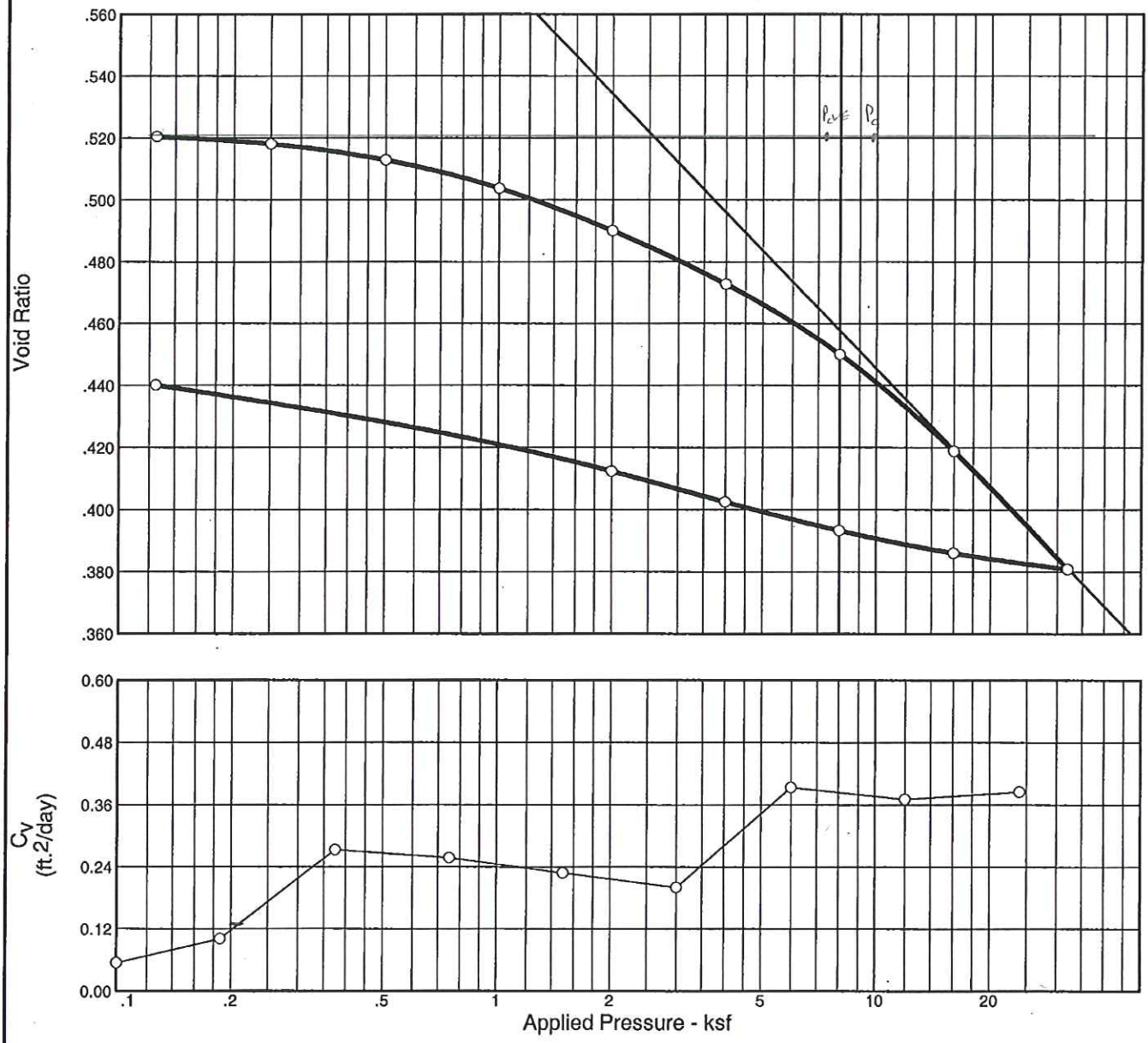
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JST 9-30-08

RKK-86

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf)	C_c	C_r	Initial Void Ratio
96.0 %	18.9 %	108.7	36	21	2.650		9.91 / 7.25	0.13	0.03	0.522

MATERIAL DESCRIPTION	USCS	AASHTO
Mottled Red & Gray LEAN CLAY.	CL	

Final P_c => 8.58 ksf

Project No. 14678 **Client:** RUMMELL,KLEPPER & KAHL. LLC

Project: DELAWARE TURNPIKE IMPROVEMENTS -Interchange
RK & K Job No. 103-059

Location: IRW-23,T-2@24.5-26.5

Remarks:
Undisturbed Sample

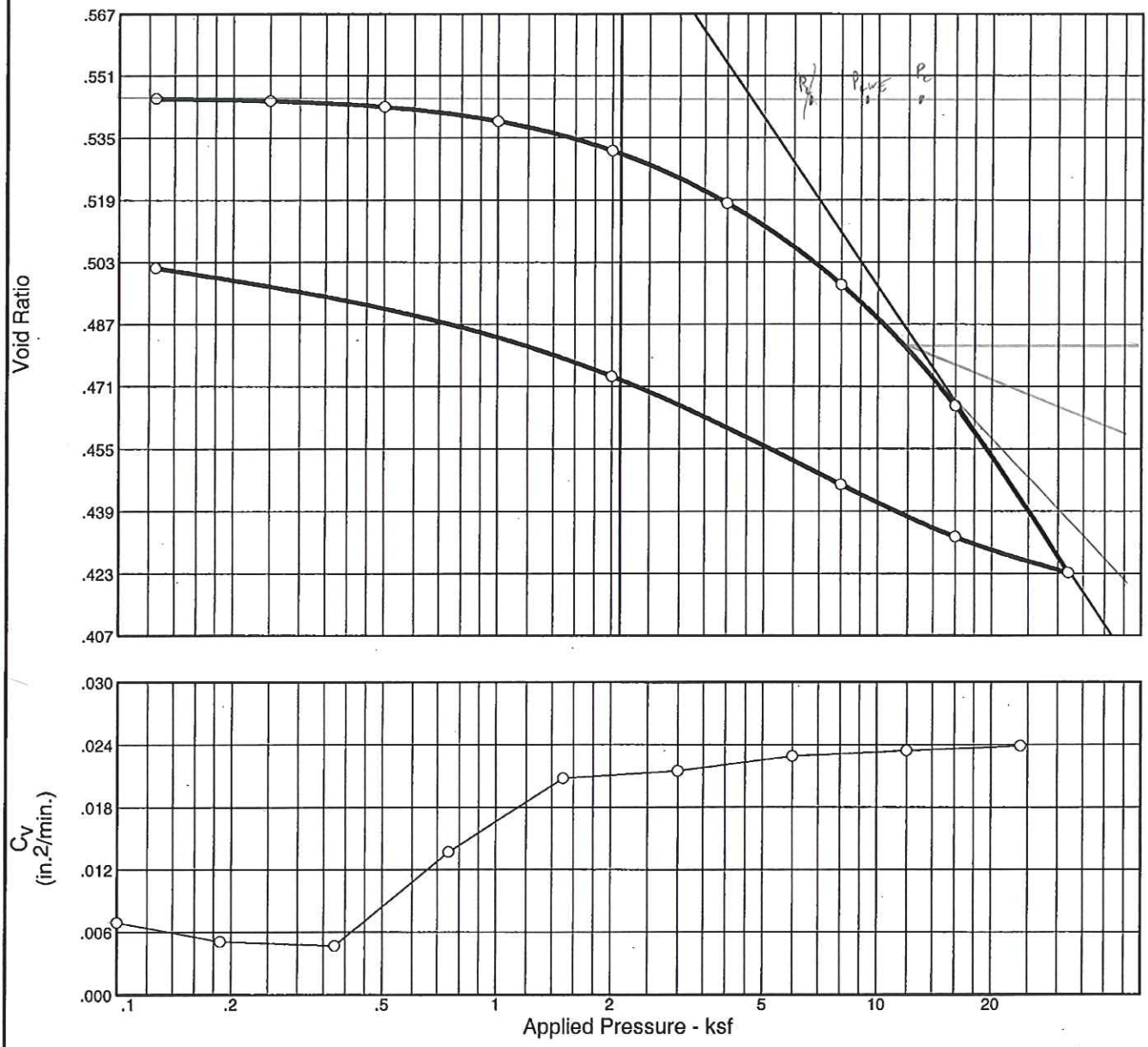
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 9-30-08

RKK-87

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf)	C_c	C_r	Initial Void Ratio
Saturation	Moisture									
96.8 %	19.0 %	114.2	39	20	2.78		6.68/9.2 Final	0.14	0.04	0.545

MATERIAL DESCRIPTION	USCS	AASHTO
Mottled Red & Gray LEAN CLAY (CL)	CL	

Project No. 14678 **Client:** RUMMEL, KLEPPER AND KAHL

Project: DELAWARE TURNPIKE IMPROVEMENTS - INTERCHANGE (103-059)

Location: IRW-32, T-1 @ 25.0'-27.0'

Remarks:
Undisturbed sample

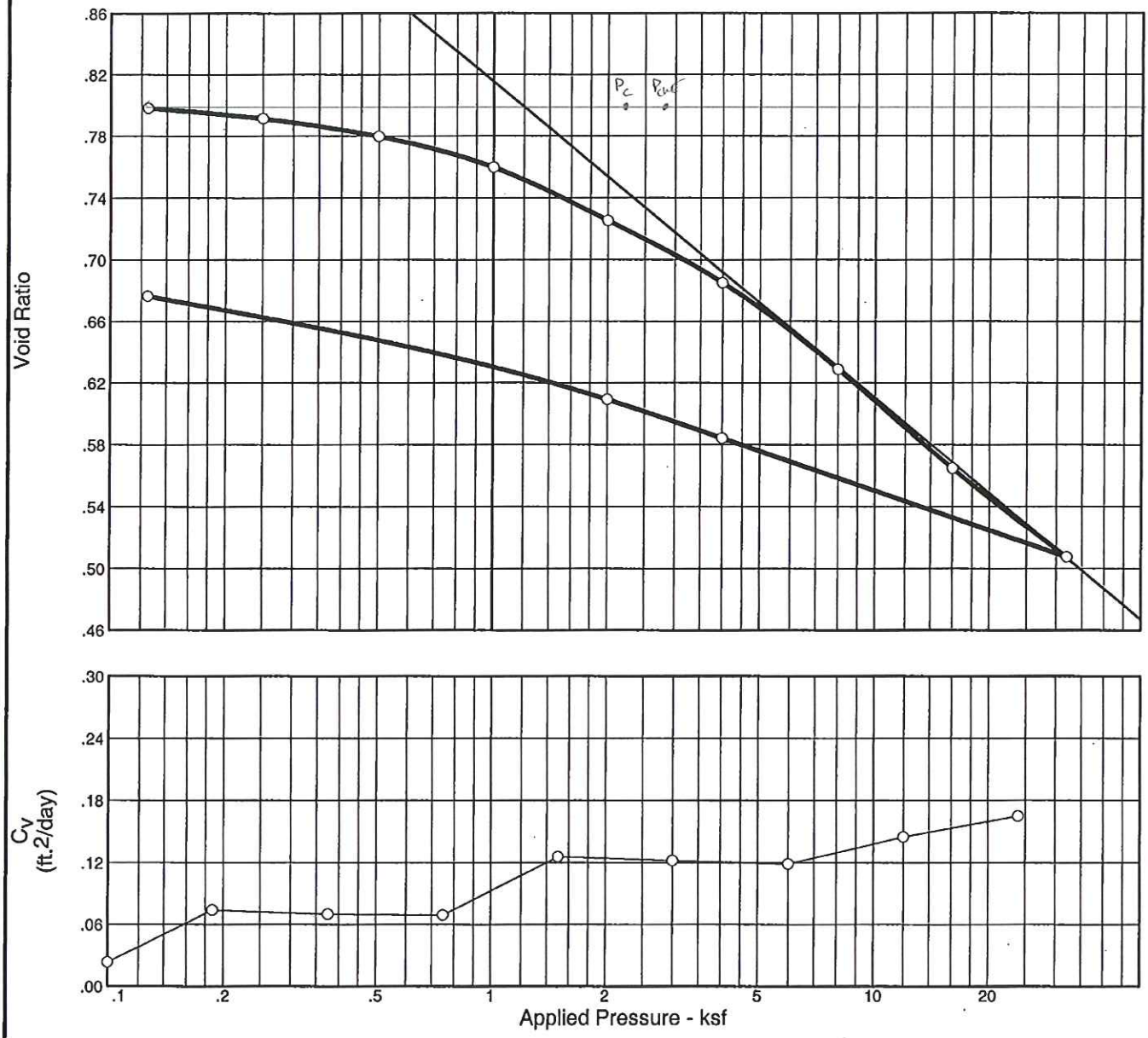
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JST 9-30-08

RKK-88

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	Pc (ksf) Pcwc	Cc	Cr	Initial Void Ratio
94.6 %	26.1 %	100.5	47	25	2.90		2.24 2.52	0.20	0.07	0.801

MATERIAL DESCRIPTION	USCS	AASHTO
Red LEAN CLAY.	CL	

Final Pc ⇒ 2.52 ksf

Project No. 14678 **Client:** RUMMELL,KLEPPER & KAHL. LLC

Project: DELAWARE TURNPIKE IMPROVEMENTS -Interchange
RK & K Job No. 103-059

Location: IRW-33,T-1@27.0-29.0

Remarks:
Undisturbed Sample

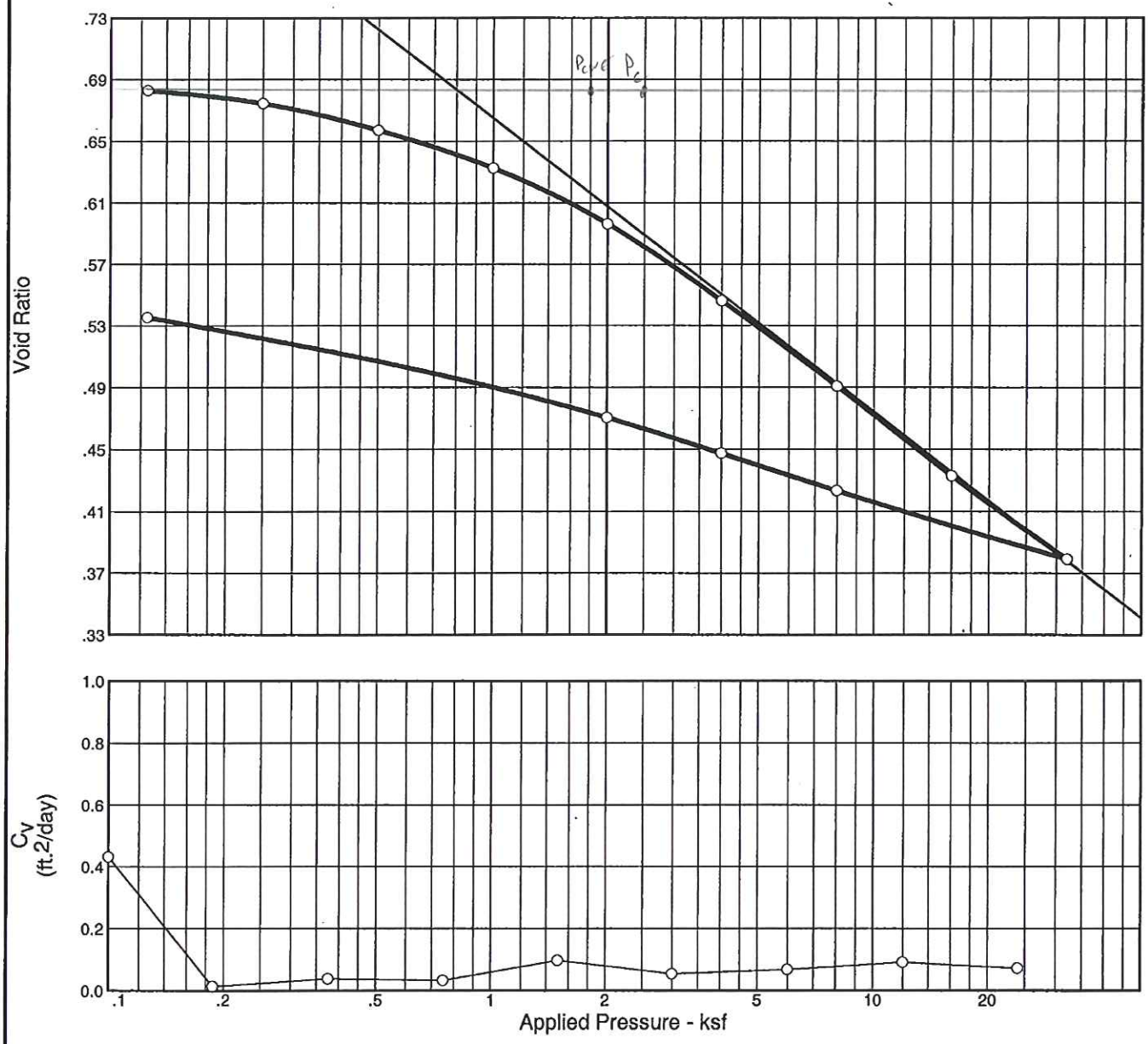
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JBT 9-30-08

RKK-89

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf)	C_c	C_r	Initial Void Ratio
88.6 %	21.8 %	107.8	42	21	2.787		2.49 / 1.8 Pc we	0.19	0.07	0.685

MATERIAL DESCRIPTION	USCS	AASHTO
Red LEAN CLAY. Final Pc ⇒ 2.15 ksf	CL	

Project No. 14678 **Client:** RUMMELL,KLEPPER & KAHL. LLC

Project: DELAWARE TURNPIKE IMPROVEMENTS -Interchange
RK & K Job No. 103-059

Location: IRW-33A,T-1@24.0'-26.0'

Remarks:
Undisturbed Sample

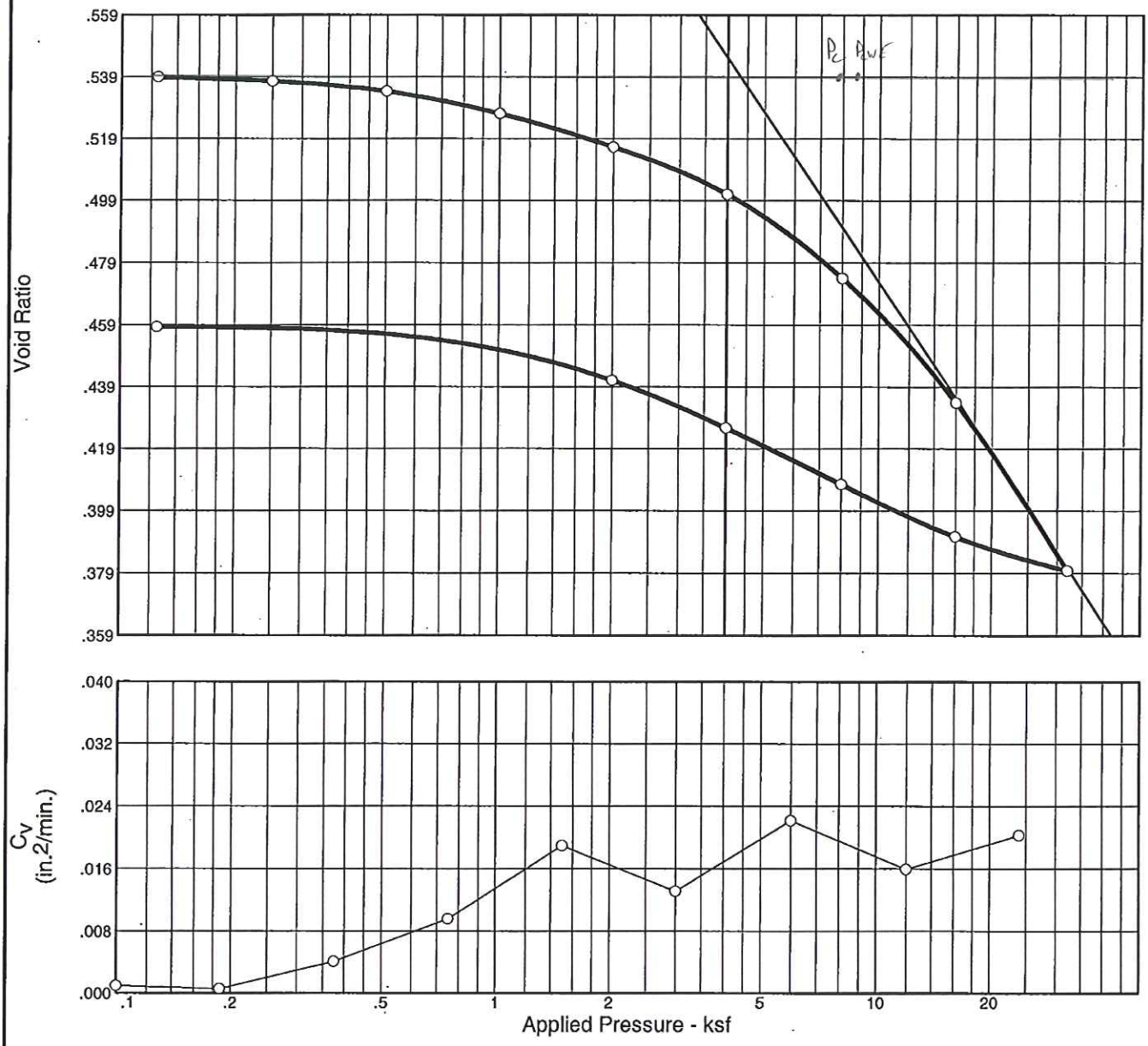
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JST 9-30-08

RKK-90

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf) Pave	C_c	C_r	Initial Void Ratio
Saturation	Moisture									
134.6 %	25.7 %	114.7	44	22	2.83		7.92 / 8.75	0.18	0.04	0.541

MATERIAL DESCRIPTION	USCS	AASHTO
Mottled Red & Gray Lean CLAY (CL)	CL	

Final P_c ⇒ 8.34 ksf

Project No. 14678 **Client:** RUMMEL, KLEPPER AND KAHL

Project: DELAWARE TURNPIKE IMPROVEMENTS - INTERCHANGE (103-059)

Location: IRW-42, T-2 @ 30.0-32.0

Remarks: UNDISTURBED SPECIMEN

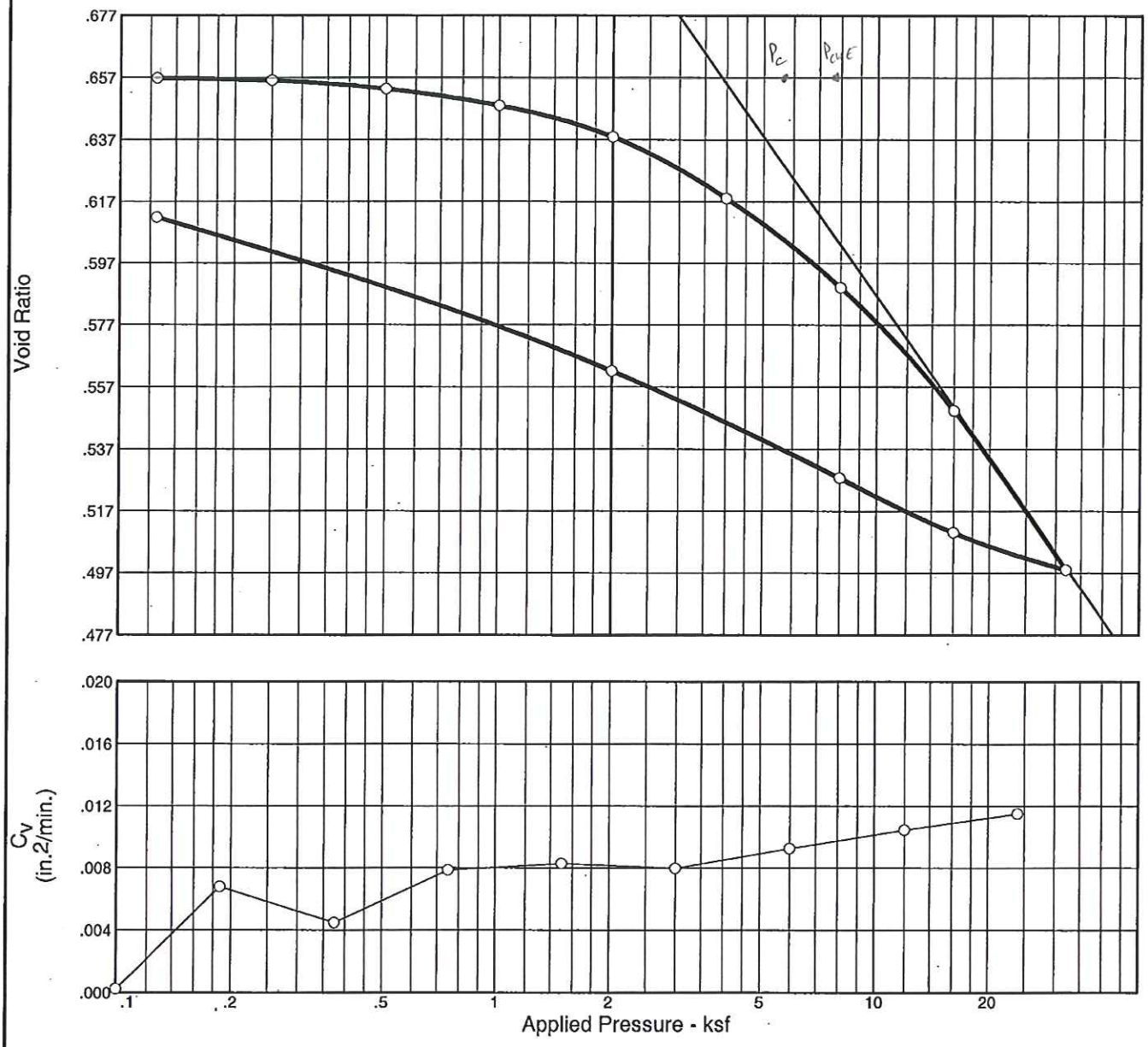
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JST 9-30-08

RKK-91

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf) Final Pc	C_c	C_r	Initial Void Ratio
Saturation	Moisture									
98.5 %	23.5 %	103.6	40	21	2.75		5.81 / 6.83 ksf	0.17	0.05	0.657

MATERIAL DESCRIPTION	USCS	AASHTO
Brown LEAN CLAY (CL)	CL	

Project No. 14678 **Client:** RUMMEL, KLEPPER AND KAHL

Project: DELAWARE TURNPIKE IMPROVEMENTS - INTERCHANGE (103-059)

Location: IRW-44, T-1 @ 25.0'-27.0'

Remarks:
UNDISTURBED SAMPLE

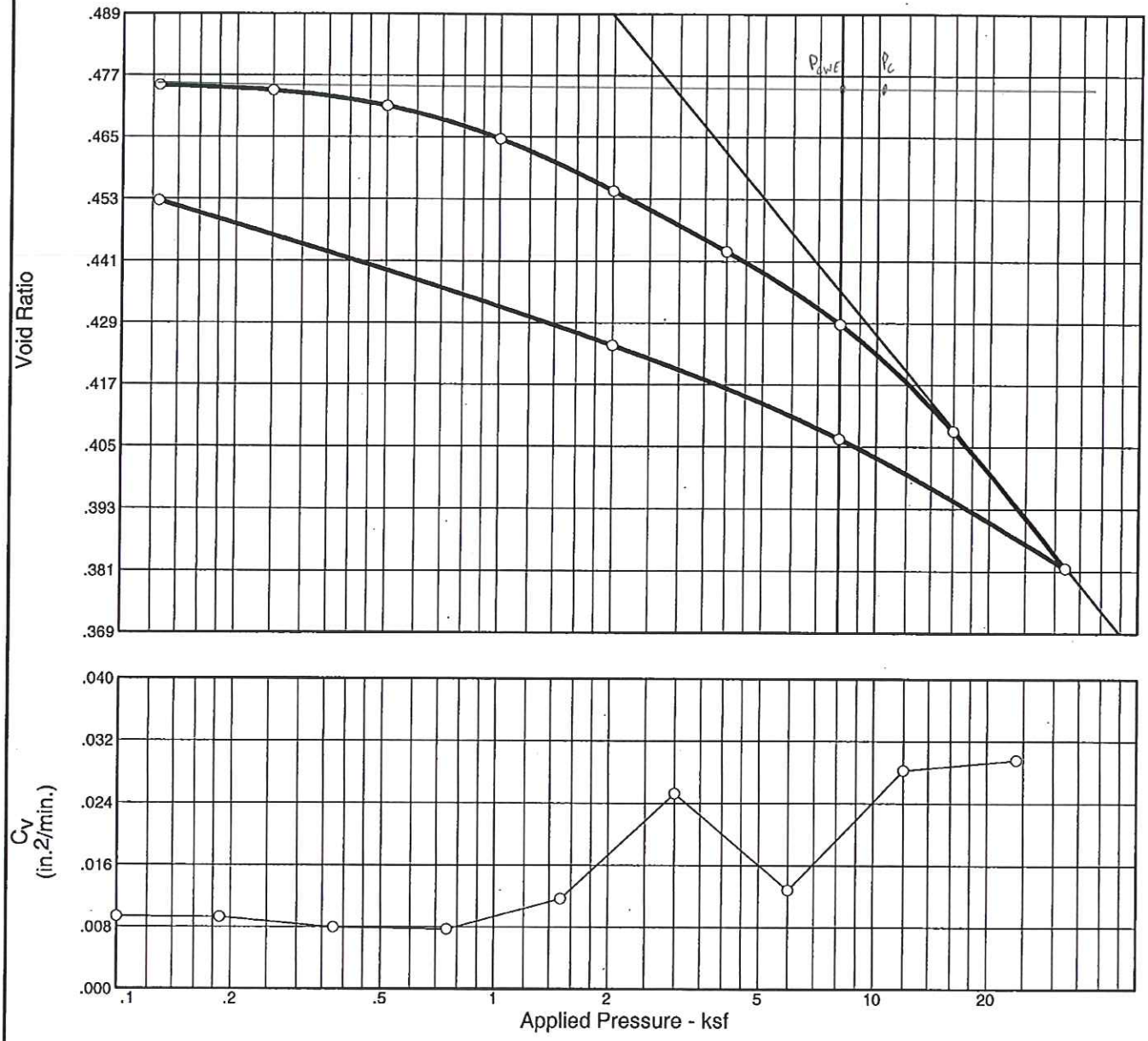
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

SDT 9-30-08

RKK-92

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf)	C_c	C_r	Initial Void Ratio
Saturation	Moisture									
97.7 %	17.3 %	113.4	60	41	2.68		10.21 / 8	0.09	0.03	0.475

MATERIAL DESCRIPTION	USCS	AASHTO
Dark Gray FAT CLAY (CH)	CH	

Final Pc ⇒ 9.11 ksf

Project No. 14678 **Client:** RUMMEL, KLEPPER AND KAHL

Project: DELAWARE TURNPIKE IMPROVEMENTS - INTERCHANGE (103-059)

Location: IRW-49, T-2 @ 30.0'-32.0'

Remarks:
Undisturbed Sample

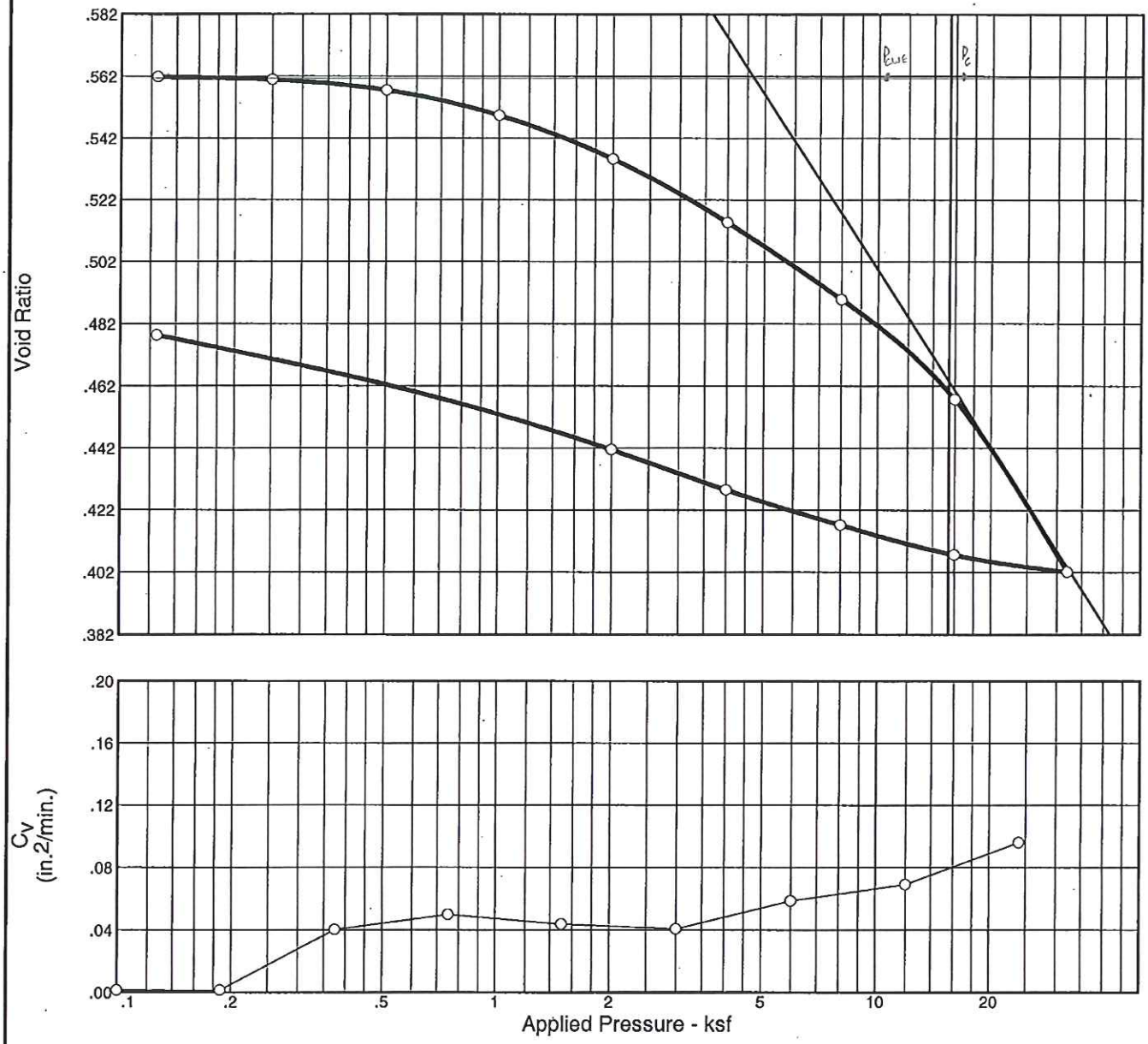
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 9-30-08

RKK-93

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf)	C_c	C_r	Initial Void Ratio
Saturation	Moisture									
86.7 %	17.5 %	111.2	NP	NP	2.785		16.55 / 10.5 Pc used	0.19	0.03	0.563

MATERIAL DESCRIPTION	USCS	AASHTO
Light Brown Silty SAND (SM) Final Pc	SM	

Project No. 14678 **Client:** RUMMEL, KLEPPER AND KAHL

Project: DELAWARE TURNPIKE IMPROVEMENTS - INTERCHANGE (103-059)

Location: IRW-50, T-1 @ 25.0'-27.0'

Remarks: Undisturbed Specimen

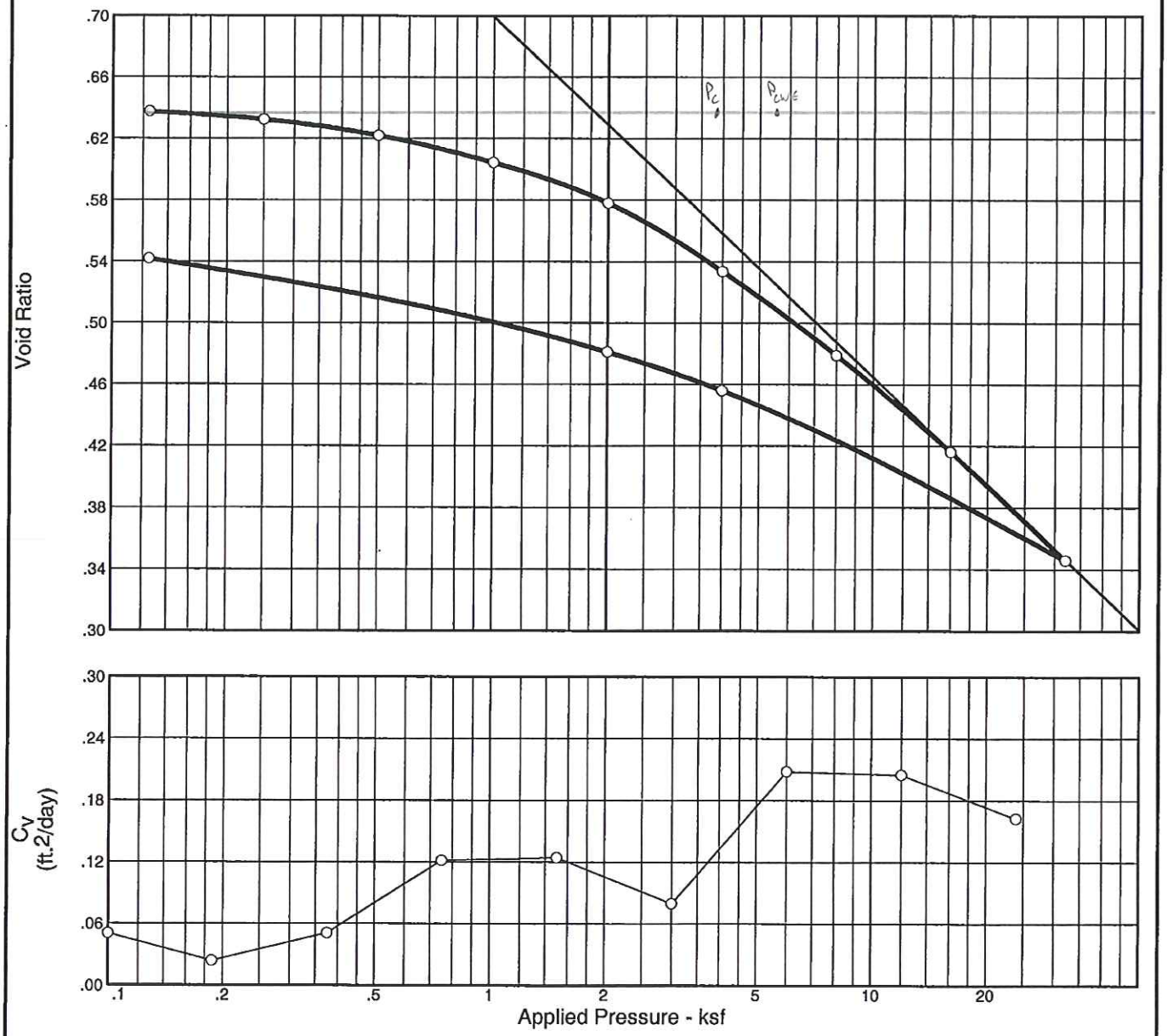
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JBS 9-30-08

RKK-94

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf)	C_c	C_r	Initial Void Ratio
96.9 %	22.3 %	105.8	38	19	2.779		3.88 / 5.5 (Pcwe)	0.23	0.09	0.640

MATERIAL DESCRIPTION	USCS	AASHTO
Mottled Red & Tan LEAN CLAY.	CL	

Final Pc => 4.69 ksf

Project No. 14678 **Client:** RUMMELL,KLEPPER & KAHL. LLC

Project: DELAWARE TURNPIKE IMPROVEMENTS -Interchange
RK & K Job No. 103-059

Location: IRW-51,T-1@25.0'-27.0'

Remarks:
Undisturbed Sample

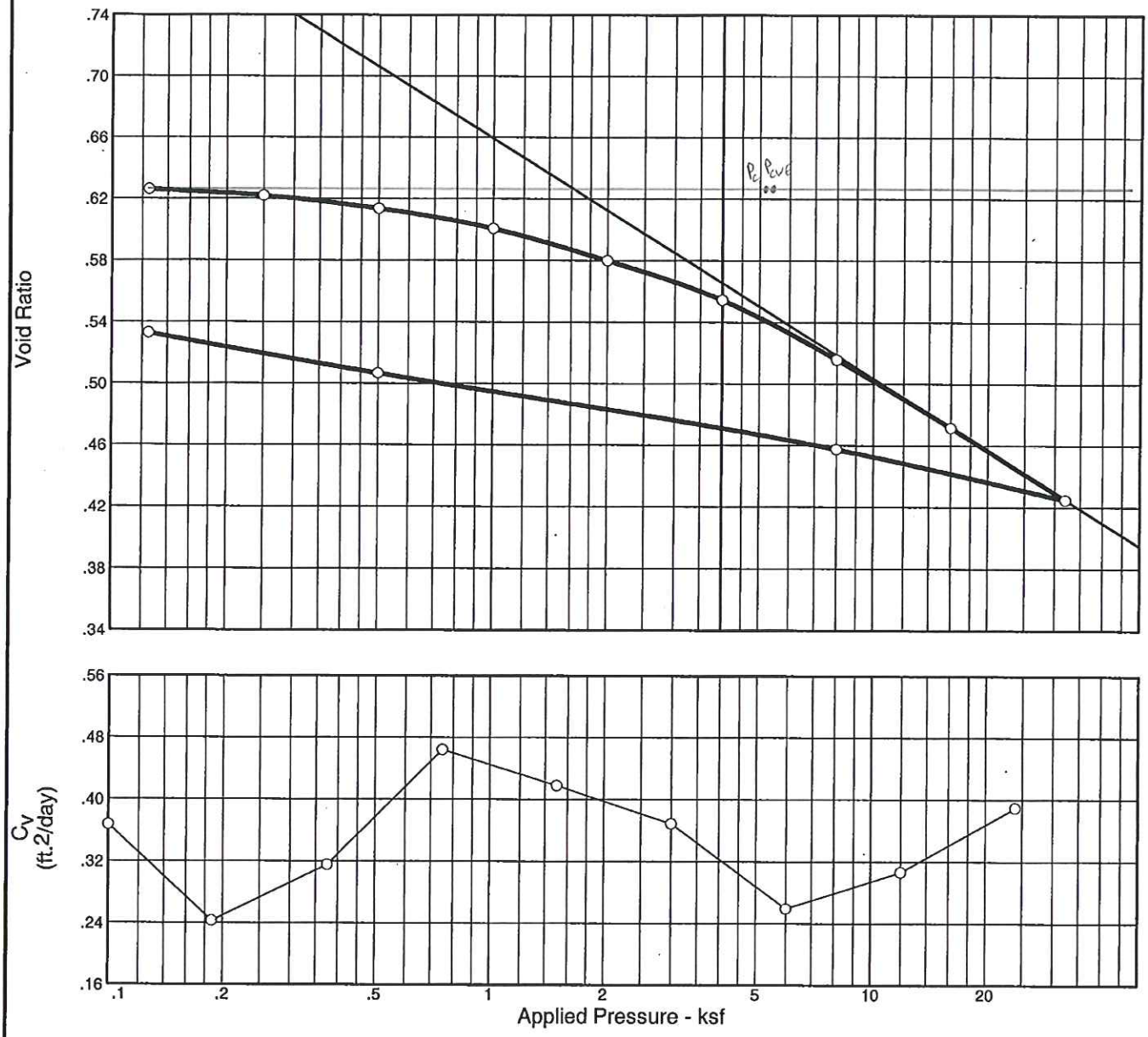
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 9-30-08

RKK-95

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf)	C_c	C_r	Initial Void Ratio
Saturation	Moisture									
95.4 %	21.6 %	108.3	44	25	2.777		5.12 / 5.2	0.16	0.05	0.628

MATERIAL DESCRIPTION Final P_c ⇒ 5.16 ksf

USCS	AASHTO
CL	

Mottled Red & Tan LEAN CLAY.

Project No. 14678 **Client:** RUMMELL,KLEPPER & KAHL. LLC

Project: DELAWARE TURNPIKE IMPROVEMENTS -Interchange
RK & K Job No. 103-059

Location: IRW-52,T-2@35.0'-37.0'

Remarks:
Undisturbed Sample

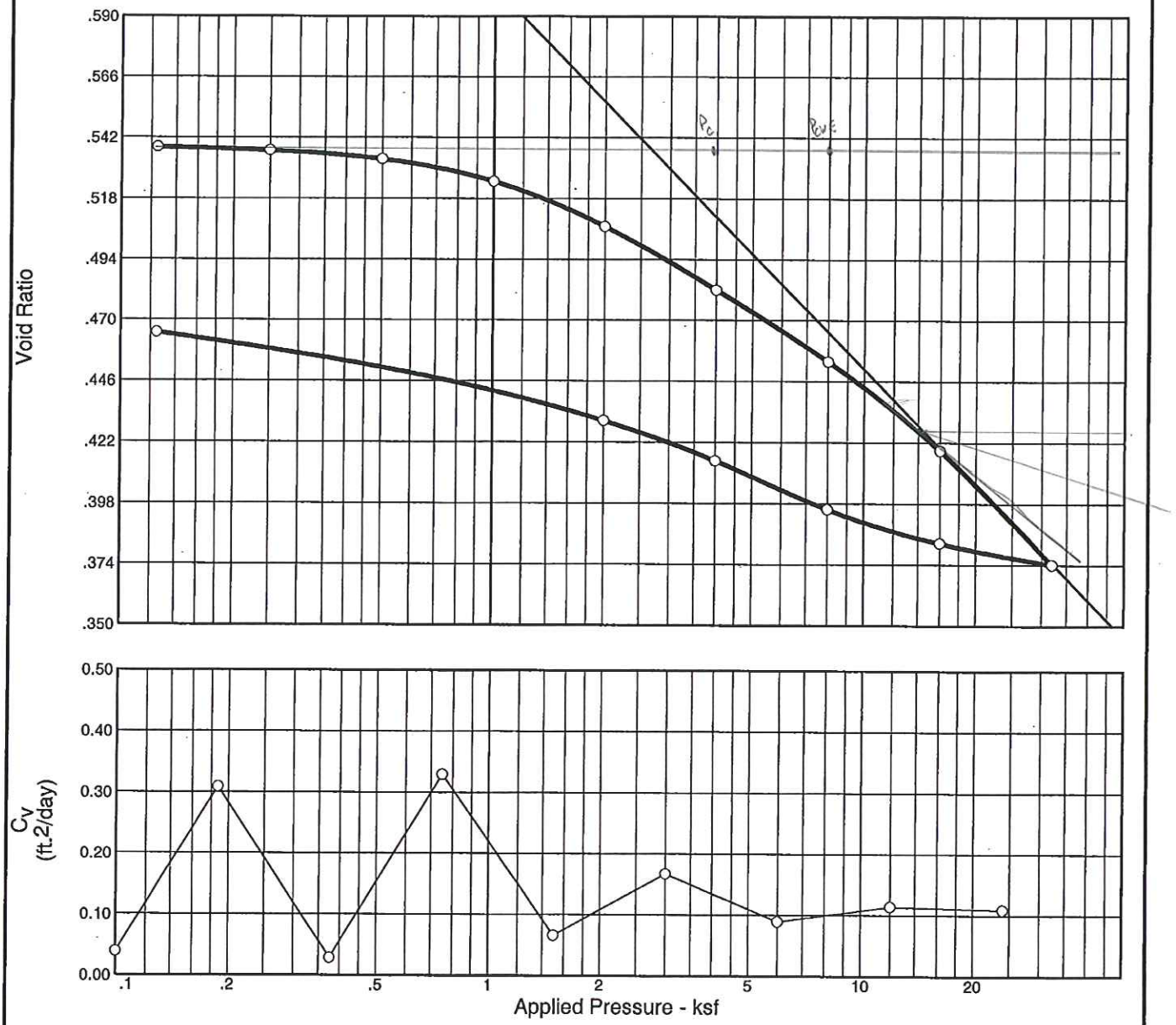
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

SJT 9-30-08

RKK-96

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf)	C_c	C_r	Initial Void Ratio
97.9 %	19.9 %	107.6	39	22	2.653		3.92 Final Pc	0.15	0.04	0.539

MATERIAL DESCRIPTION	USCS	AASHTO
Gray LEAN CLAY. NV	CL	

Project No. 14678 **Client:** RUMMELL,KLEPPER & KAHL. LLC

Project: DELAWARE TURNPIKE IMPROVEMENTS -Interchange
RK & K Job No. 103-059

Location: IRW-53,T-1@15.0-17.0

Remarks:
Undisturbed Sample

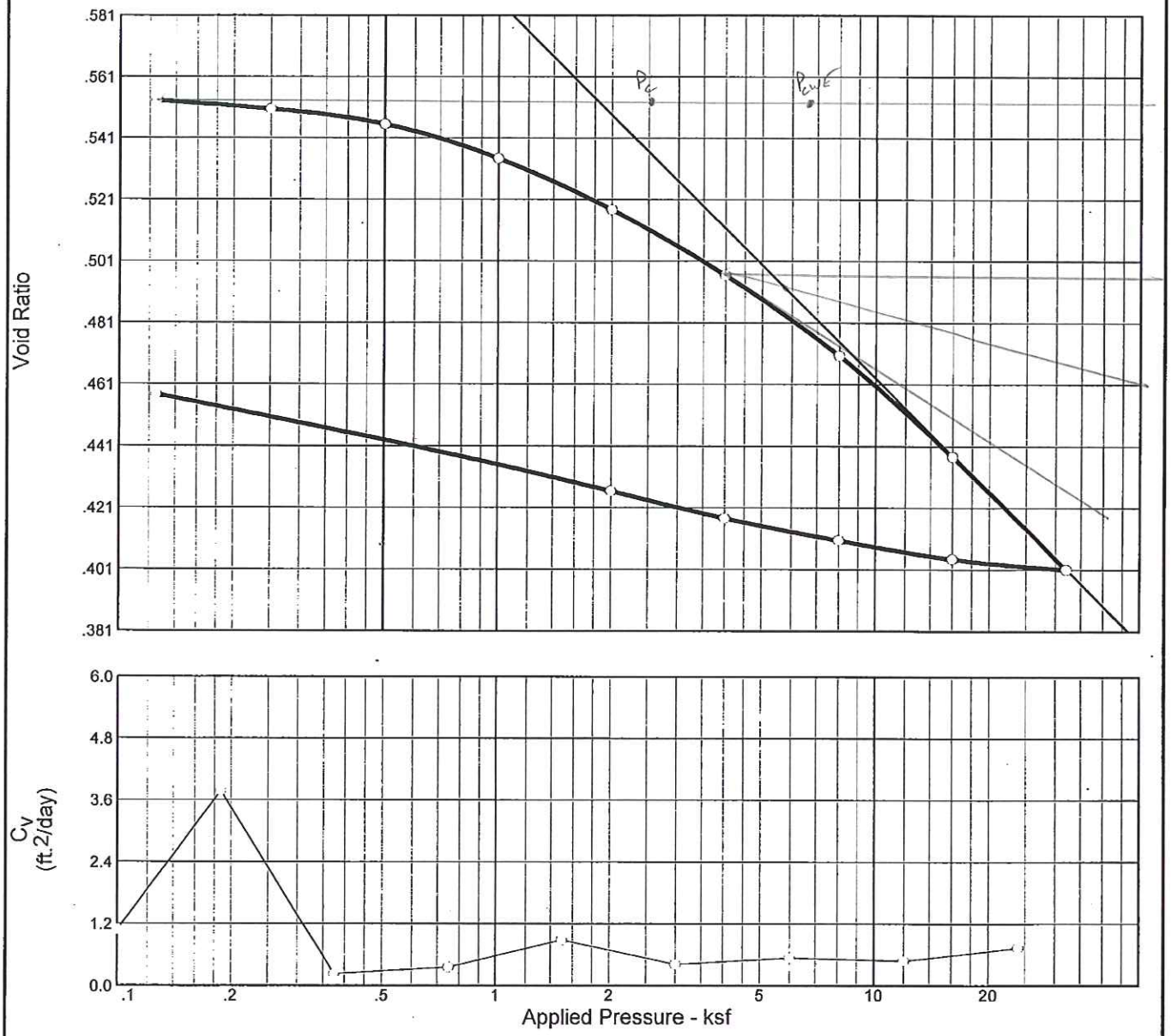
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JST 9-30-08

RKK-97

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf)	C_c	C_r	Initial Void Ratio
88.4 %	17.7 %	66.0	33	14	2.772		~~2.51~~ 6.6 Pc we	0.12	0.02	0.554

MATERIAL DESCRIPTION	USCS	AASHTO
Brown LEAN CLAY with SAND. Final Pc ~~5.9 ksf~~ ~6.25 ksf	CL	

Project No. 14678 **Client:** RUMMELL,KLEPPER & KAHL. LLC

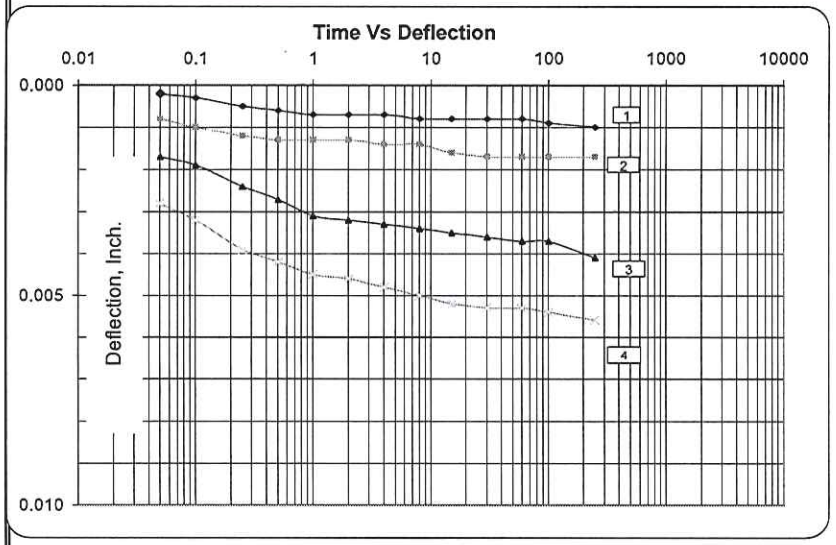
Project: DELAWARE TURNPIKE IMPROVEMENTS -Interchange
RK & K Job No. 103-059

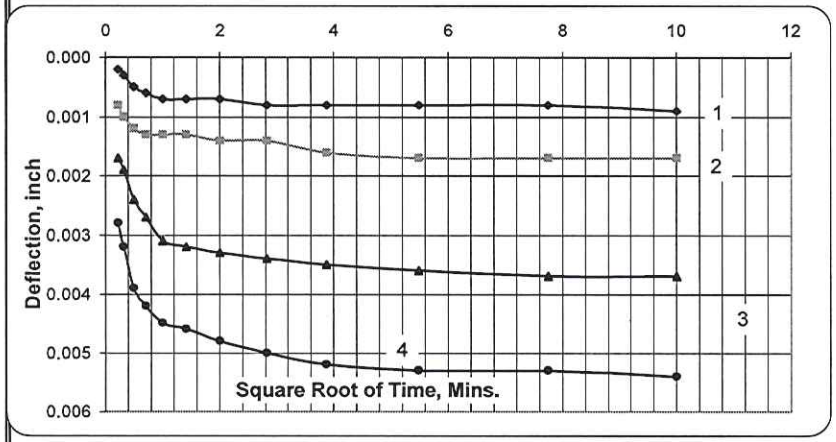
Location: IEB-13A,T-1@ 15.0'-17.0'

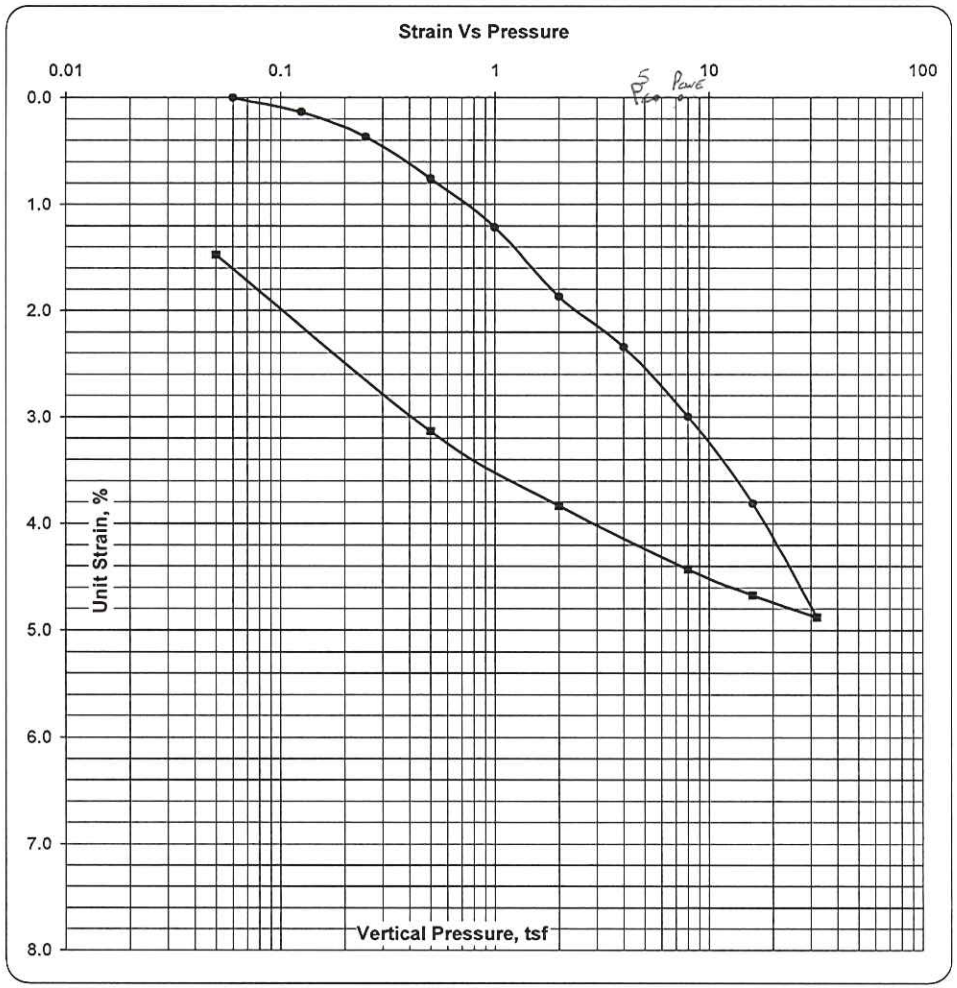
Remarks:
Undisturbed Sample

CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company







One-Dimensional Consolidation Test (ASTMD-2435)

Curve No.	Pressure Increment From ,tsf	To,tsf	Coeff. Of Consolidation Cv, ft^2/day
1	0.5	1	2.47
2	1	2	5.27
3	2	4	5.12
4	4	8	6.87
5	8	16	6.68
6	16	32	3.45
7			
8			
10			

Description of Specimen:	Brown-gray Mottled silty clay		
Nat.Water Content (%)	15.5	(From Trims.)	
Liquid Limit (%)	28	(From Trims.)	
Plastic Limit (%)	17	(From Trims.)	
Plastic Index (%)	11	(From Trims.)	
Specific Gravity(assumed)	2.7	(From Trims.)	
Test Specimen Properties			
Diameter,inch.	2.490		
Initial And Final Thickness, inch.	0.860	0.857	
Initial And Final Water Content (%)	16.1	16.2	
Initial And Final Void Ratio	0.454	0.449	
Initial And Final Saturation (%)	95.8	97.8	
Unit Dry Weight (pcf)	115.9		

Consolidation Properties (Unit Strain Basis)	
Compression Ratio (Cc') *	
Recompression Ratio (Cr')*	
Swelling Ratio (Cs')*	
Preconsolidation Stress, Pc (tsf)*	5.7/7.25
Existing Overburden Stress, Po (tsf)*	Final Pc = 6.48 tsf
* Unit Strain Basis	

Project No	19996251
Project Name	RKK
	I-95 Delaware TP Improve
Boring No.	IEB-13B
Sample No.	T-2
Depth, ft.	32.0-34.0
Tested By	rmm
Reviewed By	enm
Date	07-May-05
File No.	19996251C-1

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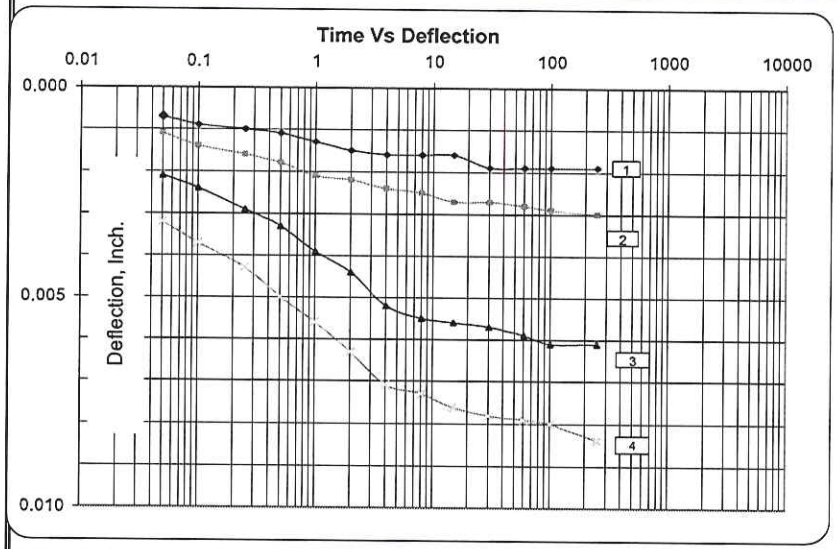
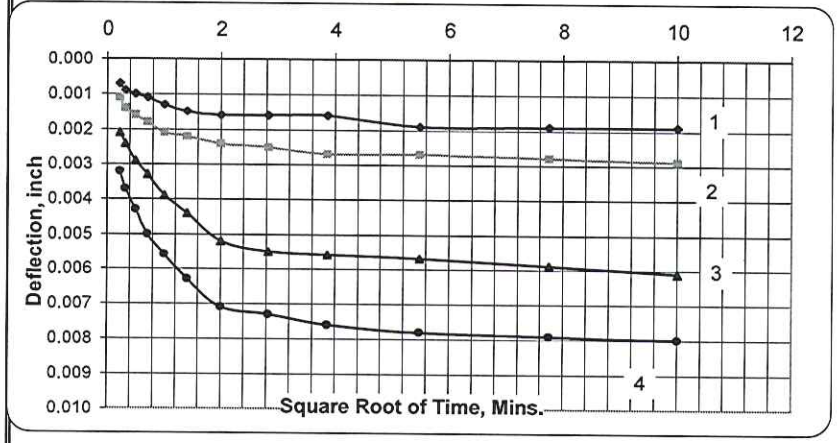
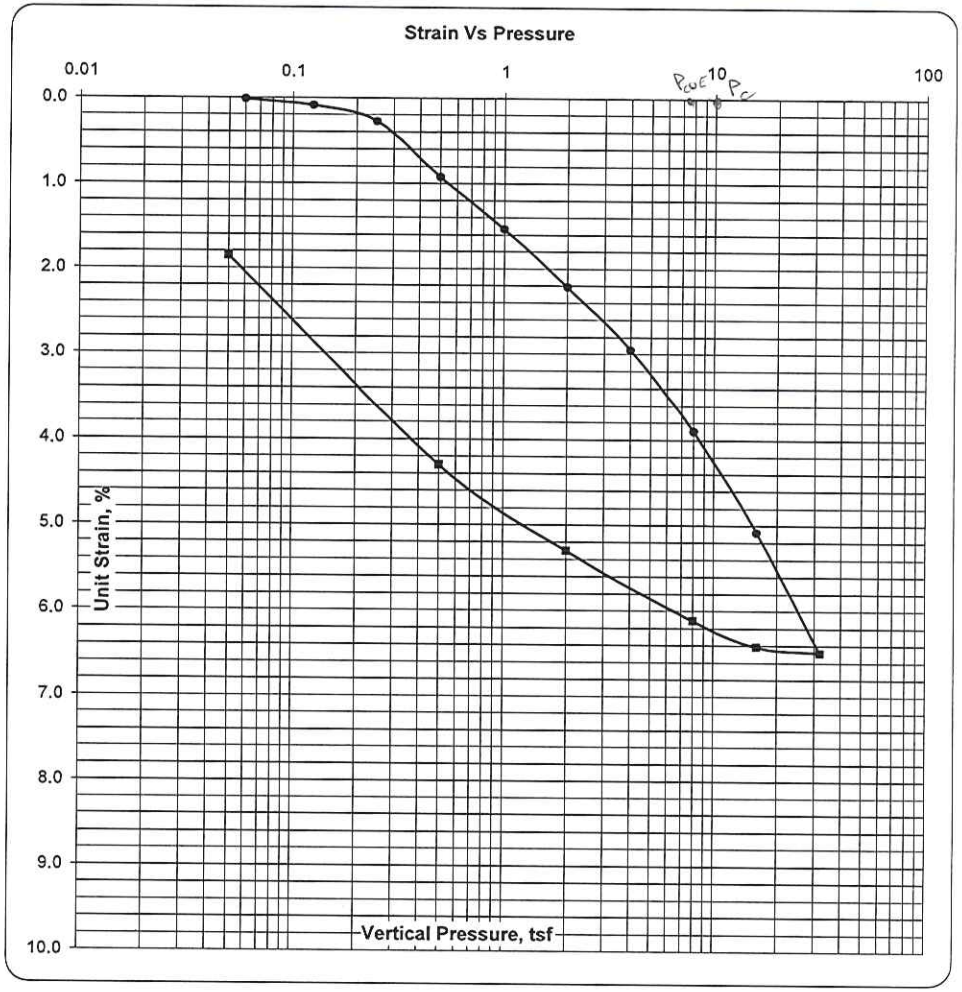
RKK-98

9-30-08







One-Dimensional Consolidation Test (ASTMD-2435)

Curve No.	Pressure Increment From ,tsf	To,tsf	Coeff. Of Consolidation Cv, ft^2/day
1	0.5	1	2.22
2	1	2	4.99
3	2	4	1.59
4	4	8	3.58
5	8	16	2.58
6	16	32	1.67
7			
8			
10			

Description of Specimen:	Light gray silty clay		
Nat.Water Content (%)	15.2	(From Trims.)	
Liquid Limit (%)	27	(From Trims.)	
Plastic Limit (%)	14	(From Trims.)	
Plastic Index (%)	13	(From Trims.)	
Specific Gravity(assumed)	2.71	(From Trims.)	
Test Specimen Properties			
Diameter,inch.	2.490		
Initial And Final Thickness, inch.	0.860	0.852	
Initial And Final Water Content (%)	15.7	15.4	
Initial And Final Void Ratio	0.447	0.434	
Initial And Final Saturation (%)	95.4	96.0	
Unit Dry Weight (pcf)	116.9		

Consolidation Properties (Unit Strain Basis)	
Compression Ratio (Cc') *	
Recompression Ratio (Cr')*	
Swelling Ratio (Cs')*	
Preconsolidation Stress, Pc (tsf)*	10/17/25
Existing Overburden Stress, Po (tsf)*	
Final P_c =	8.63 tsf
* Unit Strain Basis	

Project No	19996251
Project Name	RKK
	I-95 Delaware TP Improve
Boring No.	IEB-13B
Sample No.	T-3
Depth, ft.	38.0-40.0
Tested By	rmm
Reviewed By	enm
Date	07-May-05
File No.	19996251C-2

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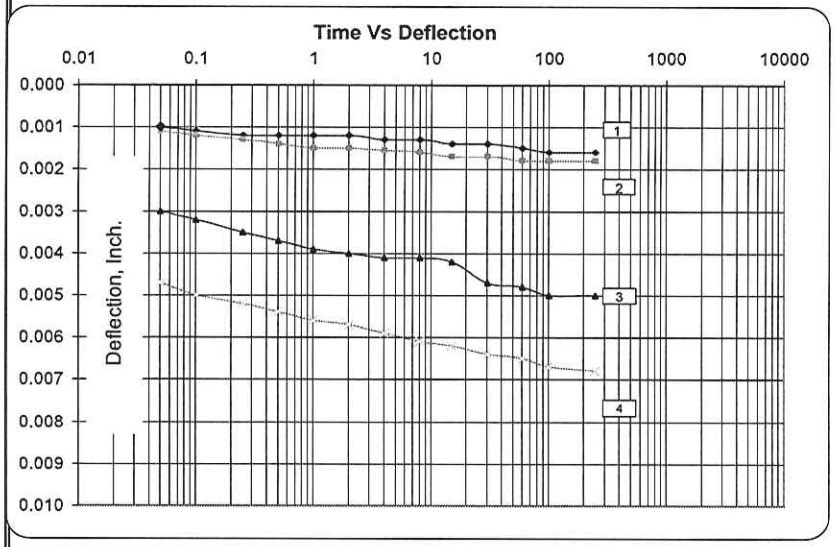
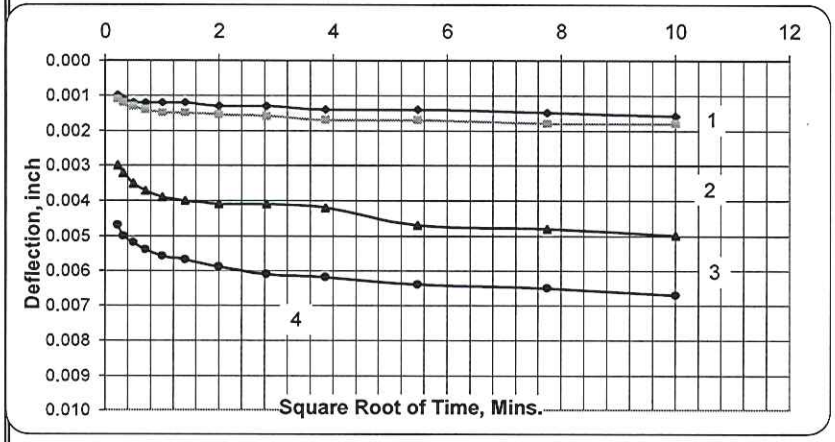
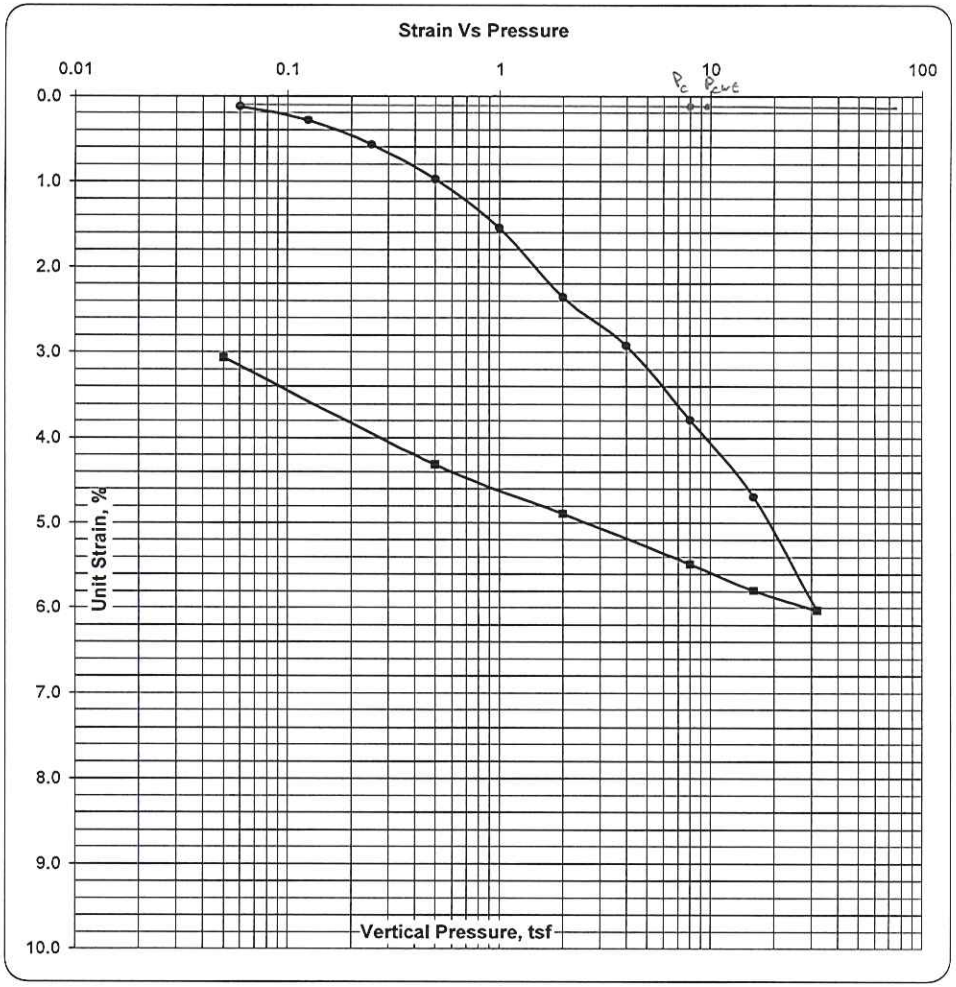
RKK-99







One-Dimensional Consolidation Test (ASTMD-2435)

Curve No.	Pressure Increment From ,tsf	To,tsf	Coeff. Of Consolidation Cv, Ft^2/day
1	0.5	1	1.46
2	1	2	1.20
3	2	4	1.38
4	4	8	0.34
5	8	16	1.76
6			
7			
8			
10			

Description of Specimen:	Light gray silty sand		
Nat.Water Content (%)	22.1	(From Trims.)	
Liquid Limit (%)	N.P	(From Trims.)	
Plastic Limit (%)		(From Trims.)	
Plastic Index (%)		(From Trims.)	
Specific Gravity(assumed)	2.51	(From Trims.)	
Test Specimen Properties			
Diameter,inch.	2.490		
Initial And Final Thickness, inch.	0.870	0.870	
Initial And Final Water Content (%)	21.4	20.3	
Initial And Final Void Ratio	0.505	0.505	
Initial And Final Saturation (%)	106.1	100.6	
Unit Dry Weight (pcf)	104.1		

Consolidation Properties (Unit Strain Basis)	
Compression Ratio (Cc') *	
Recompression Ratio (Cr')*	
Swelling Ratio (Cs')*	
Preconsolidation Stress, Pc (tsf)*	8 / 96
Existing Overburden Stress, Po (tsf)*	1
Final P_o =	8.8 tsf
* Unit Strain Basis	

Project No	19996251
Project Name	RKK I-95 Delaware TP Improve
Boring No.	IEB-13B
Sample No.	T-4
Depth, ft.	58.0-60.0
Tested By	rmm
Reviewed By	enm
Date	07-May-05
File No.	19996251C-3

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RKK-100

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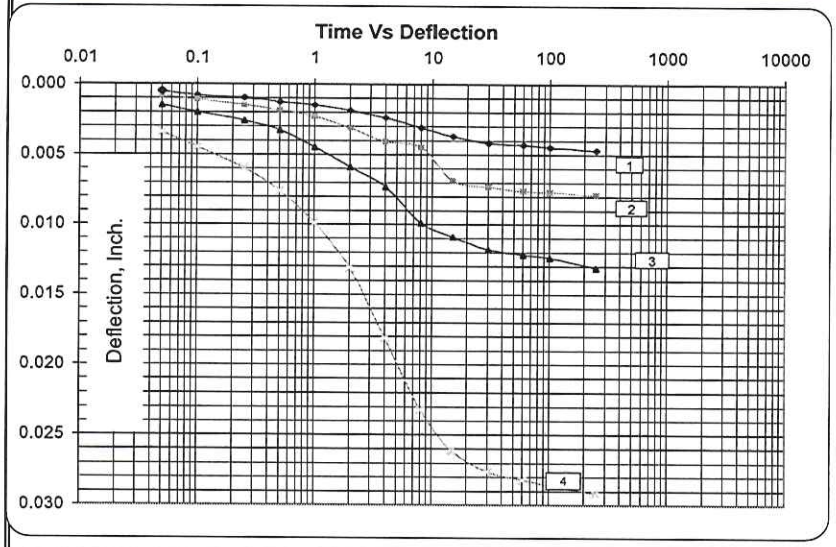

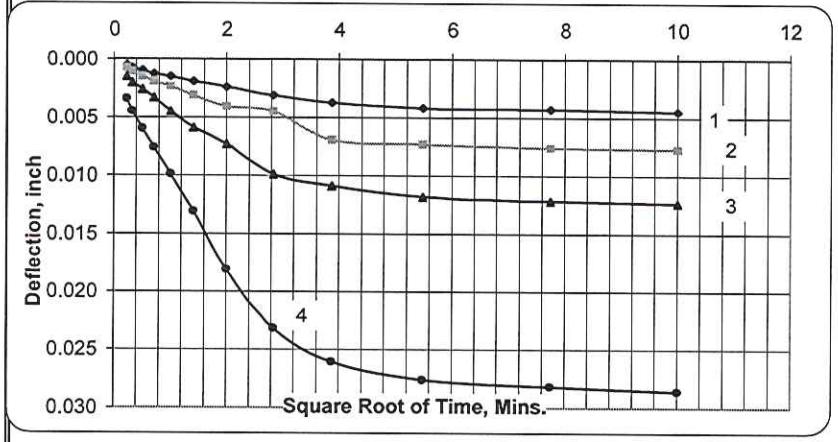

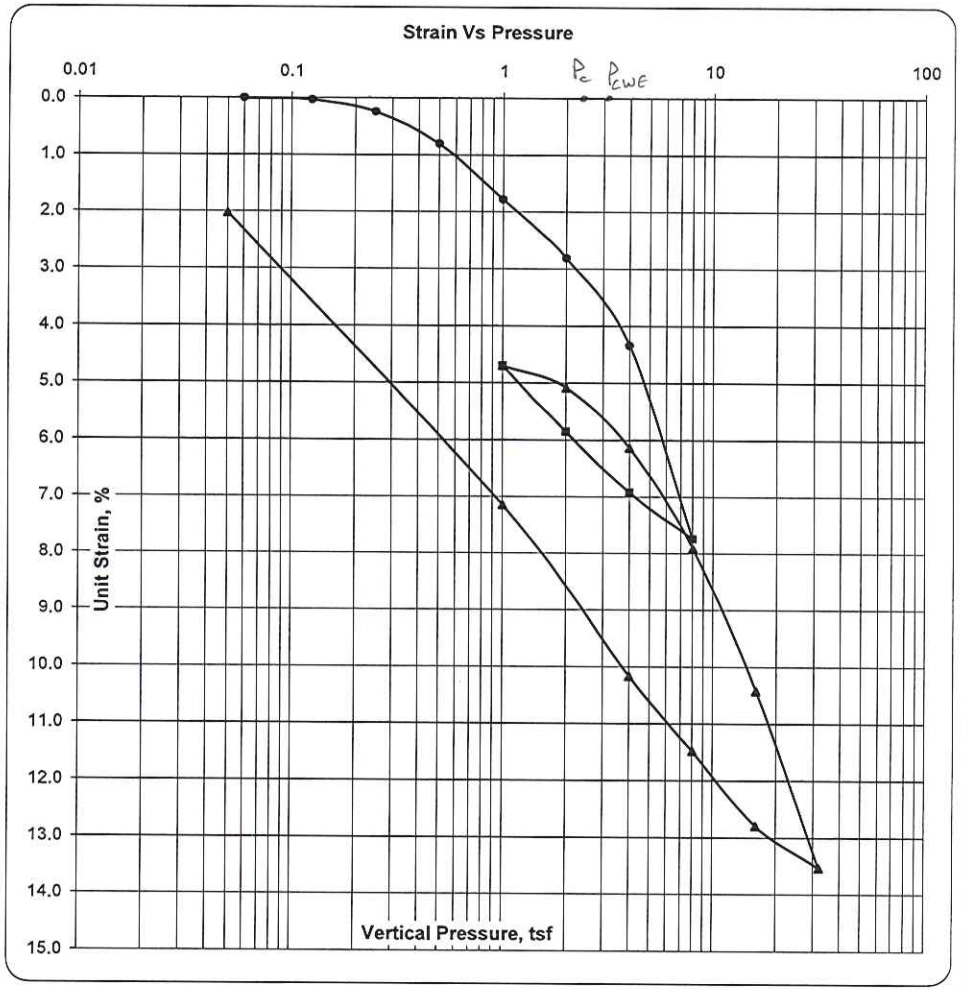

One-Dimensional Consolidation Test (ASTMD-2435)

Curve No.	Pressure Increment From ,tsf	To,tsf	Coeffi. Of Consolidation Cv, ft^2/day
1	0.5	1	0.12
2	1	2	0.09
3	2	4	0.19
4	4	8	0.18
5			
6			
7			
8			
10			

Description of Specimen:	Light gray silty clay		
Nat.Water Content (%)	23.2	(From Trims.)	
Liquid Limit (%)	49	(From Trims.)	
Plastic Limit (%)	23	(From Trims.)	
Plastic Index (%)	26	(From Trims.)	
Specific Gravity(assumed)	2.71	(From Trims.)	
Test Specimen Properties			
Diameter,inch.	2.490		
Initial And Final Thickness, inch.	0.860	0.866	
Initial And Final Water Content (%)	24.8	24.6	
Initial And Final Void Ratio	0.666	0.678	
Initial And Final Saturation (%)	100.9	98.5	
Unit Dry Weight (pcf)	101.5		

Consolidation Properties (Unit Strain Basis)	
Compression Ratio (Cc') *	
Recompression Ratio (Cr')*	
Swelling Ratio (Cs')*	
Preconsolidation Stress, Pc (tsf)*	2.3/3.1
Existing Overburden Stress, Po (tsf)*	
Final Pc =	2.7 +/-
* Unit Strain Basis	

Project No	19996251
Project Name	RKK I-95 Delaware TP Improve
Boring No.	ICP1-15A
Sample No.	T-1
Depth, ft.	18.0-20.0
Tested By	rmm
Reviewed By	enm
Date	07-May-05
File No.	19996251C-4

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RKK-101

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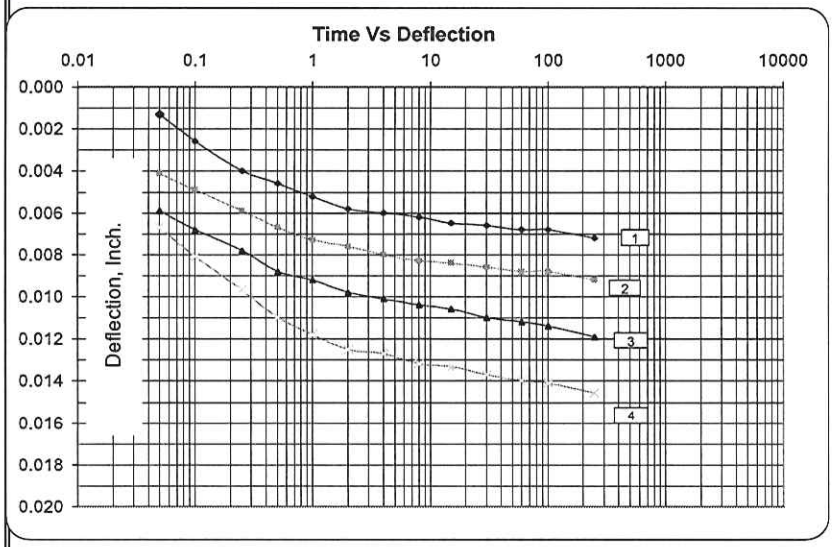

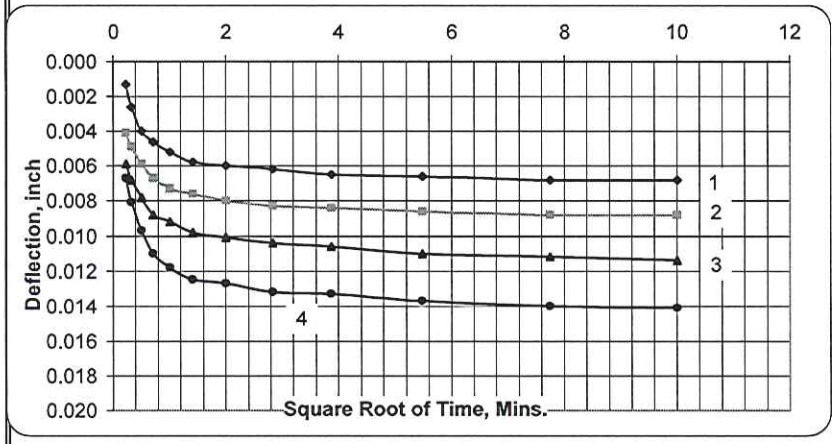

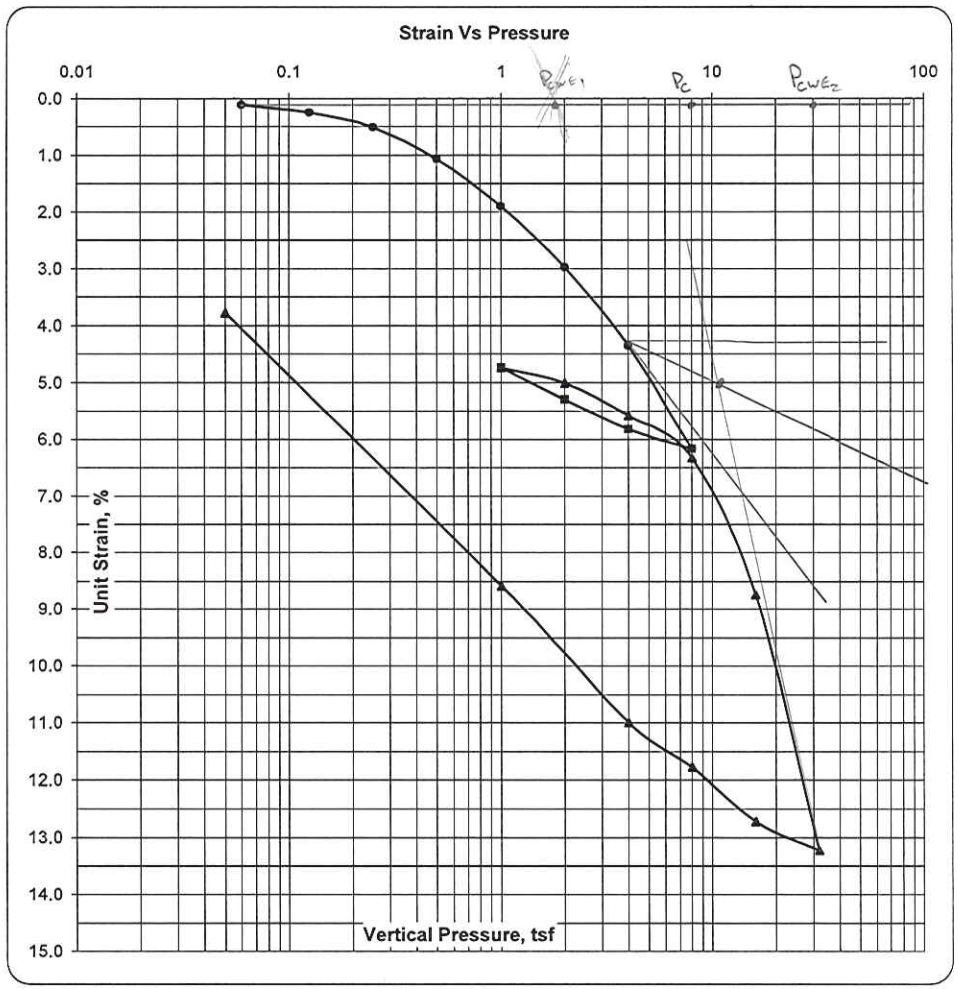

One-Dimensional Consolidation Test (ASTMD-2435)

Curve No.	Pressure Increment From ,tsf	To,tsf	Coeff. Of Consolidation Cv, ft^2/day
1	0.5	1	3.85
2	1	2	2.36
3	2	4	5.30
4	4	8	6.74
5			
6			
7			
8			
10			

Description of Specimen:	Dark gray to almost black silty clay		
Nat.Water Content (%)		(From Trims.)	
Liquid Limit (%)	50	(From Trims.)	
Plastic Limit (%)	24	(From Trims.)	
Plastic Index (%)	26	(From Trims.)	
Specific Gravity(assumed)	2.7	(From Trims.)	
Test Specimen Properties			
Diameter,inch.	2.490		
Initial And Final Thickness, inch.	0.860	0.795	
Initial And Final Water Content (%)	41.7	41.0	
Initial And Final Void Ratio	1.333	1.156	
Initial And Final Saturation (%)	84.6	95.8	
Unit Dry Weight (pcf)	72.3		

Consolidation Properties (Unit Strain Basis)	
Compression Ratio (Cc') *	
Recompression Ratio (Cr')*	
Swelling Ratio (Cs')*	
Preconsolidation Stress, Pc (tsf)*	
Existing Overburden Stress, Po (tsf)*	
* Unit Strain Basis	

Find Pc

Project No	19996251
Project Name	RKK
	I-95 Delaware TP Improve
Boring No.	ICP1-15A
Sample No.	T-2
Depth, ft.	28.0-30.0
Tested By	rmm
Reviewed By	enm
Date	07-May-05
File No.	19996251C-5

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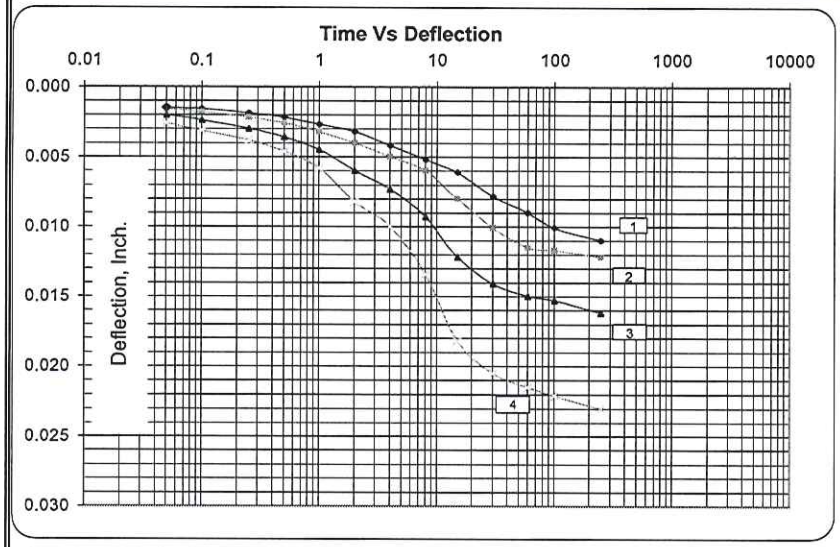
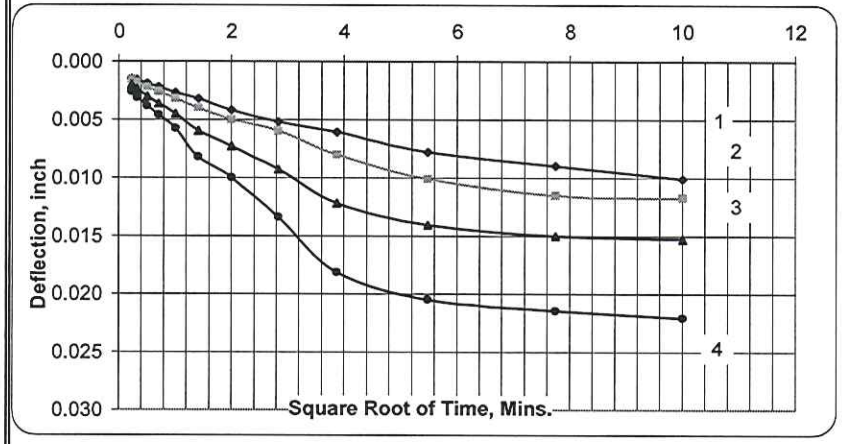
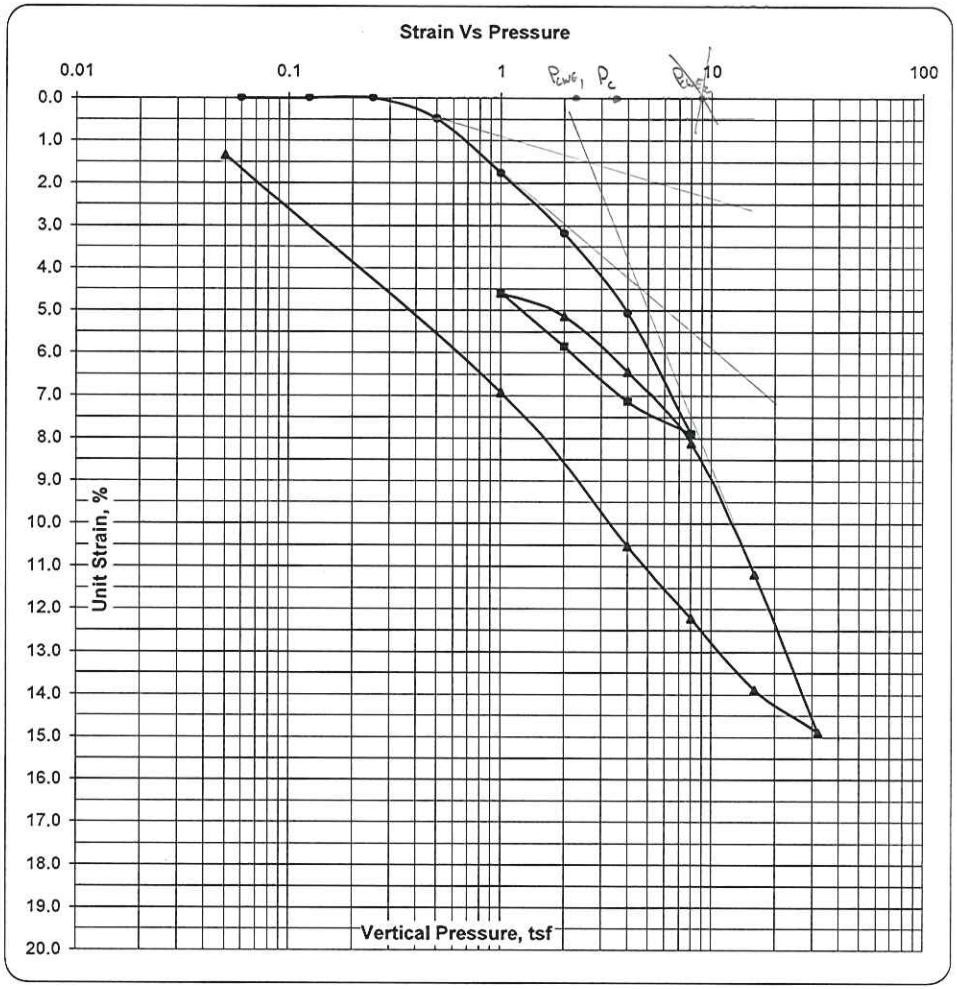
RKK-102

JDT 9-30-08







One-Dimensional Consolidation Test (ASTMD-2435)

Curve No.	Pressure Increment From ,tsf	To,tsf	Coeff. Of Consolidtion Cv, ft^2/day
1	0.5	1	0.05
2	1	2	0.05
3	2	4	0.09
4	4	8	0.09
5			
6			
7			
8			
10			

Description of Specimen:	Red-brown-gray mottled silty clay		
Nat.Water Content (%)	26.9	(From Trims.)	
Liquid Limit (%)	53	(From Trims.)	
Plastic Limit (%)	22	(From Trims.)	
Plastic Index (%)	31	(From Trims.)	
Specific Gravity(assumed)	2.71	(From Trims.)	
Test Specimen Properties			
Diameter,inch.	2.490		
Initial And Final Thickness, inch.	0.860	0.868	
Initial And Final Water Content (%)	27.7	27.9	
Initial And Final Void Ratio	0.739	0.756	
Initial And Final Saturation (%)	101.3	100.2	
Unit Dry Weight (pcf)	97.3		

Consolidation Properties (Unit Strain Basis)	
Compression Ratio (Cc') *	
Recompression Ratio (Cr')*	
Swelling Ratio (Cs')*	
Preconsolidation Stress, Pc (tsf)*	3.5 / 2.2
Existing Overburden Stress, Po (tsf)*	~2
Final P_c = 2.85 t/f	
* Unit Strain Basis	

Pc, Pcwe

Project No	19996251
Project Name	RKK I-95 Delaware TP Improve
Boring No.	ICPT-15A
Sample No.	T-3
Depth, ft.	44.0-46.0
Tested By	rmm
Reviewed By	enm
Date	07-May-05
File No.	19996251C-6

URS Corporation

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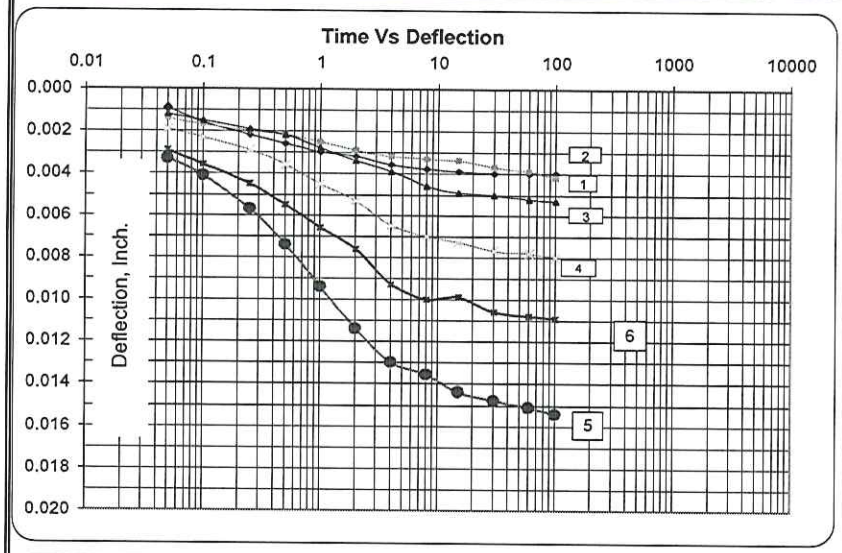
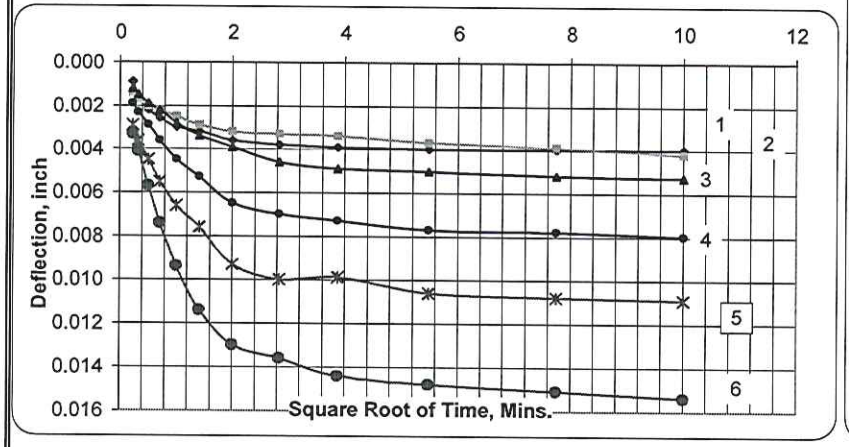
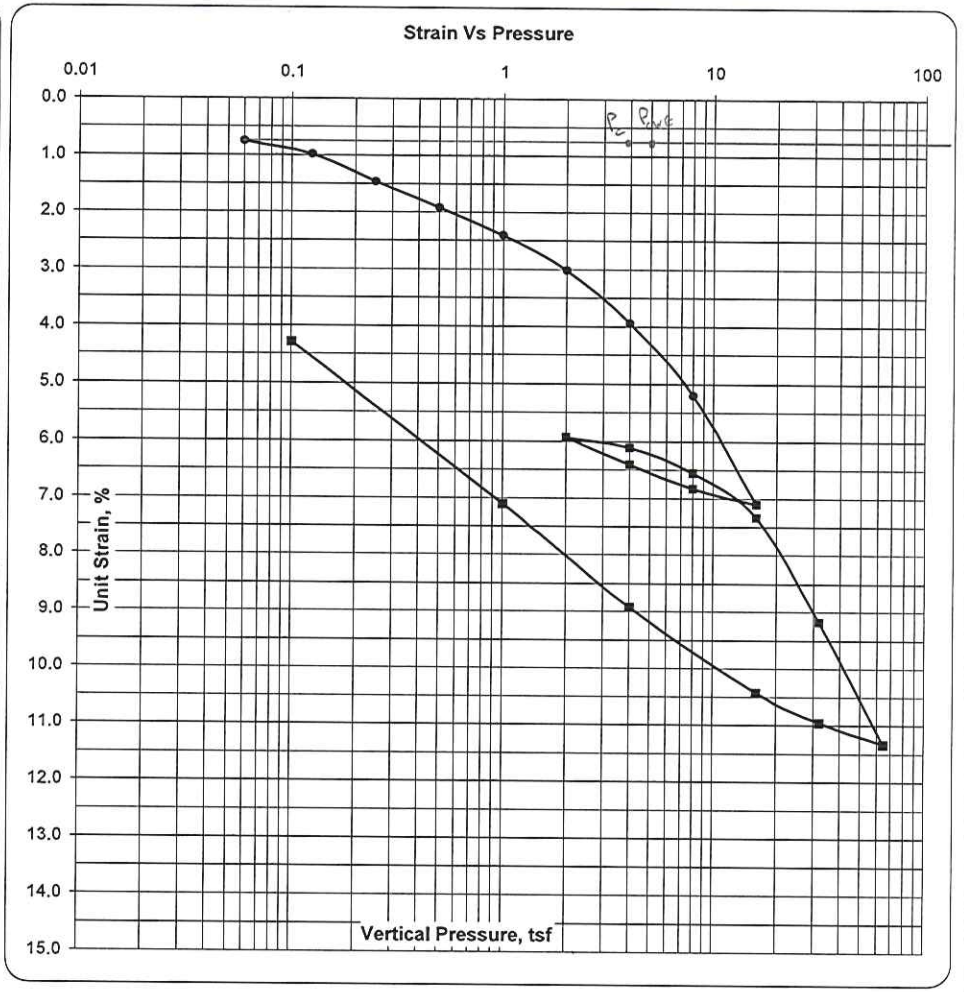
RKK-103

JDT 9-30-08







One-Dimensional Consolidation Test (ASTMD-2435)

Curve No.	Pressure Increment From ,tsf	Pressure Increment To,tsf	Coeff. Of Consolidation Cv, ft^2/day
1	0.25	0.5	2.27
2	0.5	1	0.52
3	1	2	0.47
4	2	4	0.29
5	4	8	1.20
6	8	16	0.50
7			
8			
10			

Description of Specimen:	Red-brown-gray mottled silty clay		
Nat.Water Content (%)	18.2	(From Trims.)	**Consolidation Properties (Unit Strain Basis)**
Liquid Limit (%)	34	(From Trims.)	Compression Ratio (Cc') *
Plastic Limit (%)	19	(From Trims.)	Recompression Ratio (Cr')*
Plastic Index (%)	15	(From Trims.)	Swelling Ratio (Cs')*
Specific Gravity(assumed)	2.69	(From Trims.)	Preconsolidation Stress, Pc (tsf)* 3.9/5
Test Specimen Properties			Existing Overburden Stress, Po (tsf)*
Diameter,inch.	2.490		Final Pc = 4.95 tsf
Initial And Final Thickness, inch.	0.863	0.852	
Initial And Final Water Content (%)	17.5	16.6	
Initial And Final Void Ratio	0.474	0.455	
Initial And Final Saturation (%)	99.3	98.2	* Unit Strain Basis
Unit Dry Weight (pcf)	113.9		

Project No	19996251
Project Name	RKK I-95 Delaware TP Improve
Boring No.	ICP1-16a
Sample No.	T-1
Depth, ft.	30.0-32.0
Tested By	rmm
Reviewed By	enm
Date	17-May-05
File No.	19996251C-8

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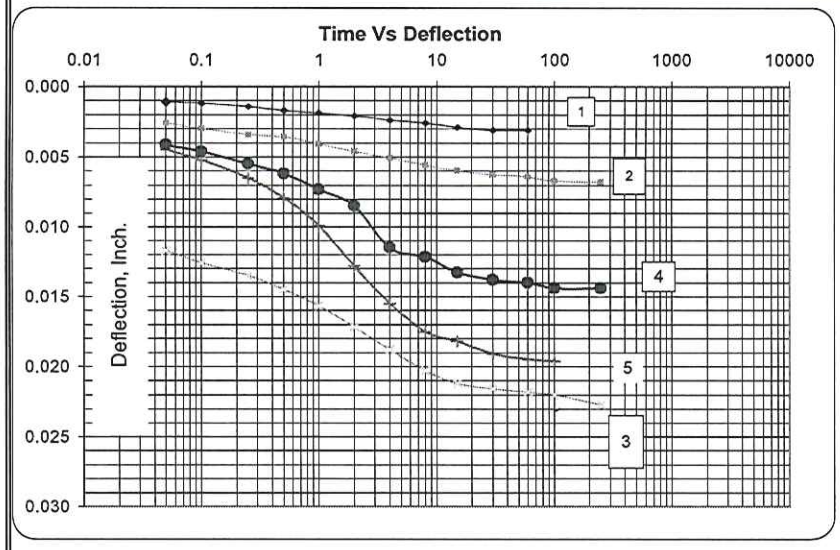
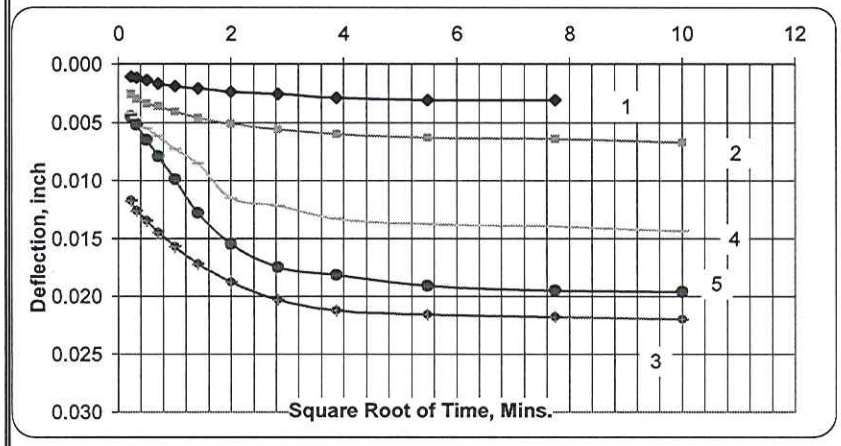
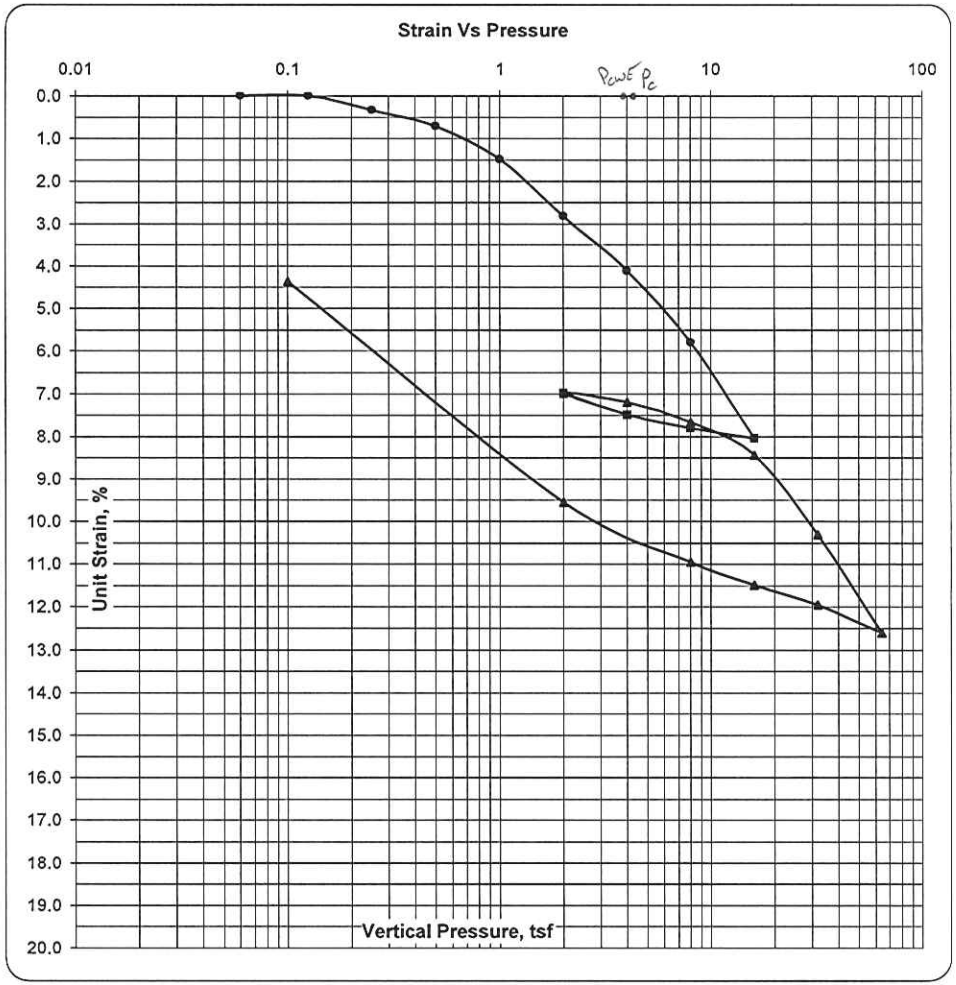
RKK-104

9-30-08







One-Dimensional Consolidation Test (ASTMD-2435)

Curve No.	Pressure Increment From ,tsf	To,tsf	Coeff. Of Consolidtion Cv, ft^2/day
1	0.25	0.5	0.54
2	1	1	0.29
3	2	4	0.99
4	4	8	0.23
5	8	16	0.30
6			
7			
8			
10			

Description of Specimen:	Red-brown-gray mottled silty clay		
Nat.Water Content (%)	13.0	(From Trims.)	**Consolidation Properties (Unit Strain Basis)**
Liquid Limit (%)	41	(From Trims.)	Compression Ratio (Cc') *
Plastic Limit (%)	18	(From Trims.)	Recompression Ratio (Cr')*
Plastic Index (%)	23	(From Trims.)	Swelling Ratio (Cs')*
Specific Gravity(assumed)	2.71	(From Trims.)	Preconsolidation Stress, Pc (tsf)* 4.2/3.9
Test Specimen Properties			Existing Overburden Stress, Po (tsf)* /
Diameter,inch.	2.490		Final Pc = 4.05+/-
Initial And Final Thickness, inch.	0.863	0.868	
Initial And Final Water Content (%)	13.4	13.2	
Initial And Final Void Ratio	0.304	0.311	
Initial And Final Saturation (%)	119.3	115.0	* Unit Strain Basis
Unit Dry Weight (pcf)	129.8		

Project No	19996251
Project Name	RKK I-95 Delaware TP Improve
Boring No.	TCP1-16a
Sample No.	T-2
Depth, ft.	44.0-46.0
Tested By	rmm
Reviewed By	enm
Date	17-May-05
File No.	19996251C-7

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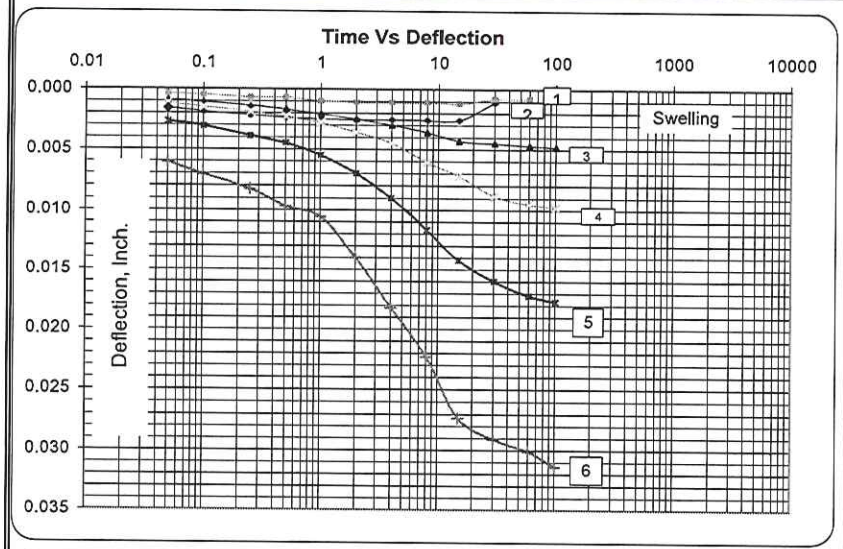
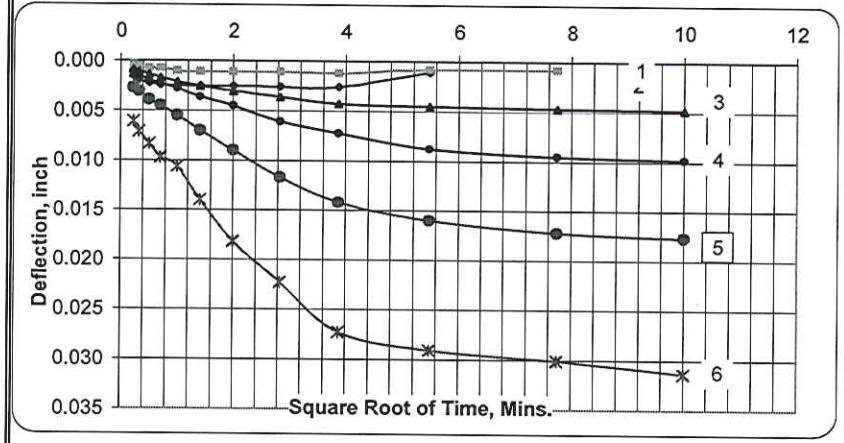
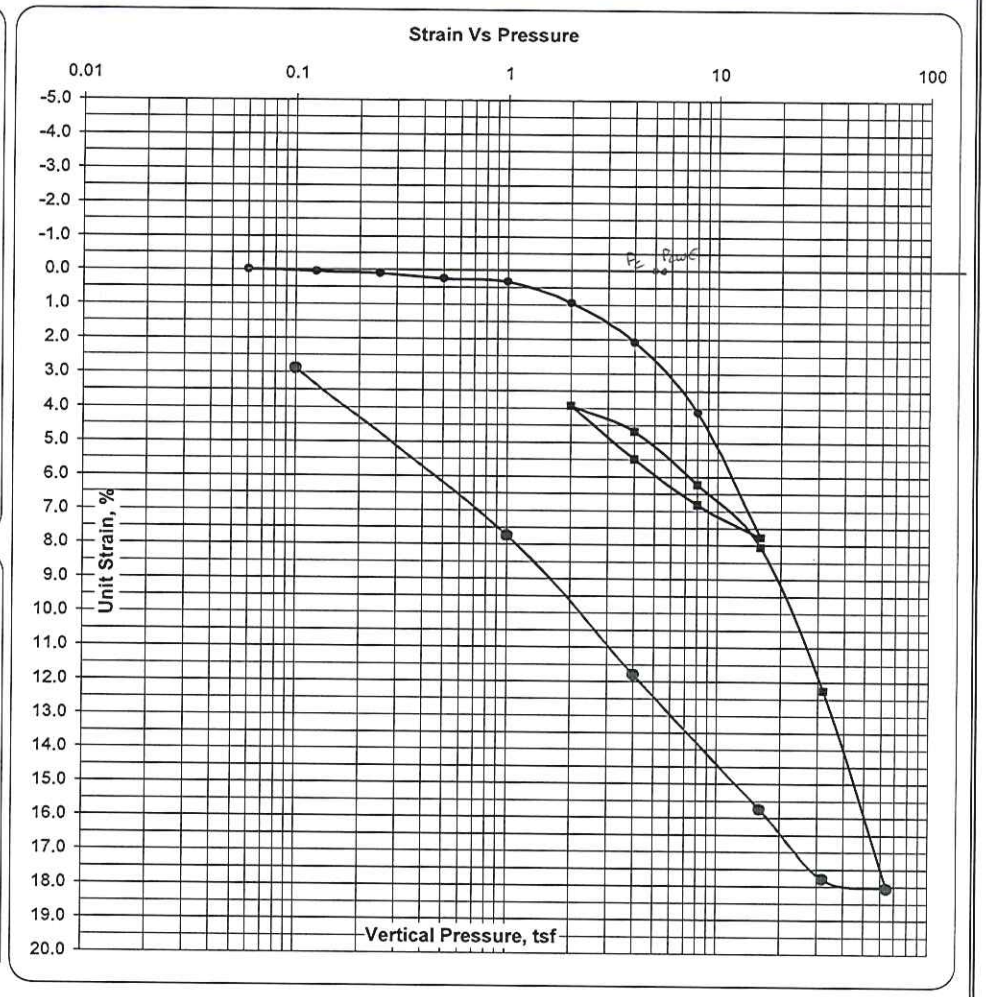
RKK-105

9-30-08







One-Dimensional Consolidation Test (ASTMD-2435)

Curve No.	Pressure Increment From ,tsf	To,tsf	Coeff. Of Consolidation Cv, ft^2/day
1	0.25	0.5	Not Measured (Swell)
2	1	1	1.08
3	2	2	0.29
4	4	4	0.08
5	8	8	0.11
6	8	16	Not Measured
7			
8			
10			

Description of Specimen:	Red-brown-gray mottled silty clay		
Nat.Water Content (%)	26.2	(From Trims.)	
Liquid Limit (%)	64	(From Trims.)	
Plastic Limit (%)	26	(From Trims.)	
Plastic Index (%)	15	(From Trims.)	
Specific Gravity(assumed)	2.79	(From Trims.)	
Test Specimen Properties			
Diameter,inch.	2.490		
Initial And Final Thickness, inch.	0.863	0.833	
Initial And Final Water Content (%)	33.2	32.6	
Initial And Final Void Ratio	0.872	0.807	
Initial And Final Saturation (%)	106.2	112.9	
Unit Dry Weight (pcf)	93.0		

Consolidation Properties (Unit Strain Basis)	
Compression Ratio (Cc') *	
Recompression Ratio (Cr')*	
Swelling Ratio (Cs')*	
Preconsolidation Stress, Pc (tsf)*	5/5.4
Existing Overburden Stress, Po (tsf)*	
Final Pc = 5.2 tsf	
* Unit Strain Basis	

Project No	19996251
Project Name	RKK
	I-95 Delaware TP Improve
Boring No.	ICP1-16a
Sample No.	T-3
Depth, ft.	54.0-56.0
Tested By	rmm
Reviewed By	enm
Date	17-May-05
File No.	19996251C-8

URS Corporation

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RKK-106

ACPT 9-30-08

CALCULATION CHECKLIST

Project: SR-11/I-95 INTERCHANGE Comm. No.: 103-059

Title of Calculation Set: SETTLEMENT PLATES

Project Manager: EMK

Calculations Prepared By: BBS

Calculation Checked By:

Computer Programs / Files: FOSSA PLAXIS 2D

Initial	Date	
BBS	2-2-09	Subsurface Characterization approved by Project Manager
BBS	2-2-09	Calculations are neat, legible and understandable.
BBS	2-2-09	Table of Contents is provided.
BBS	2-2-09	Heading on each page filled out
BBS	2-2-09	The first page contains purpose of the calculation.
BBS	2-2-09	Symbols are defined.
BBS	2-2-09	References for data, methods, formulas and computer program names and version numbers are given.
BBS	2-2-09	Assumptions are listed and those that need to be verified later are Flagged.
BBS	2-2-09	Headings on front sheet of each set of computer input and output.
BBS	2-2-09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
EMK	2/4/09	All calculations checked and each calculation sheet initialed by checker.
		Calculation set reviewed by Project Manager.
		Has this calculation been superseded? Reference new calculation, if applicable.

This sheet is to be prepared by the originator of the calculation and attached to the front of the calculation set.

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Subject SR-11/I-95 INTERCHANGE Page ____ of ____
SETTLEMENT PLATES Cm. No. 103-059
Prepared By ____ Date ____ Checked By SW Date 2/4/09

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2) TYPICAL CROSS SECTION	2
3) SUMMARY OF SETTLEMENT PLATE RESULTS	3
4) OPTIMIZED SOIL PARAMETERS	4
5) STAGE 1 EMBANKMENT SETTLEMENT ANALYSIS	5
6) SOIL PROFILE	6
7) FOSSA SETTLEMENT ANALYSIS	8
8) PLAXIS 2D SETTLEMENT ANALYSIS	16
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Subject SR-1/I-95 INTERCHANGE Page 1 of 41
SETTLEMENT PLATES Cm. No. 103-059
Prepared By BBS Date 1-30-09 Checked By EM Date 2/4/09

PURPOSE: BACK CALCULATION OF SOIL PARAMETERS FOR SETTLEMENT ANALYSIS FROM SETTLEMENT PLATE RESULTS.

REFERENCE: AASHTO LRFD BRIDGE SPECIFICATION CUSTOMARY US UNITS 4th EDITION.

FOUNDATION ANALYSIS & DESIGN BOWLES 1982.

SOFTWARE: FOSSA 1.0, PLAXIS 2D V8.0

SYMBOLS:

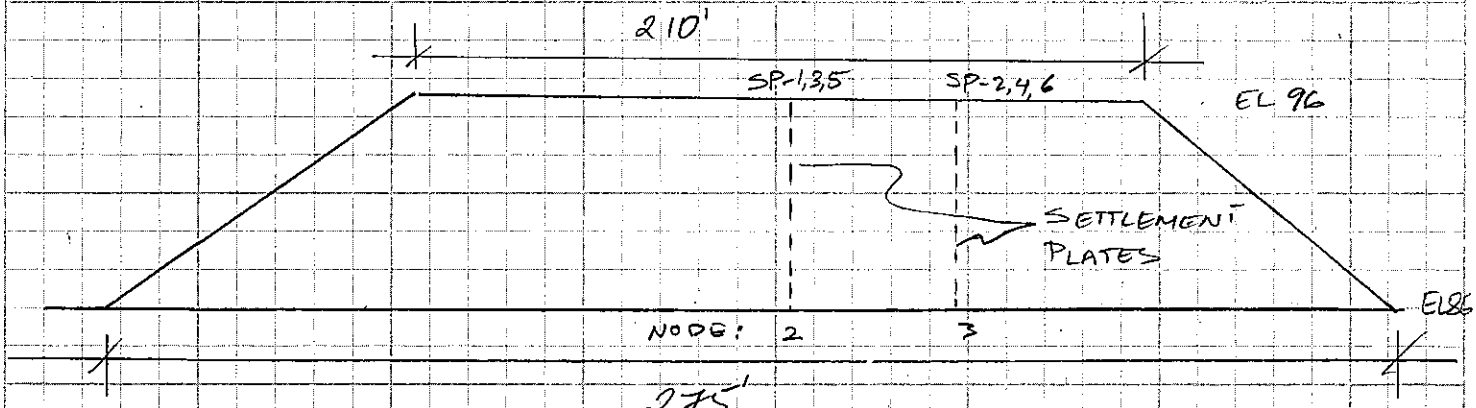
UNIT WEIGHTS → Γ	VOID RATIO → e_o
FRICTION ANGLE → ϕ	COMPRESSION INDEX → C_c
UNDRAINED SHEAR STRENGTH → S_u	RECOMPRESSION INDEX → C_r
ELASTIC MODULUS → E_s	POISSON RATIO → μ

ESTIMATING SOIL PARAMETERS FROM STAGE 1 SETTLEMENT PLATE RESULTS (ONLY 10-ft EMBANKMENT HEIGHT)

STAGE 1 CONSTRUCTION

AVG HEIGHT OF EMBANKMENT = 10-ft.

AVG SETTLEMENT FROM 6-SETTLEMENT PLATES = 1.0-inch.



TYPICAL CROSS SECTION @ STAGE 1

ASSUMPTION:

1) INFINITELY LONG EMBANKMENT

2) ELASTIC SETTLEMENT FOR COARSE GRAINED SOIL & CONSOLIDATION SETTLEMENT FOR FINE GRAINED SOIL.

3) BASED ON LAB TESTING, AVG OCR = 3.5

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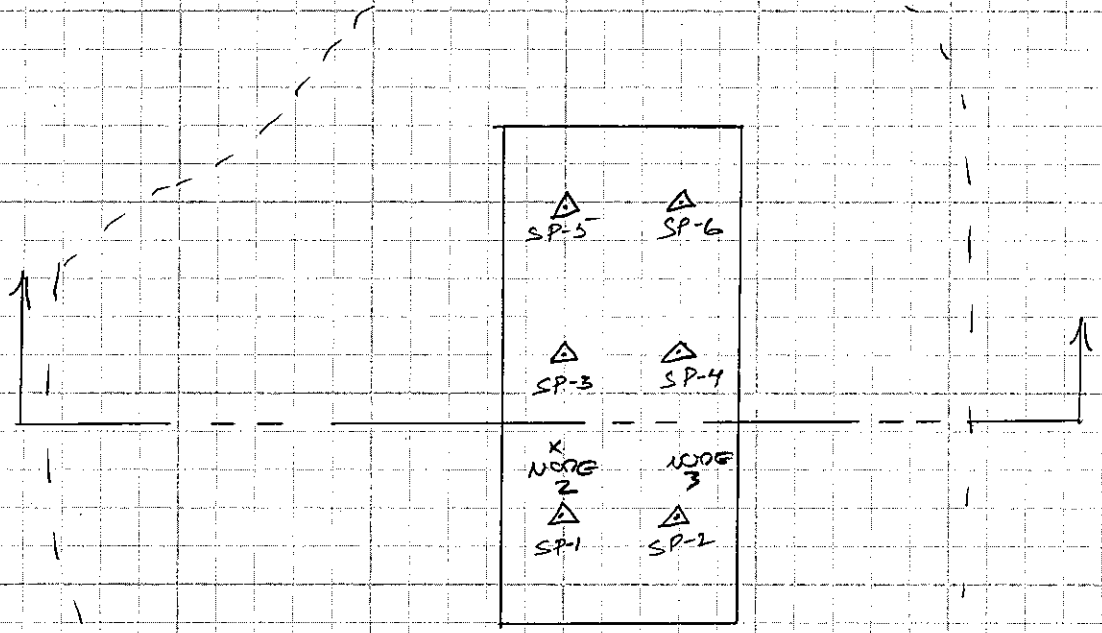
Subject SR-1/I-95 INTERCHANGE Page 3 of 41
SETTLEMENT PLATES Cm. No. 103-059.
Prepared By BBS Date 1-12-09 Checked By [illegible] Date 1/14/09

SUMMARY OF SETTLEMENT PLATE RESULTS ALONG LENGTH OF EMBANKMENT



SETTLEMENT PLATE RESULTS FOR STAGE I CONSTRUCTION

SP-1 →	0.882 inches	SP-2 →	1.44 inches
→ SP-3 →	0.378 inches	SP-4 →	0.906 inches
SP-5 →	1.422 inches	SP-6 →	1.098 inches
AVG →	1.152 inches (NODE 2)	AVG →	1.148 inches (NODE 3)

SP-3 is AN ANOMALY (NOT CONSIDERED IN CALCULATION

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Prepared By BBS Date 1-13-09 Checked By JME Date 1/14/09

THE ESTIMATE CONSOLIDATION SETTLEMENT BELOW THE EMBANKMENT IS HIGHLY INFLUENCED BY THE RECOMPRESSION INDEX (C_r) OF THE FINE GRAINED SOIL. TYPICAL C_r VALUES RANGE FROM 0.015 – 0.35 (ROSCOE et. al 1958) AND ARE OFTEN ASSUMED TO BE 5-10 % of C_c. THE G_s VALUE AND THE VOID RATIO FOR FINE GRAINED SOIL WERE SUMMARIZED FROM LAB TEST RESULTS.

ALONG WITH THE RECOMPRESSION INDEX OF FINE GRAINED SOIL THE ELASTIC MODULUS OF COARSE GRAINED SOIL WAS ALSO OPTIMIZED TO MATCH THE TOTAL SETTLMENT ESTIMATED WITH THE SETTLEMENT PLATE RESULTS. THE RECOMPRESSION INDEX WAS ADJUSTED TO $C_r = 0.015$. THE ELASTIC MODULUS(E) WAS ADJUSTED MAINTAINING THE SAME RATIO AS CALCULATED USING CPT RESULTS THE OPTIMIZED ELASTIC MODULUS FOR STRATUM I & STRATUM IIb are

$E_{s\ \text{STRATUM I}} = 1500$ ksf

$E_{s\ \text{STRATUM IIb}} = 1364$ ksf

STRATUM IIa $C_r = 0.015$

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SETTLEMENT PLATE Cm. No. 103-057.
Prepared By BBS Date 1-13-09 Checked By EMK Date 1/14/09

STAGE -1 EMBANKMENT HEIGHT RANGES FROM 9 to 12-ft.
FOR ANALYSIS PURPOSE USE 10-ft

SETTLEMENT ANALYSIS

→ ELASTIC SETTLEMENT FOR COARSE GRAINED SOIL

→ CONSOLIDATION SETTLEMENT FOR FINE GRAINED SOIL

C_c & e_o FROM LAB RESULTS.

BACK CALCULATED SOIL PARAMETERS TO MATCH SETTLEMENT PLATE RESULTS

SOIL STRATA	ELEVATION	ELASTIC MODULUS (ksf)	VOID RATIO e_o	OPTIMIZED C_c	OPTIMIZED C_r
STRATUM I COARSE GRAINED	EL 60 & ABOVE	1500	–	–	–
STRATUM IIa FINE GRAINED	EL 60 & ABOVE	818	0.655	0.092	0.015
STRATUM IIa FINE GRAINED	EL 50 TO 60	545	0.655	0.092	0.015
STRATUM IIa FINE GRAINED	EL 20 TO 50	818	0.605	0.105	0.015
STRATUM IIa FINE GRAINED	EL 20 & BELOW	1364	0.605	0.105	0.015
STRATUM IIb COARSE GRAINED	EL 0 & BELOW	1364	–	–	–

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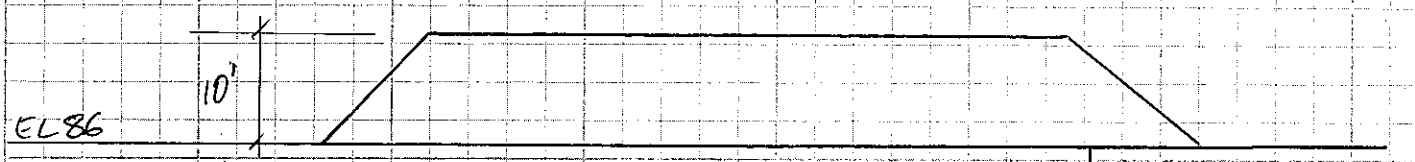
SETTLEMENT PLATE Cm. No. 103-059
Prepared By BBS Date 1-7-09 Checked By EMC Date 1/14/09

SOIL PROFILE



EL 86

STRATUM 1 $E_s = 1500$ ksf $P_c = 9000$ psf 85

$\gamma = 125$ pcf

EL 70 70

STRATUM 2a(i) $C_c = 0.092$ $e_o = 0.655$

$\gamma = 130$ pcf $C_r = 0.015$ $C_v = 0.75$ ft²/day

EL 60

STRATUM 2a(ii) $C_c = 0.092$ $e_o = 0.655$ 55

$\gamma = 130$ pcf $C_r = 0.015$ $C_v = 0.75$ ft²/day

EL 50

STRATUM 2a(iii) $C_c = 0.105$

$\gamma = 130$ pcf $C_r = 0.015$ 40

$e_o = 0.605$

$C_v = 0.75$ ft²/day 25

EL 20

STRATUM 2a(iv) $C_c = 0.105$ $C_v = 0.75$ ft²/day

$\gamma = 130$ pcf $C_r = 0.015$ 10

$e_o = 0.605$

EL 0

STRATUM 2b $E_s = 1364000$ -5

$\gamma = 125$ pcf

-20

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SETTLEMENT PLATE Cm. No. 103-059
Prepared By BBS Date 1-7-09 Checked By BMR Date 1/14/09

SETTLEMENT:

ELASTIC SETTLEMENT OF COARSE GRAINED SOIL

$= 0.0081 + 0.0199$ ft

$= 0.028$ -ft $= 0.34$ inch.

CONSOLIDATION SETTLEMENT OF FINE GRAINED SOIL

$= 0.08$ -ft

$= 0.96$ -inch.

TOTAL SETTLEMENT = 1.3 inch. ≈ 1.15 ACTUAL SETTLEMENT

THE SETTLEMENT PLATE DATA INDICATES THAT MOST OF THE SETTLEMENT OCCURS IMMEDIATELY AFTER THE EMBANKMENT WAS BUILT. READING FROM A WEEK AFTER THE EMBANKMENT WAS COMPLETE TO 4 MONTHS SINCE SHOW LITTLE OR NO SETTLEMENT AT ALL. HENCE WE CONCLUDE BOTH ELASTIC & CONSOLIDATION SETTLEMENT TAKES PLACE IMMEDIATELY OR WITHIN THE FIRST COUPLE OF WEEKS. WE RECOMMEND A 30-60 day QUARANTINE PERIOD FOR BRIDGE ABUTMENT BEFORE FOUNDATION PILES ARE DRIVEN TO AVOID ANY DOWNDRAG TO THE PILES.

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Elastic Settlement Back Calculation

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PROJECT IDENTIFICATION

Title: Elastic Settlement Back Calculation
Project Number: 103-059 -
Client: Deldot
Designer: BBS
Station Number:

Description:
Settlement Plate Back Calculation

Company's information:

Name: Rummel, Klepper & Kahl
Street: 81 Mosher Street
Baltimore, MD 21217
Telephone #:
Fax #:
E-Mail:

Original file path and name: M:\project ..... ion\settlement plate\Final SP Stage 1 Combined.2ST
Original date and time of creating this file: Mon Nov 03 12:02:51 2008

GEOMETRY: Analysis of a 2D geometry

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INPUT DATA – FOUNDATION LAYERS – 6 layers

	Wet Unit Weight, γ [lb/ft^3]	Poisson's Ratio μ	Description of Soil
1	125.00	0.30	
2	130.00	0.40	
3	130.00	0.40	
4	130.00	0.40	
5	130.00	0.40	
6	125.00	0.30	

INPUT DATA – EMBANKMENT LAYERS – 1 layers

	Wet Unit Weight, γ [lb/ft^3]	Description of Soil
1	130.00	

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	300.00	375.00

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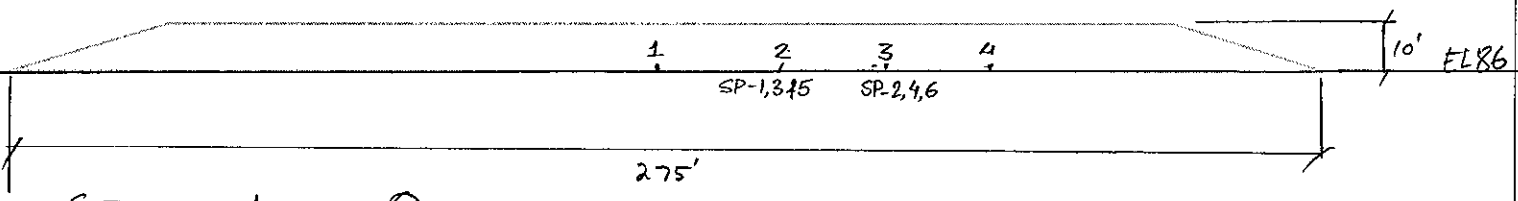
DRAWING OF SPECIFIED GEOMETRY



STRATUM 1 (1)

EL70

STRATUM 2a (2)

EL60

STRATUM 2a (3)

EL50

STRATUM 2a (4)

EL20

STRATUM 2a (5)

EL10

STRATUM 2b (6)

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INPUT DATA FOR CONSOLIDATION — $\alpha = 1/2$

Layer # Undergoing Consolidation [Yes/No]		$(\sigma'_p - \sigma'_o)$ given at layer's boundaries in [lb/ft²] at Top	Bottom	Cc	Cr	e0	Cv [ft²/day]	Drains at :
1	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Yes	7350.0	6750.0	0.09	0.01	0.66	0.7500	Top
3	Yes	6750.0	6100.0	0.09	0.01	0.66	0.7500	Top
4	Yes	6100.0	4240.0	0.11	0.01	0.60	0.7500	Bottom
5	Yes	4240.0	2990.0	0.11	0.01	0.60	0.7500	Bottom
6	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	275.00	0.00	1	1500000	0.3000	0.0081	386.00	385.92	0.08
			2	818000	0.4000	0.0068			
			3	545000	0.4000	0.0112			
			4	818000	0.4000	0.0256			
			5	1364000	0.4000	0.0112			
			6	1364000	0.3000	0.0200			
2	300.00	0.00	1	1500000	0.3000	0.0081	386.00	385.92	0.08
SP-1,3&5			2	818000	0.4000	0.0068			
			3	545000	0.4000	0.0112			
			4	818000	0.4000	0.0256			
			5	1364000	0.4000	0.0111			
			6	1364000	0.3000	0.0199			
3	325.00	0.00	1	1500000	0.3000	0.0081	386.00	385.92	0.08
SP-2,4&6			2	818000	0.4000	0.0070			
			3	545000	0.4000	0.0115			
			4	818000	0.4000	0.0257			
			5	1364000	0.4000	0.0108			
			6	1364000	0.3000	0.0191			
4	350.00	0.00	1	1500000	0.3000	0.0082	386.00	385.92	0.08
			2	818000	0.4000	0.0073			
			3	545000	0.4000	0.0119			
			4	818000	0.4000	0.0252			
			5	1364000	0.4000	0.0101			
			6	1364000	0.3000	0.0174			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

NODE	E	CONS	TOTAL (FT)	TOTAL (INCH)	ACTUAL
1	0.0081 0.0200 0.0281	0.08	0.1081	1.30"	SP1 & SP5: 1.15" SP2,4,6: 1.15"
2	0.0081 0.0199 0.0280	0.08	0.1080	1.30	SP3: 0.38" IS NOT CONSISTENT WITH OTHER 5 SP'S.
3	0.0081 0.0191 0.0272	0.08	0.1072	1.29	
4	0.0082 0.0174 0.0256	0.08	0.1056	1.27	

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	275.00	0.00	386.00	0.08	385.92
2	300.00	0.00	386.00	0.08	385.92
3	325.00	0.00	386.00	0.08	385.92
4	350.00	0.00	386.00	0.08	385.92

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	300.00	386.00	
2	1	300.00	370.00	
3	1	300.00	360.00	
4	1	300.00	350.00	
5	1	300.00	320.00	
6	1	300.00	300.00	

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TABULATED GEOMETRY: INPUT OF EMBANKMENT SOILS

Embank. Soil #		Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	X1 = 145.00 [ft]	1	178.00	396.00	
	X2 = 420.00 [ft]	2	388.00	396.00	

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"A Tradition Of Excellence" since 1923

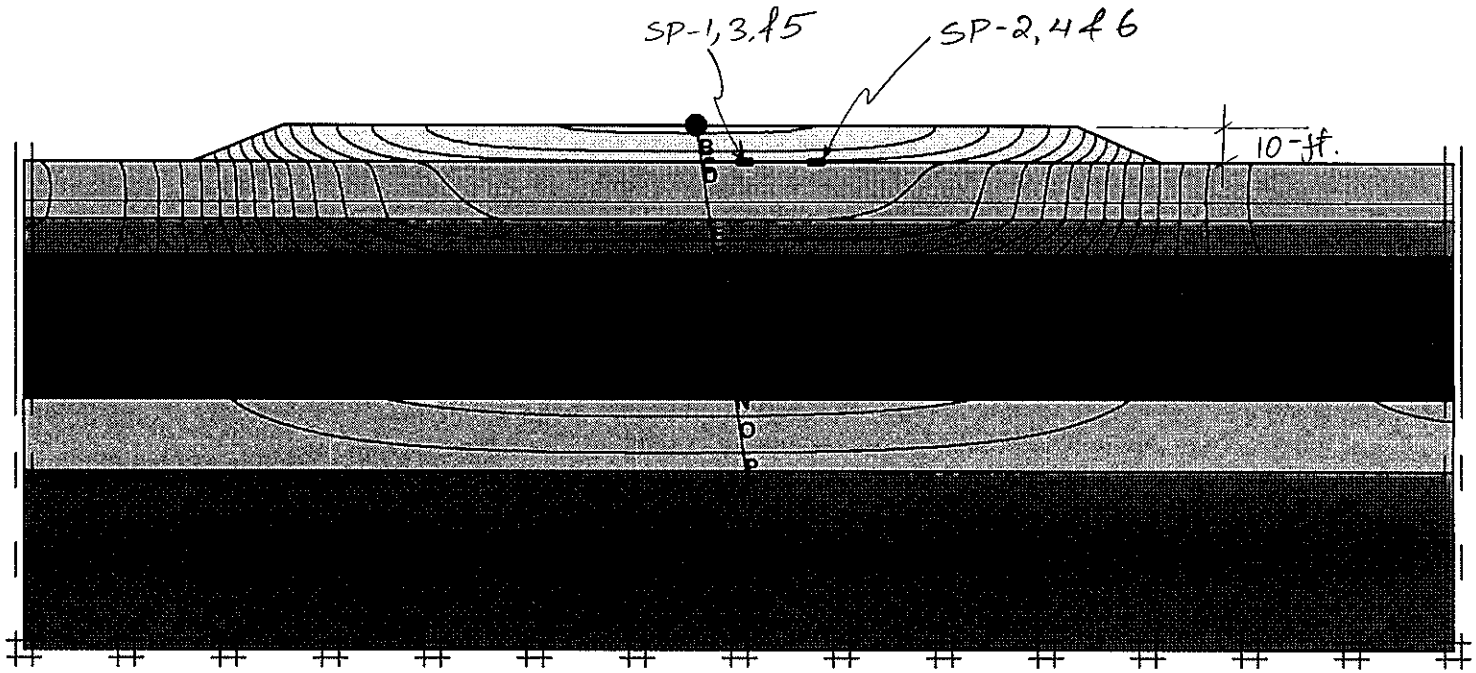
Subject SR-1 / I-95 Interchange Page 16 of 45
Settlement Plates Cm. No. 103-059
Prepared By BBS Date 1-13-09 Checked By SWA Date 1/14/09

PLAXIS 2D ANALYSIS TO ESTIMATE SETTLEMENT.

TOTAL SETTLEMENT ESTIMATED AT LOCATION OF SETTLEMENT PLATES USING HARDENING SOIL MODEL IN PLAXIS.

SETTLEMENT ANALYZED FOR STAGE-1 EMBANKMENT CONSTRUCTION (10-ft HEIGHT)

TOTAL SETTLEMENT = 0.128 ft
= 1.54 inches.



[*10^{-3}ft]

A : -160.000
B : -150.000
C : -140.000
D : -130.000
E : -120.000
F : -110.000
G : -100.000
H : -90.000
I : -80.000
J : -70.000
K : -60.000
L : -50.000
M : -40.000
N : -30.000
O : -20.000
P : -10.000
Q : 0.000
R : 10.000
S : 20.000

STAGE-1 EMBANKMENT

Vertical displacements (Uy)
Extreme Uy -151.50*10^{-3} ft

PLAXIS Finite Element Code for Soil and Rock Analyses	Project description: SR-1 Interchange			
	Project name: S-1a	Step: 15	Date: 01/13/09	User name: Rummel Klepper & Kahl

Version 8.2.3.125

RKK-125

PLAXIS - Finite Element Code for Soil and Rock Analyses

Project description : SR-1 Interchange — **PLAXIS 8.x**

User name : Rummel Klepper & Kahl

Project name : S-1a — Date : 1/13/2009

Output : Soil and Interfaces Info - Hardening Soil — Step : 15 — Page : 1

ID	Name	Type	γ_{unsat} [lb/ft^3]	γ_{sat} [lb/ft^3]	k_x [ft/day]	k_y [ft/day]	E_{50}^{ref} [lb/ft^2]	E_{oed}^{ref} [lb/ft^2]	E_{ur}^{ref} [lb/ft^2]	c_{ref} [lb/ft^2]
1	Stratum 1a	Drained	125.0	130.0	0.2830	0.2830	5.5E5	4.0018E5	1.5E6	1.0
	Stratum 2a (iii)	Undrained	125.0	130.0	2.8000E-3	2.8000E-3	3E5	3E5	8.18E5	3500.0
	Stratum 2a (i)	Undrained	125.0	130.0	2.8000E-3	2.8000E-3	3E5	3E5	8.18E5	1500.0
	Stratum 2a (ii)	Undrained	125.0	130.0	2.8000E-3	2.8000E-3	2E5	2E5	5.45E5	2500.0
5	Stratum 2a (iv)	Undrained	125.0	130.0	2.8000E-3	2.8000E-3	5E5	5E5	1.364E6	5000.0
	Stratum 2b	Drained	125.0	130.0	0.0283	0.0283	5E5	3.5395E5	1.364E6	1.0

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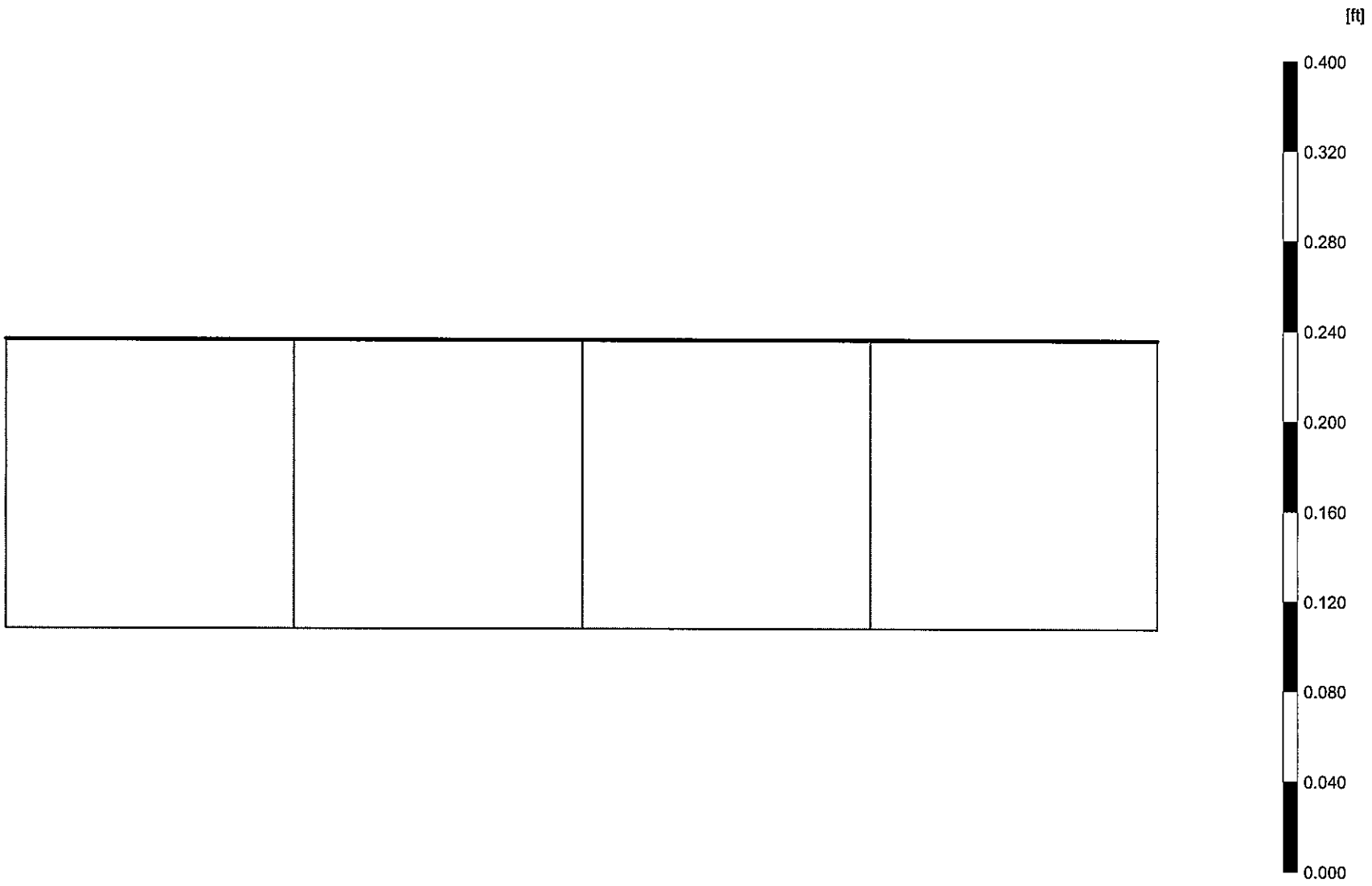
RKK126



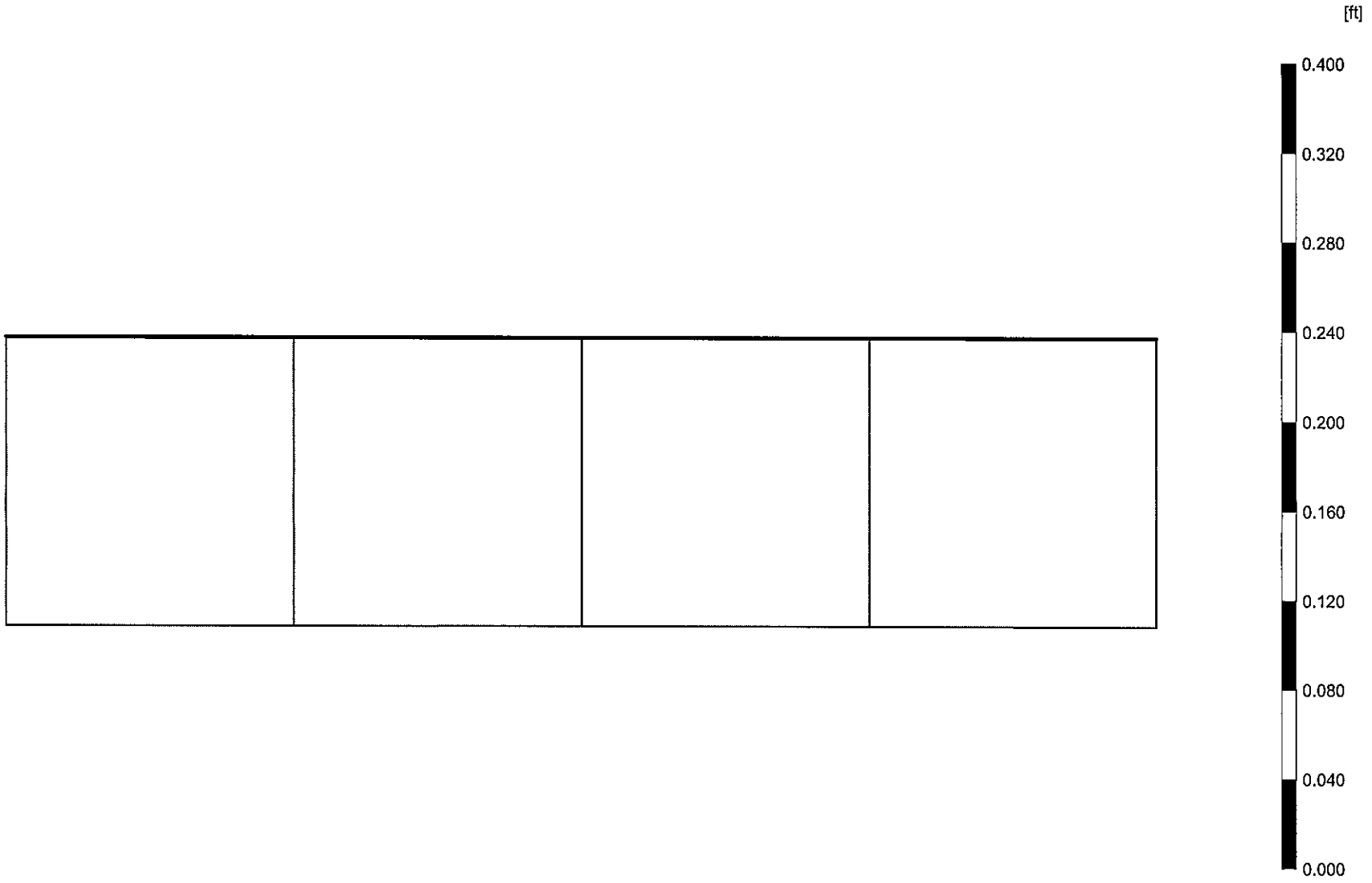
Vertical displacements (Uy)
Extreme Uy -128.33*10^{-3} ft = 1.5 inches

SP - 2, 4 & 6

RKK-127

PLAXIS Finite Element Code for Soil and Rock Analyses	Project description: SR-1 Interchange			
	Project name: S-1a	Step: 15	Date: 01/13/09	User name: Rummel Klepper & Kahl

Version 8.2.3.125



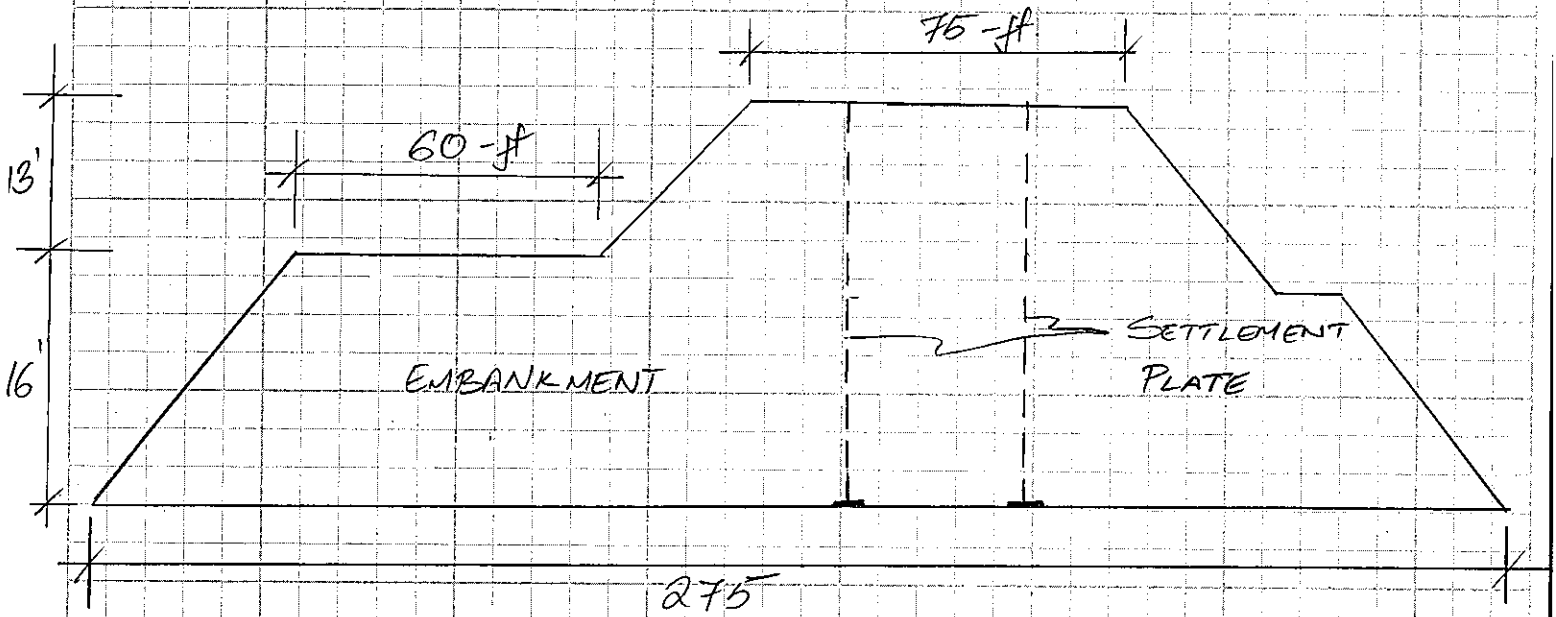
Vertical displacements (Uy)
Extreme Uy -129.11*10^{-3} ft = 1.5 inches
SP – 1, 3 & 5

PLAXIS
Finite Element Code for Soil and Rock Analyses
Version 8.2.3.125

Project description			
SR-1 Interchange			
Project name	Step	Date	User name
S-1a	15	01/13/09	Rummel Klepper & Kahl

RKK-128

ESTIMATING TOTAL SETTLEMENT FOR FULL HEIGHT EMBANKMENT (29-ft HIGH)



TYPICAL CROSS-SECTION OF EMBANKMENT

ASSUMPTION:

1) TOTAL SETTLEMENT MEASURED BY SETTLEMENT PLATES IS ASSUMED TO BE CONSOLIDATION SETTLEMENT IN CLAY & ELASTIC IN COARSE GRAINED
2) INFINITELY LONG EMBANKMENT IS ASSUMED
3) MODIFIED CONSOLIDATION SOIL PARAMETERS FROM STAGE 1 SETTLEMENT CALCULATION
4) MODIFIED ELASTIC MODULUS FROM STAGE 1 SETTLEMENT CALCULATION

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject SR-1/I-95 INTERCHANGE SETTLEMENT PLATE Page 22 of 41
Cm. No. 103-059
Prepared By BBS Date 1-13-09 Checked By EMK Date 1/14/09

SETTLEMENT ESTIMATE FOR FULL HEIGHT (29-ft HIGH) EMBANKMENT @ LOCATION OF SETTLEMENT PLATES:

SP's 1, 3 & 5 TOTAL SETTLEMENT = 2.99-inches

SP-2, 4 & 6 TOTAL SETTLEMENT = 2.99-inches.

SETTLEMENT PLATE READINGS RANGED FROM 1.4 inches to 3.4 inches.

THE SP READINGS FOR PHASE II ARE NOT ACCURATE IN THAT ELEVATIONS OF THE RISER PIPES WAS NOT RECORDED PRIOR TO INSTALLING EACH EXTENSION. THESE TOTAL SETTLEMENTS FOR PHASE II ASSUME NO SETTLEMENT OCCURRED DURING PLACING OF NEW FILL.

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Elastic Settlement Back Calculation

Report created by FoSSA(2.0): Copyright (c) 2003-2006, ADAMA Engineering, Inc.

PROJECT IDENTIFICATION

Title: Elastic Settlement Back Calculation
Project Number: 103-059 -
Client: Deldot
Designer: BBS
Station Number:

SOIL PARAMETER DEVELOPED FROM (LAB & OPTIMIZED TO MATCH SETTLEMENT PLATE RESULTS FROM STAGE I SETTLEMENT CALCULATION)

Description:
Settlement Plate Back Calculation

Company's information:

Name: Rummel, Klepper & Kahl
Street: 81 Mosher Street
Baltimore, MD 21217
Telephone #:
Fax #:
E-Mail:

Original file path and name: M:\project ..... on\settlement plate\Final SP Consolidation LAB.2ST
Original date and time of creating this file: Mon Nov 03 12:02:51 2008

GEOMETRY: Analysis of a 2D geometry

NODE	S_E	S_C	S_{TOTAL} (FT)	S_{TOT} (INCH)	
1	0.0651	0.16	0.2251	2.70	
2	0.0690	0.18	0.2490	2.99	SP-1, 3 & 5
3	0.0689	0.18	0.2489	2.99	SP-2, 4 & 6
4	0.0643	0.16	0.2243	2.69	

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INPUT DATA – FOUNDATION LAYERS – 6 layers

	Wet Unit Weight, γ [lb/ft^3]	Poisson's Ratio μ	Description of Soil
1	125.00	0.30	
2	130.00	0.40	
3	130.00	0.40	
4	130.00	0.40	
5	130.00	0.40	
6	125.00	0.30	

INPUT DATA – EMBANKMENT LAYERS – 2 layers

	Wet Unit Weight, γ [lb/ft^3]	Description of Soil
1	130.00	
2	130.00	

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	300.00	375.00

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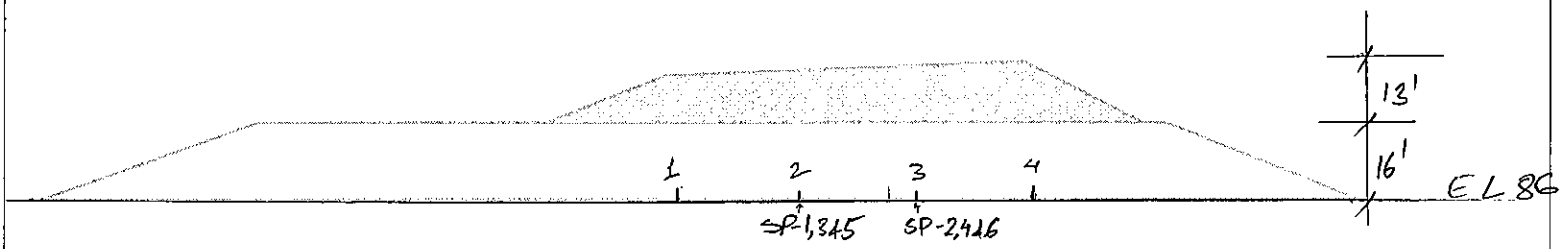
DRAWING OF SPECIFIED GEOMETRY



STRATUM 1 (1)

EL 70

STRATUM IIa (2)

EL 60

STRATUM IIa (3)

EL 50

STRATUM IIa (4)

EL 20

STRATUM IIa (5)

EL 0

STRATUM IIb (6)

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INPUT DATA FOR CONSOLIDATION — $\alpha = 1/2$

Layer # Underging Consolidation [Yes/No]		$(\sigma'_p - \sigma'_o)$ given at layer's boundaries in [lb/ft²] at Top	Bottom	Cc	Cr	e0	Cv [ft²/day]	Drains at :
1	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Yes	7400.0	6800.0	0.09	0.01	0.66	0.7500	Top
3	Yes	6800.0	6180.0	0.09	0.01	0.66	0.7500	Top
4	Yes	6180.0	4300.0	0.11	0.01	0.60	0.7500	Bottom
5	Yes	4300.0	3050.0	0.11	0.01	0.60	0.7500	Bottom
6	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	275.00	0.00	1	1500000	0.3000	0.0209	386.00	385.80	~~0.20~~ 0.0651
			2	818000	0.4000	0.0178			
			3	545000	0.4000	0.0284			
			4	818000	0.4000	0.0616			
			5	1364000	0.4000	0.0257			
			6	1364000	0.3000	0.0442			
2	300.00	0.00	1	1500000	0.3000	0.0221	386.00	385.78	~~0.22~~ 0.0690
			2	818000	0.4000	0.0203			
			3	545000	0.4000	0.0333			
			4	818000	0.4000	0.0710			
			5	1364000	0.4000	0.0284			
			6	1364000	0.3000	0.0469			
3	325.00	0.00	1	1500000	0.3000	0.0231	386.00	385.77	~~0.23~~ 0.0689
			2	818000	0.4000	0.0217			
			3	545000	0.4000	0.0353			
			4	818000	0.4000	0.0731			
			5	1364000	0.4000	0.0284			
			6	1364000	0.3000	0.0458			
4	350.00	0.00	1	1500000	0.3000	0.0237	386.00	385.79	~~0.21~~ 0.0643
			2	818000	0.4000	0.0211			
			3	545000	0.4000	0.0325			
			4	818000	0.4000	0.0644			
			5	1364000	0.4000	0.0246			
			6	1364000	0.3000	0.0406			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

ASSUME IMEDIATE SETTLEMENT IS FROM ① & ⑥ ONLY.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	275.00	0.00	386.00	0.16	385.84
2	300.00	0.00	386.00	0.18	385.82
3	325.00	0.00	386.00	0.18	385.82
4	350.00	0.00	386.00	0.16	385.84

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	300.00	386.00	
2	1	300.00	370.00	
3	1	300.00	360.00	
4	1	300.00	350.00	
5	1	300.00	320.00	
6	1	300.00	300.00	

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TABULATED GEOMETRY: INPUT OF EMBANKMENT SOILS

Embank. Soil #		Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	X1 = 145.00 [ft]	1	190.00	402.00	
	X2 = 420.00 [ft]	2	380.00	402.00	
2	X1 = 145.00 [ft]	1	190.00	402.00	
	X2 = 420.00 [ft]	2	250.00	402.00	
		3	275.00	412.00	
		4	350.00	415.00	
		5	375.00	402.00	
		6	380.00	402.00	

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SP-5
SP-6

SP-3
SP-4

SP-1
SP-2

IBR-17A
N612868.3, E432656.7
EL 80.0

ICPT-15
N612917, E432621
EL 80.0

ISC-74
N613009.2, E432718.1
EL 81.0

ISC-118
N613090.5, E432752.5
EL 82.1

IEB-13A
N613139, E432813.3
EL 84.0

ISC-103A
N613189, E432855
EL 85.0

ICPT-16
N613277, E432946
EL 88.0

IBR-42A
N613305.7, E432909.4
EL 89.0

SPT N or REC, RQD | NMC | AASHTO | S_u/Phi | Q(tsf)/OCR

IBR-17A: 21.3% (A-7-5); 16.1% (A-6); 14.8% (A-4); 18.3% (A-7-5); 18.9% (A-4); 20.2% (A-4); 15.4% (A-4); U-1; 100.5'

ICPT-15: 63.0'

ISC-74: 14.4% (A-2-4); 17.8% (A-2-4); 18.0%; 14.6% (A-2-4); 24.4% (A-7-5); 40.5'

ISC-118: 21.6% (A-6); 60.0'

IEB-13A: 14.6% (A-4); 20.8%; 11.9%; 17.7% (A-6); 18.7% (A-6); 16.9% (A-6); 17.3% (A-6); 20.1% (A-8); U-1; 40.5'

ISC-103A: 16.9% (A-6); 14.5%; 12.2% (A-6); 28.5% (A-7-5); 19.2% (A-4); U-1; 40.5'

ICPT-16: 67.0'

IBR-42A: 5.9% (A-4); 16.7% (A-1-b); 19.9% (A-6); 20.4%; 17.0% (A-6); 22.9% (A-7-5); U-2; 24.3% (A-7-5); 19.9% (A-6); 20.4% (A-3); 14.1% (A-4); 100.5'

AASHTO SOIL KEY

A	A-1-a	5	A-2-5	A-5	A-8
B	A-1-b	6	A-2-6	A-6	Asphalt
7	A-3	7	A-2-7	A-7-5	FILL
	A-2-4	+ + +	A-4	A-7-6	Decomposed Rock

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

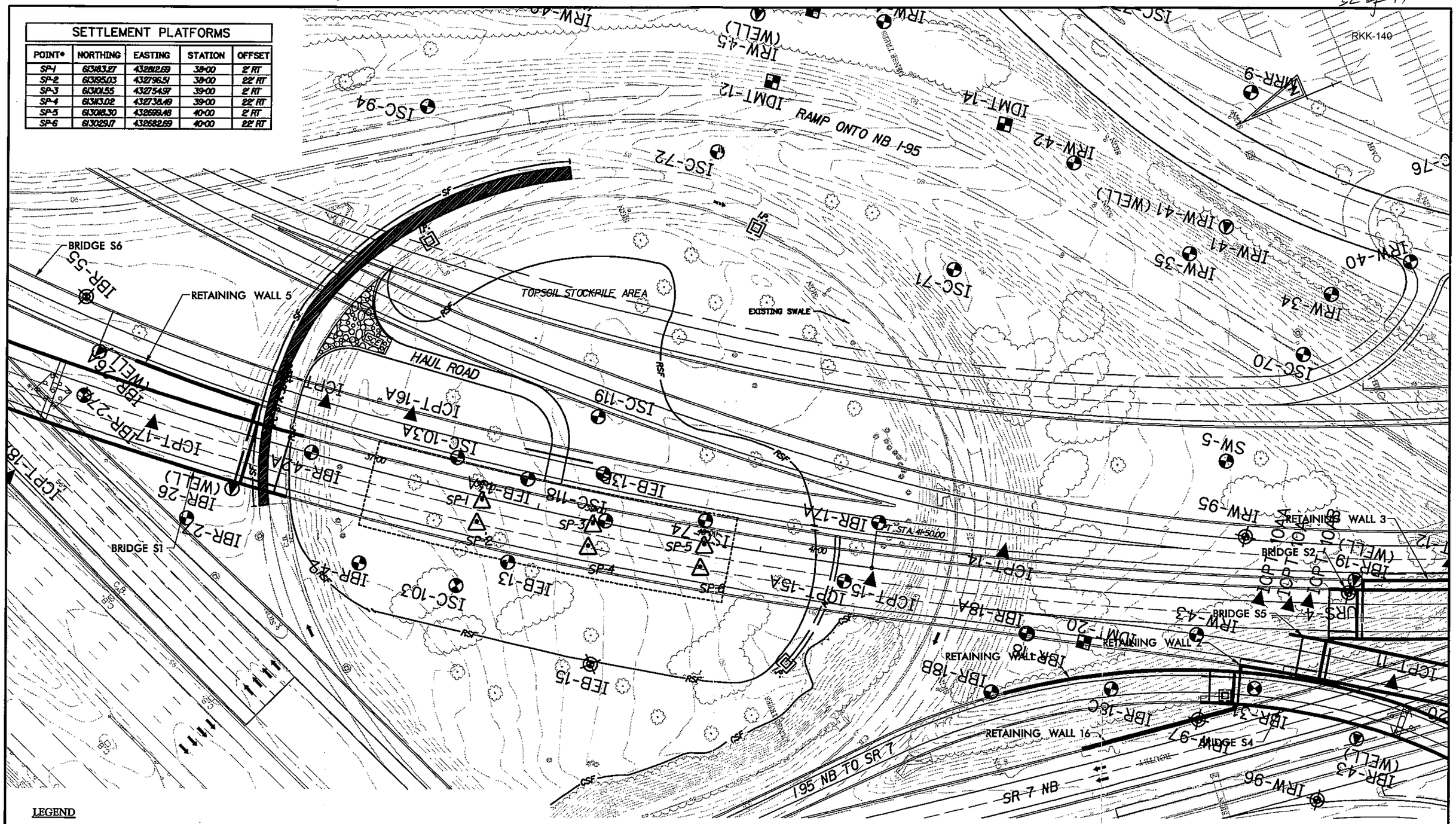
Title: Summary of Boring Data
Settlement Plate

Figure No. A-1

Drawn: BBS | Approved: EMK | Date: 10/31/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE 195 GINT FILE.GPJ RKK_CURRENT.GDT 10/31/08

SETTLEMENT PLATFORMS				
POINT#	NORTHING	EASTING	STATION	OFFSET
SP-1	613183.27	432812.69	39+00	2' RT
SP-2	613155.03	432796.51	39+00	22' RT
SP-3	613101.55	432754.97	39+00	2' RT
SP-4	613143.02	432736.49	39+00	22' RT
SP-5	613018.30	432699.48	40+00	2' RT
SP-6	613029.17	432682.69	40+00	22' RT



LEGEND

SP-3 SETTLEMENT MONITORING PLATES

80 40 0 40 80

SCALE: 1" = 80'-0"

RUMMEL, KLEPPER & KAHL, LLP CONSULTING ENGINEERS BALTIMORE, MARYLAND KDT	SR-1 MALL INTERCHANGE SETTLEMENT MONITORING PLATE LOCATION PLAN			FIGURE NO. E-1
	DRAWN BY KDT	APPROVED BY EMK	SCALE 1"=80'-0"	DATE OCTOBER 2008	COMMISSION. NO. 103-059-27U

10/31/2008
m:\projects\2003\103059 Admin\Cosmos\INTERCHANGE FINAL DESIGN 2008\CADD\sp1layout.dgn
103059 SR1MALL

CONTRACT	COUNTY	FEDERAL AID PROJECT NO.	SHEET NO.	TOTAL SHEETS

GRAPHIC SCALE

(IN FEET)
1 inch = 50 ft.

REVISIONS

CD11830dwg.DWG
SCALE: 1"=40'
9/22/08

North

N 613000
E 432500

73+34.26
74+00
75+00
76+00
77+00
I 95

N 613500
E 433000

41+50
41+00
40+00
39+00
38+00
37+00
36+00
PC = 36+00
RAMP A

baseline b

baseline a

PREL. TRACING _____ DESIGN _____ CHKD. _____

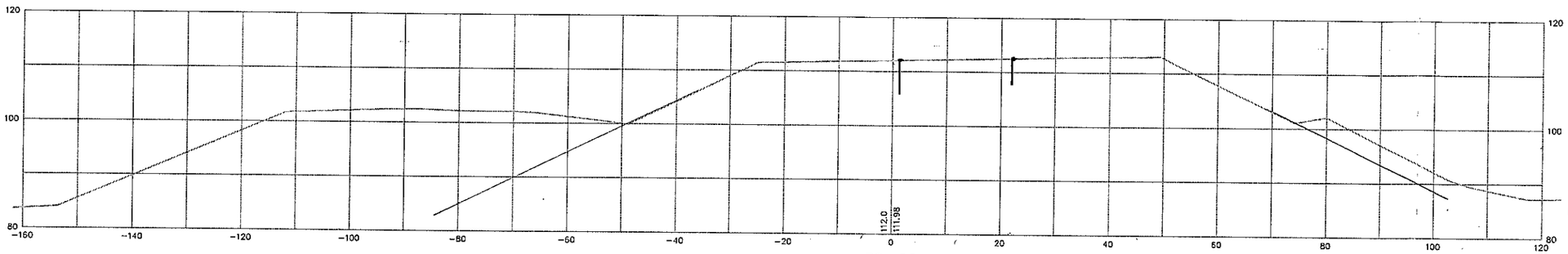
GRAPHIC SCALE

10 0 5 10 20 40

(IN FEET)
1 inch = 10 ft.

CONTRACT	COUNTY	FEDERAL AID PROJECT NO	SHEET NO.	TOTAL SHEETS

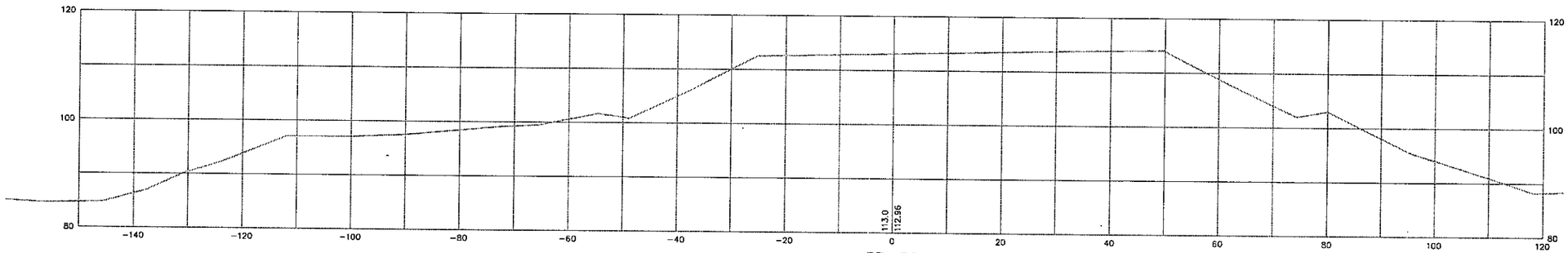
REVISIONS



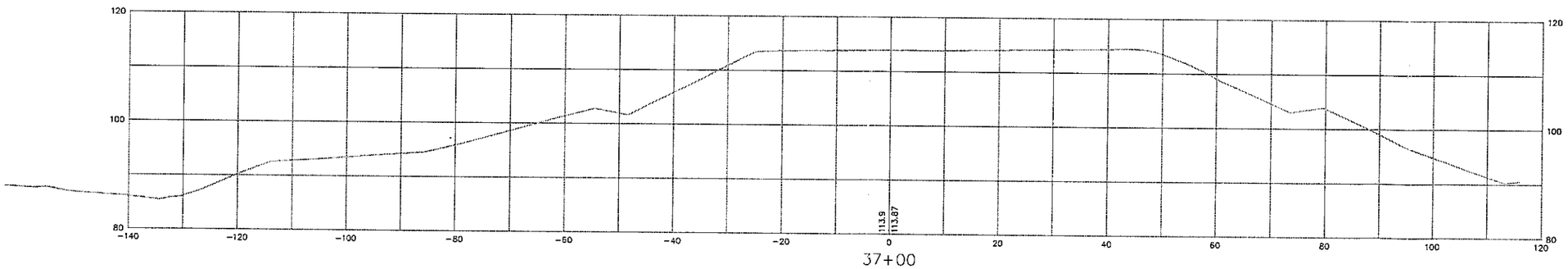
38+00

SP 1 & 2

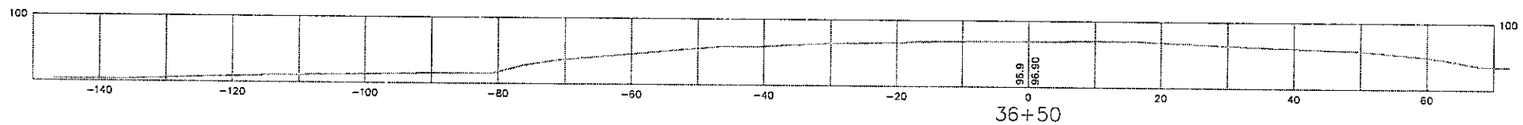
EL 86 GS



37+50



37+00



36+50

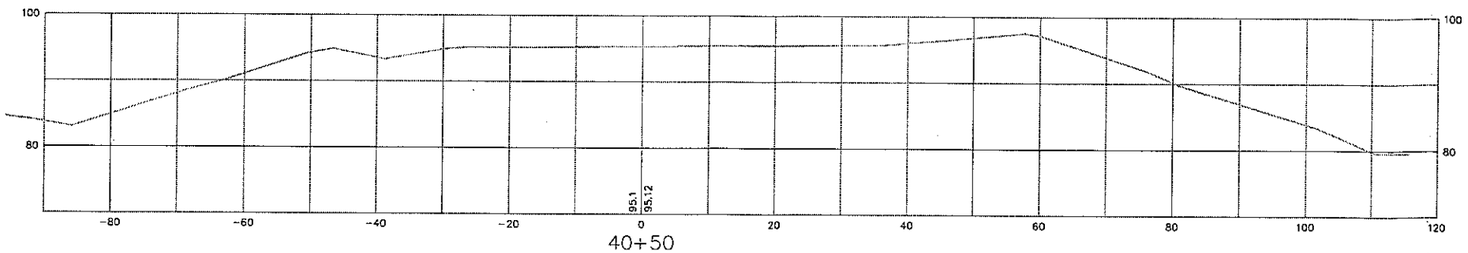
PREL. TRACING _____ DESIGN _____ CHKD. _____

CONTRACT	COUNTY	FEDERAL AID PROJECT NO	SHEET NO.	TOTAL SHEETS

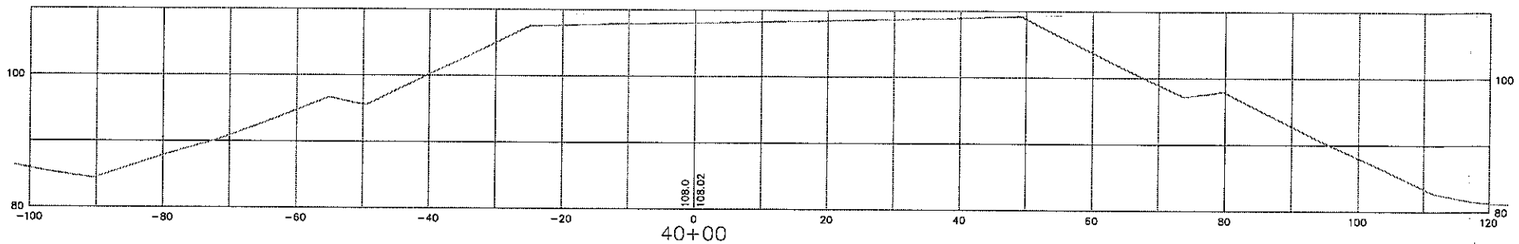
REVISIONS

GRAPHIC SCALE

(IN FEET)
1 inch = 10 ft.

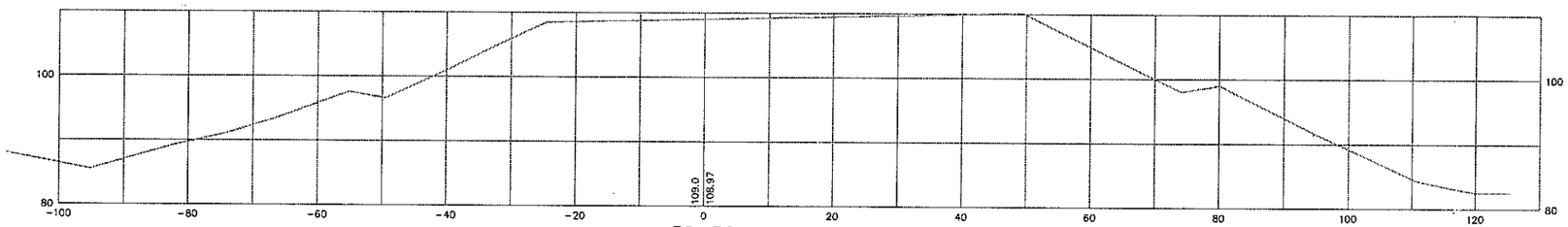


40+50

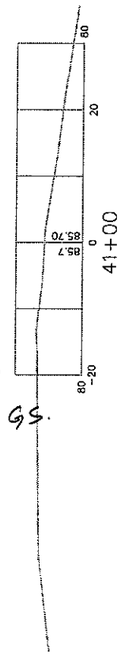


40+00

SP 5+6
EL+80 GS

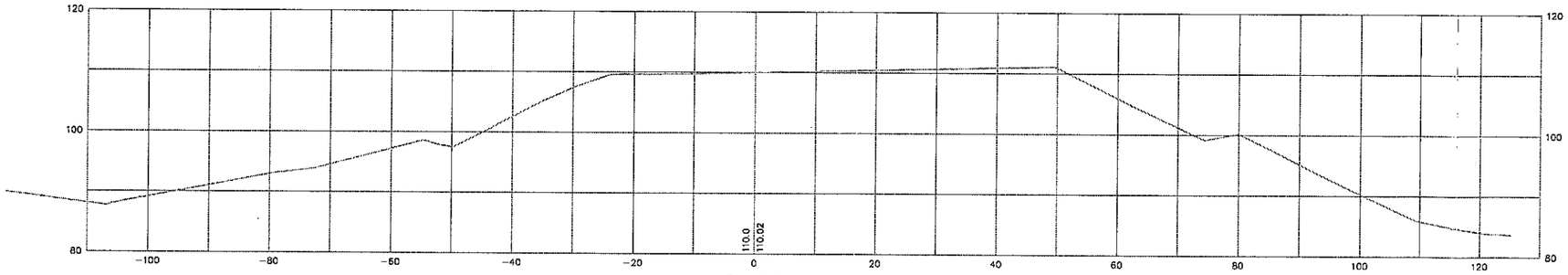


39+50



41+00

SP 3+4
EL 83 GS.



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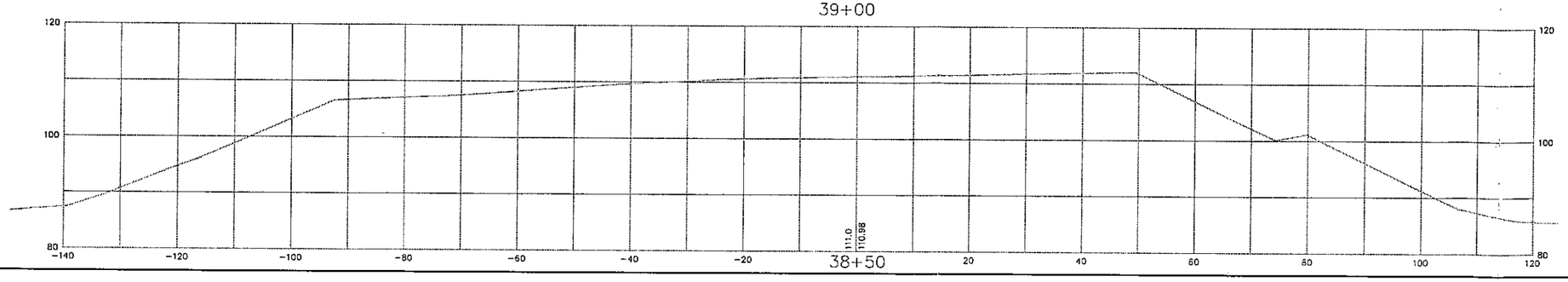


38+50

PREL. TRACING DESIGN CHKD.

Figure E-2a: Cumulative Displacement for SP-1

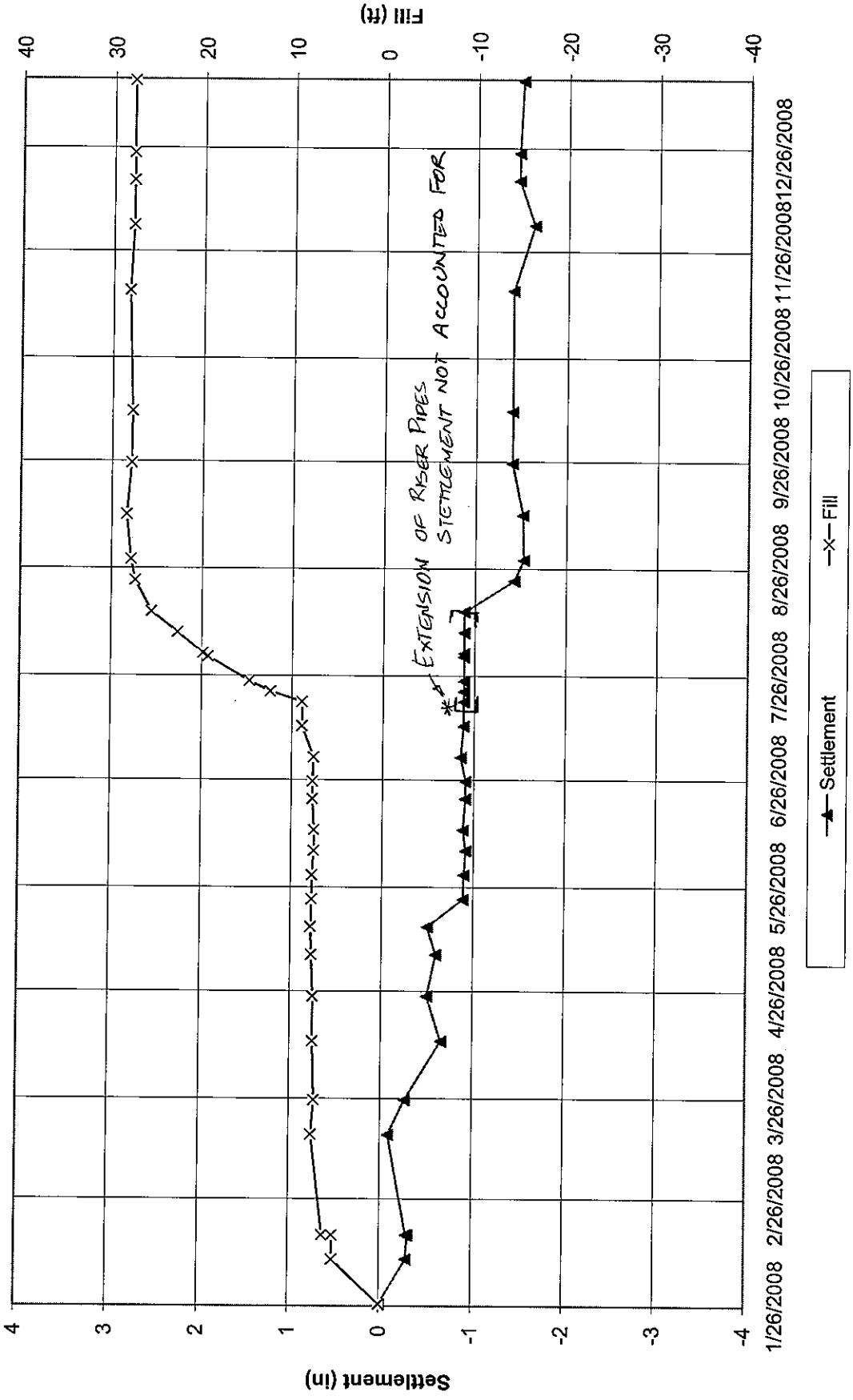


Figure E-2b: Cumulative Displacement for SP-2

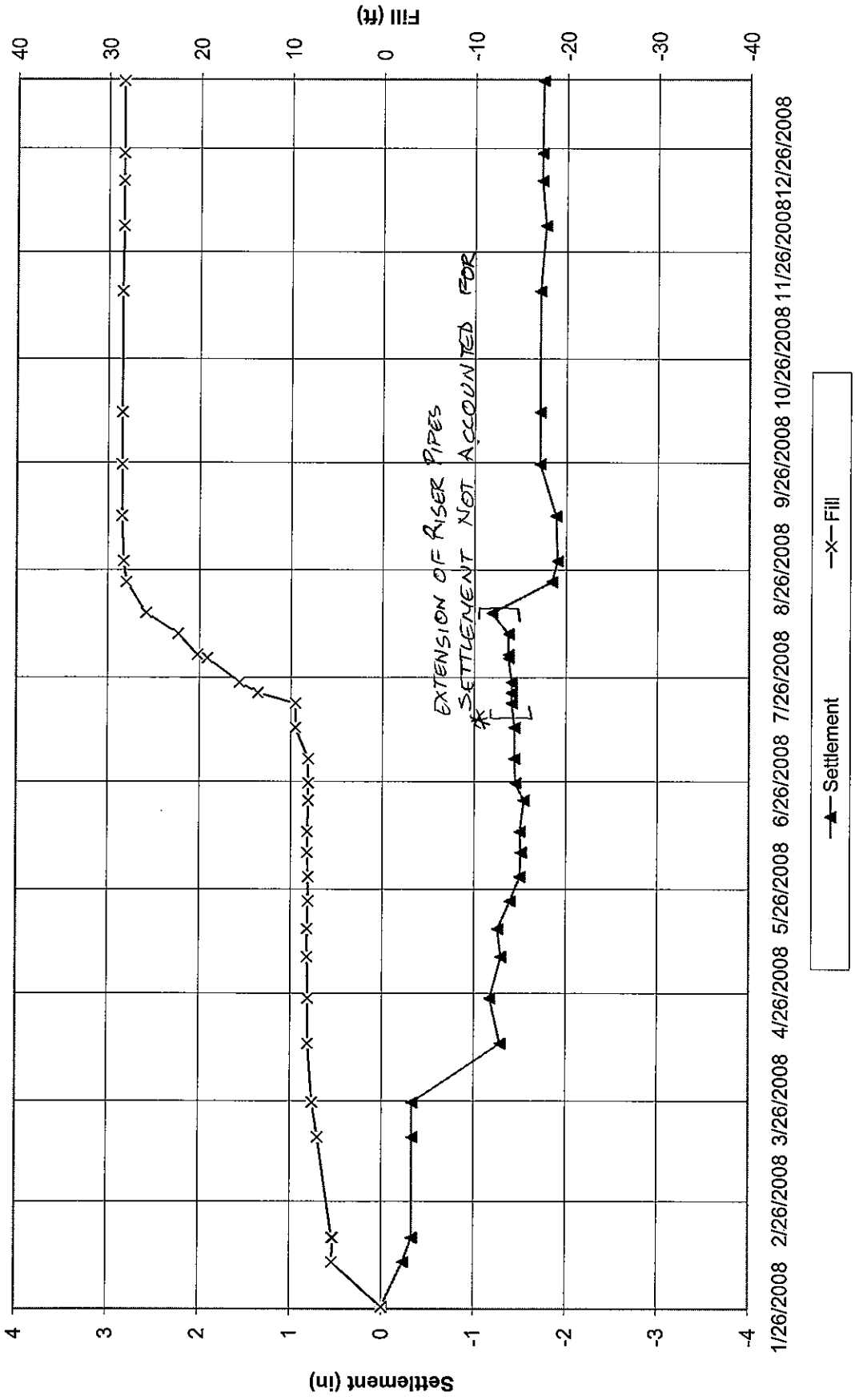


Figure E-2c: Cumulative Displacement for SP-3

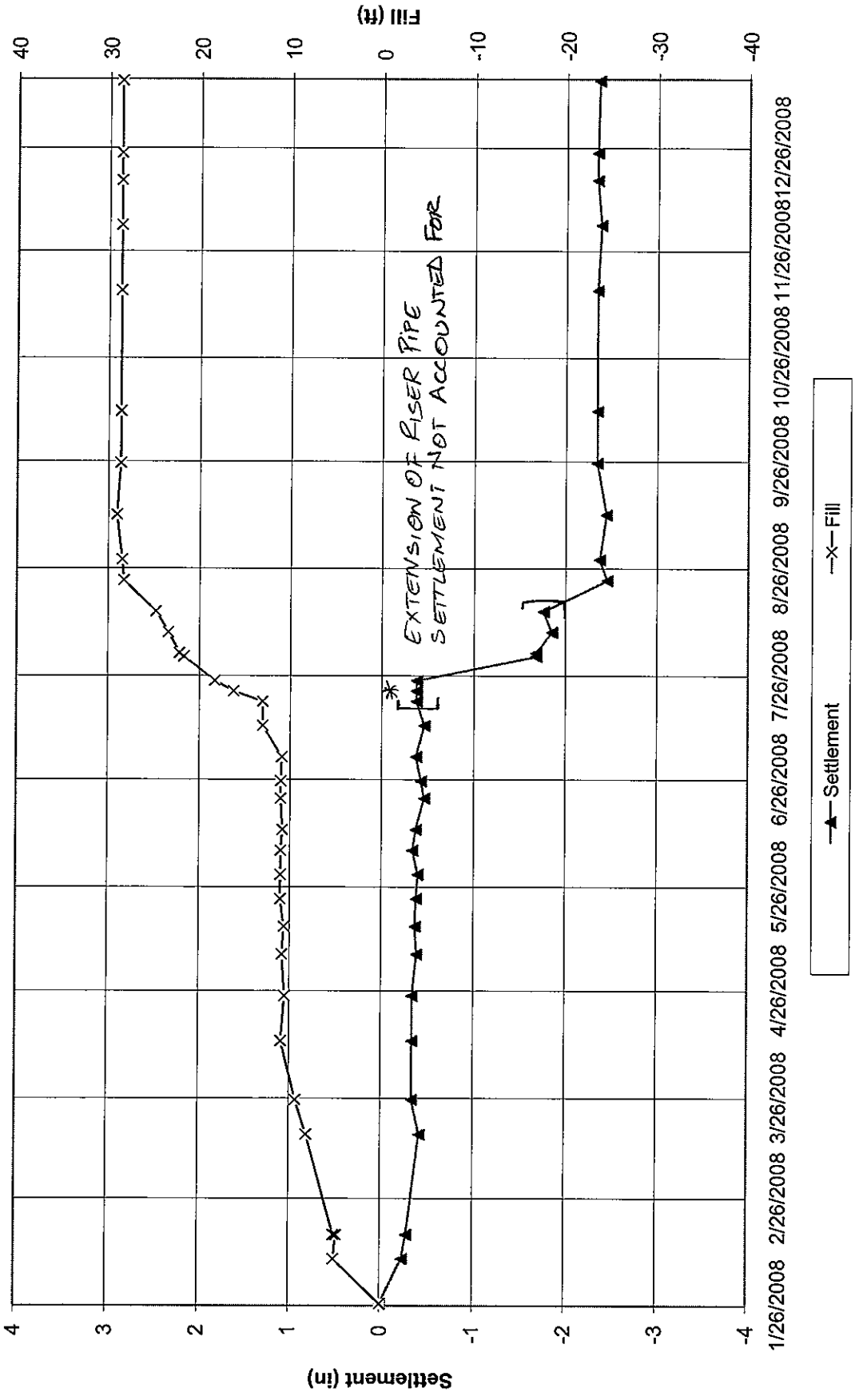


Figure E-2d: Cumulative Displacement for SP-4

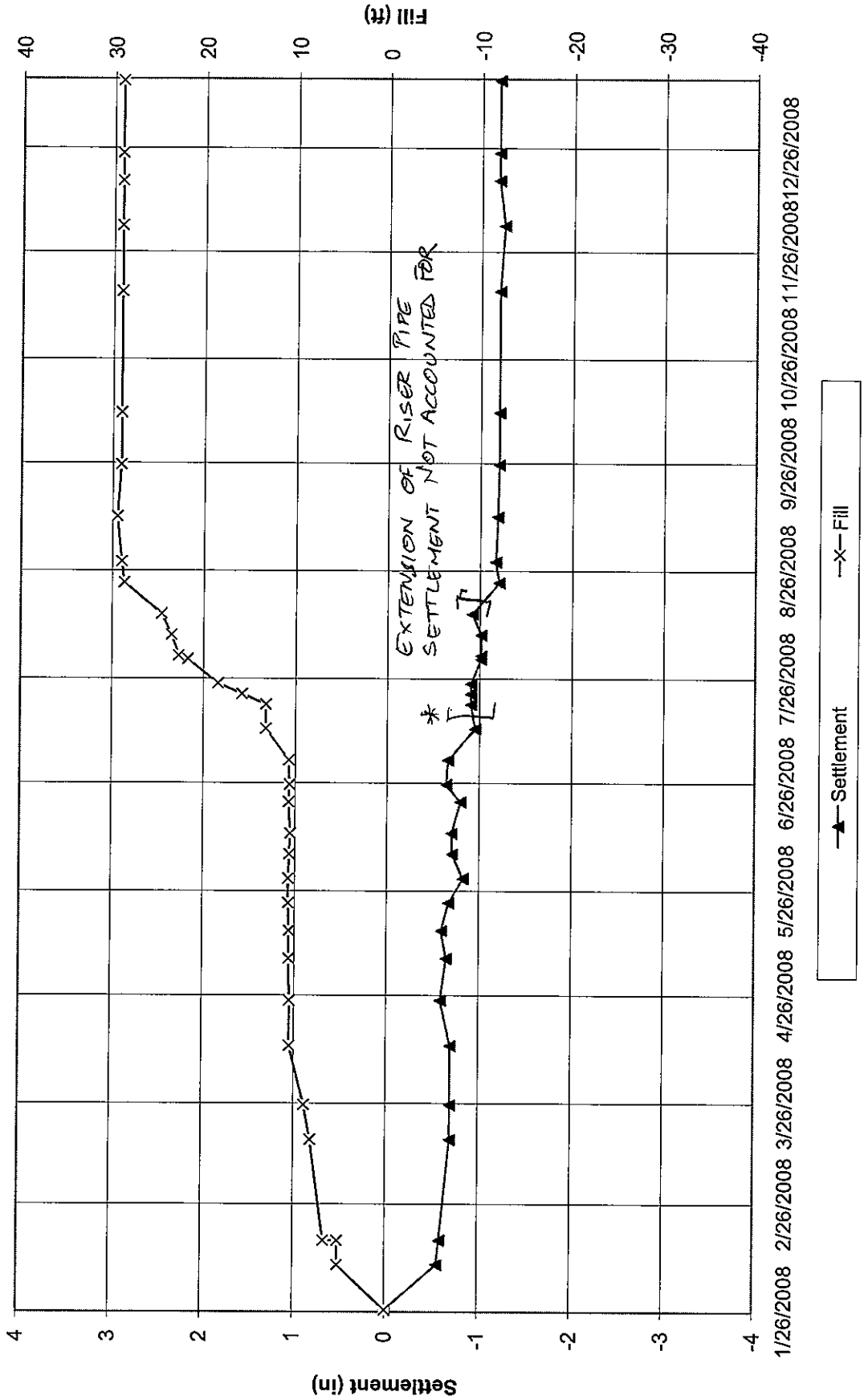


Figure E-2e: Cumulative Displacement for SP-5

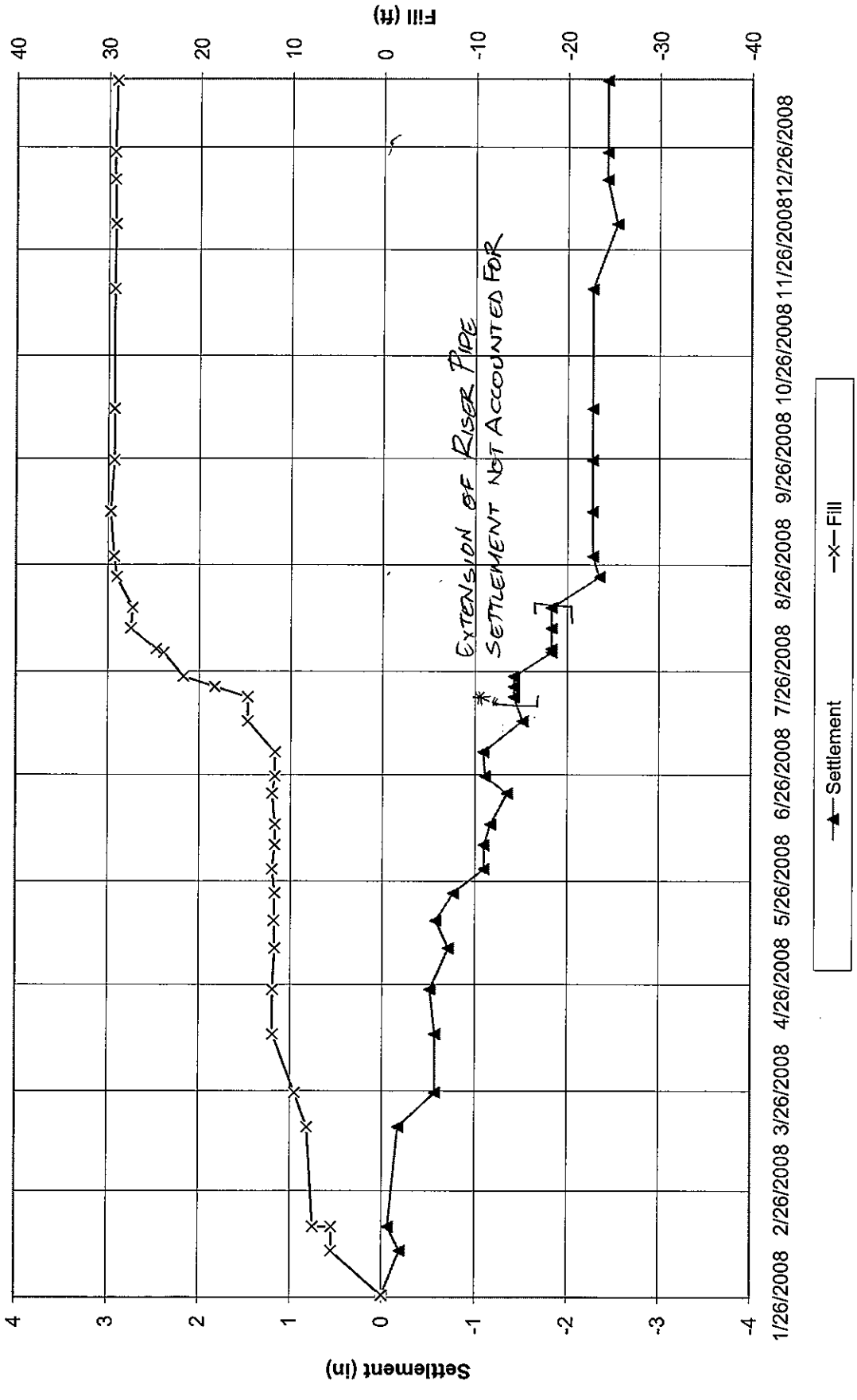
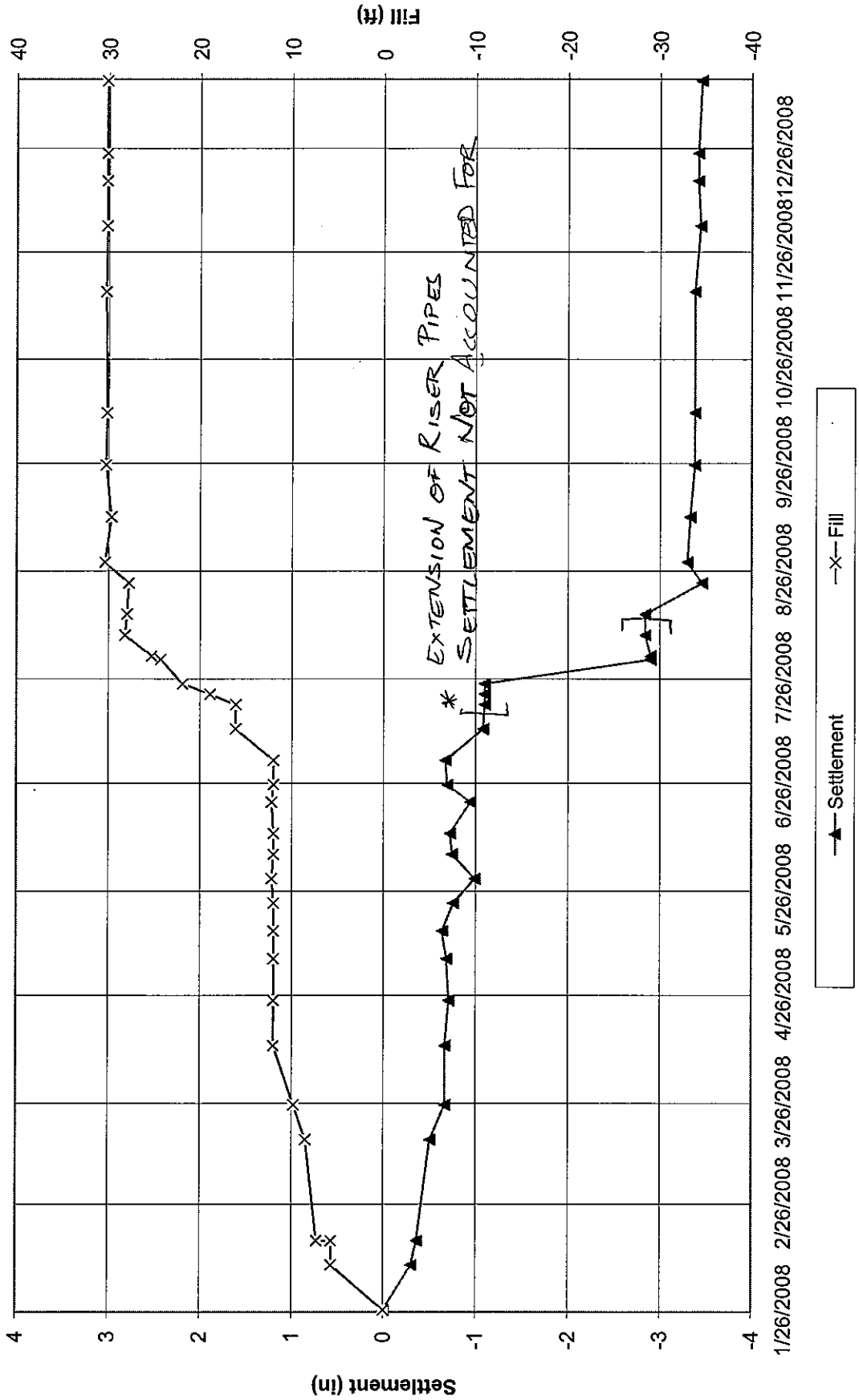


Figure E-2f: Cumulative Displacement for SP-6



RKK-150

CALCULATION CHECKLIST

Project: **SR 1/I-95 Interchange** Comm. No.: **103-059-27U**

Title of Calculation Set: **RW 9 Cost Analysis**

Project Manager: **EMK/JLT**

Calculations Prepared By: **SAB**

Calculation Checked By:

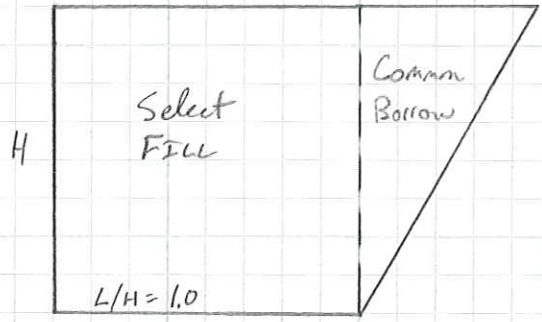
Computer Programs / Files: **MSEW 3.0, Excel**

Initial	Date	
		Subsurface Characterization approved by Project Manager
SAB	1/26/09	Calculations are neat, legible and understandable.
—	—	Table of Contents is provided.
SAB	1/26/09	Heading on each page filled out
SAB	1/26/09	The first page contains purpose of the calculation.
SAB	1/26/09	Symbols are defined.
SAB	1/26/09	References for data, methods, formulas and computer program names and version numbers are given.
SAB	1/26/09	Assumptions are listed and those that need to be verified later are Flagged.
SAB	1/26/09	Headings on front sheet of each set of computer input and output.
SAB	1/26/09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JLT	1-26-09	All calculations checked and each calculation sheet initialed by checker.
[illegible]	1/25/09	Calculation set reviewed by Project Manager.
		Has this calculation been superseded? Reference new calculation, if applicable.

This sheet is to be prepared by the originator of the calculation and attached to the front of the calculation set.

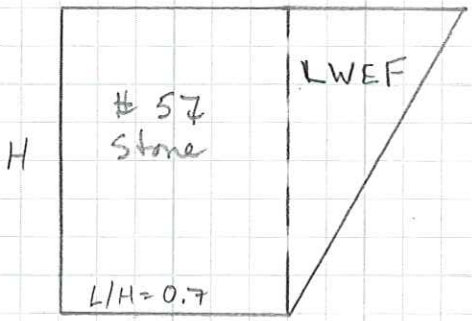
Options Summary: (Not to Scale)

Case 1:



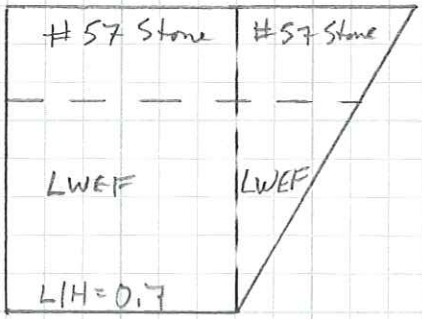
Additional Cost: $171,891
Additional Cost/Ft: $230

Case 2:



Additional Cost: $236,797
Additional Cost/ft: $320

Case 3:



Additional Cost: $470,938
Additional Cost/ft: $630

Geopiers/Stone Columns/Vibropiers:

Additional Cost: $438,571
Additional Cost/ft: $578

RKK-152

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject SR1/I-95 Interchange RW9 - Cost Analysis
Page 1 of
Cm. No. 103-059-270
Prepared By SAB Date 1/23/09 Checked By [illegible] Date 1-26-09

Objective: To evaluate Retain Wall 9 using the minimum reinforcement length to wall height ratio (L/H = 0.7) to compare the costs of special treatment options for the MSE walls.

References: 1) AASHTO LRFD Bridge Design Specifications, 4th ed.

Analysis:

Analyze STA 1252+00 where RW9 is tallest and not back-to-back with RW1.

→ Use MSEW 3.0 model from external stability analysis.

Wall Height = 29'

→ Change L/H = 0.7 & determine what material is required in reinforcement zone & retained wedge to satisfy external stability requirements.

⇒ Bearing capacity requirement NOT met using all #57 Stone in reinforced soil zone & retained wedge.

→ Perform iterations to determine the height of Lightweight Engineered Fill (LWEF) necessary to satisfy external stability requirements.

→ Calculate average unit weight for reinforcement zone using $\gamma_{57} = 105$ pcf & $\gamma_{LWEF} = 42$ pcf and the height of each material.

For 17' LWEF: $\gamma_{avg} = \left(\frac{17'}{29'}\right)(42) + \left(\frac{12'}{29'}\right)(105) = 68.1$ pcf

→ Calculate average unit weight for retained wedge using the proportional area for each material. Use 0 pcf for LWEF since it will not contribute any active earth pressure on MSE wall. (See attached spreadsheet, p. 2)

→ L/H = 1.0 w/ Select Fill in reinforcement zone previously calculated.

Subject: SR1/I-95 Interchange
RW 9 Cost Analysis

Prepared By: SAB

Comm. No.: 103-059-27U
Date: 1/23/2009

Unit Weights (pcf): No. 57: 105 LWEF: 42

Reinforced Zone:

	H (ft)	L/H	Reinforcement Length (ft)	Area (sf)	Average Unit Weight (pcf)
Total:	29	0.7	20.3	588.7	
LWEF:	17			345.1	68.1
No. 57:	12			243.6	

Wedge:

	H (ft)	Wedge Angle (deg)	Wedge Width (ft)	Area (sf)	Average Unit Weight (pcf)	Average Unit Weight for No Lateral Pressure from LWEF (pcf)
Total:	29	31	17.4	252.7		
LWEF:	17	31	10.2	86.8	83.4	
No. 57:	12	31	7.2	165.8		68.9

RKK-153

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 9\Final Design\RW 9 Cost Analysis.xls

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Subject SR1/I-95 Interchange
RW9 - Cost Analysis
Page 3 of
Cm. No. 103-059-270
Prepared By SAB Date 1/26/09 Checked By JBT Date 1-26-09

Results: For RW9 H=29', L/H=0.7 = 20.3', 17' LWEF, 12' #57 Stone:

Bearing Resistance: q_R = 4,105 psf σ_V = 4,003 psf => CDR=1.03 √OK

Sliding Resistance: CDR = 1.34 > 1.0 √OK

Overturning Resistance: CDR = 2.83 > 1.0 √OK

(See p. 4-12)

So for L/H=0.7, 17' LWEF & 12' #57 Stone in both reinforced & retained zones are required.

Cost Analysis: Extrapolate the above results for the full length of RW9. For second station, assume that the foundation soil can support 12' of #57 stone. So, the remaining height will be LWEF.

Compare the above case, along with 2 other cases, to the baseline case:

Case	L/H	Reinforced Zone	Retained Wedge
Baseline*	0.7	Select Fill	Common Borrow
1	1.0	Select Fill	Common Borrow
6	0.7	#57	LWEF
9	0.7	12' #57/LWEF	12' #57/LWEF

*Does not satisfy external stability.

→ For cost analysis, calculate material volumes for each wall section. Then calculate the total cost difference for additional/different materials as compared to the baseline case.

⇒ Calculations done using Excel. See p. 13.

Conclusion: Elongation the reinforcement straps and using conventional construction provides the most cost effective solution.

4

RKK-155
1-26-09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1252+00

Description:

Retaining Wall 9 DRAINED Analysis H = 29' L/H = 0.7 LWEF=17'
#57 Stone=12'

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....00 DRAINED Trial.BEN
Original date and time of creating this file: Mon Oct 20 13:34:41 2008

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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RKK-156
1-26-09

SOIL DATA

REINFORCED SOIL

Unit weight,	γ	68.1 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	38.0 °

RETAINED SOIL

Unit weight,	γ	68.9 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	38.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight,	$\gamma_{equiv.}$	85.0 lb/ft ^{3}
Equivalent internal angle of friction,	$\phi_{equiv.}$	24.0 °
Equivalent cohesion,	$c_{equiv.}$	0.0 lb/ft ^{2}

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2379 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2379 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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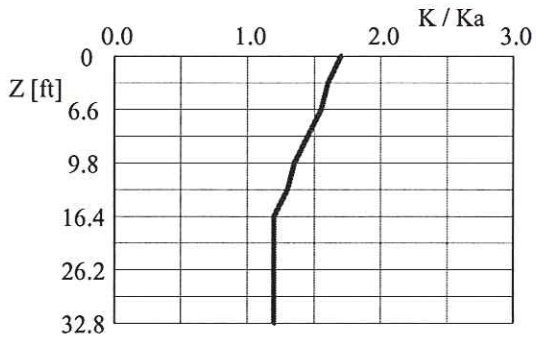
RKK-157
1-26-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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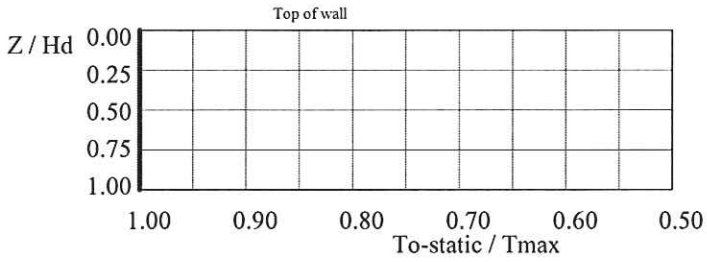
RKK-158
1-26-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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JPT RKK-159 1-26-09

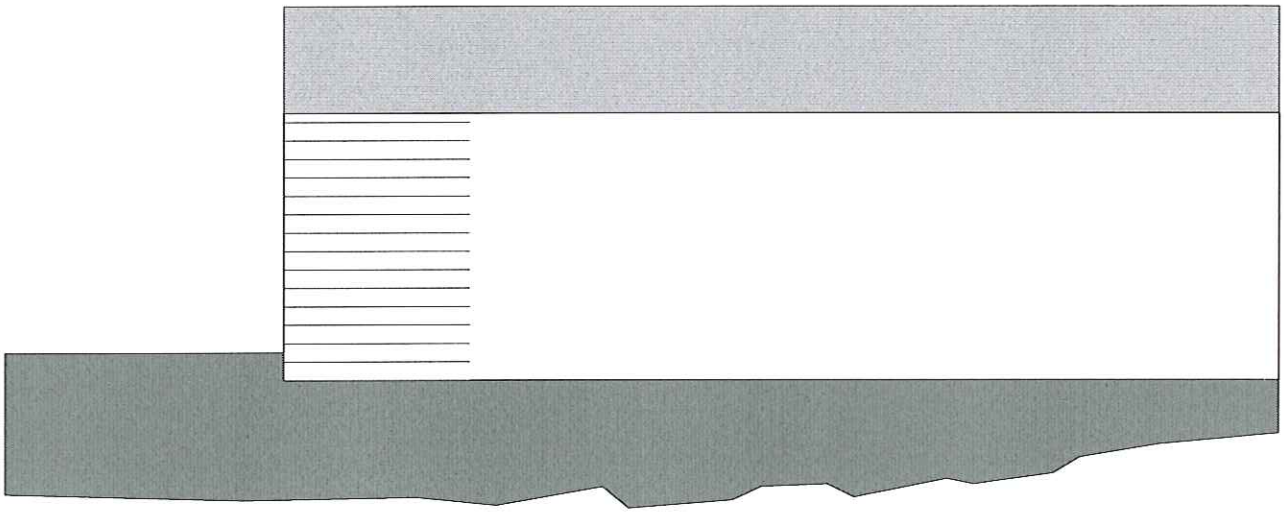
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	29.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 26.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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9

RKK-160
1-26-09

AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00
Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
	ϕ_b	0.65		0.65

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RKK-161 1-26-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.03, Meyerhof stress = 4003 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.336, Eccentricity, e/L = 0.1766, CDR-overturning = 2.83

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	20.30	1	N/A	3.91	4.35	4.346	2.820	2.319	0.1766	---
2	2.00	20.30	1	N/A	2.05	2.28	2.276	1.294	2.450	0.1565	---
3	4.00	20.30	1	N/A	2.19	2.43	2.429	1.198	2.597	0.1376	---
4	6.00	20.30	1	N/A	2.34	2.60	2.604	1.102	2.762	0.1199	---
5	8.00	20.30	1	N/A	2.53	2.81	2.806	1.007	2.949	0.1033	---
6	10.00	20.30	1	N/A	2.68	2.98	2.981	0.951	3.169	0.0879	---
7	12.00	20.30	1	N/A	2.81	3.12	3.120	0.963	3.437	0.0737	---
8	14.00	20.30	1	N/A	2.99	3.32	3.324	0.948	3.744	0.0607	---
9	16.00	20.30	1	N/A	3.23	3.59	3.593	0.980	4.093	0.0488	---
10	18.00	20.30	1	N/A	3.51	3.90	3.896	1.004	4.514	0.0381	---
11	20.00	20.30	1	N/A	3.85	4.28	4.278	0.996	5.030	0.0285	---
12	22.00	20.30	1	N/A	4.34	4.82	4.820	0.956	5.681	0.0201	---
13	24.00	20.30	1	N/A	5.09	5.65	5.653	0.870	6.525	0.0129	---
14	26.00	20.30	1	N/A	6.25	6.94	6.939	0.692	7.663	0.0069	---
15	28.00	20.30	1	N/A	8.14	9.05	9.049	0.323	9.282	0.0020	---

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RKK-162
1-26-09

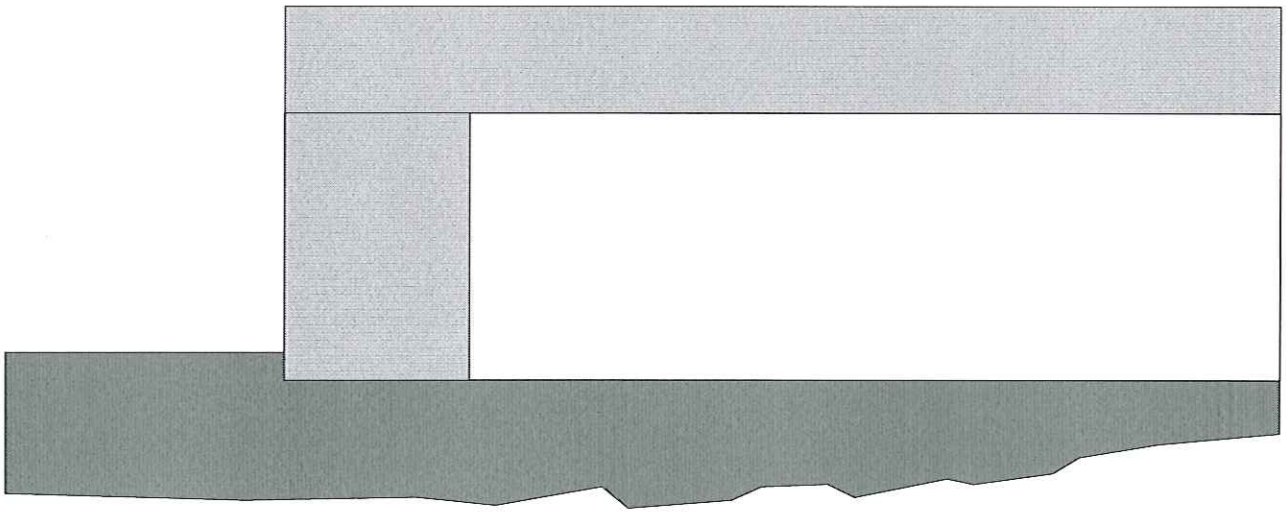
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Ultimate bearing capacity, q-ult	4105	N/A	[lb/ft ²]
Meyerhof stress, σ_V	4003.2	N/A	[lb/ft ²]
Eccentricity, e	2.28	N/A	[ft]
Eccentricity, e/L	0.112	N/A	
CDR calculated	1.03	N/A	
Base length	20.30	N/A	[ft]

$q_{ult} > \sigma_V$

CDR > 1 ∴ ok

L/H = 0.7



SCALE:

0 2 4 6 8 10[ft]

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RKK-163
1-26-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.336

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	20.30	2.319	N/A	1	---
2	2.00	20.30	2.450	N/A	1	---
3	4.00	20.30	2.597	N/A	1	---
4	6.00	20.30	2.762	N/A	1	---
5	8.00	20.30	2.949	N/A	1	---
6	10.00	20.30	3.169	N/A	1	---
7	12.00	20.30	3.437	N/A	1	---
8	14.00	20.30	3.744	N/A	1	---
9	16.00	20.30	4.093	N/A	1	---
10	18.00	20.30	4.514	N/A	1	---
11	20.00	20.30	5.030	N/A	1	---
12	22.00	20.30	5.681	N/A	1	---
13	24.00	20.30	6.525	N/A	1	---
14	26.00	20.30	7.663	N/A	1	---
15	28.00	20.30	9.282	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1766; Overturning: CDR-static = 2.83

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	20.30	0.1766	N/A	1	---
2	2.00	20.30	0.1565	N/A	1	---
3	4.00	20.30	0.1376	N/A	1	---
4	6.00	20.30	0.1199	N/A	1	---
5	8.00	20.30	0.1033	N/A	1	---
6	10.00	20.30	0.0879	N/A	1	---
7	12.00	20.30	0.0737	N/A	1	---
8	14.00	20.30	0.0607	N/A	1	---
9	16.00	20.30	0.0488	N/A	1	---
10	18.00	20.30	0.0381	N/A	1	---
11	20.00	20.30	0.0285	N/A	1	---
12	22.00	20.30	0.0201	N/A	1	---
13	24.00	20.30	0.0129	N/A	1	---
14	26.00	20.30	0.0069	N/A	1	---
15	28.00	20.30	0.0020	N/A	1	---

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Retaining Wall 9 Cost Analysis

Case	Wall Height Analyzed	L/H	Strap Length (ft)	Reinforcement Zone Material	Retained Wedge Material	Bearing Resistance CDR
1	29	1.0	29.0	Select FILL	Common Borrow	1.01
2	29	0.7	20.3	Select FILL	Common Borrow	0.46
3	29	0.7	20.3	Select FILL	Select FILL	0.57
4	29	0.7	20.3	Select FILL	# 57	0.67
5	29	0.7	20.3	Select FILL	LWEF[1]	0.95
6	29	0.7	20.3	# 57	LWEF[1]	1.10
7	29	0.7	20.3	LWEF[2]	Common Borrow	0.08
8	29	0.7	20.3	LWEF[2]	LWEF[1]	2.26
9	29	0.7	20.3	17' LWEF[2], 12' # 57	17' LWEF[2], 12' # 57	1.03

1

2

Material	Cost
LWEF	$103
Select FILL/#57	$75
Common Borrow	$30

Retaining Wall 9

Start STA	End STA	Length (ft)	Height (ft)	Width (ft)	L/H=1.0 Volume (cf)	L/H=0.7 Volume (cf)	Wedge Volume (cf)
1252+14	1252+68	54.04	30	30.0	48636	34045	12391
1252+68	1253+58	89.52	28	28.0	70184	49129	17880
1253+58	1254+46	88.52	26	26.0	59840	41888	15245
1254+46	1255+35	88.52	23.5	23.5	48885	34220	12454
1255+35	1256+23	88.52	21	21.0	39037	27326	9945
1256+23	1257+12	88.52	18.5	18.5	30296	21207	7718
1257+12	1258+00	88.52	16	16.0	22661	15863	5773
1258+00	1258+89	88.52	13.5	13.5	16133	11293	4110
1258+89	1259+50	61.32	11.5	11.5	8110	5677	2066
				TOTAL	343,781 cf	240,647 cf	87,589 cf
					12,733 cy	8,913 cy	3,244 cy

Case 9

L/H=0.7 Volume LWEF (cf)	L/H=0.7 Volume #57 (cf)	Wedge Volume LWEF (cf)	Wedge Volume #57 (cf)
20427	13618	4459	7927
28073	21055	5839	12042
22555	19333	4421	10824
16746	17474	2980	9474
11711	15615	1824	8121
7451	13756	954	6765
3966	11897	360	5413
1255	10038	53	4058
0	5677	0	2066
112,184 cf	128,463	20,889	66,689 cf
4,155 cy	4,758	774	2,470 cy

Additonal cost beyond conventional construction with L/H = 0.7:

				Total
Case 1:	$171,891		$0	$171,891
Case 6:		$0	$236,797	$236,797
Case 9:		$303,313	$167,626	$470,938

* Extend reinforcement Zone straps for most economical design.

RKK-164
1-26-09

CALCULATION CHECKLIST

Project: **SR 1/I-95 Interchange** Comm. No.: **103-059-27U**

Title of Calculation Set: **Retaining Wall 4 Analysis**

Project Manager: **EMK/JLT**

Calculations Prepared By: **SAB**

Calculation Checked By:

Computer Programs / Files: **MSEW 3.0, Slope/w, FoSSA**

Initial	Date	
		Subsurface Characterization approved by Project Manager
SAB	1/15/09	Calculations are neat, legible and understandable.
SAB	1/15/09	Table of Contents is provided.
SAB	1/15/09	Heading on each page filled out
SAB	1/15/09	The first page contains purpose of the calculation.
SAB	1/15/09	Symbols are defined.
SAB	1/15/09	References for data, methods, formulas and computer program names and version numbers are given.
SAB	1/15/09	Assumptions are listed and those that need to be verified later are Flagged.
SAB	1/15/09	Headings on front sheet of each set of computer input and output.
SAB	1/15/09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JLT	1-18-09	All calculations checked and each calculation sheet initialed by checker.
EMK	2/10/09	Calculation set reviewed by Project Manager.
		Has this calculation been superseded? Reference new calculation, if applicable.

This sheet is to be prepared by the originator of the calculation and attached to the front of the calculation set.

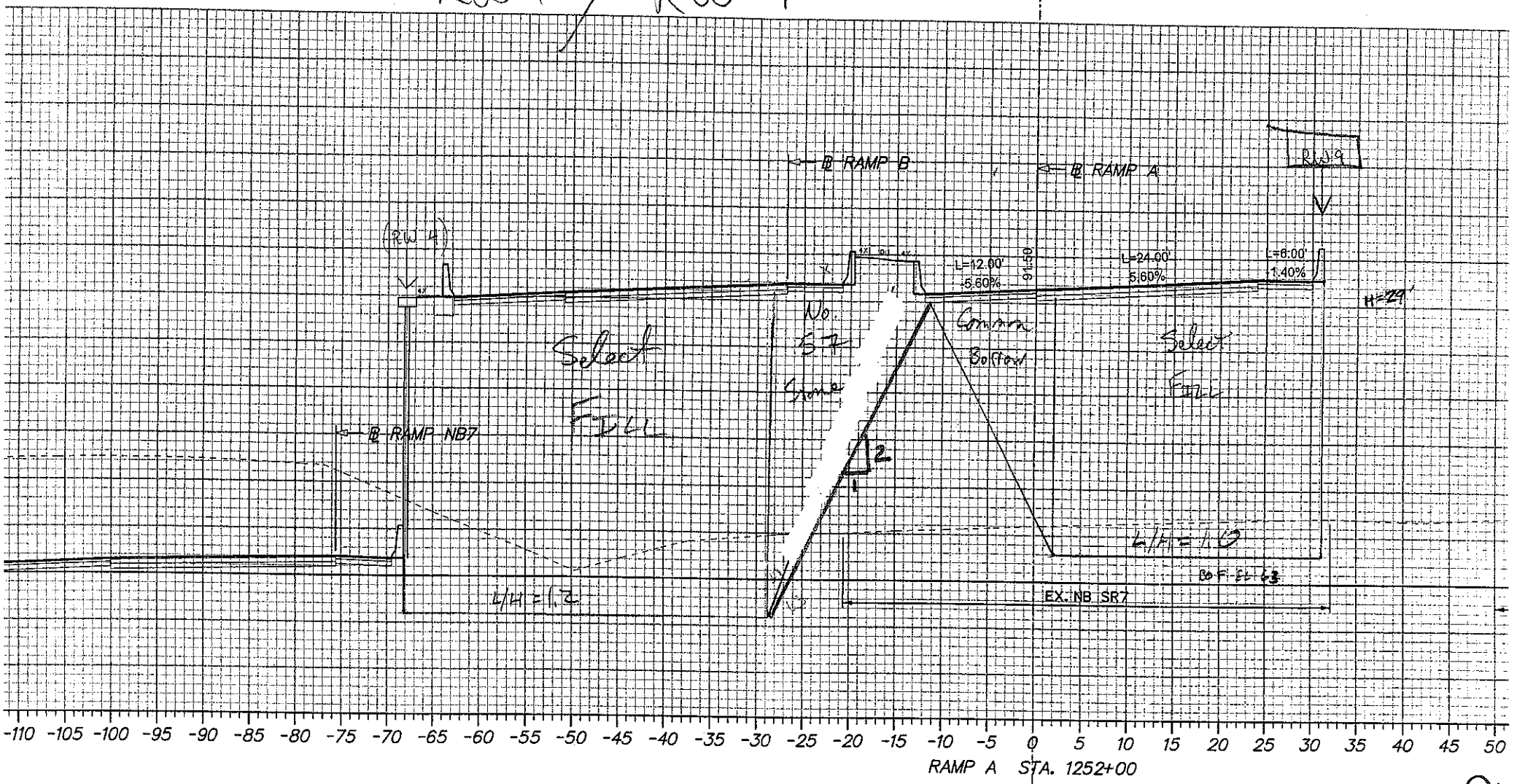
SR1/I-95 Interchange 103-051-240 12/17/08

RKK RW4-2

RW 9

JDT 1-2-09

RW4 / RW 9



JDT 1-18-09

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Subject I-95/SR1 Interchange
Retaining Wall 4 Stability Analysis
Page 1 of 43
Cm. No. 103-059-270
Prepared By SAB Date 9/23/08 Checked By JST Date 9-30-08
REV 12/9/08 JST 1-2-09

Objective: To evaluate the external and global stability of Retaining Wall 4. This wall is proposed to be a mechanically stabilized earth wall (MSE).

References: 1) AASHTO LRFD Bridge Design Specifications, 4th ed.
2) FHWA Publication No. FHWA-NHI-00-043 "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines."

Summary:

UNDRAINED ANALYSIS (L/H = 1.0)
Foundation Soil
γ_t = 130 pcf ϕ = 0° S_u = 2,500 psf
Factored Bearing Resistance, q_R = 8,355 psf
Factored Sliding Resistance, CDR = 1.79

DRAINED ANALYSIS
Foundation Soil
γ_t = 130 pcf ϕ' = 24° c' = 0 psf
* Need to increase Reinforcement length to L/H = 1.2 *
* Reinforced Soil Zone must be No. 57 Stone *
→ q_R = 5,353 psf
Sliding CDR = 1.20

With L/H = 1.2; Select Soil Reinforced Soil, & No. 57 stone in the Retained wedge:

UNDRAINED
q_R = 9,355 psf
Sliding CDR = 1.49

DRAINED
q_R = 5,851 psf
Sliding CDR = 2.56

← More cost effective option.

∴ Use Select on Reinforced Zone & 57 in wedge.

- Dewatering will be required during Const.

I-95/SR1 Interchange 103-059-27U 9/23/08
RW-4 Analysis REV 12/9/08

Wall Details:

TABLE XX Dimensions of Retaining Wall 4						
SR-7 NB STA	Ramp A	Design Wall Height (ft)	Bottom of Leveling Pad EL.	Top of Wall EL.	Front Slope/ Slope Height (ft)	Back Slope/ Slope Height (ft)
630+00	1255+00	1.6	60.5	62.1	SR-7 NB	2(H):1(V)/ 16.0
630+50	1254+50	4.6	60.5	65.1	SR-7 NB	2(H):1(V)/ 15.0
631+00	1254+00	9.3	59.5	68.8	SR-7 NB	2(H):1(V)/ 13.3
631+50	1253+50	13.6	59.5	73.1	SR-7 NB	2(H):1(V)/ 11.0
632+00	1253+00	18.5	59.5	78.0	SR-7 NB	2(H):1(V)/ 8.0
→ 632+50	1252+50	~~24.2~~ 25 *	59.5	83.7	SR-7 NB	2(H):1(V)/ 4.0 ←
633+00	1252+00	30.3	59.5	89.8	SR-7 NB	Horizontal

* Height increased to ensure 3' embedment depth below proposed ground surface elevation.

Ramp A STA 1252+50 chosen for analysis: Tallest wall section with a 2(H):1(V) Backslope.
(SR-7 NB STA. 632+50)

- Reinforcement Length, L = ~~26~~ 40' (assume L/H = ~~0.98~~ 1.0) Slant w/ 0.8 DW not used; increase to 1.0 + 1.2
- Traffic LL = 250 psf
- BOF EL = ~~EL 58.0~~ (modified for 3' embedment depth)
(E = 3')

RKK RW-4 JDT 9-30-08 JDT 1-2-09

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Subject I-95/SR 1 Interchange — RW 4 Analysis
Page 3 of 34
Cm. No. 103-059-27U
Prepared By SAB Date 9/23/08 REV 12/9/08 Checked By JJT Date 1-2-09
EMM 2/9/09

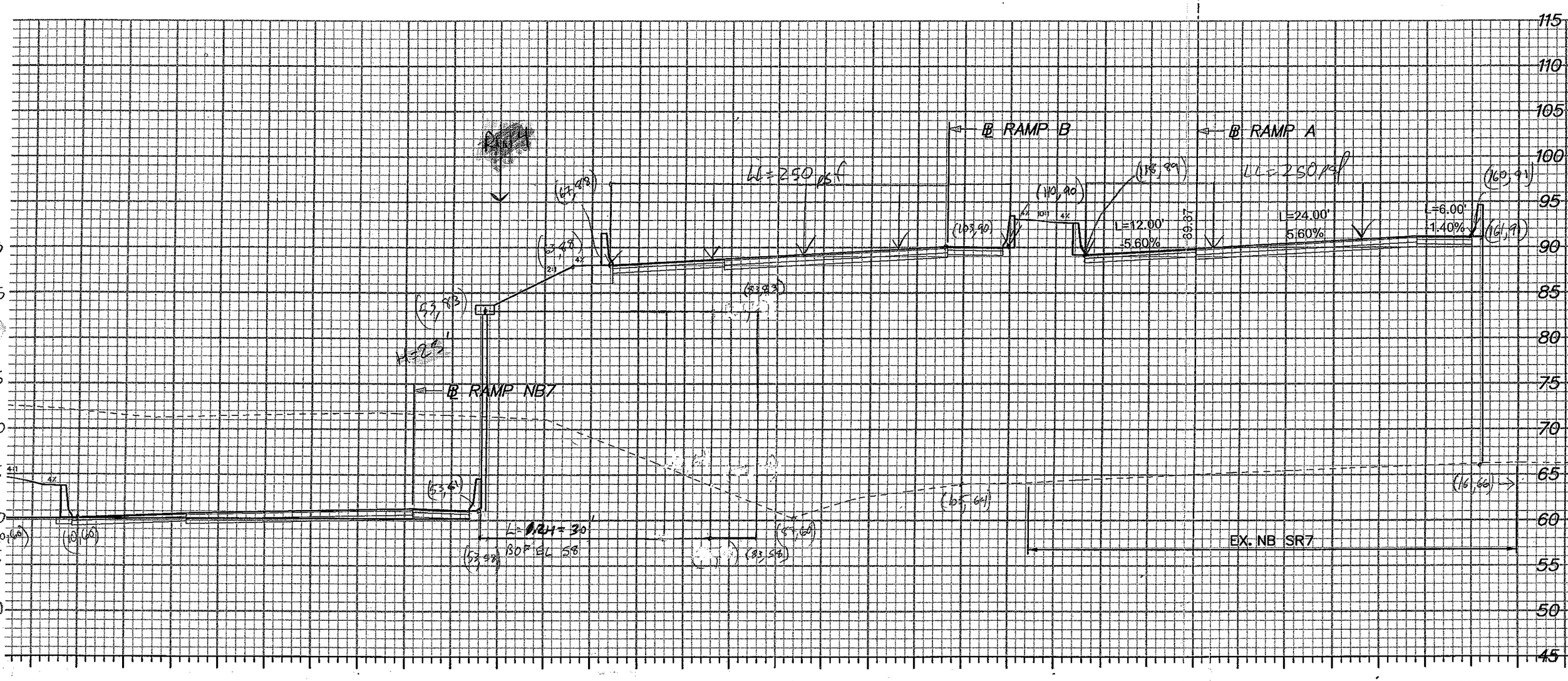
Soils: (See attached fence diagram, page 4)

Soil	γ (pcf)	ϕ' (deg)	c' (psf)	S_u (psf)	EL (ft)
Reinforced Soil (Type B)	125	34°	0	–	
Retained Soil (Type F)	130	28°	0	–	
Foundation Soil (IIa)	130	24°	–	2,500 (1)	58 - 38
IIa	130	24°	–	2,500	38 - 18
IIa	130	24°	–	3,500	18 - 0
IIa	130	24°	–	5,000	0 - -15
IIb	130	34°	0	–	Below -15
Water	62.4				62 (above proposed BOF EL) (2)

↳ This water level is consistent with RW9 boring's at surrounding areas 4' ↑ BOF

*(1): S_u = 2,500 psf is the minimum undrained shear strength from ICPT-08.

I-95/SR7 Interchange
RW 4

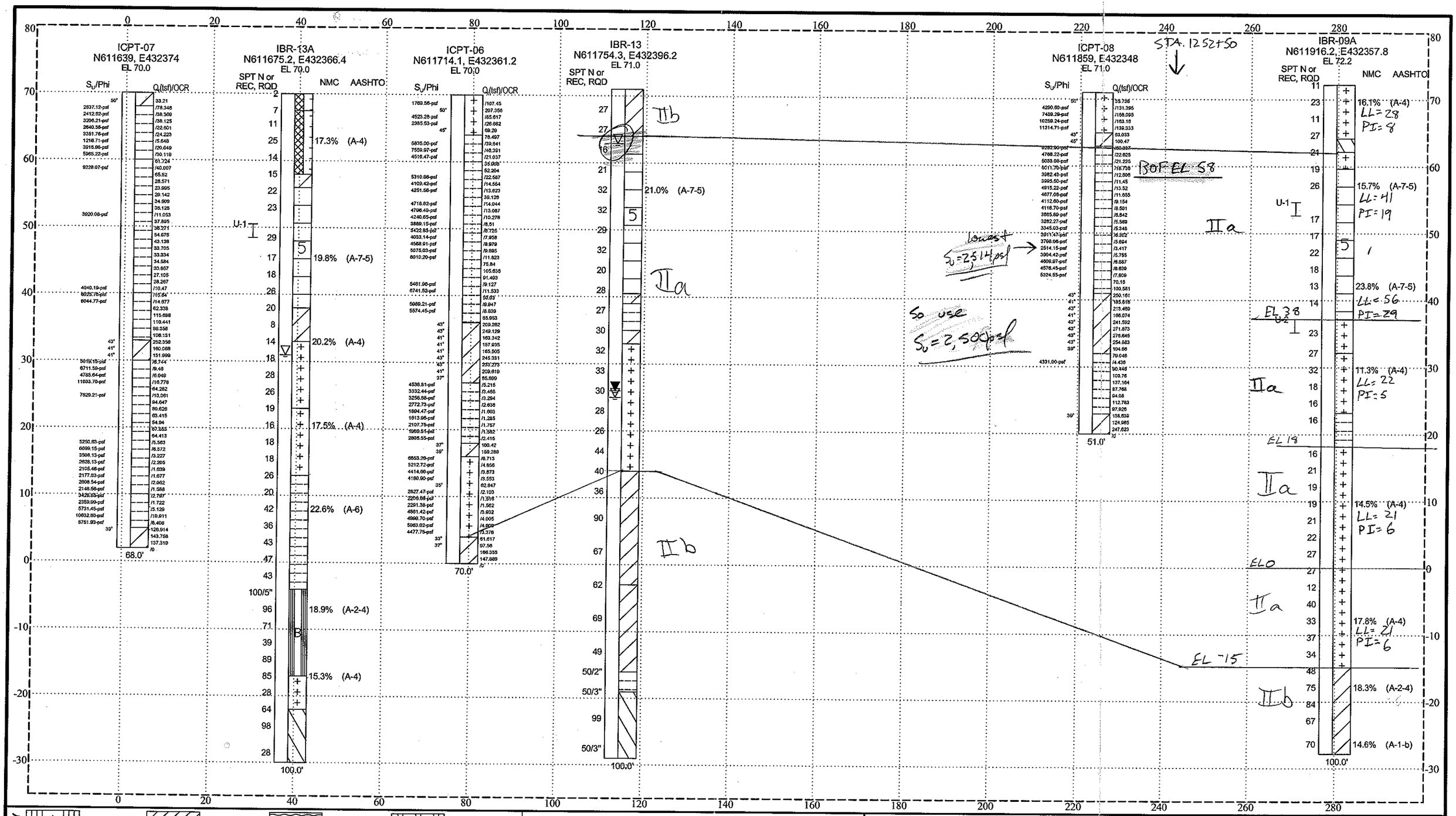


RAMP A STA. 1252+50

RW STA 632+50
(SR 7)

SR1 / I-95 Interchange 103-059-27U 12/9/08

RKK RW4-7



AASHTO SOIL KEY

A-1-a	A-2-5	A-5	A-8
A-1-b	A-2-6	A-6	Asphalt
A-3	A-2-7	A-7-5	FILL
A-2-4	A-4	A-7-6	Decomposed Rock

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data
Retaining Wall 4

Figure No.

Drawn: SAB | Approved: EMK | Date: 9/23/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE 195 GINT FILE.GPJ RKK_CURRENT.GDT 9/23/08

RUMMEL, KLEPPER & KAHL, LLP
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Subject SR1/I-95 Interchange RW 4 Analysis
Page 6 of
Cm. No. 103-059-27U
Prepared By SAB Date 12/9/08 Checked By JDT Date 1-2-09
CM 2/9/09

External Stability: Performed using MSEW 3.0 (see attached output, p. 7-24)
* See p. 12 for LRFD resistance factors used.

Undrained: * Assume L/H = 1.0 will be required for drained conditions. see p. 7-15

Results: Bearing capacity: Factored Bearing Resistance, q_R = 8,355 psf
Megerhof Stress, σ_v = 6,477 psf
CDR = 1.29 > 1.0 ✓ OK $q_R > \sigma_v$
$CDR = \frac{q_R}{\sigma_v}$

Sliding: CDR = 1.79 > 1.0 ✓ OK

Overturning: CDR = 3.37 > 1.0 ✓ OK

Drained: * Reinforcement must be lengthened to L/H = 1.2
* No. 57 stone must be used as backfill in the MSE reinforcement zone.
→ see p. 16-24

Results: Bearing Capacity: Factored Bearing Resistance, q_R = 5,353 psf
Megerhof Stress, σ_v = 5,302.5 psf
CDR = 1.01 > 1.0 ✓ OK $q_R > \sigma_v$ ✓ OK
$CDR = \frac{q_R}{\sigma_v}$

Sliding: CDR = 1.20 > 1.0 ✓ OK

Overturning: CDR = 4.08 > 1.0 ✓ OK

* Try Select Fill in Reinforced Zone → No 57 in wedge See pg 25

JDT 1-2-09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1252+50

Description:

Retaining Wall 4 UNDRAINED Analysis H=25' L/H=1.0

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....252+50 UNDRAINED.BEN
Original date and time of creating this file: Tue Dec 09 08:19:30 2008

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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JJT 1-2-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select Soil
Design value of internal angle of friction, ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ	130.0 lb/ft ^{3}	Common Borrow – Type E
Design value of internal angle of friction, ϕ	28.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}
Equivalent internal angle of friction, $\phi_{equiv.}$	0.0 °
Equivalent cohesion, $c_{equiv.}$	2500.0 lb/ft ^{2}

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3648 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 5.14 N γ= 0.00

SEISMICITY

Not Applicable

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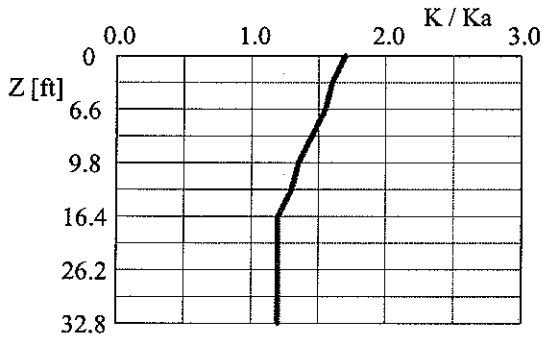
JGT 1-2-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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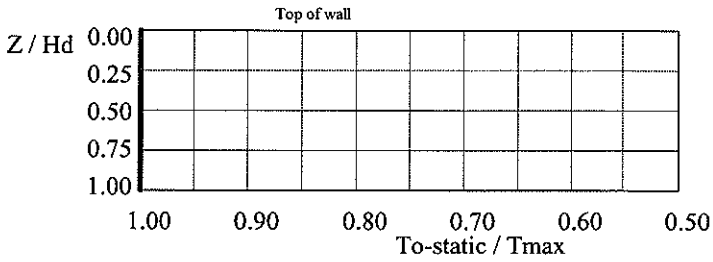
JGT 1-2-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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JGT 1-2-09

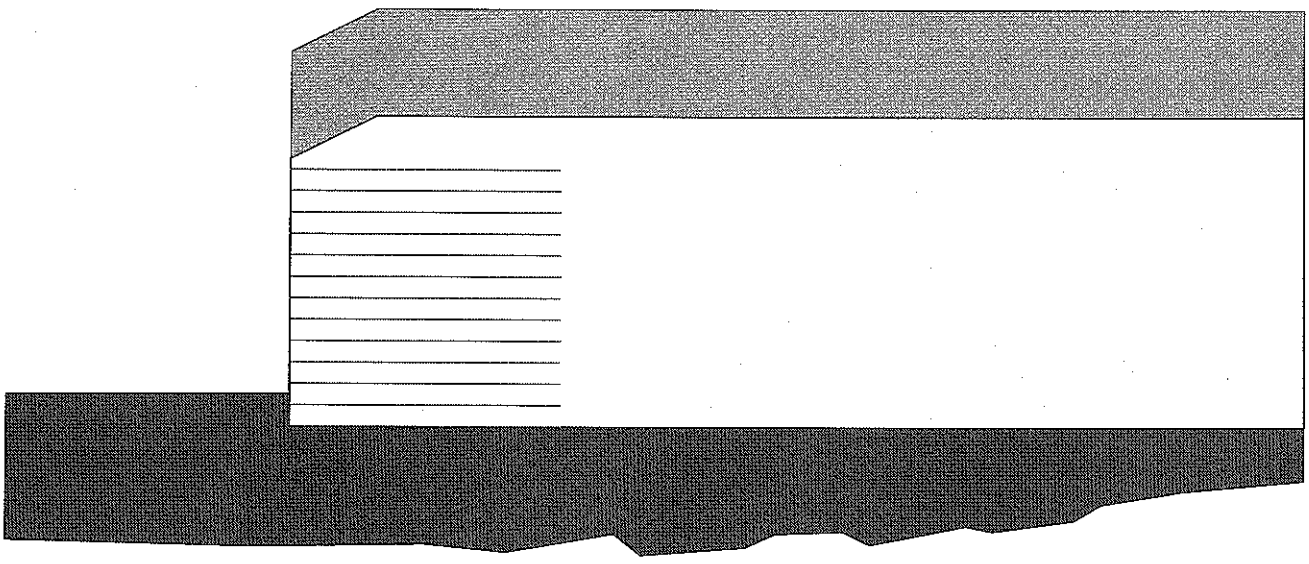
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	25.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 22.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	4.0	[ft]	Broken back equivalent angle, I = 4.57° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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JGT 1-2-09

AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00

Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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JBT 1-2-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.29, Meyerhof stress = 6477 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.790, Eccentricity, e/L = 0.1318, CDR-overturning = 3.37

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	25.00	1	N/A	1.98	2.20	2.196	3.149	1.783	0.1318	---
2	2.00	25.00	1	N/A	1.04	1.16	1.155	1.475	1.890	0.1136	---
3	4.00	25.00	1	N/A	1.12	1.24	1.242	1.400	2.010	0.0964	---
4	6.00	25.00	1	N/A	1.18	1.32	1.315	1.383	2.152	0.0803	---
5	8.00	25.00	1	N/A	1.24	1.37	1.372	1.472	2.315	0.0650	---
6	10.00	25.00	1	N/A	1.31	1.46	1.456	1.537	2.500	0.0507	---
7	12.00	25.00	1	N/A	1.41	1.57	1.566	1.573	2.716	0.0371	---
8	14.00	25.00	1	N/A	1.52	1.69	1.687	1.558	2.974	0.0243	---
9	16.00	25.00	1	N/A	1.65	1.84	1.838	1.596	3.286	0.0119	---
10	18.00	25.00	1	N/A	1.84	2.05	2.049	1.648	3.669	-0.0004	---
11	20.00	25.00	1	N/A	2.13	2.37	2.368	1.693	4.148	-0.0135	---
12	22.00	25.00	1	N/A	2.56	2.84	2.843	1.707	4.756	-0.0290	---
13	24.00	25.00	1	N/A	3.22	3.58	3.575	1.646	5.518	-0.0520	---

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807 1-2-09

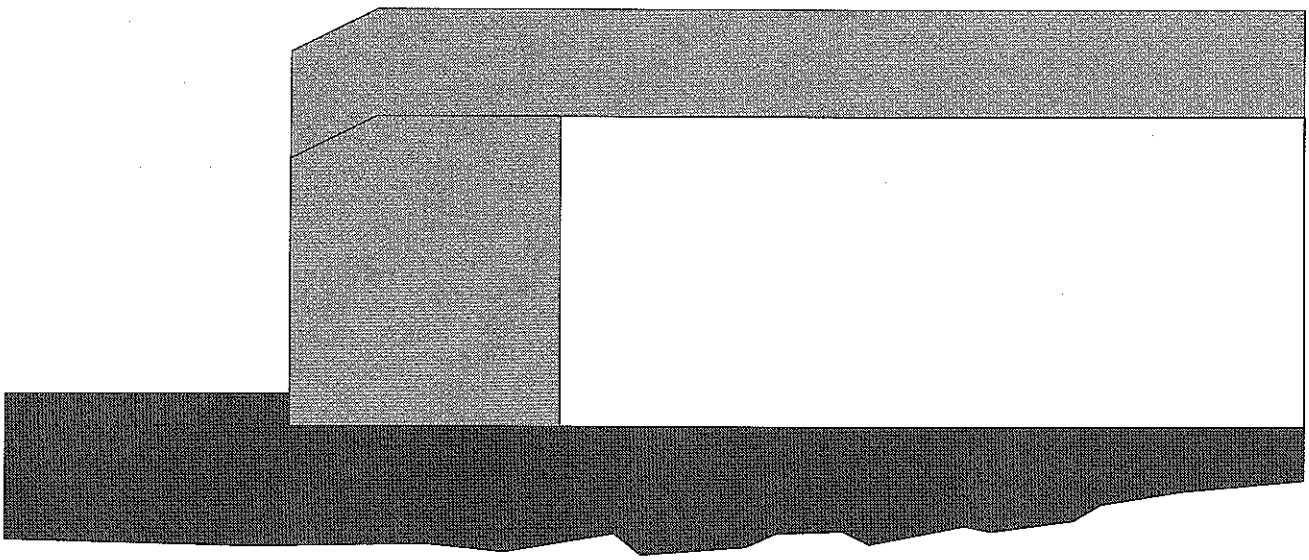
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	8355	N/A	[lb/ft ²]
Meyerhof stress, σ_V	6476.6	N/A	[lb/ft ²]
Eccentricity, e	2.21	N/A	[ft]
Eccentricity, e/L	0.088	N/A	
CDR calculated	1.29	N/A	
Base length	25.00	N/A	[ft]

$q_{ult} > \sigma_V$ 1.5K

$CDR = \frac{q_{ult}}{\sigma_V}$

* Drained Analysis Governs



SCALE:

0 2 4 6 8 10[ft]

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JBT 1-2-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.790

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	25.00	1.783	N/A	1	---
2	2.00	25.00	1.890	N/A	1	---
3	4.00	25.00	2.010	N/A	1	---
4	6.00	25.00	2.152	N/A	1	---
5	8.00	25.00	2.315	N/A	1	---
6	10.00	25.00	2.500	N/A	1	---
7	12.00	25.00	2.716	N/A	1	---
8	14.00	25.00	2.974	N/A	1	---
9	16.00	25.00	3.286	N/A	1	---
10	18.00	25.00	3.669	N/A	1	---
11	20.00	25.00	4.148	N/A	1	---
12	22.00	25.00	4.756	N/A	1	---
13	24.00	25.00	5.518	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1318; Overturning: CDR-static = 3.37

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	25.00	0.1318	N/A	1	---
2	2.00	25.00	0.1136	N/A	1	---
3	4.00	25.00	0.0964	N/A	1	---
4	6.00	25.00	0.0803	N/A	1	---
5	8.00	25.00	0.0650	N/A	1	---
6	10.00	25.00	0.0507	N/A	1	---
7	12.00	25.00	0.0371	N/A	1	---
8	14.00	25.00	0.0243	N/A	1	---
9	16.00	25.00	0.0119	N/A	1	---
10	18.00	25.00	-0.0004	N/A	1	---
11	20.00	25.00	-0.0135	N/A	1	---
12	22.00	25.00	-0.0290	N/A	1	---
13	24.00	25.00	-0.0520	N/A	1	---

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SDT 1-2-09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1252+50

Description:

Retaining Wall 4 DRAINED Analysis H = 25' L/H = 1.2 Reinforced Soil Zone = No. 57 Stone

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....2+50 DRAINED L=H.BEN
Original date and time of creating this file: Tue Dec 09 09:17:11 2008

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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SBT 1-2-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ 105.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ 34.0°

No 57 Stone

RETAINED SOIL

Unit weight, γ 130.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ 28.0°

Common Borrow Type F

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$ 130.0 lb/ft ^{3}
Equivalent internal angle of friction, $\phi_{equiv.}$ 24.0°
Equivalent cohesion, $c_{equiv.}$ 0.0 lb/ft ^{2}

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3648 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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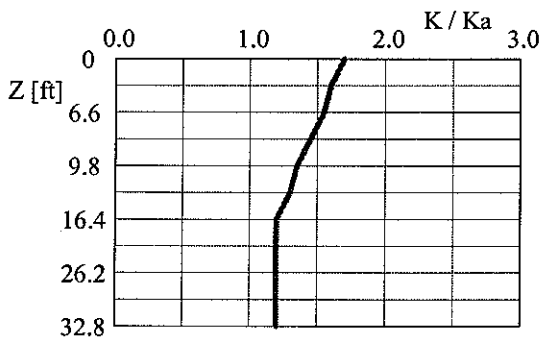
SJT 1-2-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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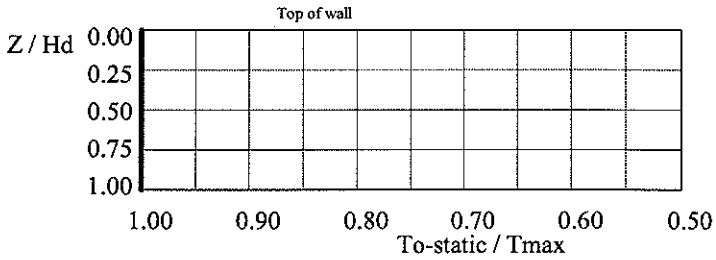
SJT 1-2-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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SDT
1-2-09

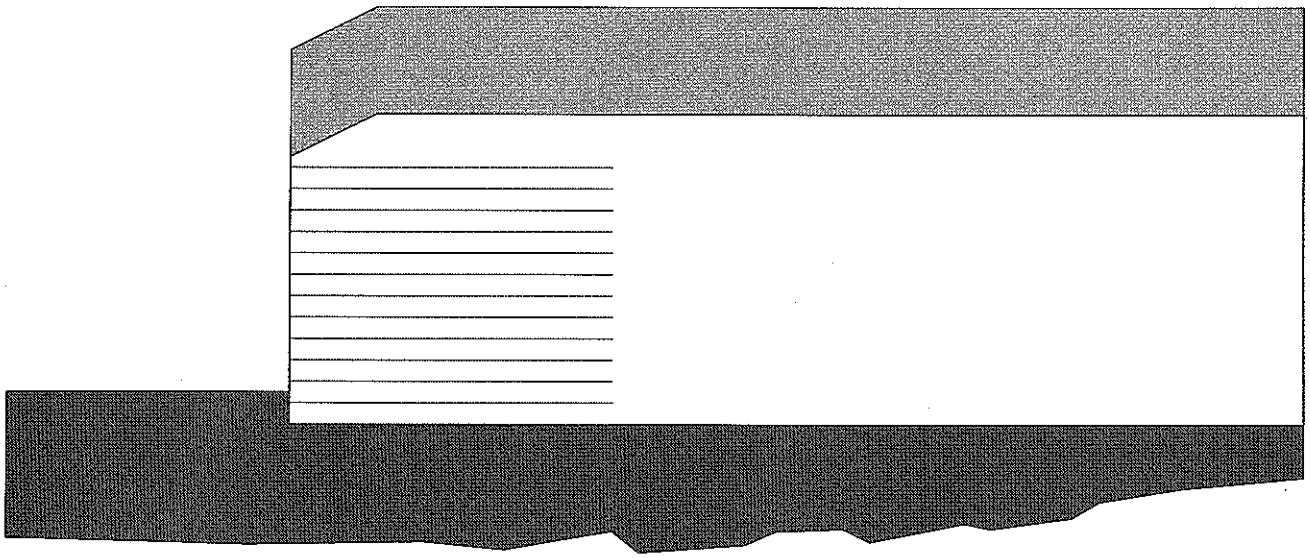
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	25.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 22.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	4.0	[ft]	Broken back equivalent angle, I = 4.57° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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SOT 1-2-09

AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35		
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00		
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75		
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50		
Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00
Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
	ϕ_b	0.65		0.65

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BBT 1-2-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.01, Meyerhof stress = 5302 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.195, Eccentricity, e/L = 0.1057, CDR-overturning = 4.08

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	30.00	1	N/A	2.31	2.57	2.572	3.733	1.803	0.1057	---
2	2.00	30.00	1	N/A	1.22	1.35	1.352	1.760	1.912	0.0908	---
3	4.00	30.00	1	N/A	1.31	1.45	1.452	1.683	2.035	0.0768	---
4	6.00	30.00	1	N/A	1.38	1.54	1.535	1.675	2.179	0.0635	---
5	8.00	30.00	1	N/A	1.44	1.60	1.599	1.800	2.345	0.0510	---
6	10.00	30.00	1	N/A	1.52	1.69	1.693	1.897	2.534	0.0393	---
7	12.00	30.00	1	N/A	1.63	1.82	1.816	1.963	2.755	0.0282	---
8	14.00	30.00	1	N/A	1.76	1.95	1.951	1.969	3.020	0.0177	---
9	16.00	30.00	1	N/A	1.91	2.12	2.117	2.017	3.340	0.0075	---
10	18.00	30.00	1	N/A	2.11	2.35	2.348	2.073	3.735	-0.0026	---
11	20.00	30.00	1	N/A	2.42	2.69	2.694	2.114	4.234	-0.0134	---
12	22.00	30.00	1	N/A	2.88	3.20	3.202	2.110	4.873	-0.0262	---
13	24.00	30.00	1	N/A	3.57	3.96	3.963	2.003	5.696	-0.0452	---

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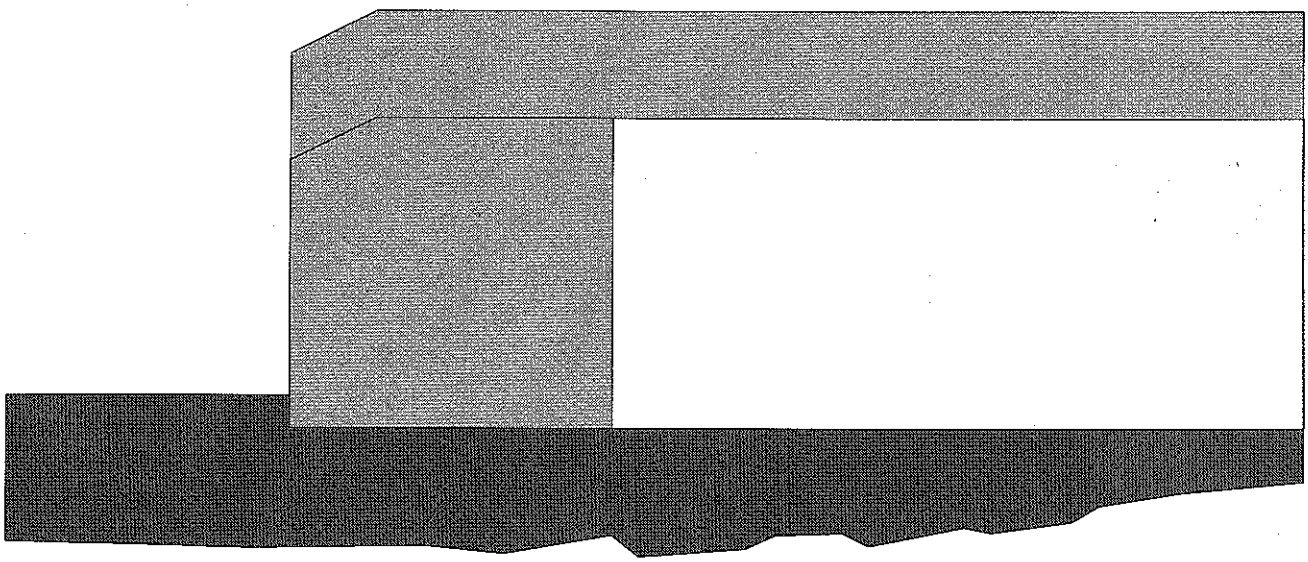
JJT 1-2-09

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	5353	N/A	[lb/ft ²]
Meyerhof stress, σ_V	5302.5	N/A	[lb/ft ²]
Eccentricity, e	2.09	N/A	[ft]
Eccentricity, e/L	0.070	N/A	
CDR calculated	1.01	N/A	
Base length	30.00	N/A	[ft]

$q_{ult} > \sigma_V$ ok

$CDR = \frac{q_{ult}}{\sigma_V}$



SCALE:

0 2 4 6 8 10[ft]

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SDT 1-2-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.195

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	30.00	1.803	N/A	1	---
2	2.00	30.00	1.912	N/A	1	---
3	4.00	30.00	2.035	N/A	1	---
4	6.00	30.00	2.179	N/A	1	---
5	8.00	30.00	2.345	N/A	1	---
6	10.00	30.00	2.534	N/A	1	---
7	12.00	30.00	2.755	N/A	1	---
8	14.00	30.00	3.020	N/A	1	---
9	16.00	30.00	3.340	N/A	1	---
10	18.00	30.00	3.735	N/A	1	---
11	20.00	30.00	4.234	N/A	1	---
12	22.00	30.00	4.873	N/A	1	---
13	24.00	30.00	5.696	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1057; Overturning: CDR-static = 4.08

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	30.00	0.1057	N/A	1	---
2	2.00	30.00	0.0908	N/A	1	---
3	4.00	30.00	0.0768	N/A	1	---
4	6.00	30.00	0.0635	N/A	1	---
5	8.00	30.00	0.0510	N/A	1	---
6	10.00	30.00	0.0393	N/A	1	---
7	12.00	30.00	0.0282	N/A	1	---
8	14.00	30.00	0.0177	N/A	1	---
9	16.00	30.00	0.0075	N/A	1	---
10	18.00	30.00	-0.0026	N/A	1	---
11	20.00	30.00	-0.0134	N/A	1	---
12	22.00	30.00	-0.0262	N/A	1	---
13	24.00	30.00	-0.0452	N/A	1	---

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"A Tradition Of Excellence" since 1923

Subject SR1/I-95 Interchange
RW4 Analysis
Page 25 of
Cm. No. 103-059-27U
Prepared By SAB Date 12/10/08 Checked By JDT Date 1-2-09
EM 2/9/09

=> Check with ~~DelDOT Type B~~ Select Fill in reinforced zone & No. 57 Stone in the Retained wedge (may be a more cost effective option).

Undrained (see p. 26 - 34)

Results: L/H = 1.2

Bearing Capacity: Factored Bearing Resistance, q_R = 8,355 psf
Meyerhof Stress, σ_v = 5,624 psf
CDR = 1.49 > 1.0 √OK

$q_R \geq \sigma_v$ 1.0 OK
$CDR = \frac{q_R}{\sigma_v}$

Sliding Resistance: CDR = 3.87 > 1.0 √OK
Overturning Resistance: CDR = 8.49 > 1.0 √OK

Drained (see p. 35 - 43)

Results: * L/H = 1.2 required.

Bearing Capacity: q_R = 5,851 psf
σ_v = 5,624 psf
CDR = 1.04 > 1.0 √OK

Sliding Resistance: CDR = 2.56 > 1.0 √OK
Overturning Resistance: CDR = 8.49 > 1.0 √OK

* Check Global Stability

* Check Settlement

26

SOT 1-2-09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1252+50

Description:

Retaining Wall 4 UNDRAINED Analysis H = 25' L/H = 1.2 Reinforced Zone = ~~DelDOT Type B Borrow~~ Select Fill Retained Soil = No. 57 Stone

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

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Original date and time of creating this file: Tue Dec 09 08:19:30 2008

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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27

JDT 1-2-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select Fill
Design value of internal angle of friction, ϕ	34.0°	

RETAINED SOIL

Unit weight, γ	105.0 lb/ft ^{3}	No 57 stone
Design value of internal angle of friction, ϕ	38.0°	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}	
Equivalent internal angle of friction, $\phi_{equiv.}$	0.0 °	
Equivalent cohesion, $c_{equiv.}$	2500.0 lb/ft ^{2}	

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2396 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 5.14 N γ= 0.00

SEISMICITY

Not Applicable

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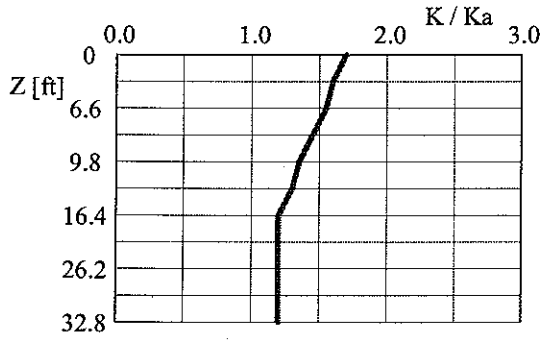
SDT 1-2-09

INPUT DATA: Metal strips (Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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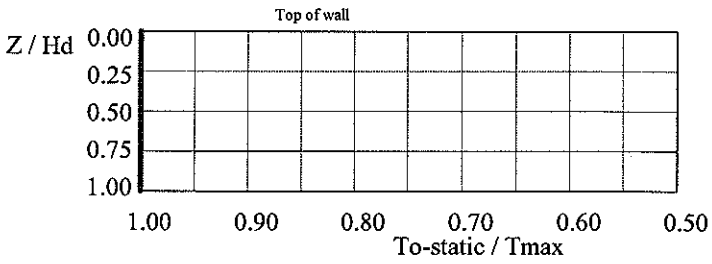
JOT 1-2-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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3C

BOT 1-2-09

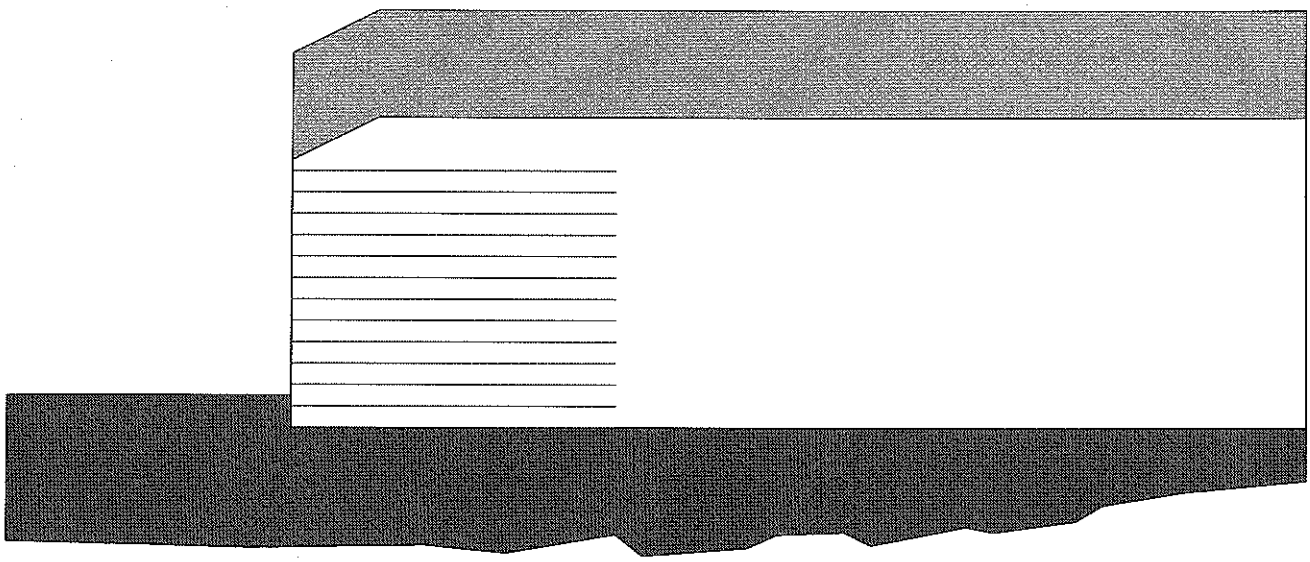
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	25.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 22.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	4.0	[ft]	Broken back equivalent angle, I = 4.57° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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BBT 1-2-09

AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00

Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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JGT 1-2-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.49, Meyerhof stress = 5624 lb/ft².

Foundation Interface: Direct sliding, CDR = 3.874, Eccentricity, e/L = 0.0461, CDR-overturning = 8.49

METAL STRIP				CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	30.00	1	N/A	1.98	2.20	2.196	3.794	3.859	0.0461	---
2	2.00	30.00	1	N/A	1.04	1.16	1.155	1.791	4.087	0.0388	---
3	4.00	30.00	1	N/A	1.12	1.24	1.242	1.714	4.344	0.0318	---
4	6.00	30.00	1	N/A	1.18	1.32	1.315	1.709	4.645	0.0252	---
5	8.00	30.00	1	N/A	1.24	1.37	1.372	1.839	4.990	0.0188	---
6	10.00	30.00	1	N/A	1.31	1.46	1.456	1.942	5.377	0.0127	---
7	12.00	30.00	1	N/A	1.41	1.57	1.566	2.015	5.829	0.0067	---
8	14.00	30.00	1	N/A	1.52	1.69	1.687	2.027	6.364	0.0008	---
9	16.00	30.00	1	N/A	1.65	1.84	1.838	2.085	7.004	-0.0053	---
10	18.00	30.00	1	N/A	1.84	2.05	2.049	2.153	7.783	-0.0119	---
11	20.00	30.00	1	N/A	2.13	2.37	2.368	2.212	8.746	-0.0196	---
12	22.00	30.00	1	N/A	2.56	2.84	2.843	2.230	9.949	-0.0300	---
13	24.00	30.00	1	N/A	3.22	3.58	3.575	2.151	11.436	-0.0471	---

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JBT 1-2-09

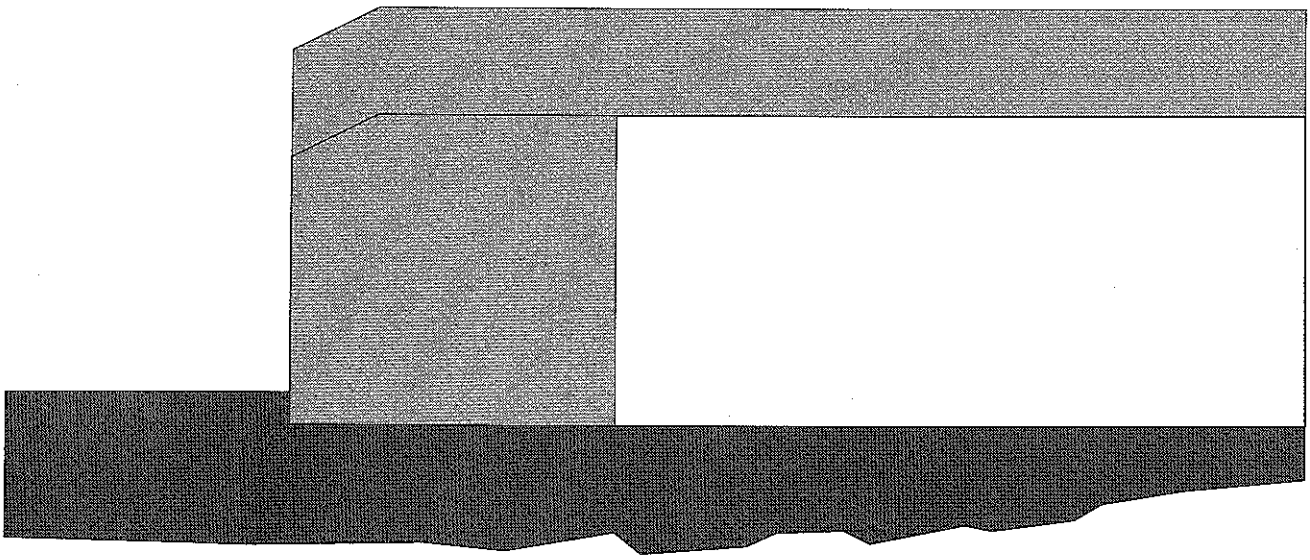
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	8355	N/A	[lb/ft ²]
Meyerhof stress, σ_V	5624.4	N/A	[lb/ft ²]
Eccentricity, e	0.89	N/A	[ft]
Eccentricity, e/L	0.030	N/A	
CDR calculated	1.49	N/A	
Base length	30.00	N/A	[ft]

$q_{ult} > \sigma_V$ ∴ OK

$CDR = \frac{q_{ult}}{\sigma_V}$

* Drained Analysis Governs.



SCALE:

0 2 4 6 8 10[ft]

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JGT 1-2-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 3.874

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	30.00	3.859	N/A	1	---
2	2.00	30.00	4.087	N/A	1	---
3	4.00	30.00	4.344	N/A	1	---
4	6.00	30.00	4.645	N/A	1	---
5	8.00	30.00	4.990	N/A	1	---
6	10.00	30.00	5.377	N/A	1	---
7	12.00	30.00	5.829	N/A	1	---
8	14.00	30.00	6.364	N/A	1	---
9	16.00	30.00	7.004	N/A	1	---
10	18.00	30.00	7.783	N/A	1	---
11	20.00	30.00	8.746	N/A	1	---
12	22.00	30.00	9.949	N/A	1	---
13	24.00	30.00	11.436	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0461; Overturning: CDR-static = 8.49

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	30.00	0.0461	N/A	1	---
2	2.00	30.00	0.0388	N/A	1	---
3	4.00	30.00	0.0318	N/A	1	---
4	6.00	30.00	0.0252	N/A	1	---
5	8.00	30.00	0.0188	N/A	1	---
6	10.00	30.00	0.0127	N/A	1	---
7	12.00	30.00	0.0067	N/A	1	---
8	14.00	30.00	0.0008	N/A	1	---
9	16.00	30.00	-0.0053	N/A	1	---
10	18.00	30.00	-0.0119	N/A	1	---
11	20.00	30.00	-0.0196	N/A	1	---
12	22.00	30.00	-0.0300	N/A	1	---
13	24.00	30.00	-0.0471	N/A	1	---

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SJT 1-2-09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title:	SR 1/I-95 Interchange
Project Number:	103-059-27U
Client:	DelDOT
Designer:	SAB
Station Number:	1252+50

Description:

Retaining Wall 4 DRAINED Analysis H=25' L/H=1.2 Reinforced Soil Zone = ~~DelDOT Type B Borrow~~ Select Soil Retained Soil = No. 57 Stone

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN..... .....ED L=1.2H 57 ret.BEN

Original date and time of creating this file: Tue Dec 09 09:17:11 2008

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select Fill
Design value of internal angle of friction, ϕ	34.0°	

RETAINED SOIL

Unit weight, γ	105.0 lb/ft ^{3}	No 57
Design value of internal angle of friction, ϕ	38.0°	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}
Equivalent internal angle of friction, $\phi_{equiv.}$	24.0°
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ^{2}

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2396 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ = 9.44

SEISMICITY

Not Applicable

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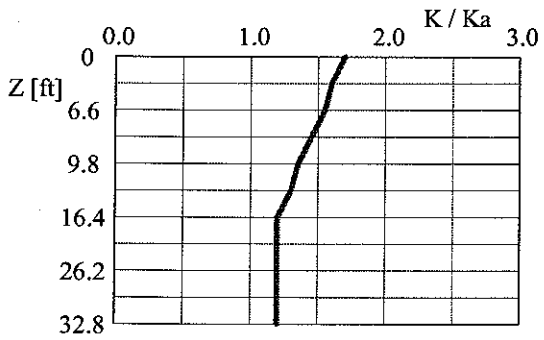
SBT 1-2-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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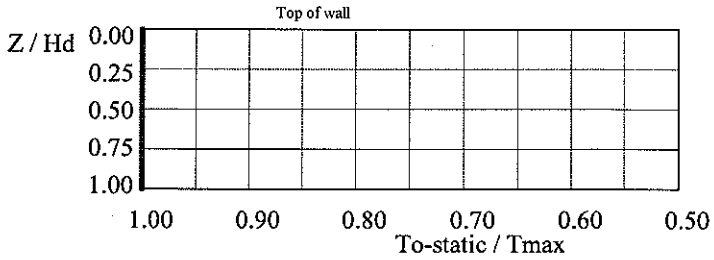
1-2-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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JPT 1-2-09

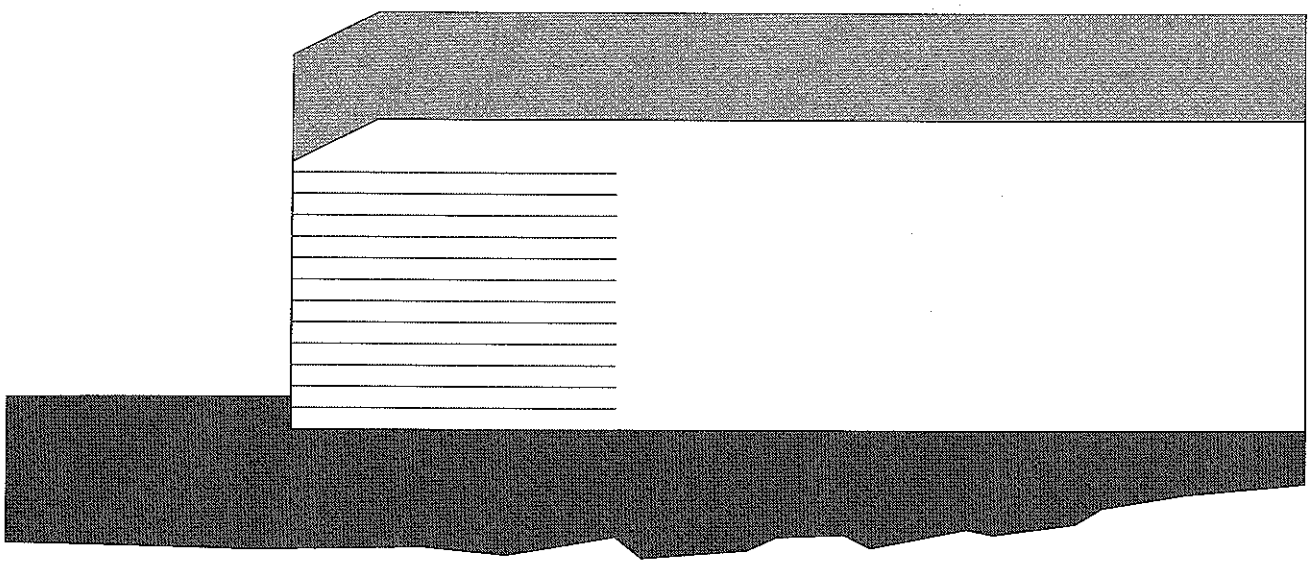
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	25.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 22.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	4.0	[ft]	Broken back equivalent angle, I = 4.57° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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JT 1-2-09

AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00

Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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SDT 1-2-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.04, Meyerhof stress = 5624 lb/ft².

Foundation Interface: Direct sliding, CDR = 2.557, Eccentricity, e/L = 0.0461, CDR-overturning = 8.49

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	30.00	1	N/A	1.98	2.20	2.196	3.794	3.859	0.0461	---
2	2.00	30.00	1	N/A	1.04	1.16	1.155	1.791	4.087	0.0388	---
3	4.00	30.00	1	N/A	1.12	1.24	1.242	1.714	4.344	0.0318	---
4	6.00	30.00	1	N/A	1.18	1.32	1.315	1.709	4.645	0.0252	---
5	8.00	30.00	1	N/A	1.24	1.37	1.372	1.839	4.990	0.0188	---
6	10.00	30.00	1	N/A	1.31	1.46	1.456	1.942	5.377	0.0127	---
7	12.00	30.00	1	N/A	1.41	1.57	1.566	2.015	5.829	0.0067	---
8	14.00	30.00	1	N/A	1.52	1.69	1.687	2.027	6.364	0.0008	---
9	16.00	30.00	1	N/A	1.65	1.84	1.838	2.085	7.004	-0.0053	---
10	18.00	30.00	1	N/A	1.84	2.05	2.049	2.153	7.783	-0.0119	---
11	20.00	30.00	1	N/A	2.13	2.37	2.368	2.212	8.746	-0.0196	---
12	22.00	30.00	1	N/A	2.56	2.84	2.843	2.230	9.949	-0.0300	---
13	24.00	30.00	1	N/A	3.22	3.58	3.575	2.151	11.436	-0.0471	---

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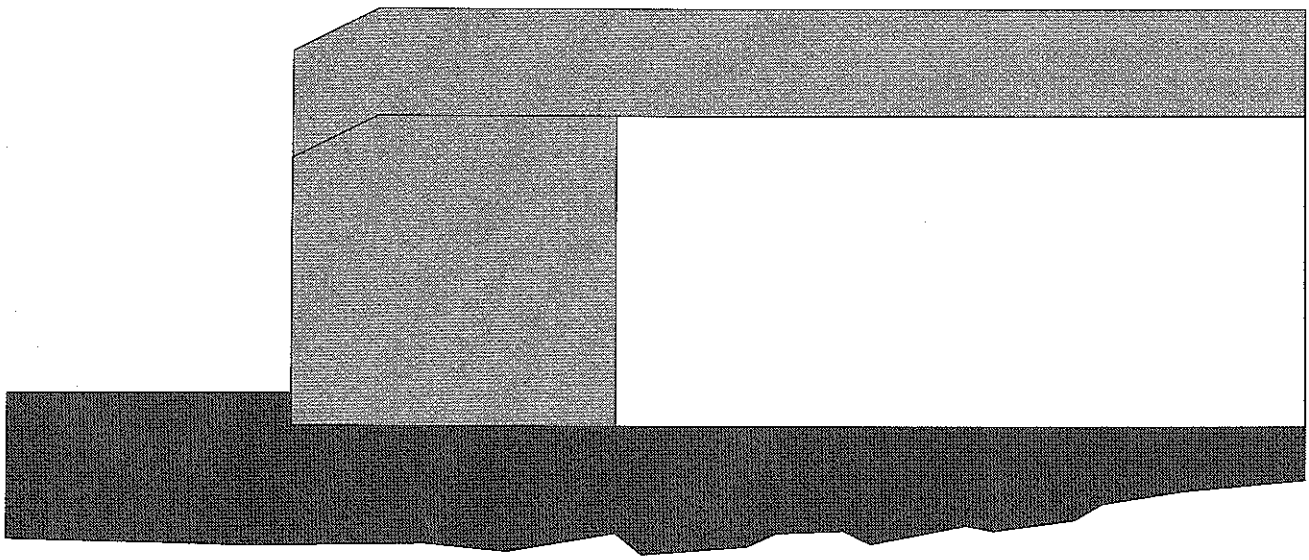
BT 1-2-09

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	5851	N/A	[lb/ft ²]
Meyerhof stress, σ_V	5624.4	N/A	[lb/ft ²]
Eccentricity, e	0.89	N/A	[ft]
Eccentricity, e/L	0.030	N/A	
CDR calculated	1.04	N/A	
Base length	30.00	N/A	[ft]

$q_{ult} > \sigma_V$ ∴ OK

$CDR = \frac{q_{ult}}{\sigma_V}$



SCALE:

0 2 4 6 8 10[ft]

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SBT 1-2-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 2.557

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	30.00	3.859	N/A	1	---
2	2.00	30.00	4.087	N/A	1	---
3	4.00	30.00	4.344	N/A	1	---
4	6.00	30.00	4.645	N/A	1	---
5	8.00	30.00	4.990	N/A	1	---
6	10.00	30.00	5.377	N/A	1	---
7	12.00	30.00	5.829	N/A	1	---
8	14.00	30.00	6.364	N/A	1	---
9	16.00	30.00	7.004	N/A	1	---
10	18.00	30.00	7.783	N/A	1	---
11	20.00	30.00	8.746	N/A	1	---
12	22.00	30.00	9.949	N/A	1	---
13	24.00	30.00	11.436	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0461; Overturning: CDR-static = 8.49

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	30.00	0.0461	N/A	1	---
2	2.00	30.00	0.0388	N/A	1	---
3	4.00	30.00	0.0318	N/A	1	---
4	6.00	30.00	0.0252	N/A	1	---
5	8.00	30.00	0.0188	N/A	1	---
6	10.00	30.00	0.0127	N/A	1	---
7	12.00	30.00	0.0067	N/A	1	---
8	14.00	30.00	0.0008	N/A	1	---
9	16.00	30.00	-0.0053	N/A	1	---
10	18.00	30.00	-0.0119	N/A	1	---
11	20.00	30.00	-0.0196	N/A	1	---
12	22.00	30.00	-0.0300	N/A	1	---
13	24.00	30.00	-0.0471	N/A	1	---

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"A Tradition Of Excellence" since 1923

Subject I-95/SR1 Interchange — Page 1 of 36
RW4 Global Stability — Cm. No. 103-059-27U
Prepared By SAB Date 9/24/08 Checked By JST Date 9-30-08
REV 12/10/08 JST 1-2-09
EMC 2/9/09

Global Stability Analysis: Performed using ~~Slope/w~~

⇒ STA 1252+50 chosen for global stability analysis - tallest wall with backslope & cut area in front of wall.

See cross section, p. 2.

Soils: See pages 3-5 of RW4 External Stability calculations for fence diagram & soil strata/parameters.

Summary:

Soil	γ_t (pcf)	ϕ' (deg)	c' (psf)	S_u (psf)	EL (ft)
Reinforced Soil	125	34°	0	-	
Retained Soil	130	28°	0	-	
Foundation Soil (IIa)	130	(See p. 3-4)	0	2,500	GSEL - 38
IIa	130	24°	-	2,500	38 - 18
IIa	130	24°	-	3,500	18 - 0
IIa	130	24°	-	5,000	0 - -15
IIb	130	34°	0	-	Below -15
Water	62.4				62 (above crossed BOF EL)

→ Check using UNDRAINED & DRAINED soil parameters.

⇒ Morgenstern-Price Method used for analysis.

See attached Slope/w reports: pages 5-20 → RW4 - UNDRAINED
pages 21-36 → RW4 - DRAINED

Summary: UNDRAINED: $FS = 3.03 > \frac{1.0}{\phi} = \frac{1.0}{0.65} = 1.538$ ✓OK

DRAINED: $FS = 2.10 > \frac{1.0}{\phi} = \frac{1.0}{0.65} = 1.538$ ✓OK

* Wall Manufacturer is using internal stability.

I-95/SR1 Interchange 103-059-270
Rw 4

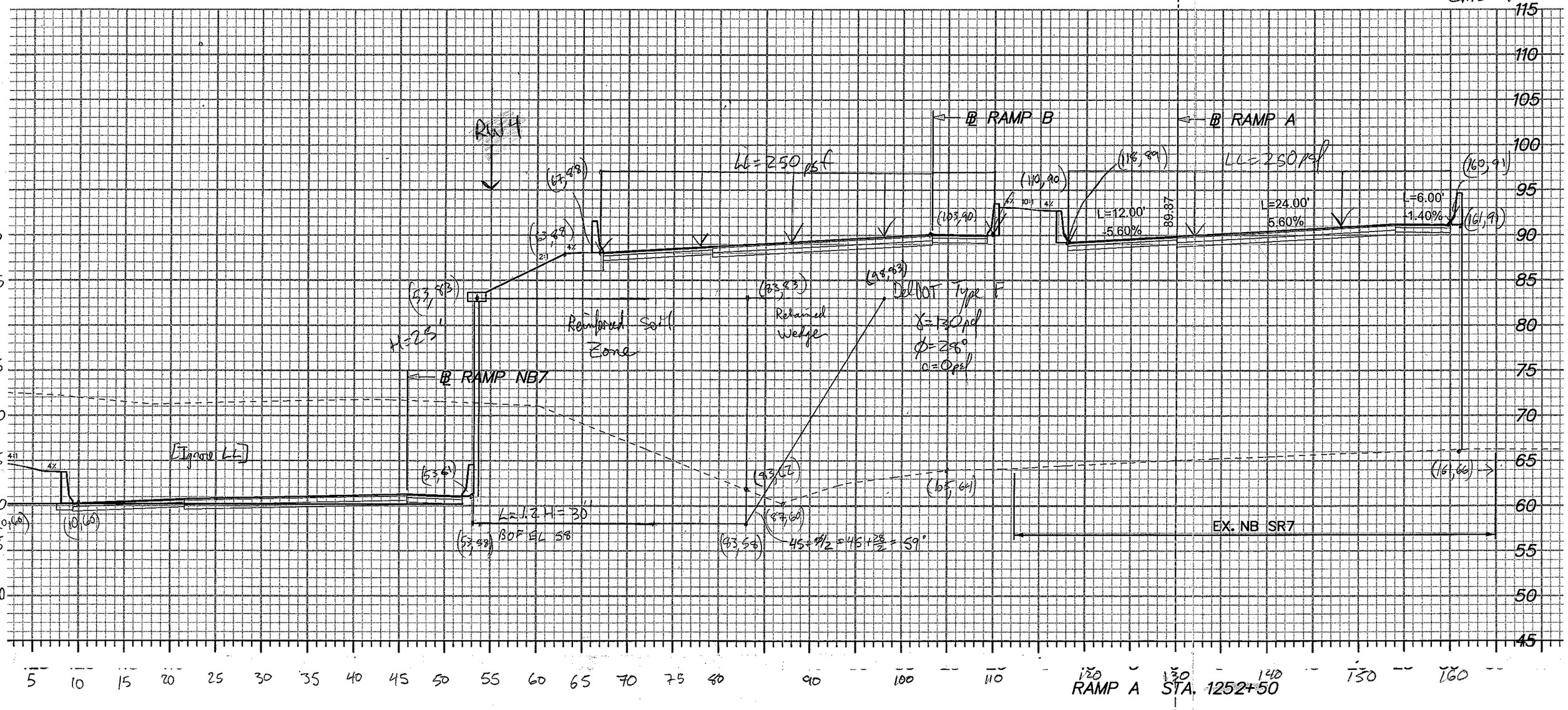
9/23/08
REV 12/10/08

RKK RW 4-7

9-30-08

1-2-09

1/2/09



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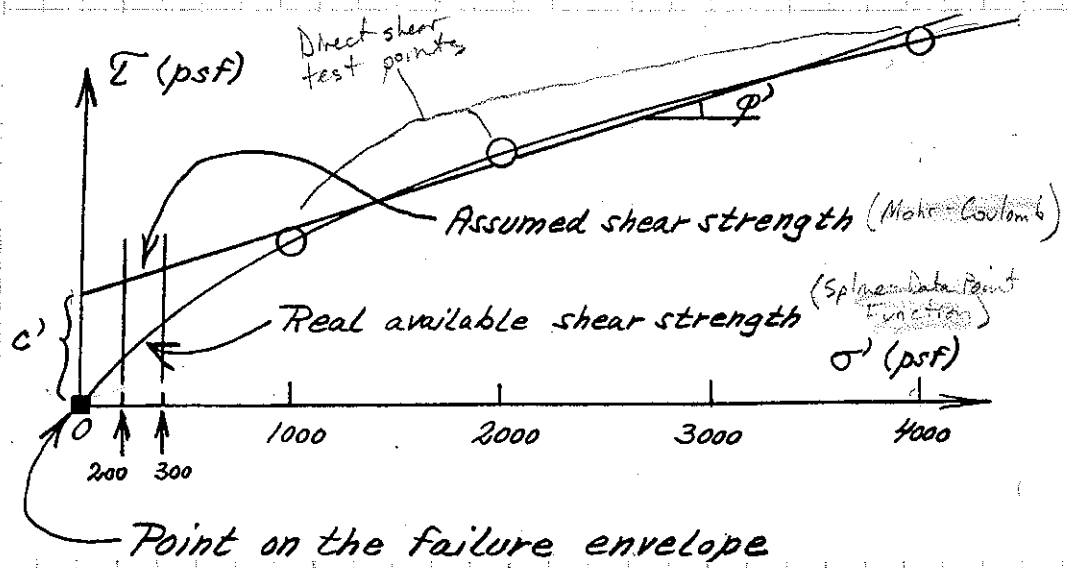
"A Tradition Of Excellence" since 1923

Subject SR1/I-95 Interchange — Page 3 of
RW 4 Global Stability — Cm. No. 103-059-27
Prepared By SAB Date 12/10/08 Checked By [illegible] Date 1-2-09
EMM 2/9/09

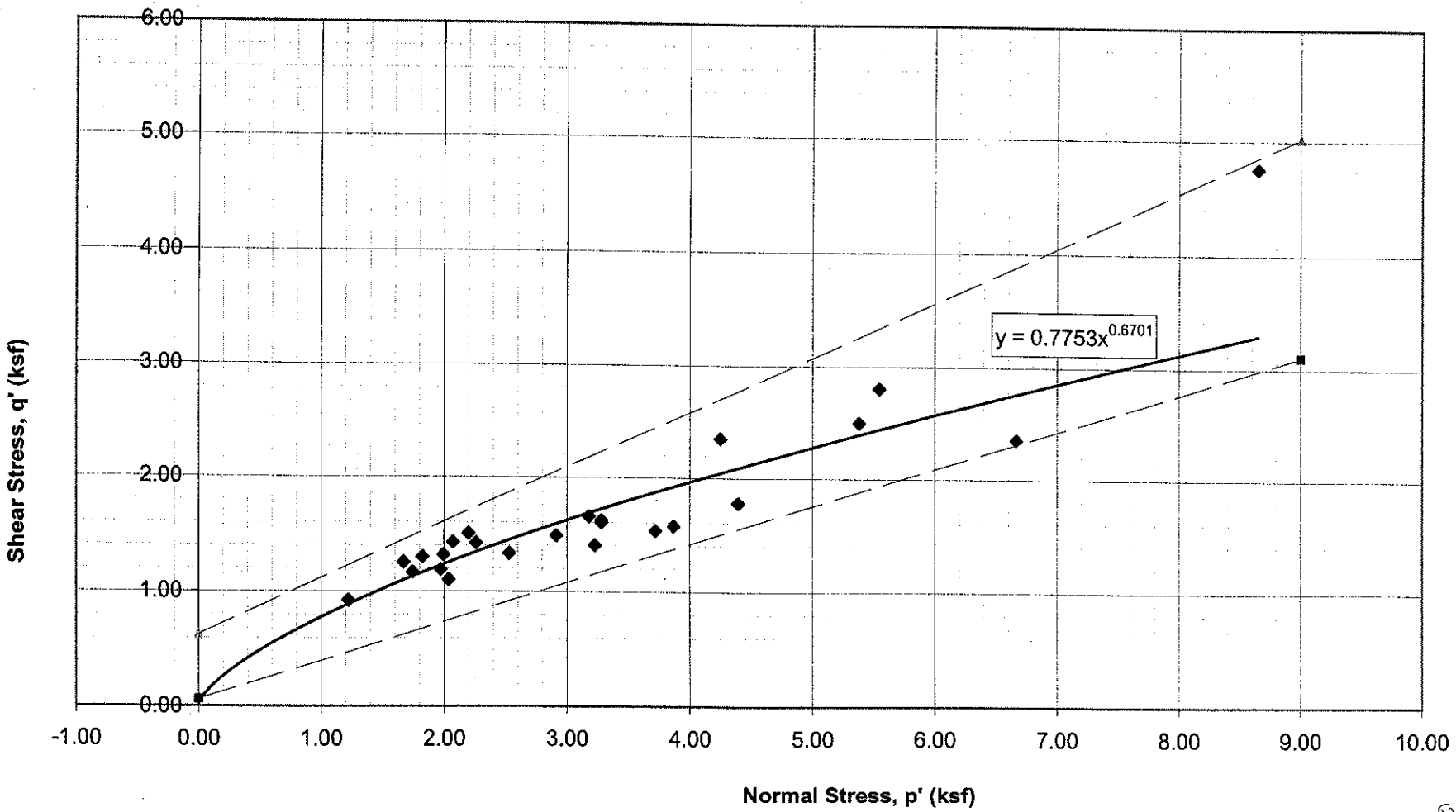
Drained soil parameters are defined using a spline-data point function.
(Reference: Dr. Paul Ladde's Class Notes)

This method develops a realistic shear strength envelope based on direct shear test results. At relatively shallow depths, the Mohr-Coulomb failure criterion overestimates the shear strength of a soil, as direct shear test are generally not performed for low effective normal stresses. This method uses an exponential function that passes through the origin to estimate the real available shear strength. See graph below.



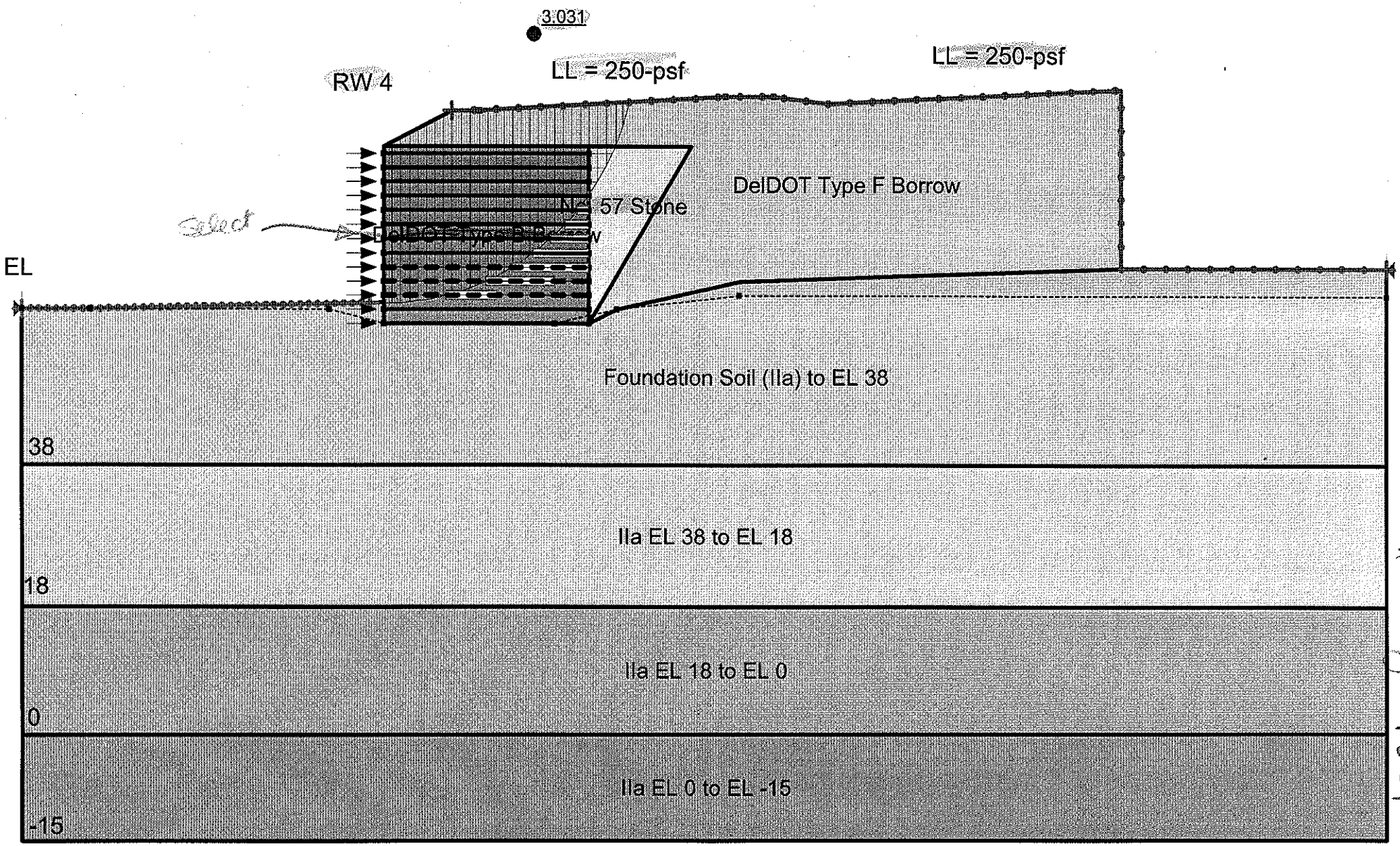
→ Spline-Data Function for Stratum IIa (above EL 38) was defined using the equation developed from Figure C-2a (see p. 5), which summarizes the CU tests for the site above EL 40.

Figure C-2a
Summary of CU with Pore Pressure
Effective Stress - Strata IIa
EL 40 & Above



RKK RW4-49

SR 1/I-95 Interchange 103-059-27U 12/10/08
Retaining Wall 4 Global Stability Analysis - Undrained
Prepared By: SAB



SW 12/09
RKK RW4-50-09
5

JST 1-2-09
EM 2/2/09

SR 1/I-95 Interchange 103-059-27U

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File Information

Revision Number: 61
Date: 12/11/2008
Time: 3:43:57 PM
File Name: RW 4 STA 1252+50 UNDRAINED 57 ret.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 4\Final Design\
Last Solved Date: 12/11/2008
Last Solved Time: 3:44:48 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SR 1/I-95 Interchange 103-059-27U

Description: Retaining Wall 4 STA 1252+50 DRAINED Analysis
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
Apply Phreatic Correction: Yes
Side Function
Interslice force function option: Half-Sine
PWP Conditions Source: Piezometric Line
Use Staged Rapid Drawdown: No
SlipSurface
Direction of movement: Right to Left
Allow Passive Mode: No
Slip Surface Option: Entry and Exit
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)

FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 32
Ending Optimization Points: 64
Complete Passes per Insertion: 1

Materials

No. 57 Stone

Model: Mohr-Coulomb
Unit Weight: 105 pcf
Cohesion: 0 psf
Phi: 38 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

DelDOT Type F Borrow

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Foundation Soil (IIa) to EL 38

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 2500 psf
Pore Water Pressure
Piezometric Line: 1

IIa EL 38 to EL 18

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 2500 psf
Pore Water Pressure
Piezometric Line: 1

IIa EL 18 to EL 0

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 3500 psf
Pore Water Pressure
Piezometric Line: 1

IIa EL 0 to EL -15

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 5000 psf
Pore Water Pressure
Piezometric Line: 1

~~DelDOT Type B Borrow~~ → Select Fill

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0, 60) ft
Left-Zone Right Coordinate: (51, 60.953488) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (63, 88) ft
Right-Zone Right Coordinate: (200, 66) ft
Right-Zone Increment: 50
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 60) ft
Right Coordinate: (200, 66) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	60
	10	60
	45	60
	53	58
	78	58
	87	60
	105	62
	200	62

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	67	88
	103	90
	110	90

Surcharge Load 2

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	118	89
	160	91

Reinforcements → Fabric used to model steel straps (not an option in Slope/W)

Reinforcement 1

Type: Fabric
Outside Point: (53, 58) ft
Inside Point: (83, 58) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 ° ← AASHTO LRFD Table 3.11.5.3-1 for steel on silty SAND
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (53, 60) ft
Inside Point: (83, 60) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (53, 62) ft
Inside Point: (83, 62) ft
Slip Surface Intersection: (62.045, 62) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 1980.5 lbs
Resisting Force Used: 265.31 lbs/ft
Available Bond Length: 20.955 ft
Required Bond Length: 7.4651 ft
Governing Component: Fabric

Reinforcement 4

Type: Fabric
Outside Point: (53, 64) ft
Inside Point: (83, 64) ft
Slip Surface Intersection: (67.891, 64) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0

Applied Load: 6000 lbs
Fabric Load Used: 1980.5 lbs
Resisting Force Used: 196.7 lbs/ft
Available Bond Length: 15.109 ft
Required Bond Length: 10.069 ft
Governing Component: Fabric

Reinforcement 5

Type: Fabric
Outside Point: (53, 66) ft
Inside Point: (83, 66) ft
Slip Surface Intersection: (71.803, 66) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 1980.5 lbs
Resisting Force Used: 177.96 lbs/ft
Available Bond Length: 11.197 ft
Required Bond Length: 11.129 ft
Governing Component: Fabric

Reinforcement 6

Type: Fabric
Outside Point: (53, 68) ft
Inside Point: (83, 68) ft
Slip Surface Intersection: (74.829, 68) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs

Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 1253.7 lbs
Resisting Force Used: 153.44 lbs/ft
Available Bond Length: 8.1709 ft
Required Bond Length: 8.1709 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (53, 70) ft
Inside Point: (83, 70) ft
Slip Surface Intersection: (77.325, 70) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 755.71 lbs
Resisting Force Used: 133.16 lbs/ft
Available Bond Length: 5.6752 ft
Required Bond Length: 5.6752 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (53, 72) ft
Inside Point: (83, 72) ft
Slip Surface Intersection: (79.441, 72) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs

Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 385.89 lbs
Resisting Force Used: 108.42 lbs/ft
Available Bond Length: 3.5591 ft
Required Bond Length: 3.5591 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (53, 74) ft
Inside Point: (83, 74) ft
Slip Surface Intersection: (81.245, 74) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 165.02 lbs
Resisting Force Used: 94.042 lbs/ft
Available Bond Length: 1.7548 ft
Required Bond Length: 1.7548 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (53, 76) ft
Inside Point: (83, 76) ft
Slip Surface Intersection: (82.82, 76) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1

Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 14.018 lbs
Resisting Force Used: 78.033 lbs/ft
Available Bond Length: 0.17965 ft
Required Bond Length: 0.17965 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (53, 78) ft
Inside Point: (83, 78) ft
Slip Surface Intersection: (84.184, 78) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 50.209 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 12

Type: Fabric
Outside Point: (53, 80) ft
Inside Point: (83, 80) ft
Slip Surface Intersection: (85.357, 80) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf

Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 32.42 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 13

Type: Fabric
Outside Point: (53, 82) ft
Inside Point: (83, 82) ft
Slip Surface Intersection: (86.358, 82) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 11.437 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Regions

	Material	Points	Area (ft^2)
Region 1	IIa EL 0 to EL -15	23,24,22,21	3000
Region	IIa EL 18 to EL 0	21,22,20,19	3600

2			
Region 3	IIa EL 38 to EL 18	19,17,18,20	4000
Region 4	Foundation Soil (IIa) to EL 38	1,2,3,4,6,25,26,15,16,18,17	4907.485
Region 5	DelDOT Type B Borrow	4,3,5,7,6	750.015
Region 6	DelDOT Type F Borrow	5,8,9,10,11,12,13,14,15,26,25,6,27,7	1958.5
Region 7	No. 57 Stone	6,27,7	187.5

Points

	X (ft)	Y (ft)	
Point 1	0	60	
Point 2	10	60	
Point 3	53	61	
Point 4	52.99	EL 58	← Toe of RW4
Point 5	53	EL 83	← Top of RW4
Point 6	83	58	
Point 7	83	83	
Point 8	63	88	
Point 9	67	88	
Point 10	103	90	
Point 11	110	90	
Point 12	118	89	
Point 13	160	91	
Point 14	161	91	
Point 15	161	66	
Point 16	200	66	
Point 17	0	38	
Point 18	200	38	
Point 19	0	18	
Point 20	200	18	
Point 21	0	0	
Point 22	200	0	

Wall Height = Point 5 - Point 4

= 83 - 58

H = 25'

Point 23	0	-15
Point 24	200	-15
Point 25	87	60
Point 26	105	64
Point 27	98	83

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	10244	3.031	(53.105, 97.69)	36.797	(88.9127, 89.2174)	(51, 60.9535)

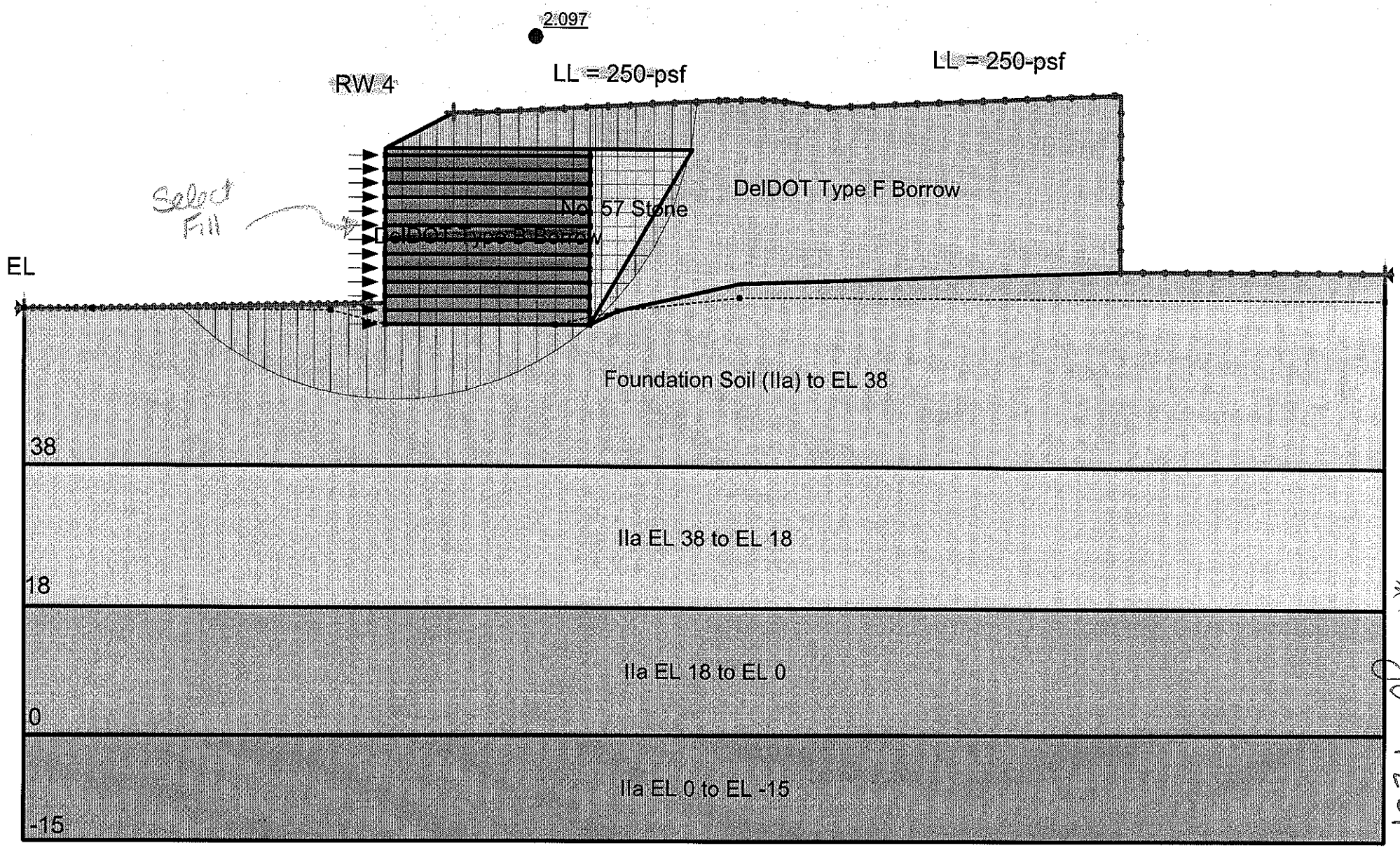
Slices of Slip Surface: 10244

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	10244	51.49991	60.931665	-150.15363	81.358947	0	2500
2	10244	52.49991	60.901615	-163.06896	147.17393	0	2500
3	10244	53.625	60.90223	-181.10189	2972.1828	2004.7626	0
4	10244	54.875	60.941175	-183.53125	3077.3927	2075.7276	0
5	10244	56.125	61.02276	-188.61727	3153.7202	2127.2112	0
6	10244	57.375	61.147275	-196.39159	3199.9847	2158.417	0
7	10244	58.625	61.31516	-206.8635	3216.6111	2169.6316	0
8	10244	59.875	61.52702	-220.08827	3205.7447	2162.3021	0
9	10244	61.125	61.783635	-236.10188	3170.511	2138.5367	0
10	10244	62.375	62.08597	-254.96332	3853.6754	2599.3369	0
11	10244	63.666665	62.4485	-277.5864	3045.7775	2054.4029	0
12	10244	65	62.87609	-	2873.5657	1938.2445	0

				304.26908			
13	10244	66.333335	63.360775	-334.51536	2699.5534	1820.8718	0
14	10244	67.61111	63.87987	-366.90274	2790.2864	1882.0719	0
15	10244	68.83333	64.431075	-401.29999	1872.6988	1263.1513	0
16	10244	70.055555	65.037325	-439.12602	1735.4598	1170.5824	0
17	10244	71.27778	65.701755	-480.58858	2325.0454	1568.2629	0
18	10244	72.5	66.42808	-525.91182	1468.846	990.74916	0
19	10244	73.72222	67.22074	-575.3708	1347.0494	908.59626	0
20	10244	74.944445	68.08508	-629.30764	1613.8271	1088.5401	0
21	10244	76.16667	69.027605	-688.13451	1106.4336	746.29888	0
22	10244	77.38889	70.056355	-752.31684	1193.2221	804.83846	0
23	10244	78.625	71.19542	-776.40109	882.12993	595.00415	0
24	10244	79.875	72.460615	-835.09094	852.31949	574.89675	0
25	10244	81.125	73.85865	-901.72971	688.96959	464.71586	0
26	10244	82.375	75.414785	-977.71947	546.24583	368.44746	0
27	10244	83.640325	77.189855	-1066.55	337.60519	263.76608	0
28	10244	84.920975	79.248375	-1172.0319	217.42365	169.86997	0
29	10244	86.201625	81.67655	-1299.5016	75.607861	59.071335	0
30	10244	86.920975	83.184225	-1379.6618	-0.477156	-0.25370835	0
31	10244	87.478165	84.626665	-1514.6967	-0.80705075	-0.4291165	0
32	10244	88.4345	87.551125	-	-0.87248417	-0.46390806	0

				1688.4064			

SR 1/I-95 Interchange 103-059-27U 12/10/08
Retaining Wall 4 Global Stability Analysis - Drained
Prepared By: SAB



RW4-66

SDT 1-2-09

SR 1/I-95 Interchange 103-059-27U

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File Information

Revision Number: 57
Date: 12/11/2008
Time: 3:47:11 PM
File Name: RW 4 STA 1252+50 DRAINED 57 ret.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 4\Final Design\
Last Solved Date: 12/11/2008
Last Solved Time: 3:48:03 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SR 1/I-95 Interchange 103-059-27U

Description: Retaining Wall 4 STA 1252+50 DRAINED Analysis
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- **Apply Phreatic Correction:** Yes
- Side Function
  - **Interslice force function option:** Half-Sine
- **PWP Conditions Source:** Piezometric Line
- **Use Staged Rapid Drawdown:** No

SlipSurface
- **Direction of movement:** Right to Left
- **Allow Passive Mode:** No
- **Slip Surface Option:** Entry and Exit
- **Critical slip surfaces saved:** 1
- **Optimize Critical Slip Surface Location:** No
- Tension Crack
  - **Tension Crack Option:** (none)

FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 32
Ending Optimization Points: 64
Complete Passes per Insertion: 1

Materials

No. 57 Stone

Model: Mohr-Coulomb
Unit Weight: 105 pcf
Cohesion: 0 psf
Phi: 38 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

DelDOT Type F Borrow

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Foundation Soil (IIa) to EL 38

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: CU Tests
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa EL 38 to EL 18

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 24 °
Phi-B: 0 °

Pore Water Pressure
Piezometric Line: 1

IIa EL 18 to EL 0

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 24 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa EL 0 to EL -15

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 24 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

~~DelDOT Type B Borrow~~ Select Fill

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0, 60) ft
Left-Zone Right Coordinate: (51, 60.953488) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (63, 88) ft
Right-Zone Right Coordinate: (200, 66) ft
Right-Zone Increment: 50
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 60) ft
Right Coordinate: (200, 66) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	60
	10	60
	45	60
	53	58
	78	58
	87	60
	105	62
	200	62

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	67	88
	103	90
	110	90

Surcharge Load 2

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	118	89
	160	91

Reinforcements ← Modeled as Fabric to represent metal straps → (not an option in Slope/W)

Reinforcement 1

Type: Fabric
Outside Point: (53, 58) ft
Inside Point: (83, 58) ft
Slip Surface Intersection: (83.017, 58) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 ° ← AASHTO LRFD Table 3.11.5.3-1 for steel on silty sand (typ
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 374.08 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (53, 60) ft
Inside Point: (83, 60) ft
Slip Surface Intersection: (85.188, 60) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 285.22 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (53, 62) ft
Inside Point: (83, 62) ft
Slip Surface Intersection: (87.138, 62) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 254.67 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (53, 64) ft
Inside Point: (83, 64) ft
Slip Surface Intersection: (88.805, 64) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0

Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 254.67 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (53, 66) ft
Inside Point: (83, 66) ft
Slip Surface Intersection: (90.32, 66) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 212.64 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (53, 68) ft
Inside Point: (83, 68) ft
Slip Surface Intersection: (91.672, 68) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs

Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 212.64 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (53, 70) ft
Inside Point: (83, 70) ft
Slip Surface Intersection: (92.86, 70) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 155.26 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (53, 72) ft
Inside Point: (83, 72) ft
Slip Surface Intersection: (93.889, 72) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs

Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 155.26 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (53, 74) ft
Inside Point: (83, 74) ft
Slip Surface Intersection: (94.918, 74) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 155.26 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (53, 76) ft
Inside Point: (83, 76) ft
Slip Surface Intersection: (95.58, 76) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1

Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 60.894 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (53, 78) ft
Inside Point: (83, 78) ft
Slip Surface Intersection: (96.21, 78) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 60.894 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 12

Type: Fabric
Outside Point: (53, 80) ft
Inside Point: (83, 80) ft
Slip Surface Intersection: (96.84, 80) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf

Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 60.894 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 13

Type: Fabric
Outside Point: (53, 82) ft
Inside Point: (83, 82) ft
Slip Surface Intersection: (97.47, 82) ft
Total Length: 30 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 60.894 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Shear/Normal Strength Functions

CU Tests

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %

Segment Curvature: 100 %
Y-Intercept: 188.17854
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (500, 487)
Data Point: (1000, 775)
Data Point: (1500, 1017)
Data Point: (2000, 1234)
Data Point: (2500, 1433)
Data Point: (3000, 1619)
Data Point: (3500, 1795)
Data Point: (4000, 1963)
Data Point: (4500, 2124)
Data Point: (5000, 2280)
Data Point: (5500, 2430)
Data Point: (6000, 2576)
Data Point: (6500, 2718)
Data Point: (7000, 2856)
Data Point: (7500, 2991)
Data Point: (8000, 3123)
Data Point: (8500, 3253)
Data Point: (9000, 3380)
Data Point: (9500, 3505)
Data Point: (10000, 3627)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	IIa EL 0 to EL -15	23,24,22,21	3000
Region 2	IIa EL 18 to EL 0	21,22,20,19	3600
Region 3	IIa EL 38 to EL 18	19,17,18,20	4000
Region 4	Foundation Soil (IIa) to EL 38	1,2,3,4,6,25,26,15,16,18,17	4907.485
Region 5	DelDOT Type B Borrow	4,3,5,7,6	750.015

Region 6	DelDOT Type F Borrow	5,8,9,10,11,12,13,14,15,26,25,6,27,7	1958.5
Region 7	No. 57 Stone	6,27,7	187.5

Points

	X (ft)	Y (ft)
Point 1	0	60
Point 2	10	60
Point 3	53	61
Point 4	52.99	EL 58 ← Toe of RW4
Point 5	53	EL 83 ← Top of RW4
Point 6	83	58
Point 7	83	83
Point 8	63	88
Point 9	67	88
Point 10	103	90
Point 11	110	90
Point 12	118	89
Point 13	160	91
Point 14	161	91
Point 15	161	66
Point 16	200	66
Point 17	0	38
Point 18	200	38
Point 19	0	18
Point 20	200	18
Point 21	0	0
Point 22	200	0
Point 23	0	-15
Point 24	200	-15
Point 25	87	60
Point 26	105	64
Point 27	98	83

Wall Height = Point 5 - Point 4

= 83 - 58

H = 25'

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	4650	2.097	(54.238, 91.86)	44.439	(98.6276, 89.7571)	(22.9515, 60.3012)

Slices of Slip Surface: 4650

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)
1	4650	23.104875	60.1506	-9.3974237	151.59949	90.601099
2	4650	24.466135	58.90866	68.09796	358.44265	173.52003
3	4650	26.88188	56.872885	195.13172	703.36509	303.73785
4	4650	29.297625	55.108745	305.21259	1014.5552	415.86934
5	4650	31.713375	53.578325	400.72653	1287.8406	495.6897
6	4650	34.129125	52.25433	483.33554	1520.3569	542.76408
7	4650	36.544875	51.116515	554.31417	1711.2395	574.70546
8	4650	38.960625	50.14956	614.68496	1860.7688	598.84277
9	4650	41.376375	49.34175	665.0921	1969.8391	615.35862
10	4650	43.792125	48.68412	706.10956	2040.0732	623.85247
11	4650	46.331665	48.150995	676.32026	2080.9087	645.35549
12	4650	48.995	47.751805	660.68003	2081.2167	650.43243
13	4650	51.663335	47.515885	635.36354	2044.7473	646.87371
14	4650	54.25	47.438595	659.04	4936.4	1373.2277
15	4650	56.75	47.50971	654.59108	4933.2949	1373.5768
16	4650	59.25	47.722435	641.31914	4899.7164	1368.9437
17	4650	61.75	48.078835	619.07409	4841.6538	1360.9268
18	4650	64	48.518525	591.62997	4711.6749	1338.6042
19	4650	66	49.01829	560.46233	4519.716	1304.9532
20	4650	68.375	49.754475	514.5376	3695.1149	1126.8013
21	4650	71.125	50.781355	450.44348	3435.2495	1080.1312
22	4650	73.875	52.024385	372.86829	3169.1521	1034.0994
23	4650	76.625	53.50472	280.50553	2895.158	988.2556
24	4650	79.25	55.159135	185.44619	2624.2236	942.41539
25	4650	81.773035	57.01702	108.30764	2351.2006	892.28347
26	4650	83.40765	58.33766	51.378757	1842.9881	952.61558

27	4650	84.224125	59.06826	18.7238	1778.692	935.79171	
28	4650	85.83951	60.659625	-54.557156	1646.704	875.56807	
29	4650	88.333685	63.434735	-202.5792	1426.6536	758.56519	
30	4650	91.001055	67.00726	-404.52286	1147.3659	610.06528	
31	4650	93.668425	71.57212	-667.62469	791.70549	420.95728	
32	4650	96.393655	78.582085	-1081.0933	265.26997	141.04655	
33	4650	98.206405	86.378545	-1549.1822	5.2593481e-012	2.796445e-012	

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Subject I-95/SR1 Interchange — Page 1 of 20
Retaining Wall 4 Settlement Analysis — Cm. No. 103-059-270
Prepared By SAB Date 9/25/08 Checked By JJT Date 9-30-08
REV 1/7/09 JJT 1-18-09

Objective: To estimate the settlement anticipated to occur from the construction of Retaining Wall 4.

Wall Details:

Length of Retaining Wall 4 = 277'

→ Analyze tallest section: 100' from Ramp A STA 1252+00 to 1253+00.

⇒ From MSEW analysis, (L/H = 1.2, No. 57 reinf.) Maximum Stress = σ_v = 4,046 psf (Service Loads) - see p. 16 B = 30' e = 0.89 → B' = 28.2'

→ 4' overburden @ back of reinforcement zone to be removed (ave); 13' @ wall face (See cross-section, p. 1a)

⇒ Avg. overburden removed ≈ 9' → Existing γ_t = 130 pcf ⇒ overburden = 9'(130 pcf) = 1,170 psf

⇒ So, New stress applied = 4,046 − 1,170 = 2,876 psf

Distance b/t RW 4 face & RW 9 Face ≈ 107'

So width of Fill behind effective reinforcement zone of RW 4 = 107 − 28.2 = 78.8'

⇒ To estimate differential settlement, model STA 1253+00 to STA 1254+00 as an embankment.

⇒ Average Height = 22.5' Average width = 120'

→ So use a 100' long 120' wide footing with σ_v = 22.5'(130 pcf) = 2925 psf

→ S-3 Abutment (Ramp B) adjoins RW 4 @ STA 1252+00.

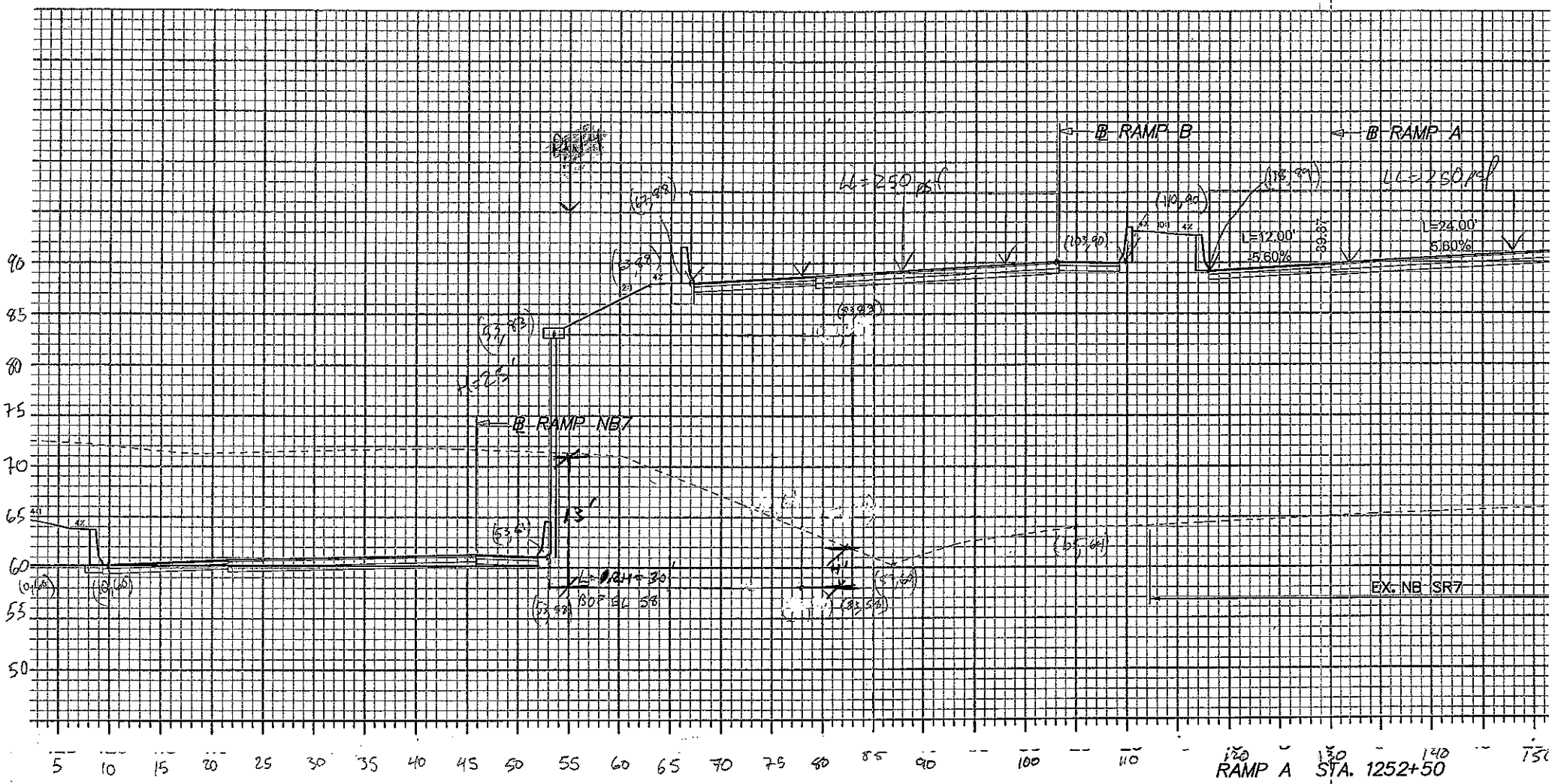
⇒ From URS, Bearing stress = 2.57 tsf = 5,140 psf, B = 26'

→ Embankment behind RW 4: Average Height ≈ 25' Fill: γ_t = 130 pcf

⇒ σ_v = 25'(130 pcf) = 3,250 psf

I-95/SR1 Interchange
RW 4 Settlement

103-059-270
1/15/09



RAMP A STA. 1252+50
RW STA 637+50
(SR 7)

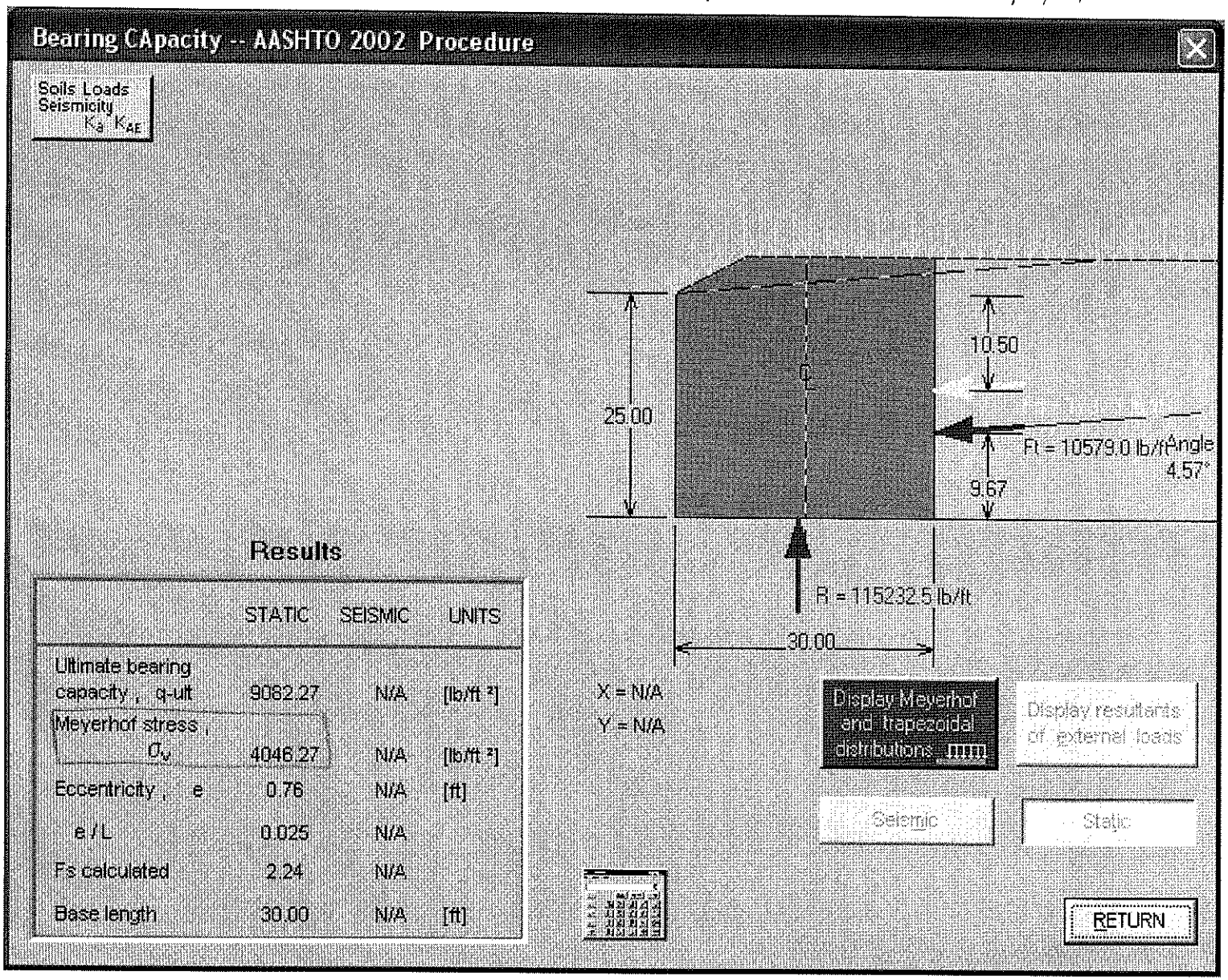
RKK RW4-83
1-18-09

1a

SR 1/I-95 Interchange 103-059-27U

RW 4 - Meyerhof stress calculated using Service loads (for settlement)

1/7/09



Results

	STATIC	SEISMIC	UNITS
Ultimate bearing capacity , q-ult	9082.27	N/A	[lb/ft ²]
Meyerhof stress , σ_v	4046.27	N/A	[lb/ft ²]
Eccentricity , e	0.76	N/A	[ft]
e / L	0.025	N/A	
Fs calculated	2.24	N/A	
Base length	30.00	N/A	[ft]

RKK RW4-84

16

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Subject I-95/SR1 Interchange — RW 4 Settlement Analysis — Page 2 of ____ — Cm. No. 103-059-270
Prepared By SAB — Date 9/25/08 REV 1/7/09 — Checked By [illegible] — Date 9-30-08, 1-18-09, 2/2/09

Soils: (See attached fence diagram, p. 4)

→ Assume BOF EL = EL 58 — Water @ EL 62 (above BOF EL)

Stratum	EL	γ_t (pcf)	S_u (ksf)	μ	Avg. N^{60}	E (ksf) (3)	C_c (1)	C_r (1)	e_o (1)	C_v (ft²/day) (1)	OCR (1)	P_c (psf) (1)	P_o @ Bottom (psf) (2)
1.) IIa	58-38	130	2.5	0.4	18	545	0.016	0.016	0.633	—	3.4	8,000	1,352
2.) IIa	38-18	130	2.5	0.4	22	818	0.016	0.016	0.654	—	2.2	10,000	2,704
3.) IIa	18-0	130	3.5	0.4	21	1,364	0.016	0.016	0.654	—	2	10,000	3,921
4.) IIa	0-15	130	5	0.4	31	1,364	0.016	0.016	0.654	—	2	(10,000)	4,935
5.) IIb	Below -15	130	—	0.3	69	1,364	—	—	—	—	—	—	—

(1) $C_c = C_r$ since $\Delta\sigma < P_c$. Use $C_r = 10\% C_c$.
Consolidation parameters derived from general site lab testing. (See page 5)

(2) P_o:
1. 20'(130-62.4) = 1,352 psf
2. 1,352 + 20'(130-62.4) = 2,704 psf
3. 2,704 + 18'(67.6) = 3,921 psf
4. 3,921 psf + 15'(67.6) = 4,935 psf

(3) E: (Equations found in Tables 2-7 & Table 5-5, attached p. 6) * IGNORE - use general site parameters for E values (calibrated w/ settlement plates)

1. Table 5-5; Clay → E = 500 to 1500 S_u = 500(1.5ksf) to 1500(1.5ksf) = 750 - 2,250 ksf
   Table 2-7: Clay (Medium) 300 - 1,000 ksf
   → So use E = 400 ksf
2. Table 5-5; Clay → E = 500 to 1500 S_u = 500(2.5ksf) to 1500(2.5ksf) = 1,250 to 3,750 ksf
   Table 2-7: Clay (Medium) 300 - 1,000 ksf
   → So use E = 450 ksf
3. Table 5-5; Clay → E = 500 to 1500 S_u = 500(3.5) = 1750 ksf
   Table 2-7: Clay (Medium) 300 - 1,000 ksf
   → Since N-value ≈ 2, use E = 450 ksf
4. Table 5-5; Clay → E = 500 S_u = 500(5) = 2,500 ksf
   Table 2-7: Clay (Medium) 300 - 1,000 ksf to (Hard) 1,000 - 2,000 ksf
   → So use E = 1,000 ksf

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Subject I-95/SR1 Interchange
RW4 Settlement Analysis
Page 3 of
Cm. No. 103-059-270
Prepared By SAB Date 9/26/08 REV 1/9/09 Checked By JJT Date 9-30-08 JJT 1-21-2009 EM

5. Table 5-5: Sand (NC), $E = 500(N+15) = 500(69+15)/50 = 840$ ksf
$E = (15{,}000 \text{ to } 22{,}000) \ln N = 1{,}270$ ksf to $1{,}860$ ksf
(Submitted) $E = 250(N+15) = 250(69+15)/50 = 420$ ksf

Table 2-7: Sand (Dense) $E = 1{,}000 - 1{,}700$ ksf

→ So use $E = 1{,}000$ ksf

* E values correlated to Settlement Plate data from Construction of Ramp A, B, C, 1 & 1A embankment.

Calculate $P_c - P_o$ for bottom of each layer:

1. $8{,}000 - 1{,}352 = 6{,}648$ psf
2. $10{,}000 - 2{,}704 = 7{,}296$ psf
3. $10{,}000 - 3{,}921 = 6{,}079$ psf
4. $10{,}000 - 4{,}935 = 5{,}065$ psf

Analysis: (Performed using FoSSA. See attached output)

→ Since Clay is O.C., use ~~C_r C_c~~ C_r & NOT C_c

→ Calculate elastic settlement to a depth of 4B below BOF EL.

⇒ Full "footing" width for RW4 & embankment = 107' (See p. 1)

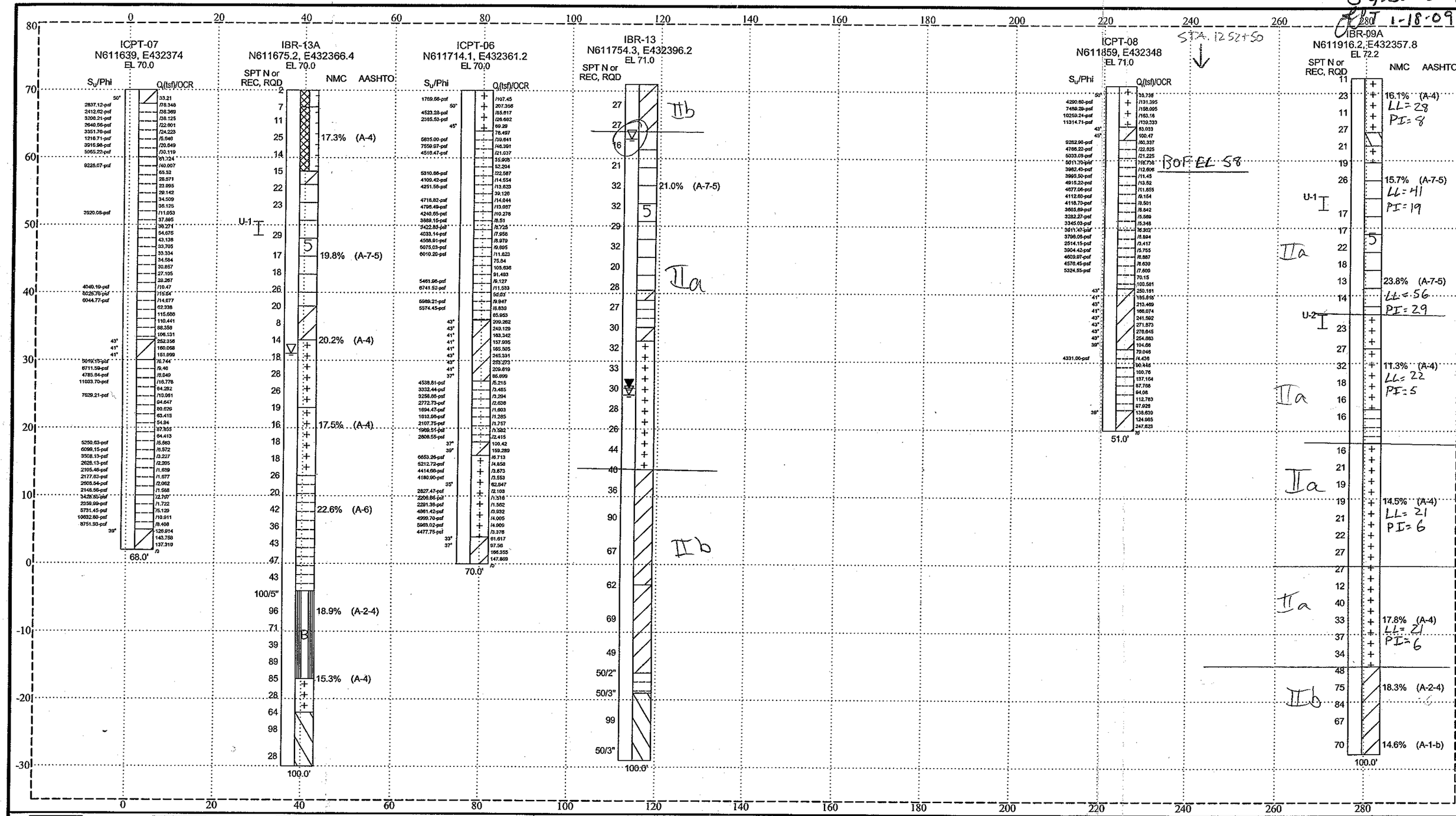
⇒ 4B = 428' BOF EL = 598, So calculate settlement to 598 − 428 = EL 370

→ Assume no elastic settlement from Clay (E_u); only consolidation settlement.

RKK RW4-87

RPT 9.30-08

RPT 1-18-09



AASHTO SOIL KEY

A	A-1-a	A-2-5	A-5	A-8	
B	A-1-b	A-2-6	A-6	Asphalt	
	A-3	A-2-7	A-7-5	FILL	
	A-2-4	A-4	A-7-6	Decomposed Rock	

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(410) 728-2900

Title: Summary of Boring Data

Retaining Wall 4

Figure No.

Drawn: SAB | Approved: EMK | Date: 9/23/08 | Comm. No. 103-059-27

DEL DOT AASHTO ALL DE 195 GINT FILE.GPJ RKK_CURRENT.GDT 9/23/08

SR 1/I-95 Interchange - Consolidation Soil Parameters - Stratum 2a

PointID	Sample	GS EL	GWL (ft)	Depth (ft)	Sample EL	γ_T (pcf)	NMC (%)	LL	PL	PI	LI	P_o (tsf)	$Pc_{Casagrande}$ (tsf)	$Pc_{Work\ Energy}$ (tsf)	OCR_C	$OCR_{W.E.}$	FINAL P_c (tsf)	FINAL OCR	e_0	c_c	c_r	$C_{v(Max)}$ (ft²/d)	$C_{v(Min)}$ (ft²/d)	cr/cc	CC	CR
IEB-15	U-1	83	52.0	12	71	129.5	26.7	49	26	23	0.03	0.78	3.53	6.00	4.5	7.7	3.53	4.5	0.669	0.19	0.05	3.17	0.02	26	11.384	0.030
IBR-61	U-1	84	24.0	14	70	123.6	30.7	34	21	13	0.75	0.87	2.91	1.85	3.4	2.1	2.91	3.4	0.748	0.24	0.05	2.64	0.03	21	13.730	0.029
IEB-13A	T-1	84	9.6	15	69	77.8	18.7	33	19	14	-0.02	0.82	2.96	3.30	3.6	4.0	3.13	3.8	0.554	0.12	0.02	0.23		17	7.722	0.013
IBR-60	U-1	86	11.4	18	68	133.3	20.5	30	19	11	0.14	0.94	1.97	1.83	2.1	2.0	1.97	2.1	0.521	0.13	0.03	2.10	0.01	23	8.547	0.020
ICPT-15A	T-1	80.19	3.0	19	61.19	101.5	24.4	49	23	26	0.05	0.69	2.30	3.10	3.3	4.5	2.7	3.9	0.666	0.12	0.03	0.19	0.09	25	7.203	0.018
IRW-33A	T-1	80	15.0	24	56	107.8	23.3	42	21	21	0.11	1.10	1.25	0.90	1.1	0.8	1.08	1.0	0.685	0.19	0.07	0.41	0.01	37	11.276	0.042
IRW-44	T-1	81	10.0	25	56	103.6	20.1	40	19	21	0.05	1.11	2.91	3.93	2.6	3.5	3.42	3.1	0.657	0.17	0.05	0.11	0	29	10.260	0.030
URS-4	U-1	77	14.0	22	55	123.9	34.7	53	28	25	0.27	1.12	1.78	3.10	1.6	2.8	3.1	2.8	0.851	0.25	0.09	2.50	0.01	36	13.506	0.049
IRW-51	T-1	80	10.7	25	55	105.8	21.6	38	19	19	0.14	1.17	1.94	2.75	1.7	2.4	2.35	2.0	0.64	0.23	0.09	0.2	0.03	39	14.024	0.055
IRW-32	T-1	79	13.4	25	54	114.2	19.5	39	19	20	0.03	1.24	6.50	4.60	5.3	3.7	NV	NV	0.545	0.14	0.04	0.24	0.05	29	9.061	0.026
ICPT-16A	T-1	84.87	14.4	31	53.87	134.1	16.4	34	19	15	-0.17	1.90	3.90	5.00	2.1	2.6	4.45	2.3	0.474	0.07	0.01	2.27	0.29	14	4.749	0.007
IRW-52	T-2	88	15.2	35	53	108.3	22.3	44	19	25	0.13	1.63	2.56	2.60	1.6	1.6	2.58	1.6	0.628	0.16	0.05	0.47	0.24	31	9.828	0.031
IRW-50	T-1	77.69	5.2	25	52.69	111.2	19.9	NP	NP	NP		1.02	8.20	6.25	8.1	5.2	NV	NV	0.563	0.19	0.03	1.0	0	16	12.156	0.019
IEB-15	U-2	83	52.0	31	52	132.8	22.6	36	20	16	0.16	2.02	5.29	1.91	2.6	0.9	5.29	2.6	0.527	0.17	0.05	1.10	0.01	29	11.133	0.033
IRW-33	T-1	79	DRY	27	52	100.5	26.1	47	22	25	0.16	1.30	1.12	1.40	0.9	1.1	1.26	1.0	0.801	0.20	0.07	0.16	0.02	35	11.105	0.039
ICPT-15A	T-2	80.19	3.0	29	51.19	72.3	36.7	50	24	26	0.49	1.00	11.00	12.00	11.0	12.0	11.5	11.5	1.333	0.15	0.02	6.74	2.36	13	6.429	0.009
IBR-15	T-1	70	2.0	19.5	50.5	96.9	24.6	42	20	22	0.21	0.72	1.63	2.30	2.3	3.2	1.97	2.7	0.772	0.22	0.06	0.15	0.03	27	12.415	0.034
URS-1	U-1	73	6.0	24	49	126.0	33.5	48	24	24	0.40	0.95	0.67	0.70	0.7	0.7	NV	NV	0.792	0.23	0.07	0.17	0.03	30	12.835	0.039
IEB-13B	T-2	81.64	7.0	33	48.64	115.9	16.1	28	17	11	-0.08	1.40	5.70	7.25	4.1	5.2	6.48	4.6	0.454	0.04	0.01	6.87	2.47	25	2.751	0.007
IRW-53	T-1	69.39	18.5	16	48.39	107.6	19.9	39	17	22	0.13	0.96	1.96	4.00	2.0	4.2	NV	NV	0.539	0.15	0.04	0.32	0.04	27	9.747	0.026
URS-3	U-1	82	6.0	35	47	132.3	26.1	40	22	18	0.23	1.33	2.59	2.40	1.9	1.8	2.59	1.9	0.614	0.20	0.07	1.92	0.02	35	12.392	0.043
IBR-04	T-1	65	2.0	18	47	115.5	12.6	22	17	5	-0.88	0.67	3.00	2.75	4.5	4.1	2.88	4.3	0.487	0.05	0.01	1.5	0	20	3.362	0.007
IRW-49	T-2	77	2.6	30	47	113.4	20.7	60	19	41	0.04	1.12	5.11	4.00	4.5	3.6	4.56	4.1	0.475	0.09	0.03	0.3	0.08	33	6.102	0.020
IRW-42	T-2	75	1.0	30	45	114.7	26.1	44	22	22	0.19	1.18	3.96	4.38	3.4	3.7	4.17	3.5	0.541	0.18	0.04	0.22	0.01	22	11.681	0.026
IEB-13B	T-3	81.64	7.0	39	42.64	116.9	15.5	27	14	13	0.12	1.63	10.00	7.25	6.1	4.5	8.63	5.3	0.447	0.05	0.03	4.99	1.59		3.455	0.021
IBR-52	U-1	57	11.5	16	41	126.9	29.8	43	23	20	0.34	0.88	1.10	3.75	1.3	4.3	3.75	4.3	0.678	0.18	0.07	0.22	0.02	39	10.727	0.042
IBR-60	U-2	86	11.4	46	40	132.3	24.2	36	21	15	0.21	1.90	1.23	2.00	0.6	1.1	2.00	1.1	0.602	0.16	0.04	1.11	0.01	25	9.988	0.025
URS-4	U-2	77	14.0	37	40	131.2	26.9	42	22	20	0.25	1.64	1.01	1.12	0.6	0.7	NV	NV	0.458	0.20	0.06	2.35	0.01	30	13.717	0.041
														Above EL 40 Averages:			3.75	3.37	0.633	0.16	0.05	1.56	0.28	27	9.689	0.028
ICPT-16A	T-2	84.87	14.4	45	39.87	134.1	16.7	41	18	23	-0.06	2.45	4.20	3.90	1.7	1.6	4.05	1.7	0.304	0.07	0.01	0.99	0.23	14	5.368	0.008
IBR-32	T-3	89		50	39	132.7	16.7	31	18	13	-0.10	2.11	3.00	3.38	1.4	1.6	3.19	1.5	0.519	0.16	0.05	0.02		31	10.533	0.033
IRW-23	T-2	60	36.7	24.5	35.5	108.7	18.4	36	21	15	-0.17	0.81	4.96	3.63	6.1	4.5	4.29	5.3	0.522	0.13	0.03	0.38	0.06	23	8.541	0.020
ICPT-15A	T-3	80.19	3.0	45	35.19	97.3	22.3	53	22	31	0.01	1.47	3.50	2.20	2.4	1.5	2.85	1.9	0.739	0.12	0.04	0.09	0.05	33	6.901	0.023
IBR-05	T-2	66	38.0	31.5	34.5	119.0	16.0	21	18	3	-0.67	1.17	4.75	2.70	4.1	2.3	NV	NV	0.661	0.15	0.02	1.0		13	9.031	0.012
URS-3	U-2	82	6.0	50	32	117.0	42.8	51	24	27	0.70	1.74	0.84	1.20	0.5	0.7	NV	NV	0.987	0.27	0.08	0.33	0.01	30	13.588	0.040
ICPT-16A	T-3	84.87	14.4	55	29.87	134.1	13.2	64	26	38	-0.34	3.39	5.00	5.40	1.5	1.6	5.20	1.5	0.872	0.19	0.04	1.08	0.08	21	10.150	0.021
URS-5	U-1	63	4.0	35.5	27.5	121.5	34.5	55	29	26	0.21	1.24	2.01	1.60	1.6	1.3	2.01	1.6	0.786	0.23	0.09	1.61	0.01	39	12.878	0.050
IEB-15	U-3	83	52.0	56	27	132.8	25.5	47	25	22	0.02	3.56	2.40	4.05	0.7	1.1	4.05	1.1	0.582	0.20	0.06	1.70	0.01	30	12.642	0.038
IBR-61	U-2	84	24.0	59	25	123.3	33.3	46	24	22	0.42	2.55	0.69	2.50	0.3	1.0	2.50	1.0	0.839	0.22	0.06	0.56	0.01	27	11.963	0.033
IRW-09	T-2	59	DRY	35	24	110.9	17.5	23	18	5	-0.10	1.39	3.92	2.30	2.8	1.7	NV	NV	0.536	0.11	0.03	2.8	0.2	27	7.161	0.020
IEB-13B	T-4	81.64	7.0	59	22.64	104.1	22.1	NP	NP	NP		2.13	8.00	9.60	3.8	4.5	8.8	4.1	0.505	0.04	0.01	1.76	0.34	25	2.658	0.007
														EL 40 to 20 Averages:			4.10	2.2	0.654	0.16	0.04	1.03	0.10	26	9.285	0.025
														Total Average:			3.85	3.0	0.639	0.16	0.05	1.40	0.23	27	9.567	0.027

NV: Consolidation Test Not Valid

RW4-88
1-18-09

I-95/SR1 Interchange
RW 4

9/26/08

RKK RW4-89 - 270
Page 6

SPT 9-30-08

SPT 1-18-09

BOWLES, 4th Ed

TABLE 5-5 Equations for stress-strain modulus E_s by several test methods

E_s in kPa for SPT and units of q_c for CPT; divide kPa by 50 to obtain ksf. The N values should be estimated as N_{55} and not N_{70}

Soil	SPT	CPT
Sand (normally consolidated)	$E_s = 500(N + 15)$ $E_s = (15\,000 \text{ to } 22\,000) \ln N$ $E_s§ = (35\,000 \text{ to } 50\,000) \log N$	$E_s = 2 \text{ to } 4q_c$ $E_s† = (1 + D_r^2)q_c$
Sand (saturated)	$E_s = 250(N + 15)$	
Sand (overconsolidated)	$E_s‡ = 18\,000 + 750N$ $E_{s(OCR)} = E_{s(nc)}(OCR)^{1/2}$	$E_s = 6 \text{ to } 30q_c$
Gravelly sand and gravel	$E_s = 1200(N + 6)$ $E_s = 600(N + 6) \quad N \leq 15$ $E_s = 600(N + 6) + 2000 \quad N > 15$	
Clayey sand	$E_s = 320(N + 15)$	$E_s = 3 \text{ to } 6q_c$
Silty sand	$E_s = 300(N + 6)$	$E_s = 1 \text{ to } 2q_c$
Soft clay	—	$E_s = 3 \text{ to } 8q_c$
Clay	Using the undrained shear strength s_u in units of s_u $I_P > 30$ or organic $I_P < 30$ or stiff $E_{s(OCR)} = E_{s(nc)}(OCR)^{1/2}$	$E_s = 100 \text{ to } 500s_u$ $E_s = 500 \text{ to } 1500s_u$

† Vesić (1970).
‡ Author's equation from plot of D'Appolonia et al. (1970).
§ USSR (and may not be standard blow count N).
General sources: European Conference on Standard Penetration Testing (1974), vol. 2.1, pp. 150–151; CGJ, November 1983, pp. 726–737; Use of In Situ Tests in Geotechnical Engineering, ASCE (1986), p. 1173; Mitchel and Gardner (1975).

CLAYS

	S_u (ksf)
HARD	>4
VERY STIFF	2–4
STIFF	1–2
MEDIUM	0.5–1
SOFT	0.25–0.5
VERY SOFT	0–0.25

TRIAXIAL $E = 2.5q_c$

PLANE-STRAIN $E = 3.5q_c$

SHALLOW $E_s = 1500$ (ksf)

TABLE 2-7 Typical range of values for the static stress-strain modulus E_s for selected soils

Field values depend on stress history, water content, density, etc.

Soil	E_s ksf	E_s Mpa
Clay		
Very soft	50–250	2–15
Soft	100–500	5–25
Medium	300–1000	15–50
Hard	1000–2000	50–100
Sandy	500–5000	25–250
Glacial till		
Loose	200–3200	10–150
Dense	3000–15 000	150–720
Very dense	10 000–30 000	500–1440
Loess	300–1200	15–60
Sand		
Silty	150–450	5–20
Loose	200–500	10–25
Dense	1000–1700	50–81
Sand and gravel		
Loose	1000–3000	50–150
Dense	2000–4000	100–200
Shale	3000–300 000	150–5000
Silt	40–400	2–20

Fig 99 Bowles

TABLE 2-8 Values or value ranges for Poisson's ratio μ

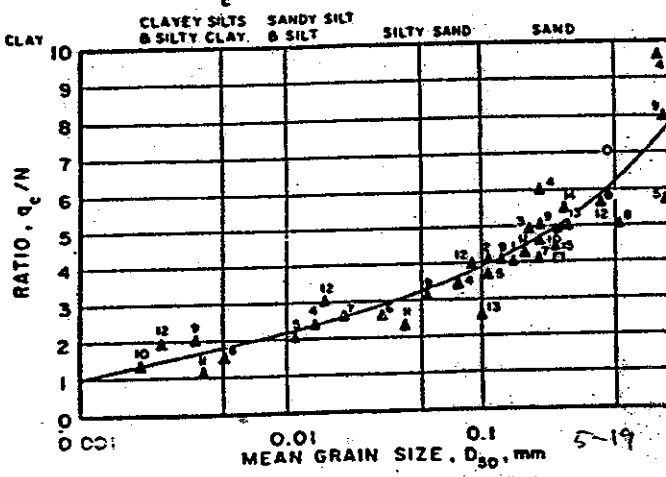
Type of soil	μ
Clay, saturated	0.4–0.5
Clay, unsaturated	0.1–0.3
Sandy clay	0.2–0.3
Silt	0.3–0.35
Sand, gravelly sand	–0.1–1.00
commonly used	0.3–0.4
Rock	0.1–0.4 (depends somewhat type of rock)
Loess	0.1–0.3
Ice	0.36
Concrete	0.15

μ FOR SAND $= \frac{1 - \sin\phi}{2 - \sin\phi}$

$\mu = 0.1 + 0.3\phi_r$

$\phi_r = \frac{\phi - 25°}{95° - 25°}$

FAIR $\phi = 40$

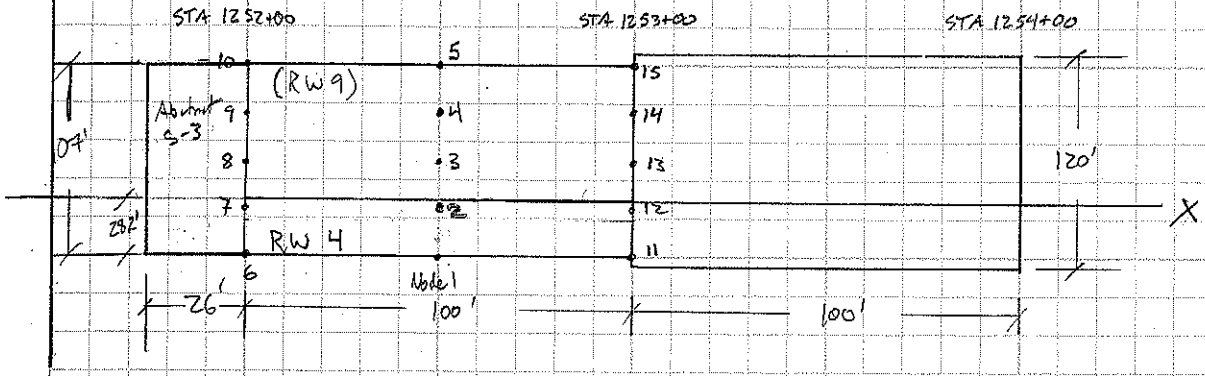


5-19

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject I-95/SR 1 Interchange RW4 Settlement
Page 7 of
Cm. No. 103-059.270
Prepared By SNB Date 9/26/08 Checked By JGT Date 9-30-08
REV 1/7/09 JGT 1-18-09
2M 2/9/09

Bird's Eye View of Settlement Points: (NTS)



Summary:

Maximum Elastic Settlement = 0.23' = 2.7" @ Points 3, 13

Maximum Consolidation Settlement = 0.35' = 4.2" @ Point 8

Maximum Total Settlement = 0.55' = 6.6" @ Points 3, 8, 13

Time-rate Settlement: Based on the settlement plate data, it is anticipated that a majority of the consolidation settlement will occur within less than a month of construction completion.

=> See page 20 for differential settlements. [AASHTO Tolerance = 1/100]

* Settlement from STA 1254+00 to wall and will be minimal because the height of overburden removed to build Ramp E @ the base of the wall & RW4 is equal to the proposed wall height. Only the fill added to build the 2(H):1(V) Backslope of create the embankment will cause very small settlements.

8

SPT
1-18-09
BW 2/9/09

SR 1/I-95 Interchange

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PROJECT IDENTIFICATION

Title:	SR 1/I-95 Interchange
Project Number:	103-059-27U -
Client:	DelDOT
Designer:	SAB
Station Number:	1252+50 RW 4

Description:
Retaining Wall 4

Company's information:

Name:	RK&K Engineers, LLP
Street:	81 Mosher Street Baltimore, MD 21217
Telephone #:	410-728-2900
Fax #:	410-728-0282
E-Mail:	

Original file path and name: M:\project ..... DESIGN 2008\Retaining Wall 4\Final Design\RW4.2ST
Original date and time of creating this file: Thu Jan 08 09:29:20 2009

GEOMETRY: Analysis of a Multiple Footings

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JJT 1-18-09

INPUT DATA – FOUNDATION LAYERS – 5 layers

	Wet Unit Weight, γ [lb/ft^3]	Poisson's Ratio μ	Description of Soil
1	130.00	0.40	IIa to EL 38
2	130.00	0.40	IIa to EL 18
3	130.00	0.40	IIa to EL 0
4	130.00	0.40	IIa to EL -15
5	130.00	0.30	IIb

INPUT DATA – MULTIPLE FOOTINGS – 4 footings

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	0.00	358.00
2	300.00	358.00

GW @ base of wall EL 358
actual EL = Z - 300

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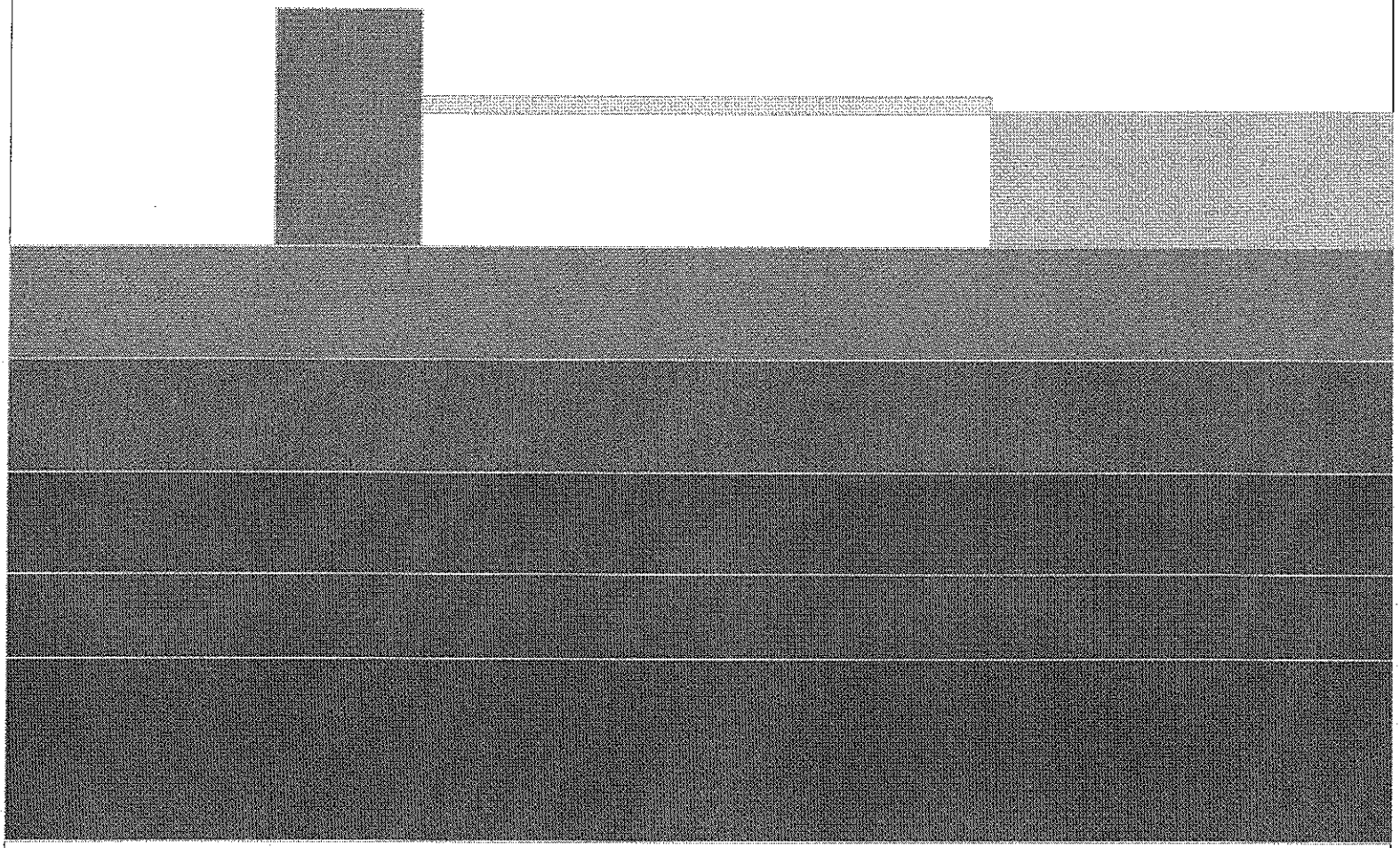
SJT
1-18-09

DRAWING OF SPECIFIED GEOMETRY



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JBT 1-18-09

INPUT DATA FOR CONSOLIDATION -- $\alpha = 1/6$

Layer # Underging Consolidation [Yes/No]		$(\sigma'_p - \sigma'_o)$ given at layer's boundaries in [lb/ft²] at Top	Bottom	Cc	Cr	e0	Cv [ft²/day]	Drains at :
1	Yes	8000.0	6648.0	0.02	0.02	0.63	0.0921	Top
2	Yes	6648.0	7296.0	0.02	0.02	0.65	0.7617	Bottom
3	Yes	7296.0	6079.0	0.02	0.02	0.65	0.7617	Bottom
4	Yes	6079.0	5065.0	0.02	0.02	0.65	0.7617	Bottom
5	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Rounded from 0.016

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JJT 1-18-09

TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	358.00	IIa to EL 38
	2	100.00	358.00	
	3	150.00	358.00	
	4	200.00	358.00	
	5	300.00	358.00	
2	1	0.00	338.00	IIa to EL 18
	2	100.00	338.00	
	3	150.00	338.00	
	4	200.00	338.00	
	5	300.00	338.00	
3	1	0.00	318.00	IIa to EL 0
	2	100.00	318.00	
	3	150.00	318.00	
	4	200.00	318.00	
	5	300.00	318.00	
4	1	0.00	300.00	IIa to EL -15
	2	100.00	300.00	
	3	150.00	300.00	
	4	200.00	300.00	
	5	300.00	300.00	
5	1	0.00	285.00	IIb
	2	100.00	285.00	
	3	150.00	285.00	
	4	200.00	285.00	
	5	300.00	285.00	

Actual EL = Z - 360

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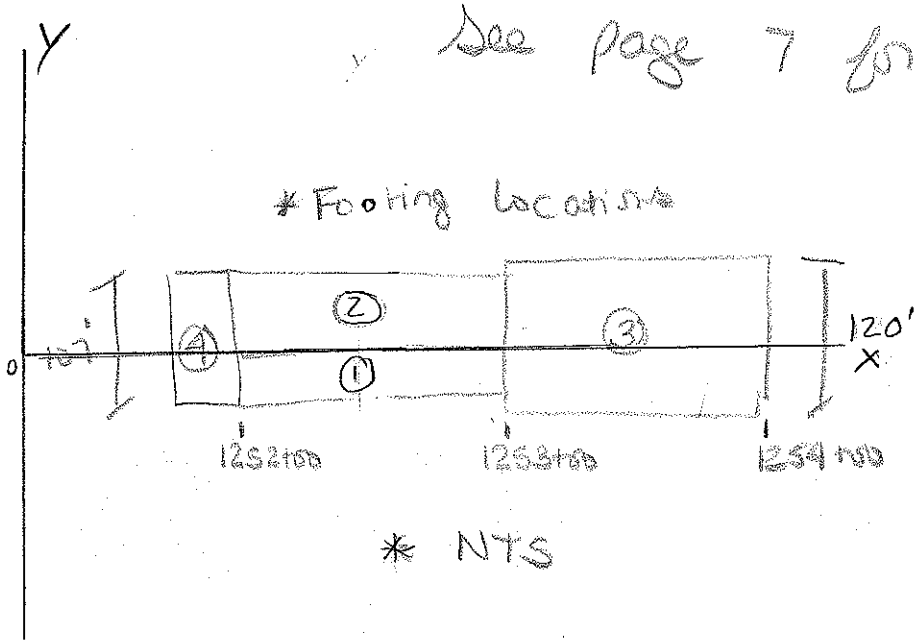
JJT 1-18-09

TABULATED GEOMETRY: INPUT OF MULTIPLE FOOTINGS – 4 footings

Footing #	L (in X direction) [ft]	B (in Y direction) [ft]	X of center [ft]	Y of center [ft]	q [ft]l [lb/ft²]
1	100.00	28.20	150.00	-39.40	2876.00
2	100.00	78.80	150.00	14.10	3250.00
3	100.00	120.00	250.00	0.00	2925.00
4	26.00	107.00	87.00	0.00	5140.00

RW 4 behind Emb
½ RW 4 Emb
other RW 4 S3 About

See page 7 for plan view



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1-18-09

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	150.00	-53.50	1	545000	0.4000	~~0.0180~~	358.00	~~357.75~~	~~0.25~~
			2	818000	0.4000	~~0.0178~~			
			3	1364000	0.4000	~~0.0124~~			
			4	1364000	0.4000	~~0.0114~~			0.186'
			5	1364000	0.3000	0.1859			2.2"
2	150.00	-26.75	1	545000	0.4000	~~0.0464~~	358.00	~~357.65~~	~~0.35~~
			2	818000	0.4000	~~0.0421~~			
			3	1364000	0.4000	~~0.0234~~			
			4	1364000	0.4000	~~0.0187~~			0.215'
			5	1364000	0.3000	0.2147			2.58"
3	150.00	0.00	1	545000	0.4000	~~0.0493~~	358.00	~~357.63~~	~~0.37~~
			2	818000	0.4000	~~0.0471~~			
			3	1364000	0.4000	~~0.0273~~			
			4	1364000	0.4000	~~0.0217~~			0.226'
			5	1364000	0.3000	0.2263			2.7"
4	150.00	26.75	1	545000	0.4000	~~0.0515~~	358.00	~~357.64~~	~~0.36~~
			2	818000	0.4000	~~0.0453~~			
			3	1364000	0.4000	~~0.0246~~			
			4	1364000	0.4000	~~0.0194~~			0.216'
			5	1364000	0.3000	0.2162			2.59"
5	150.00	53.50	1	545000	0.4000	~~0.0220~~	358.00	~~357.74~~	~~0.26~~
			2	818000	0.4000	~~0.0207~~			
			3	1364000	0.4000	~~0.0136~~			
			4	1364000	0.4000	~~0.0122~~			0.188'
			5	1364000	0.3000	0.1881			2.3"

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

Ignore elastic settlement of strata IIa

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SST 1-18-09

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
~~6~~	100.00	-53.50	1	545000	0.4000	~~0.0335~~	358.00	~~357.75~~	~~0.25~~
			2	818000	0.4000	~~0.0274~~			
			3	1364000	0.4000	~~0.0142~~			0.164'
			4	1364000	0.4000	~~0.0112~~			1.97"
			5	1364000	0.3000	0.1635			
~~7~~	100.00	-26.75	1	545000	0.4000	~~0.0753~~	358.00	~~357.63~~	~~0.37~~
			2	818000	0.4000	~~0.0584~~			
			3	1364000	0.4000	~~0.0262~~			
			4	1364000	0.4000	~~0.0185~~			0,189'
			5	1364000	0.3000	0.1885			2.3"
~~8~~	100.00	0.00	1	545000	0.4000	~~0.0756~~	358.00	~~357.61~~	~~0.39~~
			2	818000	0.4000	~~0.0626~~			
			3	1364000	0.4000	~~0.0298~~			
			4	1364000	0.4000	~~0.0212~~			0,198'
			5	1364000	0.3000	0.1984			2.38"
~~9~~	100.00	26.75	1	545000	0.4000	~~0.0778~~	358.00	~~357.63~~	~~0.37~~
			2	818000	0.4000	~~0.0600~~			
			3	1364000	0.4000	~~0.0268~~			
			4	1364000	0.4000	~~0.0188~~			0.190'
			5	1364000	0.3000	0.1896			2.28"
~~10~~	100.00	53.50	1	545000	0.4000	~~0.0359~~	358.00	~~357.74~~	~~0.26~~
			2	818000	0.4000	~~0.0289~~			
			3	1364000	0.4000	~~0.0148~~			
			4	1364000	0.4000	~~0.0116~~			0.165'
			5	1364000	0.3000	0.1650			1.98"

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

Ignore elastic settlement & Strata IIa

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JST 1-18-09

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	200.00	-53.50	1	545000	0.4000	~~0.0322~~	358.00	~~357.73~~	~~0.27~~
			2	818000	0.4000	~~0.0227~~			
			3	1364000	0.4000	~~0.0135~~			0.188'
			4	1364000	0.4000	~~0.0118~~			2.26"
			5	1364000	0.3000	0.1877			
2	200.00	-26.75	1	545000	0.4000	~~0.0477~~	358.00	~~357.65~~	~~0.35~~
			2	818000	0.4000	~~0.0424~~			
			3	1364000	0.4000	~~0.0232~~			0.216'
			4	1364000	0.4000	~~0.0185~~			2.59"
			5	1364000	0.3000	0.2155			
3	200.00	0.00	1	545000	0.4000	~~0.0483~~	358.00	~~357.63~~	~~0.37~~
			2	818000	0.4000	~~0.0454~~			
			3	1364000	0.4000	~~0.0262~~			0.226'
			4	1364000	0.4000	~~0.0210~~			2.71"
			5	1364000	0.3000	0.2264			
4	200.00	26.75	1	545000	0.4000	~~0.0503~~	358.00	~~357.65~~	~~0.35~~
			2	818000	0.4000	~~0.0441~~			
			3	1364000	0.4000	~~0.0239~~			0.217'
			4	1364000	0.4000	~~0.0189~~			2.60"
			5	1364000	0.3000	0.2166			
5	200.00	53.50	1	545000	0.4000	~~0.0343~~	358.00	~~357.73~~	~~0.27~~
			2	818000	0.4000	~~0.0242~~			
			3	1364000	0.4000	~~0.0142~~			0.189'
			4	1364000	0.4000	~~0.0123~~			2.27"
			5	1364000	0.3000	0.1893			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

Ignore elastic settlement of Strata IIa

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JCT 1-18-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]	Sc (in)
1	150.00	-53.50	358.00	0.21	357.79	2.52
2	150.00	-26.75	358.00	0.30	357.70	3.6
3	150.00	0.00	358.00	0.32	357.68	3.8
4	150.00	26.75	358.00	0.31	357.69	3.7
5	150.00	53.50	358.00	0.22	357.78	2.6

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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JDT 1-18-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]	Sc (in)
#6	100.00	-53.50	358.00	0.24	357.76	2.88
#7	100.00	-26.75	358.00	0.33	357.67	3.96
#8	100.00	0.00	358.00	0.35	357.65	4.2
#9	100.00	26.75	358.00	0.34	357.66	4.08
#10	100.00	53.50	358.00	0.24	357.76	2.88

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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JLT 1-18-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]	Sc (in)
1	200.00	-53.50	358.00	0.24	357.76	2.88
2	200.00	-26.75	358.00	0.30	357.70	3.60
3	200.00	0.00	358.00	0.32	357.68	3.84
4	200.00	26.75	358.00	0.31	357.69	3.72
5	200.00	53.50	358.00	0.24	357.76	2.88

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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SR 1/I-95 Interchange 103-059-27U 1/15/2009
Retaining Wall 4 Settlement Results

Point	Settlement (ft)		
	Elastic	Consolidation	Total
1	0.19	0.21	0.40
2	0.22	0.30	0.52
3	0.23	0.32	0.55
4	0.22	0.31	0.53
5	0.19	0.22	0.41
6	0.16	0.24	0.40
7	0.19	0.33	0.52
8	0.20	0.35	0.55
9	0.19	0.34	0.53
10	0.17	0.24	0.41
11	0.19	0.24	0.43
12	0.22	0.30	0.52
13	0.23	0.32	0.55
14	0.22	0.31	0.53
15	0.19	0.24	0.43

Point	Settlement (in)		
	Elastic	Consolidation	Total
1	2.2	2.5	4.8
2	2.6	3.6	6.2
3	2.7	3.8	6.6
4	2.6	3.7	6.3
5	2.3	2.6	4.9
6	2.0	2.9	4.8
7	2.3	4.0	6.2
8	2.4	4.2	6.6
9	2.3	4.1	6.4
10	2.0	2.9	4.9
11	2.3	2.9	5.1
12	2.6	3.6	6.2
13	2.7	3.8	6.6
14	2.6	3.7	6.3
15	2.3	2.9	5.1

rounded in Excel

Max 6.6"
Min 4.8"

	RW 4 Differential Settlement				
	Along Front RW 4		Along Back RW 4		Front to Back
	6 to 1	1 to 11	7 to 2	2 to 12	1 to 2
Inches	-0.1	0.4	0.0	0.0	1.4
Ratio	1/6250	2/3125	-	-	1/237

All differential settlements are within the AASHTO tolerance of 1/100.

* For point locations see P8 7

RW4-103
1-18-09
EM
2/9/09

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 4\Final Design\RW 4 Settlement Results Final.xls

CALCULATION CHECKLIST

Project: SR-1/I-95 INTERCHANGE Comm. No.: 108-059

Title of Calculation Set: DESIGN OF RETAINING WALL - 5

Project Manager: EMK

Calculations Prepared By: BBS

Calculation Checked By:

Computer Programs / Files: MSEW, SLOPE W, FOSSA

Initial	Date	
BBS	1-22-09	Subsurface Characterization approved by Project Manager
BBS	1-22-09	Calculations are neat, legible and understandable.
BBS	1-22-09	Table of Contents is provided.
BBS	1-22-09	Heading on each page filled out
BBS	1-22-09	The first page contains purpose of the calculation.
BBS	1-22-09	Symbols are defined.
BBS	1-22-09	References for data, methods, formulas and computer program names and version numbers are given.
BBS	1-22-09	Assumptions are listed and those that need to be verified later are Flagged.
BBS	1-22-09	Headings on front sheet of each set of computer input and output.
BBS	1-22-09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JJT	1-23-09	All calculations checked and each calculation sheet initialed by checker.
EMK	2/9/09	Calculation set reviewed by Project Manager.
		Has this calculation been superseded? Reference new calculation, if applicable.

This sheet is to be prepared by the originator of the calculation and attached to the front of the calculation set.

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Subject SR-1/I-95 INTERCHANGE Page ____ of ____
RETAINING WALL RW-5 Cm. No. 103-059
Prepared By BBS Date 1-22-09 Checked By JJT Date 1-23-09

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PURPOSE	1
SOIL PROFILE	2
SOIL PARAMETERS	3
WALL DESIGN	9
(STRAP LENGTH = 0.8H)	11
GLOBAL STABILITY	25
SETTLEMENT	52
FENCE DIAGRAM	66
TYPICAL CROSS-SECTION	67
LOCATION PLAN	69

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RETAINING WALL RW-5
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PURPOSE: DESIGN OF RETAINING WALL 5

REFERENCE: AASHTO LRFD BRIDGE DESIGN SPECIFICATION
CUSTOMARY US UNITS 14th EDITION 2007.

SOFTWARE: MSEW 2.0
FOSSA 2.0

SYMBOLS:

UNIT WEIGHT → γ
FRICTION ANGLE → ϕ
UNDRAINED SHEAR STRENGTH → S_u
MODULUS OF ELASTICITY → E_s
POISSON'S RATIO → μ

COMPRESSION INDEX → C_c
RE-COMPRESSION/SWELL INDEX → C_s ; C_R
COEFFICIENT OF CONSOLIDATION, C_v

WALL: LENGTH OF WALL = 128-ft
MAX HEIGHT OF WALL = 35-ft.
DEPTH OF EMBEDMENT = 3-ft
MAX EXPOSED HEIGHT OF WALL = 32-ft.

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RETAINING WALL RW-5 Cm. No. 103-059
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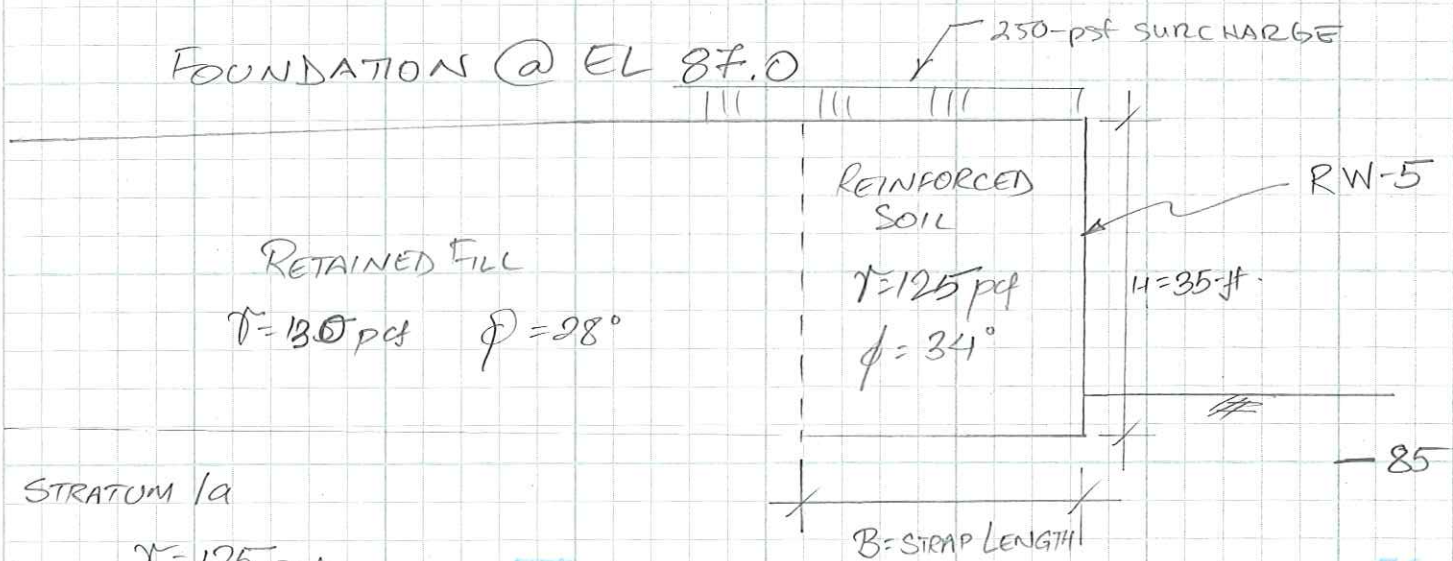
SOIL PARAMETERS RW-5

FOUNDATION @ EL 87.0



STRATUM 1a
γ=125 pcf
φ=32°
C=0
E_s=1500 ksf μ=0.3

STRATUM 2a (i)
γ=130 pcf
φ=0
C=1500 psf
E_s=818 ksf
μ=0.4
C_c=0.092 OCR=5.3
C_R=0.015

STRATUM 2a (ii)
γ=130 pcf
φ=0
C=2500 psf
E_s=818 ksf
μ=0.4
C_c=0.092 OCR=5.3
C_R=0.015

STRATUM 2a (iii)
γ=130 pcf
φ=0
C=3500 psf
E_s=818 ksf
μ=0.4
C_c=0.105 OCR=2.3
C_R=0.015

STRATUM 2a(iv) γ=130 pcf C=5000 psf
E_s=1364 ksf μ=0.4 C_c 0.105 C_R 0.015 OCR=2.3

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RETAINING WALL -5 Cm. No. 103-059
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EM 2/8/09

SOIL PARAMETERS

UNDRAINED SHEAR STRENGTH OF SOIL DEVELOPED FROM UU & UC TEST RESULTS. SEE CHART

DRAINED SOIL PARAMETERS DEVELOPED FROM CU RESULTS.

DRAINED FRICTION ANGLE USED FOR BEARING CAPACITY

SPLINE FUNCTION USED FOR GLOBAL STABILITY.

DRAINED LONGTERM PARAMETER

STRATUM IIa $\phi = 24°$ $C = 0$

SPLINE FUNCTION.

SHEAR STRENGTH = $0.7753\,(\text{SHEAR STRESS})^{0.6701}$

YOUNGS MODULUS ESTIMATED FROM BACK CALCULATED E_s VALUES FROM SETTLEMENT PLATE RESULTS

CONSOLIDATION SOIL PARAMETERS

COMPRESSION INDEX (C_c) & VOID RATIO (e_o) OBTAINED FROM CONSOLIDATION TEST RESULTS

RECOMPRESSION INDEX (C_r) BACK CALCULATED FROM SETTLEMENT PLATE RESULTS.

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RETAINING WALL - 5
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EM 2/8/09

SOIL PARAMETERS

STRATUM 1 EL 65 & ABOVE (COARSE GRAINED)

$\gamma = 125$ pcf $E_s = 1500$ ksf

$\phi = 32°$ $\mu = 0.3$

STRATUM 2a (FINE GRAINED)

$\gamma = 130$ pcf $\phi = 0$ $\mu = 0.4$

EL 40 & ABOVE

$S_u = 1500$ psf $C_c = 0.092$ $e_o = 0.655$

$E_s = 818$ ksf $C_r = 0.015$ OCR = 5.3

EL 20 TO EL 40

$S_u = 2500$ psf $C_c = 0.092$ $e_o = 0.655$

$E_s = 818$ ksf $C_r = 0.015$ OCR = 5.3

EL 0 TO EL 20

$S_u = 3500$ psf $C_c = 0.105$ $e_o = 0.605$

$E_s = 818$ ksf $C_r = 0.015$ OCR = 2.3

EL 0 & BELOW

$S_u = 5000$ psf $C_c = 0.105$ $e_o = 0.605$

$E_s = 1364$ ksf $C_r = 0.015$ OCR = 2.3

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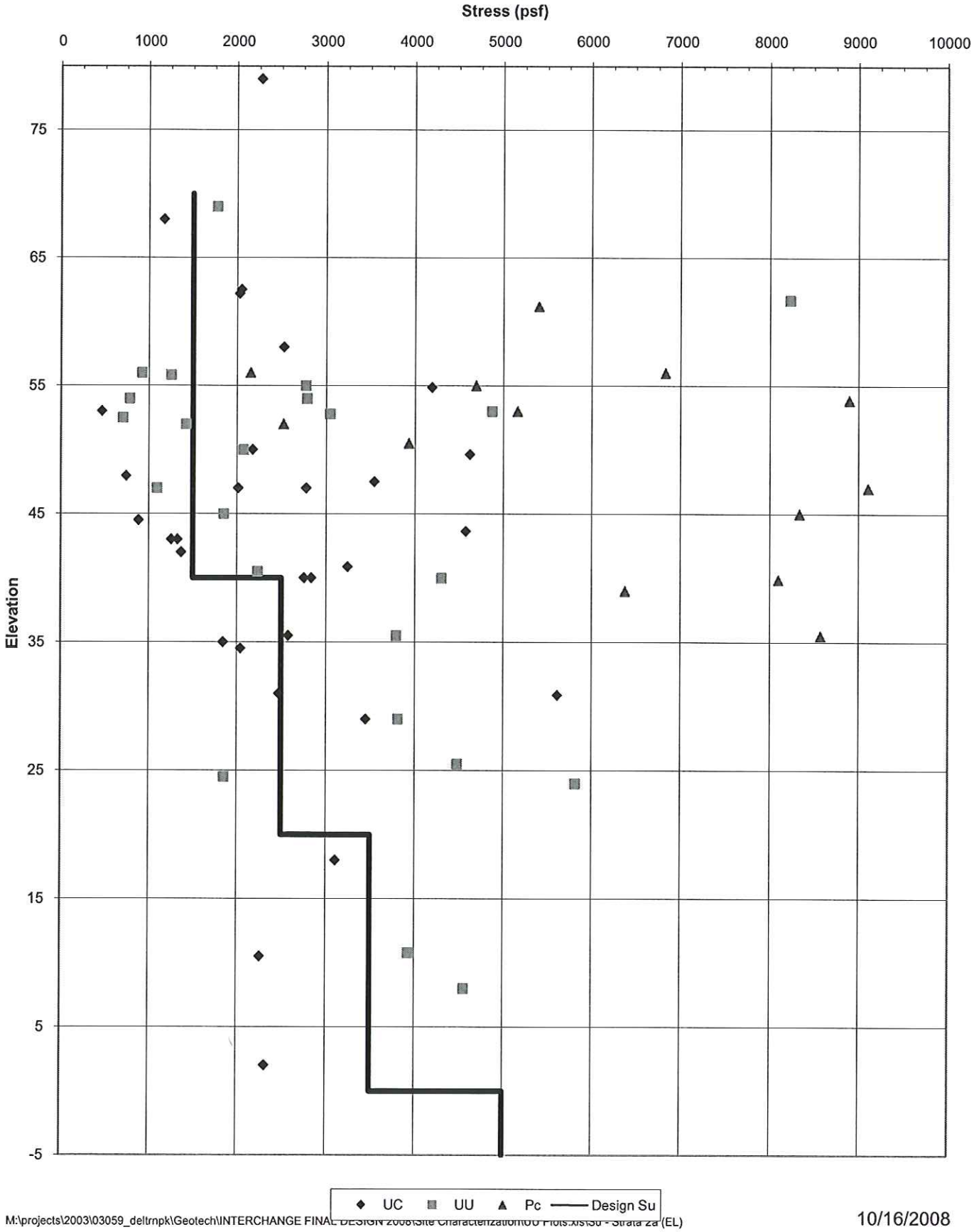
AT 1-23-09
Am 2/8/09

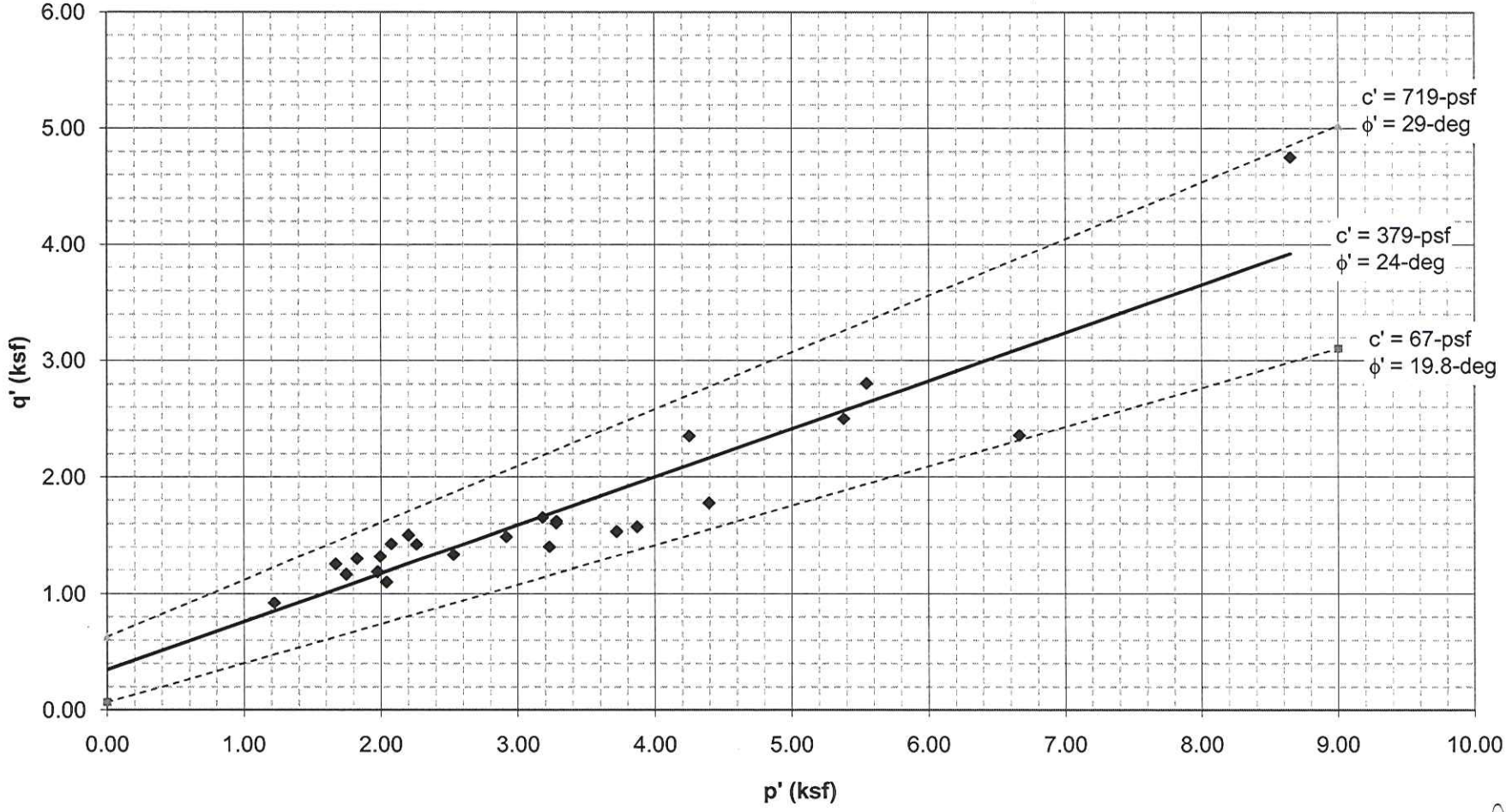
Figure C-1
Summary of Undrained Shear Testing with Stress History
Strata IIa



M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\00 Plots.xls\Su - Strata 2a (EL)

10/16/2008

Figure C-2a
Summary of CU with Pore Pressure
Effective Stress - Strata IIa
EL 40 & Above



RKK RW5-8

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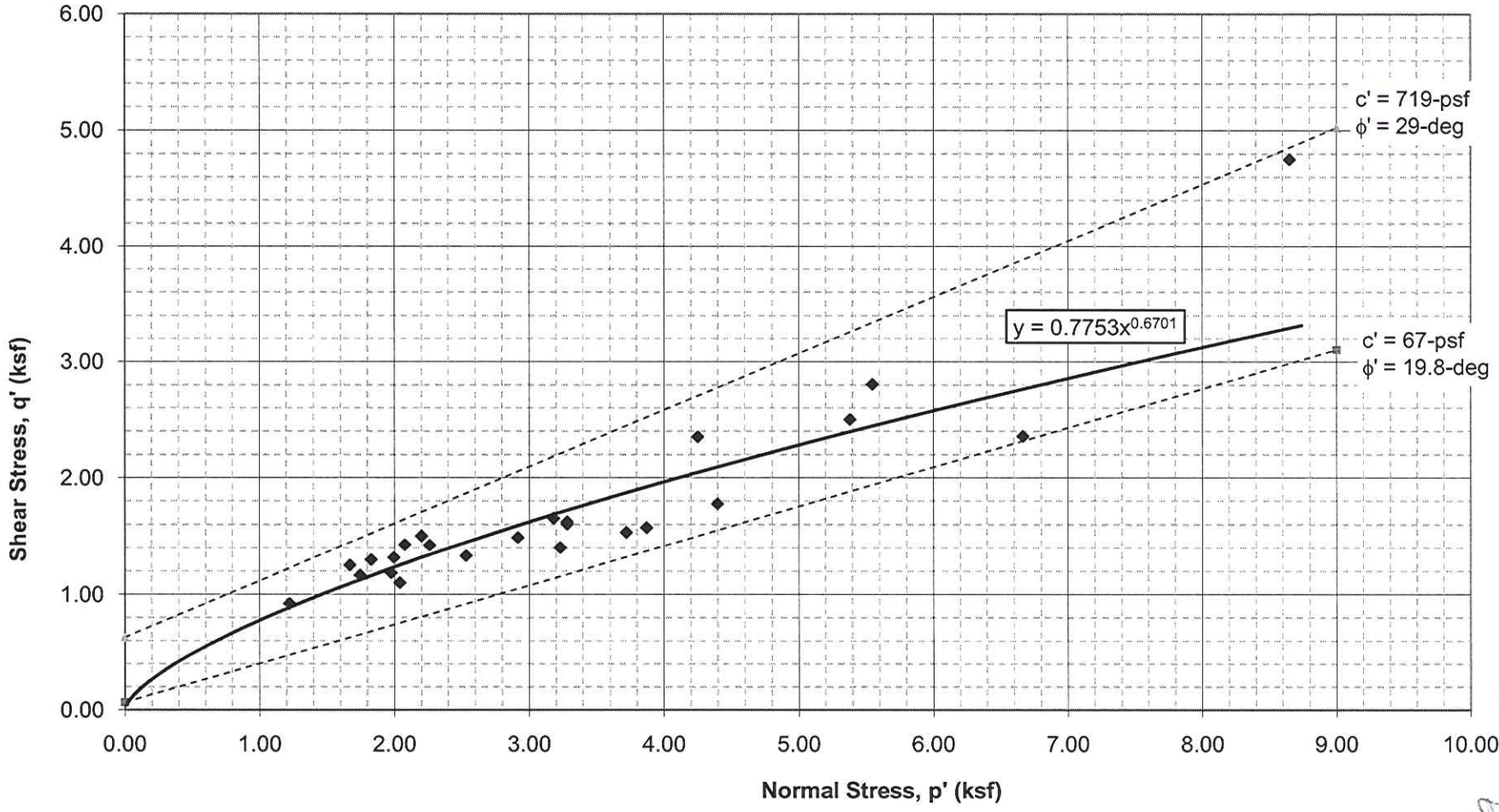
DOT 1-23-09

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\CICU Plots(Revised).xls\CU Effect Plot EL 40&Above

1/22/2009

Figure C-2a
Summary of CU with Pore Pressure
Effective Stress - Strata IIa
EL 40 & Above



RKK RW5-9

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\CICU Plots(Revised).xls\CU Effect Plot EL 40&Above (SP)

1/22/2009

SR 1/I-95 Interchange - Consolidation Soil Parameters - Stratum 2a (Abutment A)																	
PointID	Sample	GS EL	GWL (ft)	Depth (ft)	Sample EL	P_0 (tsf)	$Pc_{Casagrande}$ (tsf)	$Pc_{Work\ Energy}$ (tsf)	OCR_C	$OCR_{W.E.}$	FINAL P_c (tsf)	FINAL OCR	Avg OCR	e_0	Avg e_o	C_c	Avg C_c
IEB-13A	T-1	84	9.6	15	69	0.82	2.95	3.30	3.6	4.0	3.13	3.8	5.3	0.554	0.655	0.12	0.092
ICPT-15A	T-1	80.19	3.0	19	61.19	0.69	2.30	3.10	3.3	4.5	2.7	3.9		0.666		0.12	
ICPT-16A	T-1	84.87	14.4	31	53.87	1.90	3.90	5.00	2.1	2.6	4.45	2.3		0.474		0.07	
ICPT-15A	T-2	80.19	3.0	29	51.19	1.00	11.00	12.00	11.0	12.0	11.5	11.5		1.333		0.15	
IEB-13B	T-2	81.64	7.0	33	48.64	1.40	5.70	7.25	4.1	5.2	6.48	4.6		0.454		0.04	
IEB-13B	T-3	81.64	7.0	39	42.64	1.63	10.00	7.25	6.1	4.5	8.63	5.3		0.447		0.05	
ICPT-16A	T-2	84.87	14.4	45	39.87	2.45	4.20	3.90	1.7	1.6	4.05	1.7	2.3	0.304	0.605	0.07	0.105
ICPT-15A	T-3	80.19	3.0	45	35.19	1.47	3.50	2.20	2.4	1.5	2.85	1.9		0.739		0.12	
ICPT-16A	T-3	84.87	14.4	55	29.87	3.39	5.00	5.40	1.5	1.6	5.20	1.5		0.872		0.19	
IEB-13B	T-4	81.64	7.0	59	22.64	2.13	8.00	9.60	3.8	4.5	8.8	4.1		0.505		0.04	

RKK RW5-10

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JT 1-23-09
NWC 2/8/09

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EM 2/6/09

MSE WALL DESIGN PARAMETERS

REINFORCED SOIL

$\gamma_R = 125$ pcf $\phi_R = 34°$ Select

RETAINED SOIL

$\gamma = 130$ pcf $\phi = 26°$ ISRIDOT Type E Borrow

FOUNDATION SOIL

$\gamma_f = 125$ pcf $\phi_f = 32°$ FOR SAND (STRATUM 1)
~22' THICK BELOW LP

STRENGTH LIMIT STATE FOR BEARING CAPACITY SLIDING & ECCENTRICITY CALCULATION

SERVICE LIMIT STATE FOR SETTLEMENT ANALYSIS

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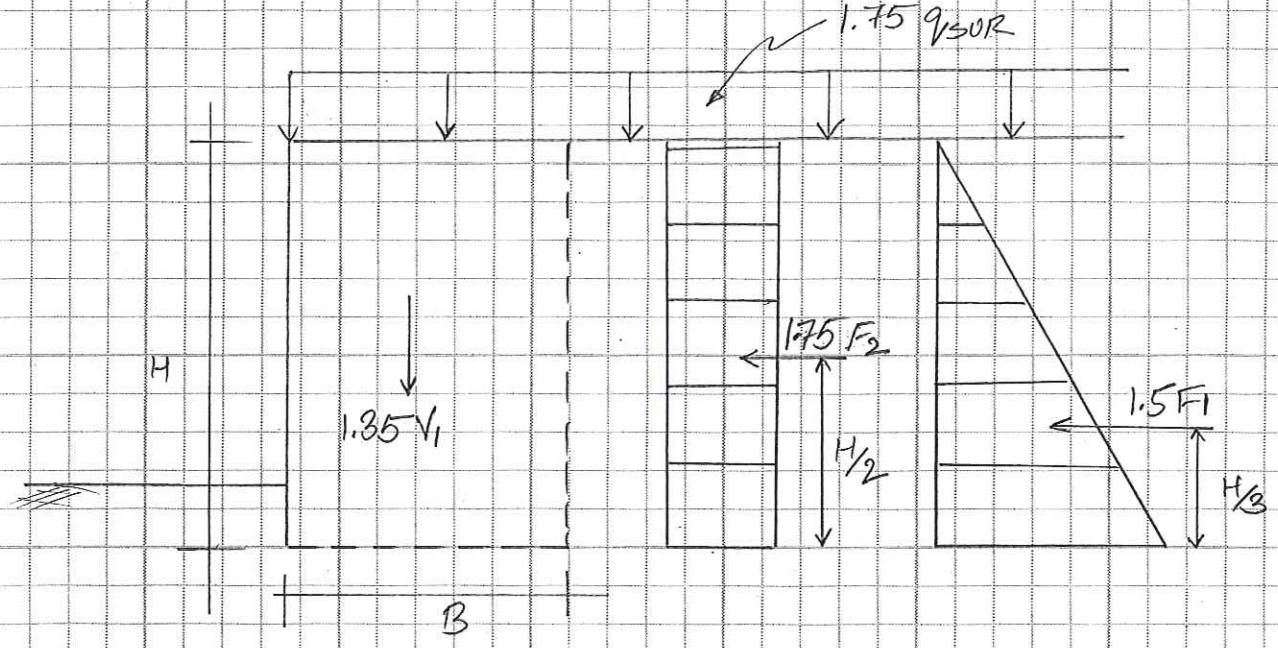
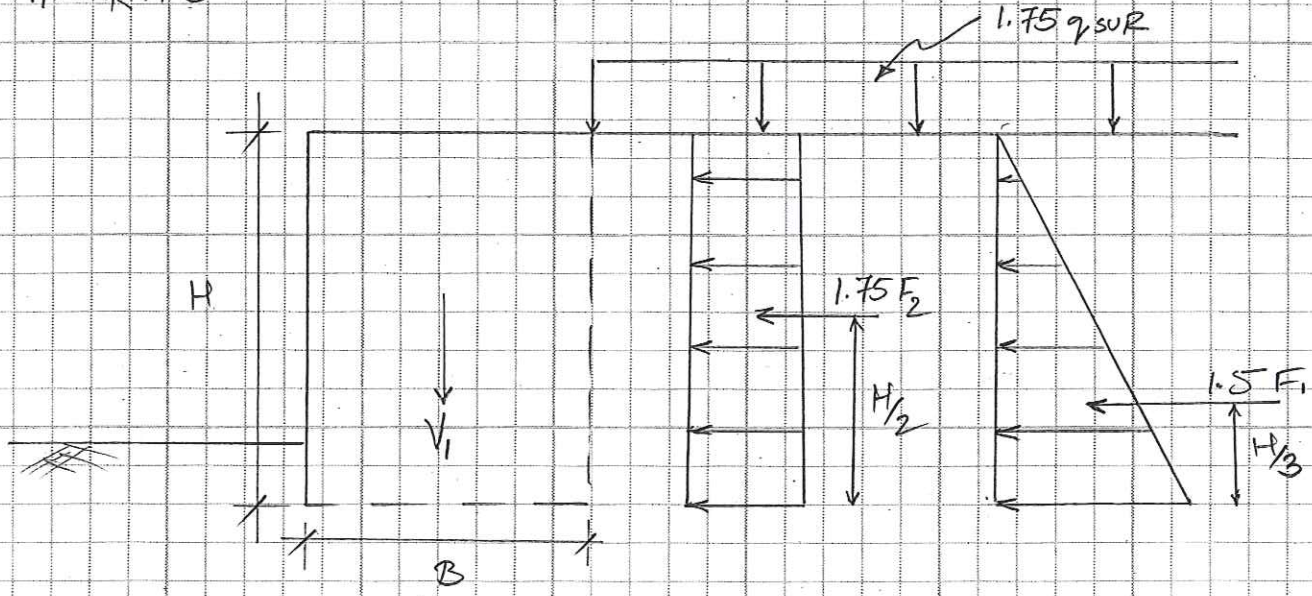


FOR BEARING PRESSURE CALCULATION

$F_1 = \frac{1}{2} K_a \gamma H^2$

$F_2 = K_a q_{SUR} H$

$V_1 = \gamma_R H B$



FOR ECCENTRICITY & SLIDING CALCULATION

STRENGTH LIMIT STATE

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1-23-09

2/8/09

AASHTO 2007 (LRFD)
SR-1 Interchange Retaining Wall RW-5

PROJECT IDENTIFICATION

Title:	SR-1 Interchange Retaining Wall RW-5
Project Number:	103-059 27U
Client:	DelDot
Designer:	BBS
Station Number:	450+00

Description:

Retaining Wall RW-5 Maximum Height of Wall = 35-ft

L = 28'
L/H = 0.80

Company's information:

Name: Rummel, Klepper & Kahl, LLP.
Street: 81 Mosher Street

Baltimore, MD 21030
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....g Wall RW-5\RW-5.BEN

Original date and time of creating this file: Fri Sep 19 13:57:40 2008

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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SOIL DATA

REINFORCED SOIL
Unit weight, γ 125.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ 34.0 °

Select.

RETAINED SOIL
Unit weight, γ 130.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ 28.0 °

DelDOT Type F Borrow

FOUNDATION SOIL (Considered as an equivalent uniform soil)
Equivalent unit weight, $\gamma_{equiv.}$ 125.0 lb/ft ^{3}
Equivalent internal angle of friction, $\phi_{equiv.}$ 32.0 °
Equivalent cohesion, $c_{equiv.}$ 0.0 lb/ft ^{2}

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3610 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 35.49 N γ= 30.21

SEISMICITY

Not Applicable

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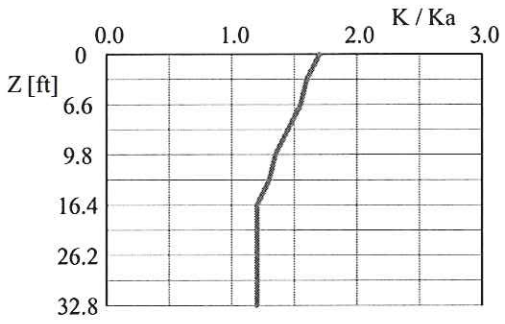
INPUT DATA: Metal strips (Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Smooth steel strips.					
Friction angle along reinforcement-soil interface, ρ					
@ the top	17.35	N/A	N/A	N/A	N/A
@ 19.7 ft or below	17.35	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	0.31	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.31	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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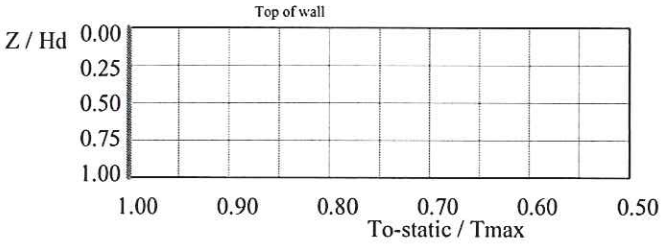
INPUT DATA: Facia and Connection (Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.31 ft. Horizontal distance to Center of Gravity of panel is 0.66 ft.
Average unit weight of panel is $\gamma_f = 152.78$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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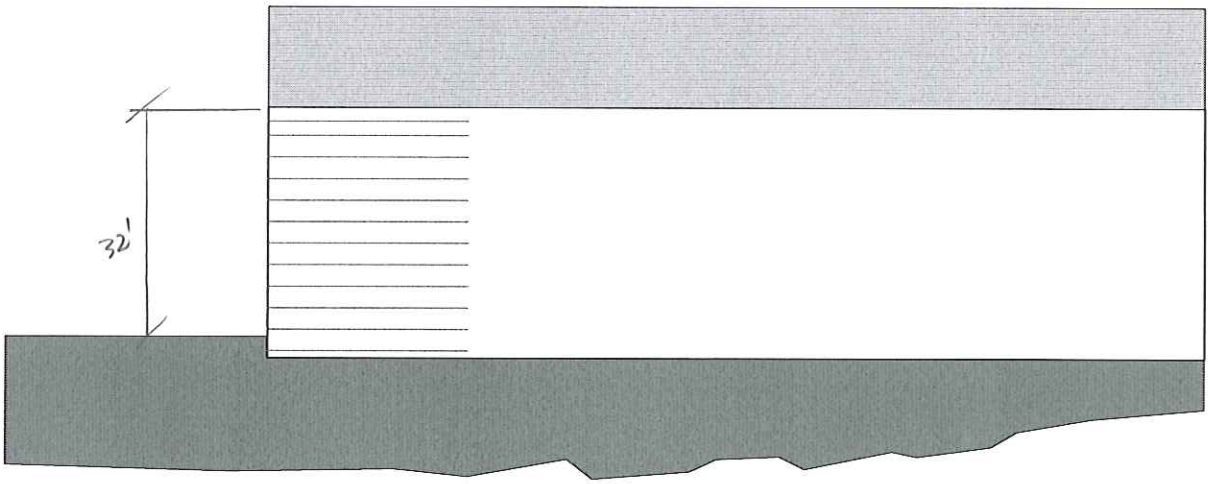
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	35.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 32.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE

Uniformly distributed dead load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 5 10 15 20 25 30 [ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35		
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00		
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75		
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50		
Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00
Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
	ϕ_b	0.65		0.65

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ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.59, Meyerhof stress = 8243 lb/ft²

Foundation Interface: Direct sliding, CDR = 1.691, Eccentricity, e/L = 0.1616, CDR-overturning = 3.09

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	1.00	28.00	1	N/A	0.66	0.74	0.737	0.735	1.821	0.1529	---
2	4.00	28.00	1	N/A	0.60	0.66	0.665	0.568	1.989	0.1282	---
3	7.00	28.00	1	N/A	0.66	0.73	0.731	0.528	2.190	0.1057	---
4	10.00	28.00	1	N/A	0.73	0.81	0.811	0.488	2.437	0.0853	---
5	13.00	28.00	1	N/A	0.82	0.91	0.912	0.447	2.748	0.0671	---
6	16.00	28.00	1	N/A	0.91	1.01	1.015	0.397	3.149	0.0510	---
7	19.00	28.00	1	N/A	1.01	1.12	1.123	0.358	3.690	0.0371	---
8	22.00	28.00	1	N/A	1.15	1.28	1.280	0.340	4.459	0.0253	---
9	25.00	28.00	1	N/A	1.36	1.51	1.506	0.320	5.642	0.0157	---
10	28.00	28.00	1	N/A	1.70	1.89	1.888	0.301	7.717	0.0083	---
11	31.00	28.00	1	N/A	2.79	3.10	3.104	0.330	12.445	0.0031	---
12	33.00	28.00	1	N/A	3.92	4.35	4.353	0.308	22.270	0.0009	---

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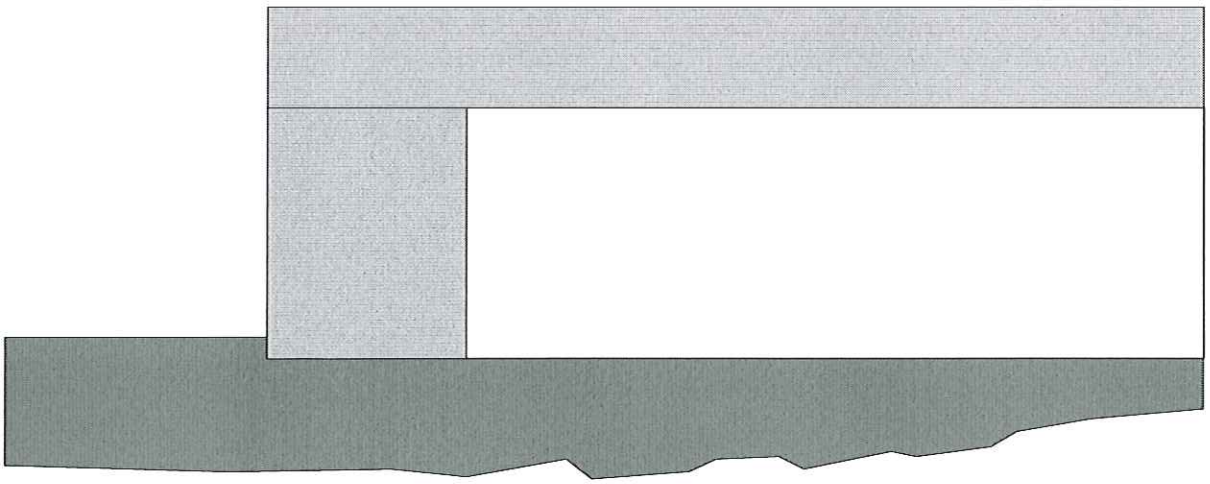
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	13106	N/A	[lb/ft ²]
Meyerhof stress, σ_v	8243.1	N/A	[lb/ft ²] ← BEARING STRESS.
Eccentricity, e	3.33	N/A	[ft]
Eccentricity, e/L	0.119	N/A	
CDR calculated	1.59	N/A	
Base length	28.00	N/A	[ft]

$q_{ult} > \sigma_v$ ∴ ok

CDR > 1 ∴ ok



SCALE:

0 5 10 15 20 25 30 [ft]

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DIRECT SLIDING for GIVEN LAYOUT (for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.691

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	1.00	28.00	1.821	N/A	1	---
2	4.00	28.00	1.989	N/A	1	---
3	7.00	28.00	2.190	N/A	1	---
4	10.00	28.00	2.437	N/A	1	---
5	13.00	28.00	2.748	N/A	1	---
6	16.00	28.00	3.149	N/A	1	---
7	19.00	28.00	3.690	N/A	1	---
8	22.00	28.00	4.459	N/A	1	---
9	25.00	28.00	5.642	N/A	1	---
10	28.00	28.00	7.717	N/A	1	---
11	31.00	28.00	12.445	N/A	1	---
12	33.00	28.00	22.270	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1616; Overturning: CDR-static = 3.09

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	1.00	28.00	0.1529	N/A	1	---
2	4.00	28.00	0.1282	N/A	1	---
3	7.00	28.00	0.1057	N/A	1	---
4	10.00	28.00	0.0853	N/A	1	---
5	13.00	28.00	0.0671	N/A	1	---
6	16.00	28.00	0.0510	N/A	1	---
7	19.00	28.00	0.0371	N/A	1	---
8	22.00	28.00	0.0253	N/A	1	---
9	25.00	28.00	0.0157	N/A	1	---
10	28.00	28.00	0.0083	N/A	1	---
11	31.00	28.00	0.0031	N/A	1	---
12	33.00	28.00	0.0009	N/A	1	---

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RETAINING WALL 5 Cm. No. 103-059
Prepared By BBS Date 12/1/08 Checked By JJT Date 1-23-09
EM 2/6/09

BEARING CAPACITY CHECK FOR TWO LAYERED SYSTEM

STRONG COHESIONLESS LAYER OVER WEAK LAYER

$q_n = q_2 \, e^{0.67 [1+(B/L)] H/B}$ → C 10.6.3.1.2f-1

q_2 = BEARING RESISTANCE OF A FICTICIOUS FOOTING OF THE SAME SIZE & SHAPE AS THE ACTUAL FOOTING SUPPORTED ON THE LOWER WEAK LAYER

B = FOOTING WIDTH

L = LENGTH OF FOOTING

H = THICKNESS OF TOP LAYER BELOW FOUNDATION ELEVATION

$q_2 = c N_c S_c i_c + \gamma D_f N_q S_q d_q i_q C_{wq} + \frac{1}{2} \gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$

$N_q = 0$ FOR MSE WALL BEARING RESISTANCE

✳ DRAINED CONDITION

$\phi = 24°$ $C = 0$

$N_c = 19.3$ $N_\gamma = 9.4$ (10.6.3.1.2a-1)

$B' = 28 - 3.33 = 24.67$ ft $C_{w\gamma} = 0.5$ (10.6.3.1.2a-2)

B' = B - e
e = 3.33' e from MSEW

$L = 128$ ft.

$H = 22$ ft.

$q_2 = \frac{1}{2} \times 130 \times 24.67 \times 9.4 \times \left(1 - 0.4 \times \frac{25}{128}\right) \times \frac{1}{2}$

$= 6947$ psf

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Prepared By BBS Date 12-1-08 Checked By JBT Date 1-23-09
GM 2/8/09

$q_n = q_2 e^{0.67[1+B/L]\,4/B}$

$= 6947\, e^{0.67[1+\frac{24.67}{128}]\frac{22}{24.67}}$

$= 14167$ psf

$q_R = \phi_b q_n$ $\phi_b = 0.65$ Table 11.5.6.1

$q_R = 0.65 \times 14167$

$= 9208$ psf $> \sigma_r = 8243.0$ psf.

From MSE w ∴ ok

✳ UNDRAINED CONDITION

$\phi = 0$ $c = 1500$ psf

$B = 24.67$ ft.

$q_2 = cN_c S_c i_c + \frac{1}{2}\gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$

$\phi = 0$ $N_c = 5.14$ $N_\gamma = 0$

$S_c = 1 + \frac{B}{5L} = 1 + \frac{2467}{5\times 128} = 1.039$

$q_2 = 1500 \times 5.14 \times 1.039$

$= 8010$ psf

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$$q_n = q_2 \, e^{0.67\left[1 + \frac{B}{L}\right]\frac{H}{B}}$$

$$= 8010 \times e^{0.67\left[1 + \frac{24.67}{128}\right]\frac{22}{24.67}}$$

$$= 8010 \times 2.039$$

$$= 16335 \text{ psf}$$

$$q_R = \phi_b \, q_n$$

$$= 0.65 \times 16335$$

$$= 10618 > \sigma_v = 8243 \text{ psf OK}$$

From MSEW : OK

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RETAINING WALL -5
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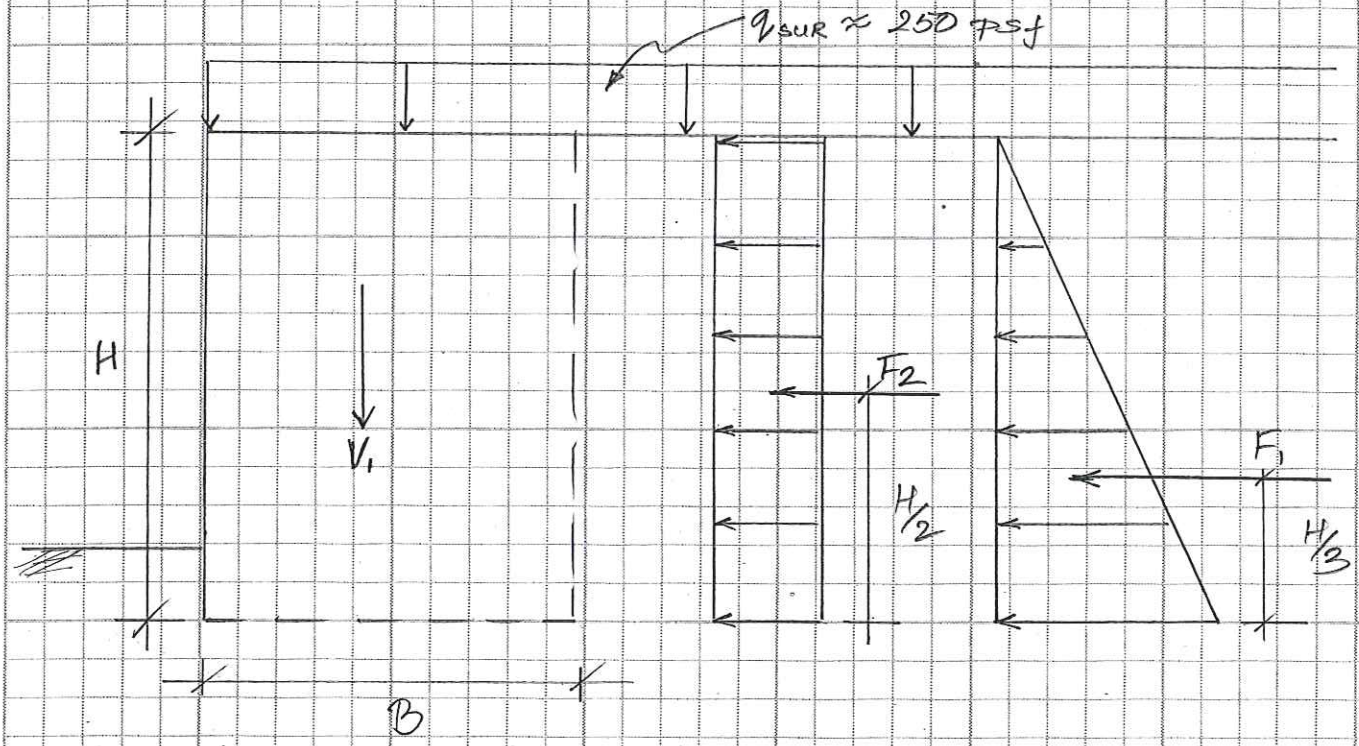

$F_1 = \frac{1}{2} K_a \gamma H^2$ γ = RETAINED SOIL

$F_2 = K_a H q_{SUR}$

$V_1 = \gamma_R H B$ γ_R = REINFORCED SOIL

SERVICE LIMIT STATE

FOR SETTLEMENT ANALYSIS

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2/5/09

SERVICE LIMIT STATE

ACTIVE EARTH PRESSURE COEFFICIENT
$K_a = 0.361$ for EXTERNAL STABILITY

H = 35 ft
γ = 130 pcf (retained)
q_{SUR} = 250 psf
B = 25 ft
γ_R = 125 pcf (reinforced)
$\alpha = 0°$

$F_1 = \frac{1}{2} K_a \gamma H^2 = 28744.6$ lb/ft.

$F_2 = K_a H q_{SUR} = 3158.75$ lb/ft

$V_1 = \gamma_R H B = 113750$ lb/ft ?
$(125)(25)(35) = 109{,}375$ lb/ft

$$e = \frac{F_1 \cos\alpha \, H/3 + F_2 \cos\alpha \, H/2}{V_1}$$

$= 3.43$ ~~3.57 ft~~

MYERHOF STRESS

$$\sigma_V = \frac{V_1 + qB}{B - 2e}$$

$$= \frac{109375 + 250 \times 25}{25 - 2 \times 3.43 \; 3.57}$$

$= 6615$ psf ~~6474 psf~~ ← FOR SETTLEMENT ANALYSIS.

$B' = B - 2e = 18.14$
$= 17.86$ ft.

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Cm. No. 103-059
Prepared By BBS Date 1-7-09 Checked By JST Date 1-23-09
GM 2/8/09

GLOBAL STABILITY

RETAINING WALL 5 RAMP B STA 450+00

SOIL PARAMETERS

STRATA	UNIT WT pcf	UNDRAINED SHEAR STRENGTH (psf)	DRAINED ϕ	DRAINED c
EL 65 & ABOVE	125	0	32	0
EL 40 to 65	130	1500		
EL 20 TO 40	130	2500		
EL 0 to 20	130	3500		
EL 0 & BELOW	130	5000		

Spline Function

$y = 0.7753\, x^{0.6701}$

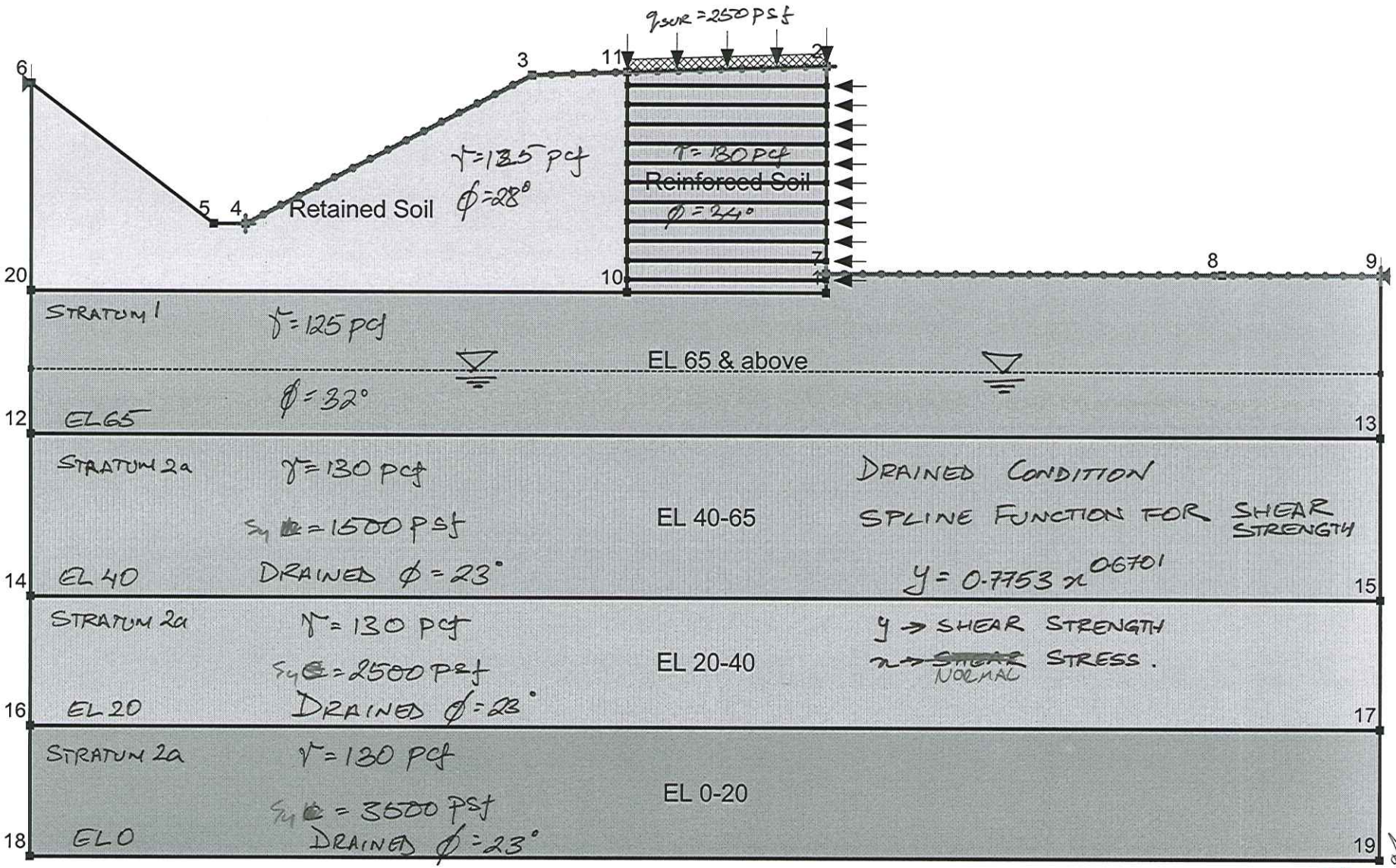
(y: shear strength; x: normal stress)

WATER TABLE @ EL 75

SUMMARY OF RESULTS.

CONDITION	FACTOR OF SAFETY	FACTORED RESISTANCE
UNDRAINED	1.756	0.57 < 0.65 OK
DRAINED	1.756	0.57 < 0.65 OK

GLOBAL STABILITY ANALYSIS



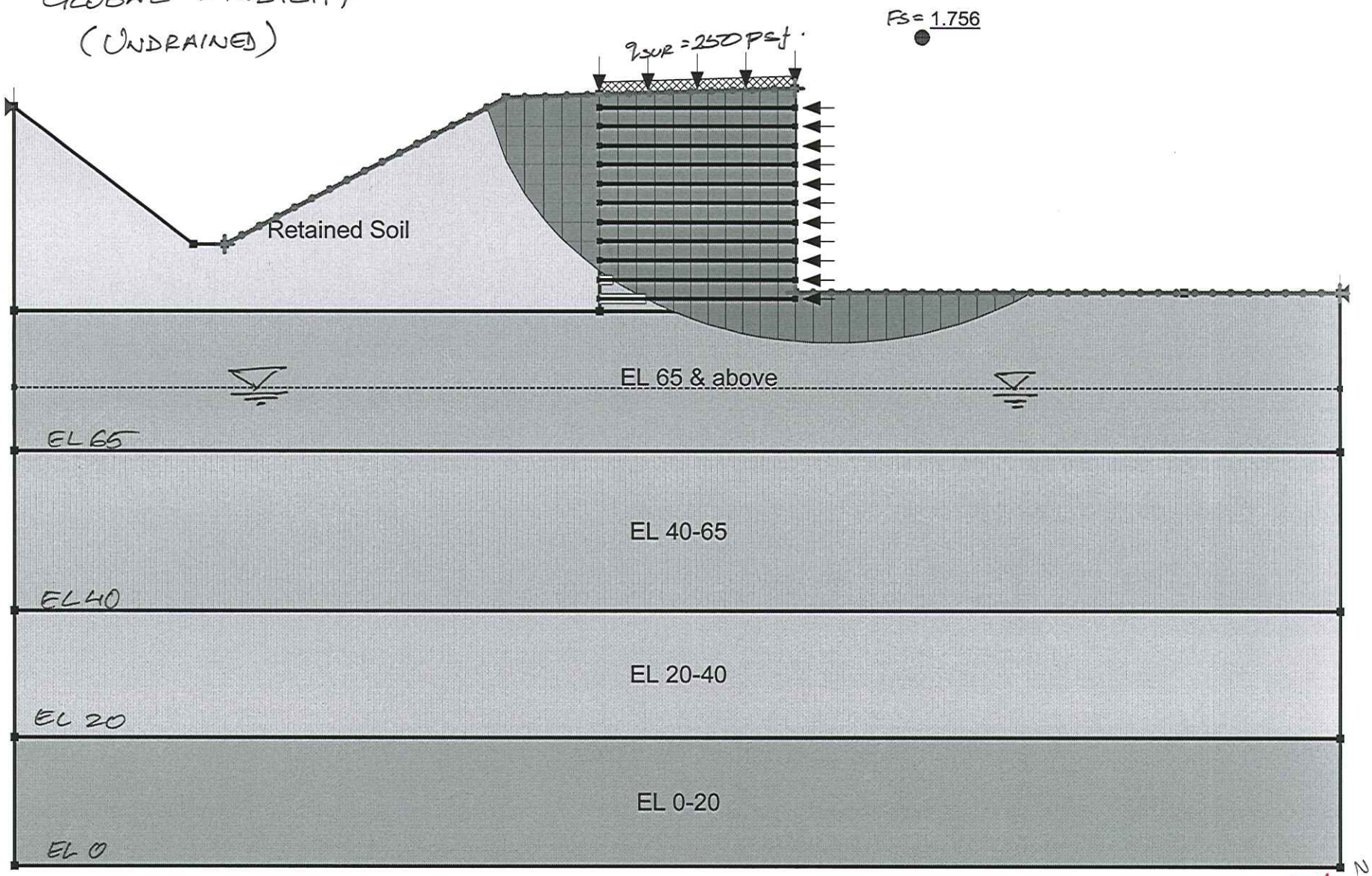
RETAINING WALL 5

RAMP B STA 450+00

26469
EJT 1-23-09
BMC 2/09

RKK RW5-28

GLOBAL STABILITY
(UNDRAINED)



RETAINING WALL 5
RAMP B STA 450+00

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BM Block 21

RKK RW5-29

JM 1-23-09

BM 7/8/09

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SLOPE/W Analysis

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File Information

Revision Number: 37
Date: 10/14/2008
Time: 9:13:34 AM
File Name: RW-5.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Retaining Wall RW-5\Global Stability\

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Description: Retaining Wall 5
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
    Apply Phreatic Correction: No
    Side Function
        Interslice force function option: Half-Sine
    PWP Conditions Source: Piezometric Line
    Use Staged Rapid Drawdown: No
SlipSurface
    Direction of movement: Left to Right
    Allow Passive Mode: No
    Slip Surface Option: Entry and Exit
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: No
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution
    FOS Calculation Option: Constant

Advanced
- Number of Slices: 30
- Optimization Tolerance: 0.01
- Minimum Slip Surface Depth: 0.1 ft
- Optimization Maximum Iterations: 2000
- Optimization Convergence Tolerance: 1e-007
- Starting Optimization Points: 8
- Ending Optimization Points: 16
- Complete Passes per Insertion: 1

Materials

Retained Soil
Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

WeIDOT Type E Borrow

Reinforced Soil
Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °

Select

EL 65 & above
Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 32 °
Phi-B: 0 °
Pore Water Pressure
- Piezometric Line: 1

EL 40-65
Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 1500 psf
Pore Water Pressure
- Piezometric Line: 1

EL 20-40
Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 2500 psf

Pore Water Pressure
Piezometric Line: 1

EL 0-20

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 3500 psf
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (27, 110.5) ft
Left-Zone Right Coordinate: (100, 135) ft
Left-Zone Increment: 30
Right Projection: Range
Right-Zone Left Coordinate: (100, 103) ft
Right-Zone Right Coordinate: (170, 103) ft
Right-Zone Increment: 30
Radius Increments: 20

Slip Surface Limits

Left Coordinate: (0, 132) ft
Right Coordinate: (170, 103) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	88
	170	88

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

TOTAL LOAD
= UNIT WEIGHT x HEIGHT
= 125 x 2 = 250 PSF

Coordinates

	X (ft)	Y (ft)
	75	136
	100	137

Reinforcements

Reinforcement 1

Type: Fabric
Outside Point: (100, 132) ft
Inside Point: (75, 132) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Reinforcement 2

Type: Fabric
Outside Point: (100, 129) ft
Inside Point: (75, 129) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Reinforcement 3

Type: Fabric
Outside Point: (100, 126) ft
Inside Point: (75, 126) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Reinforcement 4

Type: Fabric
Outside Point: (100, 123) ft
Inside Point: (75, 123) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Reinforcement 5

Type: Fabric
Outside Point: (100, 120) ft
Inside Point: (75, 120) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf

Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Reinforcement 6

Type: Fabric
Outside Point: (100, 117) ft
Inside Point: (75, 117) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Reinforcement 7

Type: Fabric
Outside Point: (100, 114) ft
Inside Point: (75, 114) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Reinforcement 8

Type: Fabric
Outside Point: (100, 111) ft
Inside Point: (75, 111) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Reinforcement 9

Type: Fabric
Outside Point: (100, 108) ft
Inside Point: (75, 108) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Reinforcement 10

Type: Fabric
Outside Point: (100, 105) ft
Inside Point: (75, 105) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf

Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Reinforcement 11

Type: Fabric
Outside Point: (100, 102) ft
Inside Point: (75, 102) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Regions

	Material	Points	Area (ft^2)
Region 1	EL 0-20	18,19,17,16	3400
Region 2	EL 20-40	16,14,15,17	3400
Region 3	EL 40-65	14,15,13,12	4250
Region 4	Retained Soil	20,6,5,4,3,11,10	1727.75
Region 5	Reinforced Soil	11,10,1,7,2	862.5
Region 6	EL 65 & above	20,12,13,9,8,7,1,10	3950

Points

	X (ft)	Y (ft)
Point 1	100	100

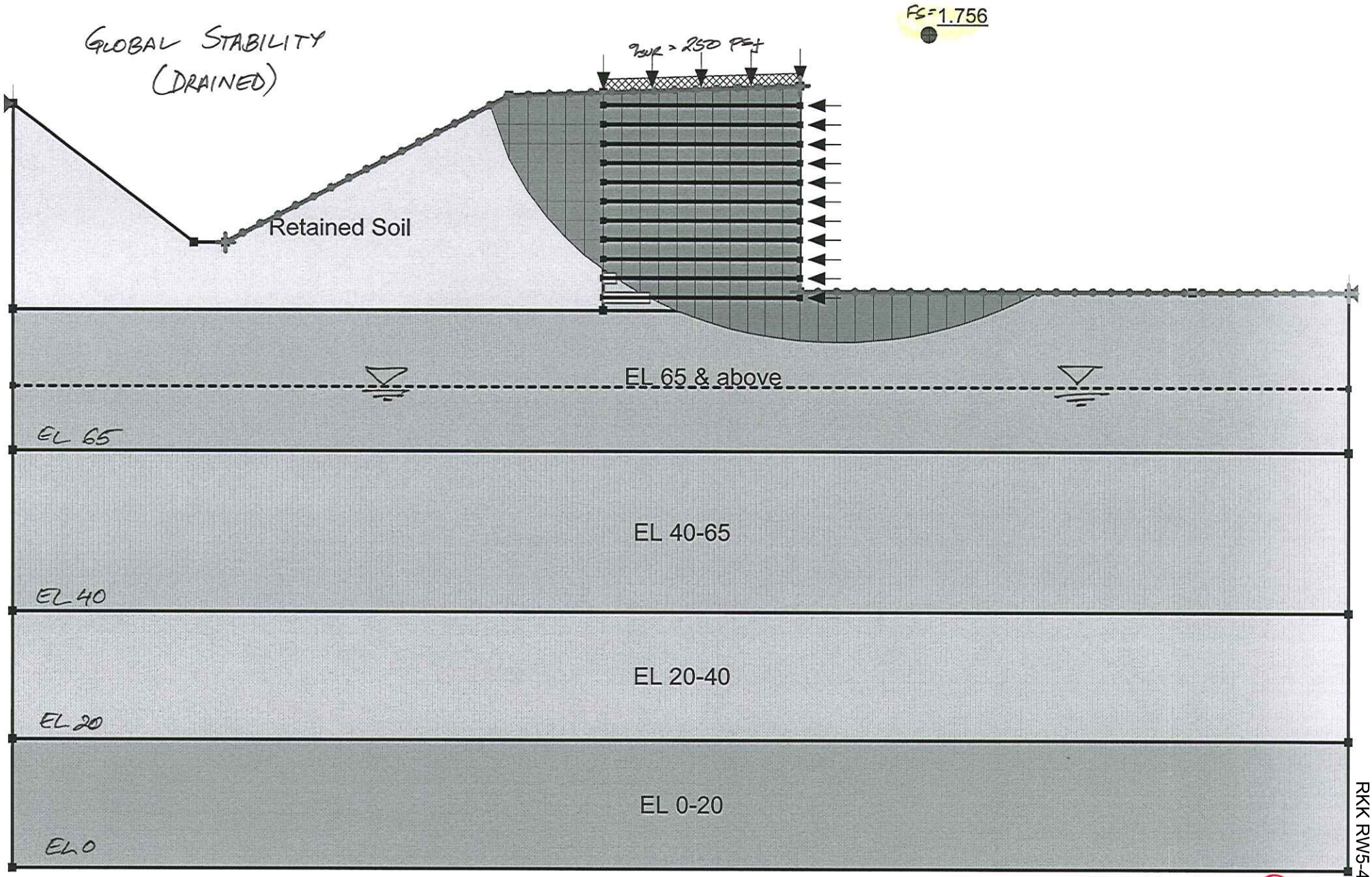
Point 2	100	135
Point 3	63	133.5
Point 4	27	110.5
Point 5	23	110.5
Point 6	0	132
Point 7	100	103
Point 8	150	103
Point 9	170	103
Point 10	75	100
Point 11	75	134
Point 12	0	78
Point 13	170	78
Point 14	0	53
Point 15	170	53
Point 16	0	33
Point 17	170	33
Point 18	0	13
Point 19	170	13
Point 20	0	100

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	10056	1.756	(104.842, 140.05)	44.972	(60.6027, 131.968)	(130.333, 103)

Slices of Slip Surface: 10056

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	10056	61.801345	127.7678	0	277.05543	147.31298	0
2	10056	64.2	121.0062	0	820.72823	436.38894	0
3	10056	66.6	116.49675	0	1177.796	626.24524	0
4	10056	69	112.96055	0	1474.135	783.81148	0
5	10056	71.4	110.03575	0	1740.6495	925.51975	0
6	10056	73.8	107.5524	0	1994.3314	1060.4048	0
7	10056	76.1732	105.43445	0	2549.7035	1719.7967	0
8	10056	78.5196	103.6152	0	2744.8767	1851.4427	0
9	10056	80.866	102.0278	0	3547.0887	2392.5416	0
10	10056	83.212395	100.644	0	3390.218	2286.7309	0
11	10056	85.500905	99.468425	-715.61252	3710.8008	2318.7657	0
12	10056	87.731535	98.47779	-653.80449	4030.447	2518.5028	0
13	10056	89.962165	97.627515	-600.75089	4367.8282	2729.322	0
14	10056	92.192795	96.909265	-555.93675	4720.9239	2949.9606	0
15	10056	94.423425	96.316515	-518.9572	5084.4723	3177.1309	0



RETAINING WALL 5
RAMP B STA 450+00

RKK RW5-40

28 of 29
CPT
1-23-09
Bmm
2/4/09

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SLOPE/W Analysis

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File Information

Revision Number: 44
Date: 10/29/2008
Time: 8:45:02 AM
File Name: RW-5 (Drained).gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Retaining Wall RW-5\Global Stability\
Last Solved Date: 10/29/2008
Last Solved Time: 8:45:22 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Description: Retaining Wall 5
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Apply Phreatic Correction: No
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

SlipSurface
- Direction of movement: Left to Right
- Allow Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: No
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1

Materials

Retained Soil

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Type F Borrow

Reinforced Soil

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °

Select

EL 65 & above

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 32 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

EL 40-65

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: SPLINE
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

EL 20-40

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: SPLINE
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

EL 0-20

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: SPLINE
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (27, 110.5) ft
Left-Zone Right Coordinate: (100, 135) ft
Left-Zone Increment: 30
Right Projection: Range
Right-Zone Left Coordinate: (100, 103) ft
Right-Zone Right Coordinate: (170, 103) ft
Right-Zone Increment: 30
Radius Increments: 20

Slip Surface Limits

Left Coordinate: (0, 132) ft
Right Coordinate: (170, 103) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	88
	170	88

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

TOTAL SURCHARGE LOAD
= UNIT WEIGHT x HEIGHT
= 125 x 2 = 250 PSF.

Coordinates

	X (ft)	Y (ft)
	75	136
	100	137

Reinforcements

Reinforcement 1

Type: Fabric
Outside Point: (100, 132) ft
Inside Point: (75, 132) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (100, 129) ft
Inside Point: (75, 129) ft
Slip Surface Intersection: (61.45, 129) ft
Total Length: 25 ft

Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 88.159 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (100, 126) ft
Inside Point: (75, 126) ft
Slip Surface Intersection: (62.306, 126) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 88.159 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (100, 123) ft
Inside Point: (75, 123) ft

Slip Surface Intersection: (63.266, 123) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 222.67 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (100, 120) ft
Inside Point: (75, 120) ft
Slip Surface Intersection: (64.671, 120) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 222.67 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric

Outside Point: (100, 117) ft
Inside Point: (75, 117) ft
Slip Surface Intersection: (66.29, 117) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 304.49 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (100, 114) ft
Inside Point: (75, 114) ft
Slip Surface Intersection: (68.214, 114) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 369.03 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (100, 111) ft
Inside Point: (75, 111) ft
Slip Surface Intersection: (70.535, 111) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 422.73 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (100, 108) ft
Inside Point: (75, 108) ft
Slip Surface Intersection: (73.331, 108) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 468.58 lbs/ft
Available Bond Length: 0 ft

Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (100, 105) ft
Inside Point: (75, 105) ft
Slip Surface Intersection: (76.698, 105) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 957.06 lbs
Resisting Force Used: 563.72 lbs/ft
Available Bond Length: 1.6978 ft
Required Bond Length: 1.6978 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (100, 102) ft
Inside Point: (75, 102) ft
Slip Surface Intersection: (80.91, 102) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 3723.8 lbs

Resisting Force Used: 630.08 lbs/ft
Available Bond Length: 5.91 ft
Required Bond Length: 5.91 ft
Governing Component: Bond

Shear/Normal Strength Functions

SPLINE

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 27 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (1000, 775.3)
Data Point: (2000, 1233.6)
Data Point: (3000, 1618.8)
Data Point: (4000, 1963)
Data Point: (5000, 2279)
Data Point: (10000, 3627)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft^2)
Region 1	EL 0-20	18,19,17,16	3400
Region 2	EL 20-40	16,14,15,17	3400
Region 3	EL 40-65	14,15,13,12	4250
Region 4	Retained Soil	20,6,5,4,3,11,10	1727.75
Region 5	Reinforced Soil	11,10,1,7,2	862.5
Region 6	EL 65 & above	20,12,13,9,8,7,1,10	3950

Points

	X (ft)	Y (ft)

Point 1	100	100
Point 2	100	135
Point 3	63	133.5
Point 4	27	110.5
Point 5	23	110.5
Point 6	0	132
Point 7	100	103
Point 8	150	103
Point 9	170	103
Point 10	75	100
Point 11	75	134
Point 12	0	78
Point 13	170	78
Point 14	0	53
Point 15	170	53
Point 16	0	33
Point 17	170	33
Point 18	0	13
Point 19	170	13
Point 20	0	100

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	10056	1.756	(104.842, 140.05)	44.972	(60.6027, 131.968)	(130.333, 103)

Slices of Slip Surface: 10056

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	10056	61.801345	127.7678	0	277.05543	147.31298	0
2	10056	64.2	121.0062	0	820.72823	436.38894	0
3	10056	66.6	116.49675	0	1177.796	626.24524	0
4	10056	69	112.96055	0	1474.135	783.81148	0

5	10056	71.4	110.03575	0	1740.6495	925.51975	0
6	10056	73.8	107.5524	0	1994.3314	1060.4048	0
7	10056	76.1732	105.43445	0	2549.7035	1719.7967	0
8	10056	78.5196	103.6152	0	2744.8767	1851.4427	0
9	10056	80.866	102.0278	0	3547.0887	2392.5416	0
10	10056	83.212395	100.644	0	3390.218	2286.7309	0
11	10056	85.500905	99.468425	-715.61252	3710.8008	2318.7657	0
12	10056	87.731535	98.47779	-653.80449	4030.447	2518.5028	0
13	10056	89.962165	97.627515	-600.75089	4367.8282	2729.322	0
14	10056	92.192795	96.909265	-555.93675	4720.9239	2949.9606	0
15	10056	94.423425	96.316515	-518.9572	5084.4723	3177.1309	0
16	10056	96.654055	95.844205	-489.47005	5451.8782	3406.7116	0
17	10056	98.884685	95.488495	-467.27851	5812.9873	3632.3576	0
18	10056	101.16665	95.24367	-451.99584	1202.6882	751.52301	0
19	10056	103.5	95.113105	-443.8449	1316.4129	822.58606	0
20	10056	105.83335	95.10397	-443.29234	1405.6729	878.36192	0
21	10056	108.16665	95.21619	-450.30683	1463.1553	914.28089	0
22	10056	110.5	95.450685	-	1481.6125	925.81424	0

				464.91714			
23	10056	112.83335	95.80941	-487.28644	1455.2801	909.35991	0
24	10056	115.16665	96.29542	-517.64217	1380.6989	862.75643	0
25	10056	117.5	96.913035	-556.1932	1257.7574	785.93405	0
26	10056	119.83335	97.66803	-603.2737	1089.8603	681.02033	0
27	10056	122.16665	98.56793	-659.44383	883.83269	552.27996	0
28	10056	124.5	99.622435	-725.25101	648.74448	405.38055	0
29	10056	126.83335	100.8441	-801.47182	394.60582	246.57708	0
30	10056	129.16665	102.24925	-889.14662	130.81855	81.744501	0

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Subject SR-1 INTERCHANGE
RETAINING WALL RW-5
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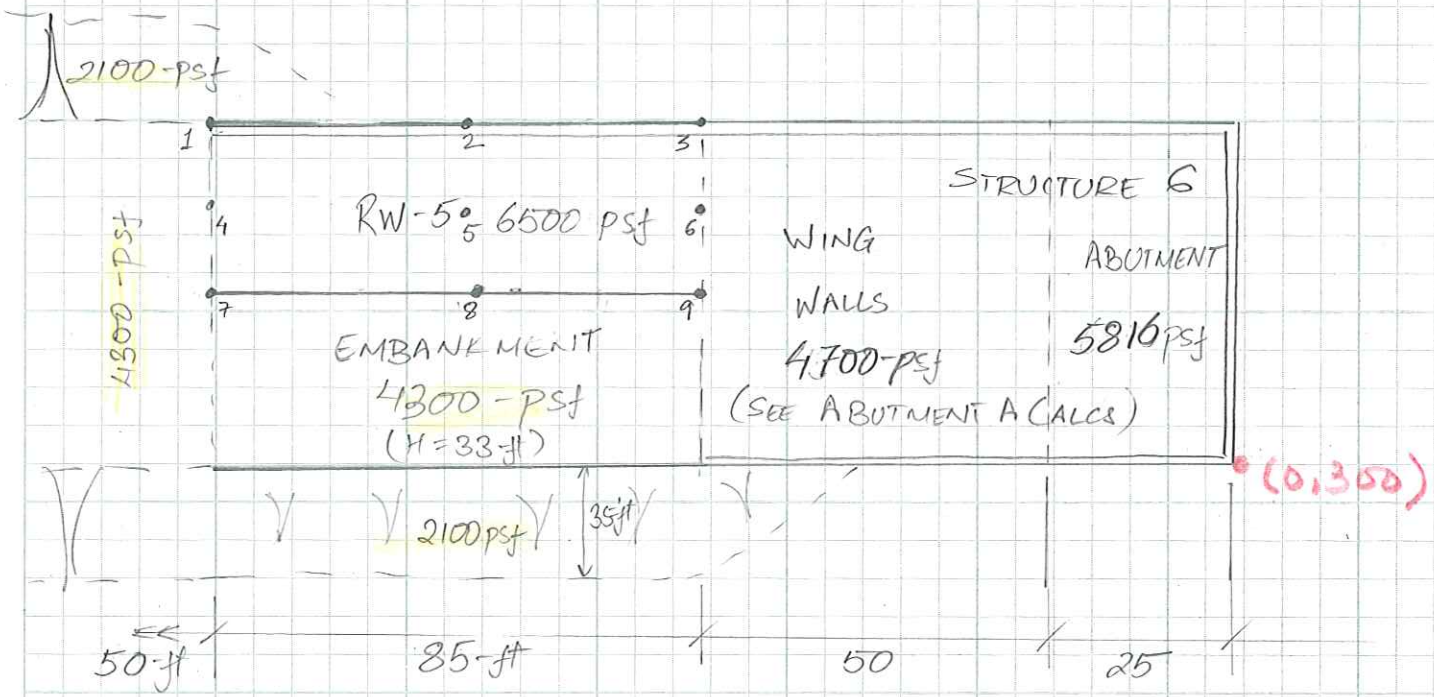
Cm. No. 103-059
Prepared By BBS Date 9-25-08 Checked By JJT Date 1-23-09
EM 2/5/09

ELASTIC & CONSOLIDATION SETTLEMENT



FOR STRESS DUE TO ABUTMENT & WING WALLS SEE ABUTMENT A CALCS.

EMBANKMENT ⇒ 33-ft HIGH.

STRESS = γH = 130 × 33 ≈ 4300 psf

FOR SLOPE IN EMBANKMENT

STRESS = $\frac{1}{2}\gamma H$ ≈ 2100 psf

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Subject SR-1 INTERCHANGE RETAINING WALL RW-5 Page 53 of 69
Cm. No. 103-059.
Prepared By BBS Date 9-25-08 Checked By JJT Date 1-23-09

MAX ELASTIC SETTLEMENT

$\delta_E = 0.7\text{-in}$

MAX CONSOLIDATION SETTLEMENT

$\delta_C = 2.3\text{-in}$

TOTAL SETTLEMENT = 3.0-in

MAX DIFFERENTIAL SETTLEMENT IS ALONG THE MIDDLE CROSS SECTION OF THE WALL

BETWEEN POINTS 2 & 5

$\Delta\delta = 0.6\text{-in}$ over $\frac{25}{2}\text{-ft} = 12.5$

$$\text{RATIO} = \frac{0.6}{12 \times 12.5} = \frac{0.6}{150} = \frac{1}{250} < \frac{1}{100} \text{ OK}$$

I-95/SR 1 Interchange 103-059-27U 1/21/2009
Retaining Wall 5 Settlement Results

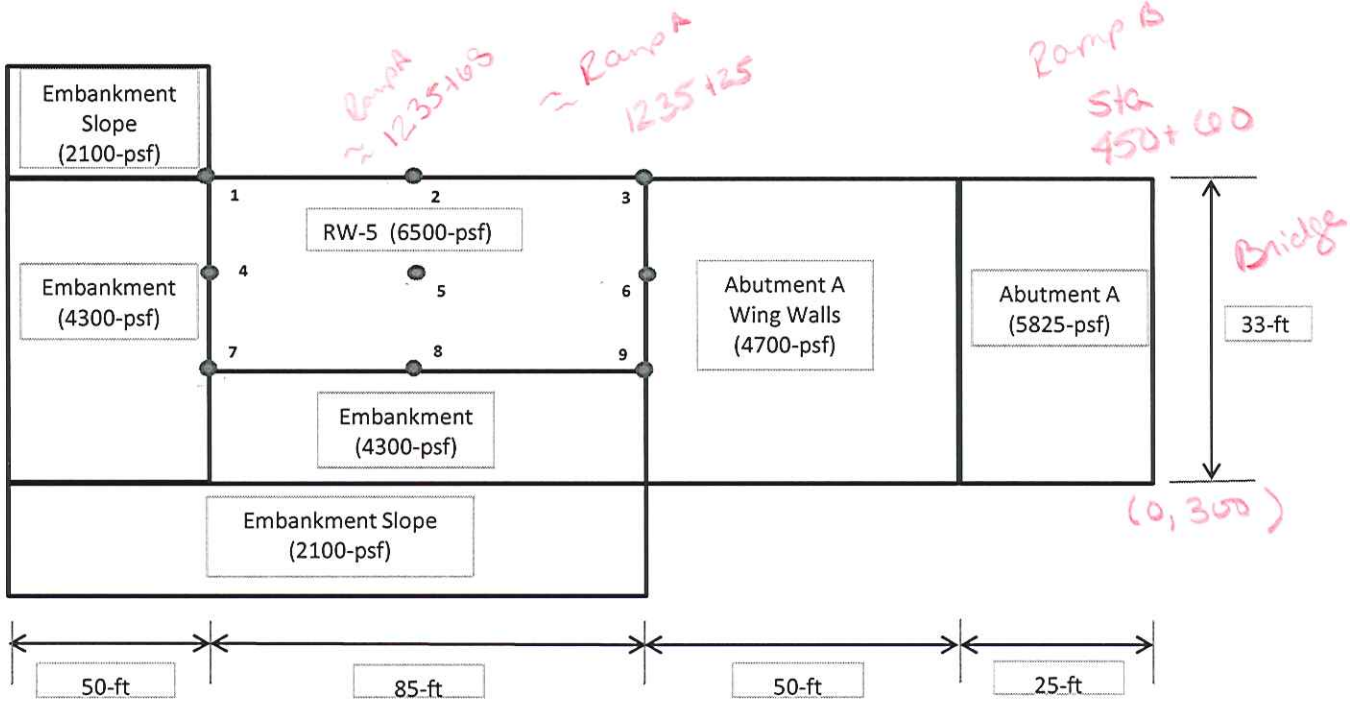
	Settlement (ft)		
Point	Elastic	Consolidation	Total
1	0.03	0.15	0.18
2	0.03	0.16	0.19
3	0.03	0.14	0.17
4	0.05	0.17	0.22
5	0.06	0.19	0.25
6	0.06	0.17	0.23
7	0.03	0.16	0.19
8	0.03	0.18	0.21
9	0.03	0.15	0.18
10			
11			
12			
13			
14			
15			

	Settlement (in)		
Point	Elastic	Consolidation	Total
1	0.4	1.8	2.2
2	0.4	1.9	2.3
3	0.3	1.7	2.0
4	0.6	2.0	2.7
5	0.7	2.3	3.0
6	0.7	2.0	2.7
7	0.4	1.9	2.3
8	0.4	2.2	2.6
9	0.3	1.8	2.1
10			
11			
12			
13			
14			
15			

Max = 3.0"
Min = 2.0

	RW 5 Differential Settlement						
	Along Front RW 5		Along Center RW 5		Along Back RW 5		Front to Back
	1 to 3	2 to 3	4 to 5	4 to 6	8 to 9	7 to 9	2 to 5
Inches	-0.2	-0.3	-0.3	0.0	0.4	0.2	-0.7
Ratio	- 1/5862	- 2/3617	- 2/2931	##	2/2471	1/5986	- 4/821

↑ 1/250



RKK RW5.56
1-23-09
5 of 69

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Retaining Wall RW-5\Settlement\RW 5 Settlement Results.xls

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JPT 1-23-09
SM 1/8/09

SR-1 Interchange Ramp B Settlement

Report created by FoSSA(2.0): Copyright (c) 2003-2006, ADAMA Engineering, Inc.

PROJECT IDENTIFICATION

Title: SR-1 Interchange Ramp B Settlement
Project Number: 103-059 -
Client: DelDot
Designer: BBS
Station Number:

Description:
Retaining Wall 5 Settlement Analysis

Company's information:

Name: Rummel, Klepper & Kahl
Street: 81 Mosher Street
Baltimore, MD 21217
Telephone #:
Fax #:
E-Mail:

Original file path and name: M:\project ..... alculation\Retaining Wall RW-5\Settlement\RW-5.2ST
Original date and time of creating this file: Tue Sep 23 14:39:03 2008

GEOMETRY: Analysis of a Multiple Footings

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JT 1-23-09

INPUT DATA – FOUNDATION LAYERS – 6 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	125.00	0.30	
2	130.00	0.40	
3	130.00	0.40	
4	130.00	0.40	
5	130.00	0.40	
6	125.00	0.30	

INPUT DATA – MULTIPLE FOOTINGS – 7 footings

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	0.00	175.00
2	311.68	175.00
3	328.08	175.00
4	344.49	175.00
5	360.89	175.00

Active EL = Z - 100

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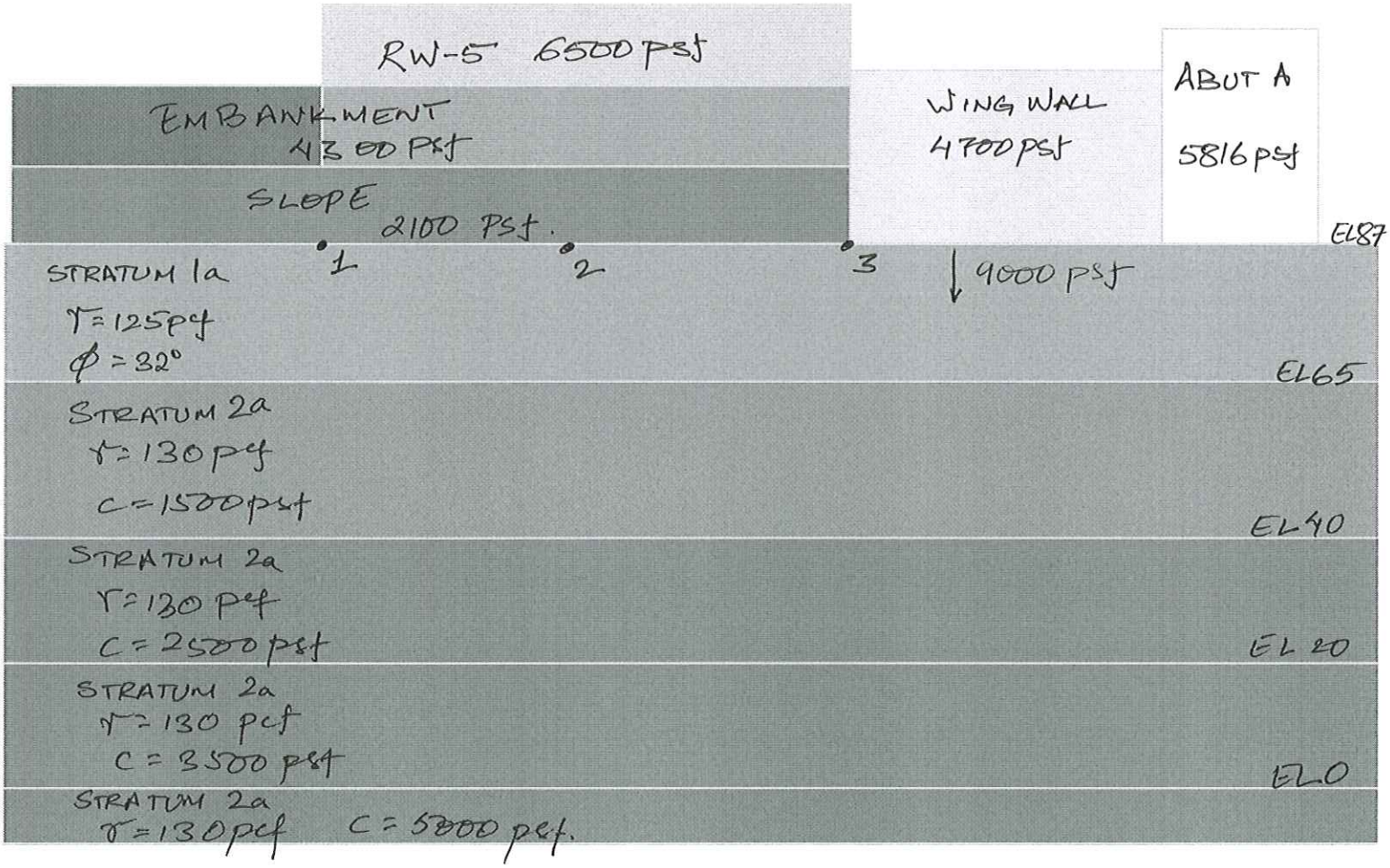
DRAWING OF SPECIFIED GEOMETRY



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JST 1-23-09

INPUT DATA FOR CONSOLIDATION --- $\alpha = 1/2$

Layer # Undergoing Consolidation [Yes/No]		$(\sigma'_p - \sigma'_o)$ given at layer's boundaries in [lb/ft²] at Top	Bottom	Cc	Cr	e0	Cv [ft²/day]	Drains at :
1	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Yes	6850.0	5150.0	0.09	0.01	0.66	3.5500	Top
3	Yes	5150.0	3800.0	0.09	0.01	0.66	3.5500	Top
4	Yes	3800.0	2450.0	0.11	0.01	0.60	0.9800	Bottom
5	Yes	2450.0	0.0	0.11	0.01	0.60	0.9800	Bottom
6	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

$\sigma_p = P_c = 9000 psf$ CALCULATE $(\sigma_p' - \sigma_o')$
WATER TABLE 12-ft BELOW FOUNDATION LEVEL

LAYER 2
TOP = $9000 - 125 \times 12 - (125 - 62.4) \times 10 = 6874 \approx 6850$ psf
BOTTOM = $6874 - (130 - 62.4) \times 25 = 5184 \approx 5150$ psf

Layer 3
TOP = 5150
BOTTOM = $5184 - (130 - 62.4) \times 20 = 3832 \approx 3800$ psf

LAYER 4
TOP = 3800psf
BOTTOM = $3832 - (130 - 62.4) \times 20 = 2480 \approx 2450$ psf

LAYER 5
TOP = 2450 psf
BOTTOM = 0 psf (BORING DEPTH WITHIN THIS LAYER)

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	140.00	33.00	1	1500000	0.3000	0.0322	187.00	186.80	~~0.20~~ 0.0322
			2	818000	0.4000	~~0.0613~~			
			3	818000	0.4000	~~0.0419~~			
			4	818000	0.4000	~~0.0343~~			
			5	1364000	0.4000	~~0.0305~~			
			6	1364000	0.3000	~~0.0039~~			
2	182.50	33.00	1	1500000	0.3000	0.0312	187.00	186.80	~~0.20~~ 0.0312
			2	818000	0.4000	~~0.0594~~			
			3	818000	0.4000	~~0.0418~~			
			4	818000	0.4000	~~0.0355~~			
			5	1364000	0.4000	~~0.0326~~			
			6	1364000	0.3000	~~0.0042~~			
3	225.00	33.00	1	1500000	0.3000	0.0277	187.00	186.82	~~0.18~~ 0.0277
			2	818000	0.4000	~~0.0522~~			
			3	818000	0.4000	~~0.0365~~			
			4	818000	0.4000	~~0.0311~~			
			5	1364000	0.4000	~~0.0289~~			
			6	1364000	0.3000	~~0.0038~~			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

ELASTIC SETTLEMENT ONLY FOR COARSE GRAINED SOIL (STRATUM 1)

Actual EL = 2-10

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RKK RW5-62

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JJT 1-23-09

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
~~14~~	140.00	16.50	1	1500000	0.3000	0.0531	187.00	~~186.74~~	~~0.26~~ 0.0531
			2	818000	0.4000	~~0.0820~~			
			3	818000	0.4000	~~0.0493~~			
			4	818000	0.4000	~~0.0384~~			
			5	1364000	0.4000	~~0.0328~~			
			6	1364000	0.3000	~~0.0041~~			
~~25~~	182.50	16.50	1	1500000	0.3000	0.0621	187.00	~~186.72~~	~~0.28~~ 0.0621
			2	818000	0.4000	~~0.0895~~			
			3	818000	0.4000	~~0.0520~~			
			4	818000	0.4000	~~0.0409~~			
			5	1364000	0.4000	~~0.0355~~			
			6	1364000	0.3000	~~0.0044~~			
~~36~~	225.00	16.50	1	1500000	0.3000	0.0553	187.00	~~186.75~~	~~0.25~~ 0.0553
			2	818000	0.4000	~~0.0786~~			
			3	818000	0.4000	~~0.0452~~			
			4	818000	0.4000	~~0.0356~~			
			5	1364000	0.4000	~~0.0313~~			
			6	1364000	0.3000	~~0.0041~~			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

Elastic

Ignore Settlement in Strata IIa

Actual EL = Z - 100

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RKK RW5-63

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JT 1-23-09

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	140.00	0.00	1	1500000	0.3000	0.0324	187.00	186.78	0.22
			2	818000	0.4000	0.0673			0.0324
			3	818000	0.4000	0.0456			
			4	818000	0.4000	0.0367			
			5	1364000	0.4000	0.0320			
			6	1364000	0.3000	0.0041			
2	182.50	0.00	1	1500000	0.3000	0.0326	187.00	186.77	0.23
			2	818000	0.4000	0.0717			0.0326
			3	818000	0.4000	0.0487			
			4	818000	0.4000	0.0395			
			5	1364000	0.4000	0.0347			
			6	1364000	0.3000	0.0044			
3	225.00	0.00	1	1500000	0.3000	0.0282	187.00	186.80	0.20
			2	818000	0.4000	0.0588			0.0282
			3	818000	0.4000	0.0407			
			4	818000	0.4000	0.0337			
			5	1364000	0.4000	0.0305			
			6	1364000	0.3000	0.0040			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

Ignore elastic settlement in Strata IIa

Actual EL = 2 - 100

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JPT 1-23-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	140.00	33.00	187.00	0.15	186.85
2	182.50	33.00	187.00	0.16	186.84
3	225.00	33.00	187.00	0.14	186.86

Actual EL = Z - 150

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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JJT 1-23-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1 4	140.00	16.50	187.00	0.17	186.83
2 5	182.50	16.50	187.00	0.19	186.81
3 6	225.00	16.50	187.00	0.17	186.83

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

Actual EL = Z-100

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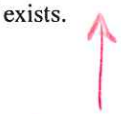
ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
27	140.00	0.00	187.00	0.16	186.84
28	182.50	0.00	187.00	0.18	186.82
29	225.00	0.00	187.00	0.15	186.85

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.



Actual EZ = Z - 100

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JST 1-23-09

TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	300.00	187.00	
2	1	300.00	165.00	
3	1	300.00	140.00	
4	1	300.00	120.00	
5	1	300.00	100.00	
6	1	300.00	60.00	

↑ actual El = 2-100

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JST 1-23-09

TABULATED GEOMETRY: INPUT OF MULTIPLE FOOTINGS – 7 footings

Footing #	L (in X direction) [ft]	B (in Y direction) [ft]	X of center [ft]	Y of center [ft]	q [ft]l [lb/ft²]	
1	25.00	33.00	287.50	16.50	5820.00	Abut A
2	50.00	33.00	250.00	16.50	4700.00	Abut A wing walls
3	85.00	25.00	182.50	20.50	6500.00	RW 5
4	85.00	8.00	182.50	4.00	4300.00	emb
5	135.00	35.00	157.50	-17.50	2100.00	slope
6	50.00	33.00	115.00	16.50	4300.00	emb
7	50.00	35.00	115.00	50.50	2100.00	slope

See pg 54 for locations + origin

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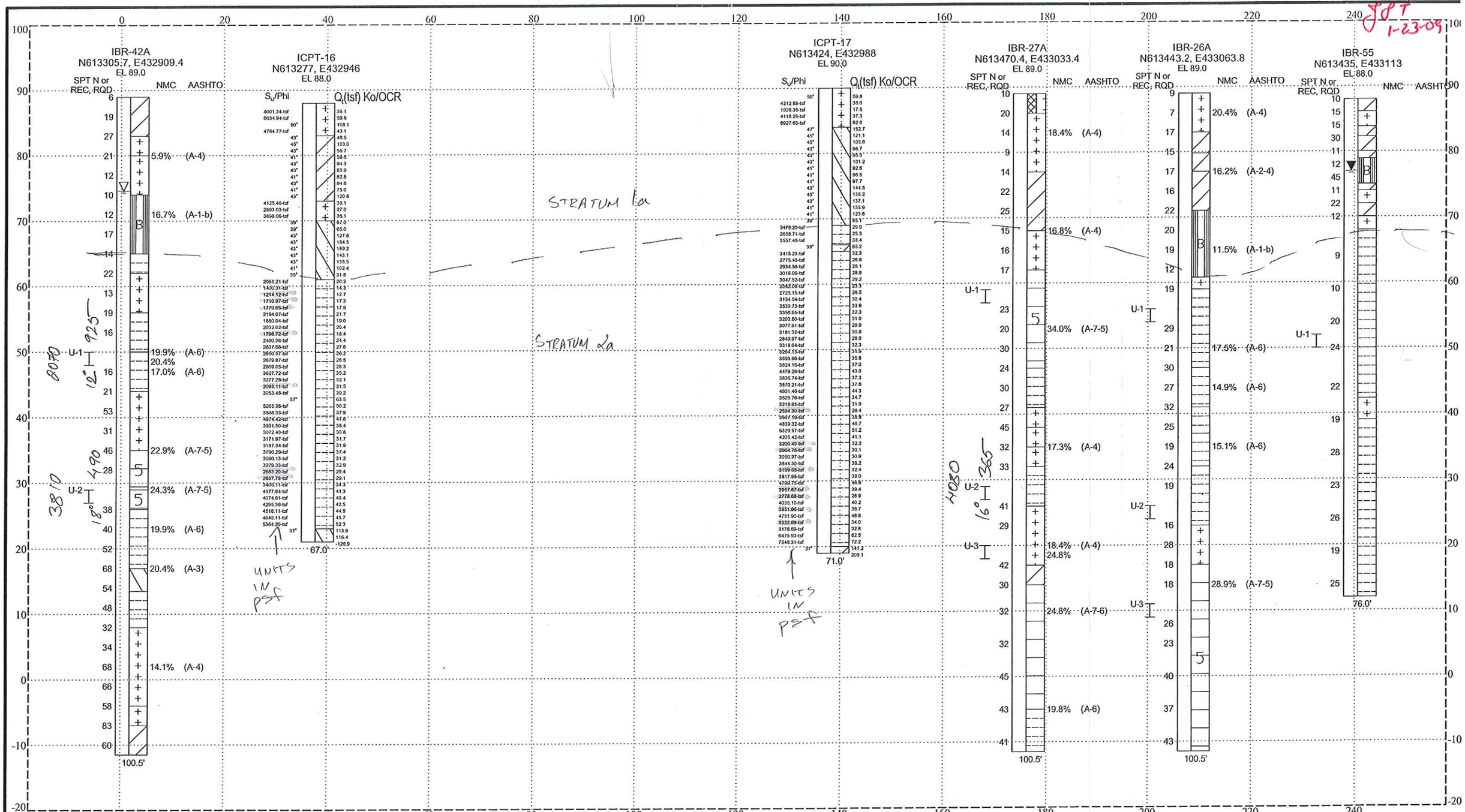

AASHTO SOIL KEY

A-1-a	A-2-5	A-5	A-8
A-1-b	A-2-6	A-6	Asphalt
A-3	A-2-7	A-7-5	FILL
A-2-4	A-4	A-7-6	Decomposed Rock

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data
ABUTMENT A

Figure No.

Drawn: TAS | Approved: | Date: 9/19/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 9/19/08

RKK RW5-70
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RT 1-23-09

℄ RAMP B

℄ RAMP A

L=12.00'
-4.00%

123.40

L=36.00'
3.80%

L=6.00'
-3.20%

BRIDGE

WINGWALL
STR 6

RW-5

H=35'-4"

2:1

4%

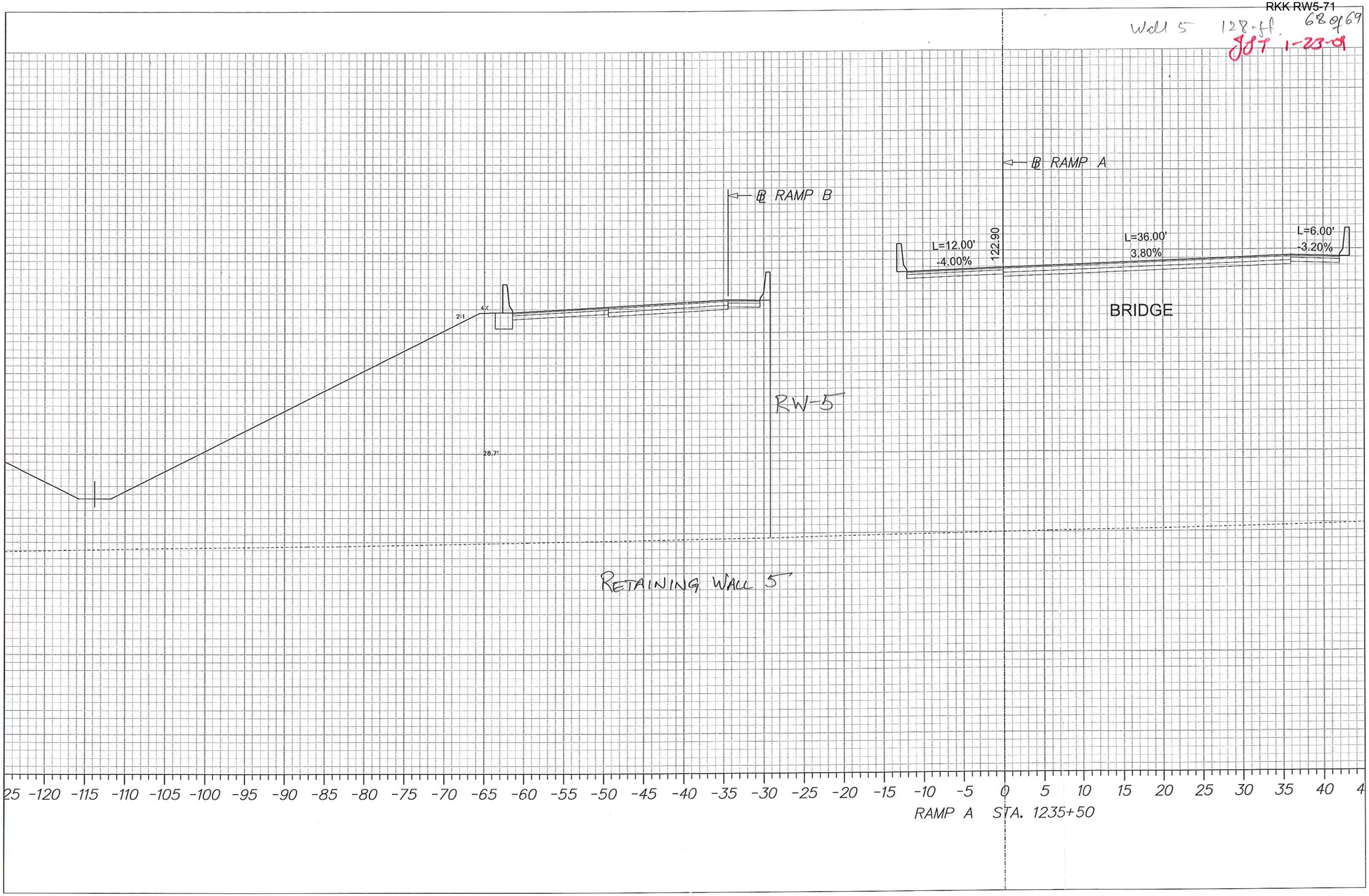
RETAING WALL - 5

-115 -110 -105 -100 -95 -90 -85 -80 -75 -70 -65 -60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50

RAMP A STA. 1235+00

RKK RW5-71

Wall 5 128 sf. 68969
JJT 1-23-09



RKK RW5-72

JPT 1-23-09

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WALL 12

WALL 13

ABUTMENT B

ABUTMENT A

RAMP E

RAMP B1

RAMP B

RAMP A

I-95 NB

I-95 SB

NAU-5

GENERAL GROWTH

CALCULATION CHECKLIST

Project: **SR 1/I-95 Interchange** Comm. No.: **103-059-27U**

Title of Calculation Set: **Retaining Wall 6 & 16 Analysis**

Project Manager: **EMK/JLT**

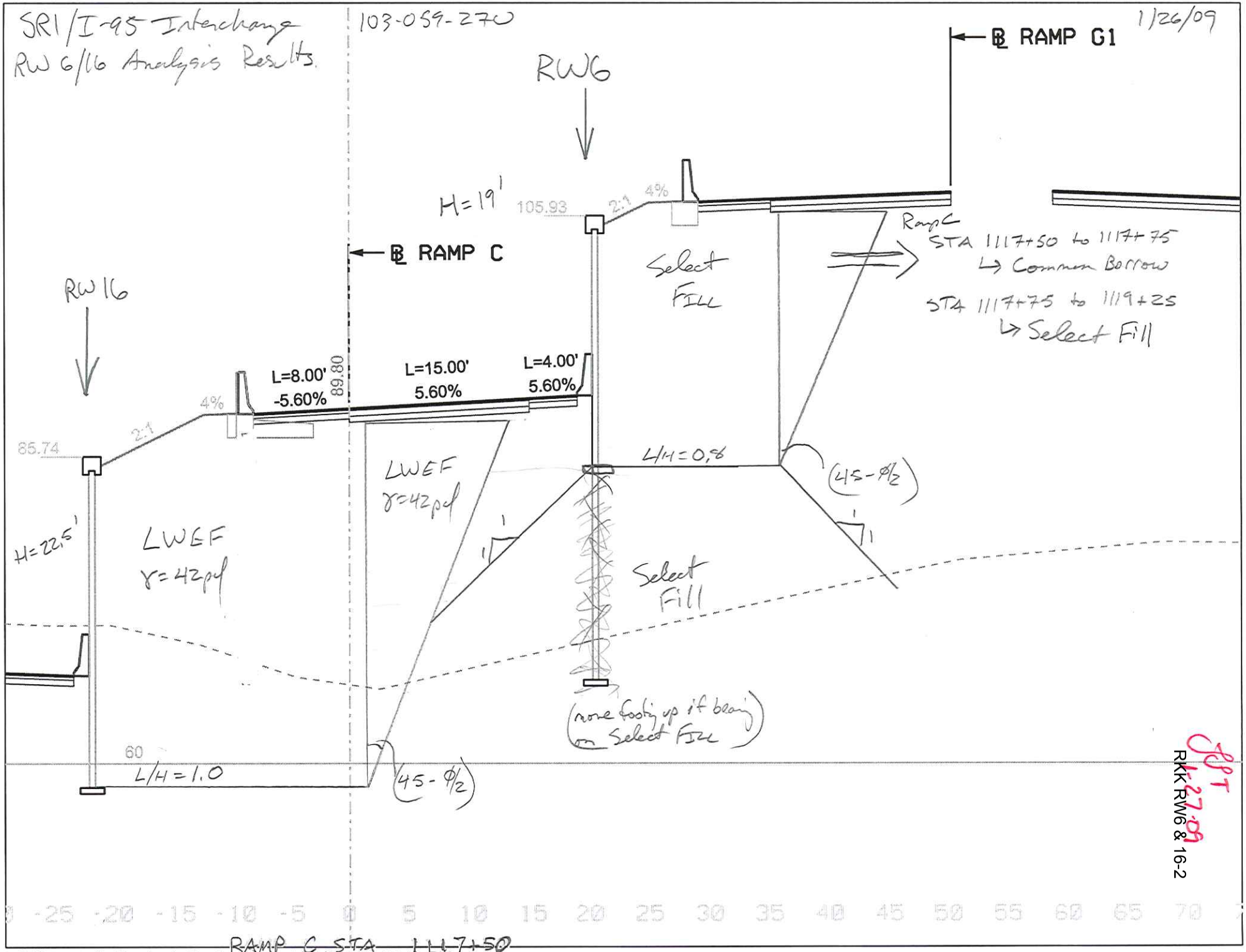
Calculations Prepared By: **SAB**

Calculation Checked By:

Computer Programs / Files: **MSEW 3.0, Slope/w, FoSSA 2.0**

Initial	Date	
		Subsurface Characterization approved by Project Manager
SAB	1/19/09	Calculations are neat, legible and understandable.
SAB	1/19/09	Table of Contents is provided.
SAB	1/19/09	Heading on each page filled out
SAB	1/19/09	The first page contains purpose of the calculation.
SAB	1/19/09	Symbols are defined.
SAB	1/19/09	References for data, methods, formulas and computer program names and version numbers are given.
SAB	1/19/09	Assumptions are listed and those that need to be verified later are Flagged.
SAB	1/19/09	Headings on front sheet of each set of computer input and output.
SAB	1/19/09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JST	1-27-09	All calculations checked and each calculation sheet initialed by checker.
JLL	1/29/09	Calculation set reviewed by Project Manager.
		Has this calculation been superseded? Reference new calculation, if applicable.

This sheet is to be prepared by the originator of the calculation and attached to the front of the calculation set.


SR1/I-95 Interchange
RW 6/16 Analysis Results
103-059-270
1/26/09
RW6
℄ RAMP C1
RW16
℄ RAMP C
H=19'
105.93
2:1
4%
Ramp C
STA 1117+50 to 1117+75
↳ Common Borrow
STA 1117+75 to 1119+25
↳ Select Fill
Select Fill
L=8.00'
-5.60%
89.80
L=15.00'
5.60%
L=4.00'
5.60%
4%
2:1
85.74
L/H=0.86
LWEF
γ=42pcf
(45-φ/2)
H=22.5'
LWEF
γ=42pcf
Select Fill
(none footing up if bearing on Select Fill)
60
L/H=1.0
(45-φ/2)
-25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
RAMP C STA 1117+50
JPT 4.27.09
RKK RW6 & 16-2
...\XS_rampC_Gradewk Geotech.dgn 1/26/2009 1:51:11 PM

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Subject I-95/SR1 Interchange
Retaining Wall 6&16 Analysis
Page 1 of
Cm. No. 103-059-270
Prepared By SAB Date 9/29/08 Checked By JT Date 1-27-09
REV: 11/25/08

Objective: To evaluate the external & global stability of Retaining Walls 6 & 16. These walls are proposed to be mechanically stabilized earth (MSE) walls.

References: 1) AASHTO LRFD Bridge Design Specifications, 4th ed.
2) FHWA Publication No. FHWA-NHI-00-043 "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines."

Summary: RW 6 STA 1117+50 ≈ 1118

DRAINED:
Foundation Soil (Select Fill/2-layer soil)
$\gamma = 125$ pcf $\phi = 32°$ $c = 0$ psf

Bearing Resistance:
$q_R = 5,754$ psf → $\sigma_V = 4684$

Sliding Resistance:
CDR = 1.09

* Foundation Soil must be Select Fill
* L/H = 0.8

STA 1118+50

DRAINED:
Foundation Soil (Stratum I/2-layer soil)
$\gamma = 125$ pcf $\phi = 32°$ $c = 0$ psf

Bearing Resistance:
$q_R = 5,774$ psf

Sliding Resistance: CDR = 1.52 L/H = 0.8

* Retained Soil must be Select Fill *

RW 16 STA 1117+50

UNDRAINED:
Foundation Soil (IIa) (2-layer system)
$\gamma = 130$ pcf $\phi = 0°$ $S_u = 1,355$ psf

Bearing Resistance:
$q_R = 4,946$

Sliding Resistance:
CDR = 1.84

DRAINED:
Foundation Soil (2-layer system)
$\gamma = 130$ pcf $\phi = 24°/17°$ $c = 0$ psf

Bearing Resistance w/ L = 1.0H: $q_R = 2,395$ psf ← governs

Sliding Resistance: CDR = 1.03

→ Reinforcement Length must be increased to L = 1.0H GOVERNS

* Lightweight Fill or CLSM required for reinforced & retained soil.

* Retaining Wall 6 Foundation Soil (as specified on p.2) must be Select Fill in all Fill areas.
* Check global stability & settlement of walls together.
* Retained Fill & Reinforced Soil zone of RW16 must be lightweight fill or Controlled Low-Strength Material (CLSM) → $\gamma = 42$ pcf may be used for both since $\phi = 38°$ is very conservative for this material

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Subject I-95/SR1 Interchange
Retaining Wall 6&16 Analysis
Page 2 of
Cm. No. 103-059-27U
Prepared By SLB Date 9/29/08 Checked By JBT Date 1-27-09
REV 11/25/08 EM 1/29/09

Wall Details: (See cross-section, p, 3)

Retaining Wall 6 and 16 are to be constructed as a 2-tier wall.

Check if walls should be analyzed as superimposed walls (per FHWA ref 2):

-Walls are designed independently if distance between wall faces, $D \geq H_2 \tan(90-\phi_r)$

where: H_2 = Height of lower wall (RW 16) ϕ_r = Retained Soil Friction Angle*

$D_{req} = (22.5') \tan(90-32^\circ) = 36'$ $D_{actual} = 42'$

So, $D > 36'$ => Design walls independently.*

* FILL below RW6 in a zone between a line extending downward from the toe of RW6 at a 1(H):1(V) slope away from the wall face and another line extending downward from the back of the reinforced soil zone at a 1(H):1(V) slope must be Select FILL (DelDOT Type B Borrow) → $\gamma = 125pcf$, $\phi = 32^\circ$. [This is required to move BOF EL up from natural soil.]

Ramp C STA 1117+50

RW 6 (Top Wall)

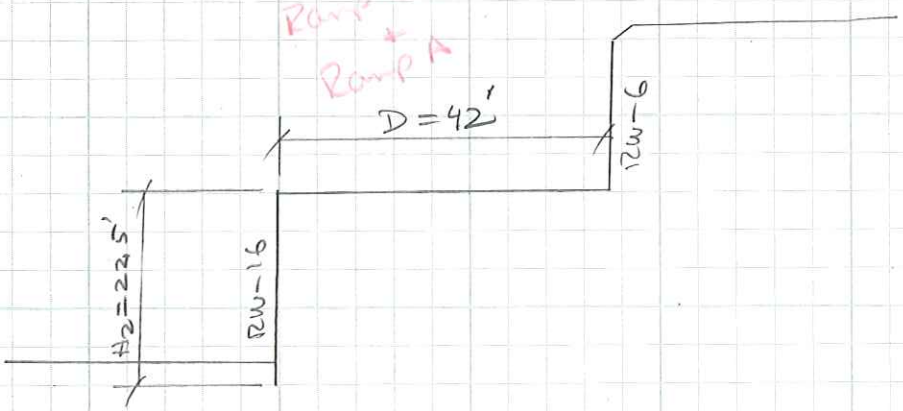
H = 19'
Embedment Depth, E = 3'
Reinforcement Length, L = 15.2' [$L/H = 0.8$ assumed]
BOF EL 86*'
Traffic LL @ top of wall only = 250psf
Backslope (2:1) Rise: 2'

RW 16 (Lower Wall)

H = 22.5'
E = 3'
L = 18' [$L/H = 0.8$ assumed]
BOF EL = EL 62.50
Traffic LL @ top of wall only = 250psf
Backslope Rise (2:1): 4.5'

Ramp C1 + Ramp A

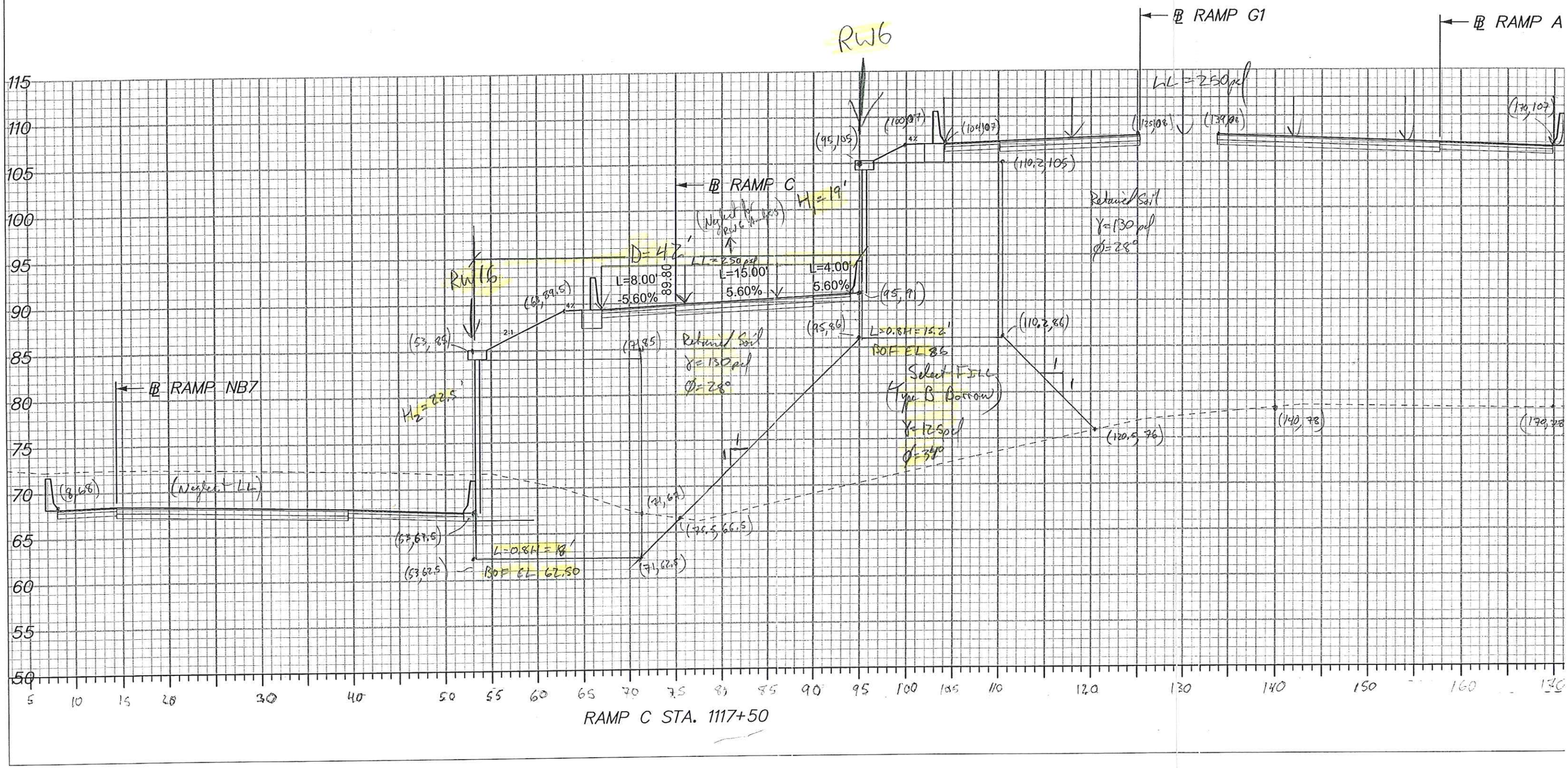
Ramp C



I-95/SR1 Interchange 103-059-27U 9/29/08
REV: 11/25/08
RW 6 & 16

JJT 1-27-09

RKK RW6 & 16-5



RAMP C STA. 1117+50

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Subject I-95/SR 1 Interchange
RW 6 & 16 Analysis
Cm. No. 103-059-270

Prepared By SAB Date 9/29/08 Checked By SBT Date 1-27-09
REV: 11/25/08 EMIC 1/29/09

Soils: (See attached fence diagram, p. 5)

STA 1117+50 → RW6

Soil	γ_T (pcf)	ϕ' (deg)	c' (psf) [Note 2]	S_u (psf)	EL (ft.)
Reinforced Soil	125	34	0	–	–
Common Borrow	130	28	0	–	–
Select Fill	125	32 [Note 1]	0	–	–
Foundation Soil:					
RW6: IIa [*1]	130	–	–	1,355	86
RW16: IIa [*1]	130	24		1,355	62.50

Note 1: 32° used due to thin natural sand layers (Stratum I) above stratum IIa

→ Assume groundwater @ approx. EL 62 (from Boring Logs – "Wet" samples)

*1)
⇒ Determine foundation soil for RW6:

RW 6 will be placed on 12'-6" of Select Fill (see p. 3), Foundation soil below is Stratum IIa. → Check to see if a Two-Layered Soil system is required.

→ AASHTO 10.6.3.1.2c-2: If 2nd soil layer is < H_{crit} below footing, use 2-layer system.

$$H_{crit} = \frac{3B \ln\left(\frac{q_1}{q_2}\right)}{2\left(1 + \frac{B}{L}\right)}$$

where: q_1 = Bearing resistance assuming upper layer is infinitely thick

q_2 = BEARING RESISTANCE ASSUMING FICTIONAL FOOTING BEARING ON LOWER STRATUM

B = FOOTING WIDTH = 15.2-Ft

L = FOOTING LENGTH = 176-Ft

FROM MSEW 3.0: q_1 = 14,166 psf USING SELECT FILL

$q_{2_{SI}}$ = 4,528 psf USING IN SITU SOIL

q_{2_ϕ} = 4,604 psf using in situ soil ($\phi' = 24°$) S_u = 1355 psf

$$\Rightarrow H_{crit} = \frac{3(15.2)\ln\left(\frac{14,166}{4,528}\right)}{2(1 + 15.2/176)} = 23.9' > 15' \therefore$$ USE 2 LAYER SOIL SYSTEM SEE PAGE 6.

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Subject SR1/I-95 Interchange RW 6 & 16 Analysis
Page 4a of
Cm. No. 103059-270
Prepared By SRB Date 1/29/09 Checked By EMK Date 1/29/09

#2) → FOUNDATION SOIL FOR RW16:

BORING IRW-97: UU @ EL55, S_u = 1,355+ psf

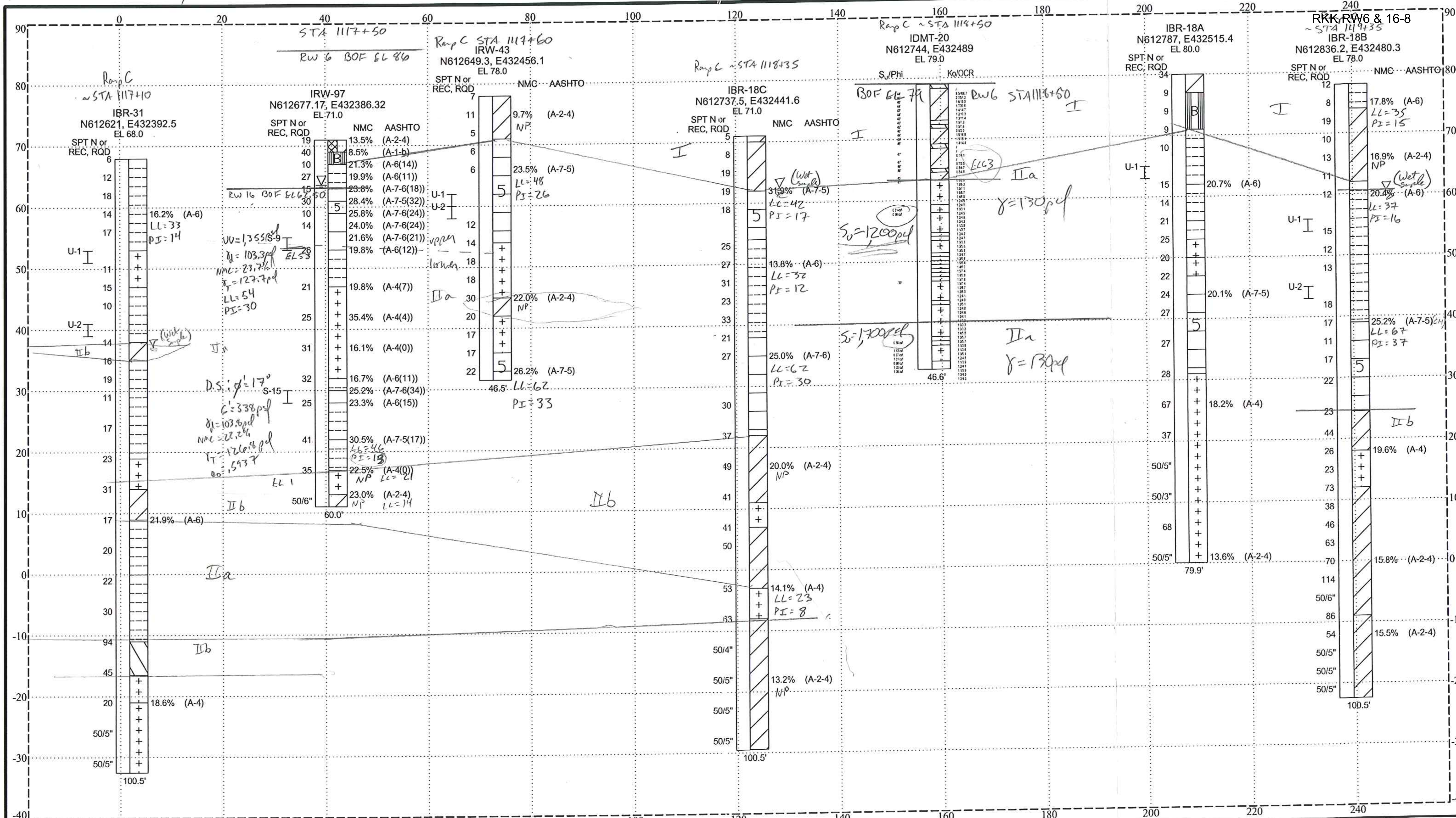
DIVIDE STRATUM IIa INTO UPPER & LOWER STRATA BASED ON SPT N-VALUES & EXPERIENCE IN OTHER AREAS OF THE INTERCHANGE.

	N_{AVG}	S_u (psf)	
EL62.5 – EL53:	17	1,355	S_u FROM UU-TRIAXIAL
EL53 – EL17:	AVG 25	25/7.5 = 3,300	
	MIN 21	21/7.5 = 2800	

CONSIDER 2-LAYER SYSTEM

SR1 / I-95 Interchange 103-059-27U
11/25/08 RW6 & 16 Analysis

JJT 1-27-09



AASHTO SOIL KEY

A-1-a	A-2-5	A-5	A-8
A-1-b	A-2-6	A-6	Asphalt
A-3	A-2-7	A-7-5	FILL
A-2-4	A-4	A-7-6	Decomposed Rock

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: **Summary of Boring Data**

Retaining Wall 6 & 16

Figure No.

Drawn: SAB | Approved: | Date: 11/25/08 | Comm. No 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 11/25/08

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Subject SR1/I-95 Interchange
RW 6 Analysis
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Cm. No. 103-059-270
Prepared By SAB Date 11/26/08 Checked By JPT Date 1-27-09
EMK 1/29/09

STA 1117+50 (RAMP C)

Evaluate 2-layer soil system using Drained conditions. (Undrained analysis not valid per AASHTO equation 10.6.3.1.2e-3 since $c_1 = 0$.)

Per AASHTO 10.6.3.1.2f, if upper layer is cohesionless w/ $25° < \phi' < 50°$,

$$q_n = q_2 e^{0.67\left[1+\left(\frac{B}{L}\right)\right]\frac{H}{B}}$$

where: q_n = nominal bearing resistance of 2-layer system
q_2 = nominal bearing resistance of lower soil
B = footing width = 15.2'
L = footing length = 176'
H = depth below footing of 2nd soil layer => 12 – 16' → use 14'

$$\rightarrow q_n = (q_2) e^{0.67\left[1+\left(\frac{15.2'}{176'}\right)\right]\left(\frac{14'}{15.2'}\right)}$$

$$= q_2 \left(e^{0.67(1.0006)}\right)$$

$= 4{,}528(1.955) = 8{,}852$ psf (Undrained)
$= 4{,}604(1.955) = 9{,}001$ psf (Drained)

per AASHTO LRFD, Table 11.5.6-1, $\phi_b = 0.65$ for MSE walls

$\Rightarrow q_{R_U} = 0.65(8{,}852) = \boxed{5{,}754 \text{ psf}}$ → check vs. Meyerhof Stress from MSEW to get CDR (Undrained case governs)

$q_{R_D} = 0.65(9{,}001) = 5{,}851$ psf

⇒ from MSEW 3.0, using Stratum II (upper): (see output, p. 7-15)

Meyerhof Stress = 4,684 psf (see p. 14)

$\Rightarrow$ CDR = $\frac{\text{capacity}}{\text{demand}} = \frac{5{,}754}{4{,}684} = \underline{1.23} > 1.0$ ✓OK

Sliding Resistance: Assuming stratum II a foundation soil (very conservative since Type B borrow will be placed below footing)

→ CDR = 1.15 > 1.0 ✓OK

Overturning Resistance:

CDR = 2.88 > 1.0 ✓OK

7

RKK RW6 & 16-10

QRT 1-30-09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: Ramp C STA 1117+50

Description:

Retaining Wall 6 DRAINED Analysis L/H = 0.8 Foundation Soil = Upper Stratum IIa Used to calculate Meyerhof Stress and check Sliding/Overturning Resistance

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....6 DRAINED L=pt8H.BEN
Original date and time of creating this file: Mon Oct 20 08:53:11 2008

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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SOIL DATA

REINFORCED SOIL - Select FILL

Unit weight, γ	125.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL - Common Borrow

Unit weight, γ	130.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ	28.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil) (Stratum IIa)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}
Equivalent internal angle of friction, $\phi_{equiv.}$	24.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ^{2}

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3627 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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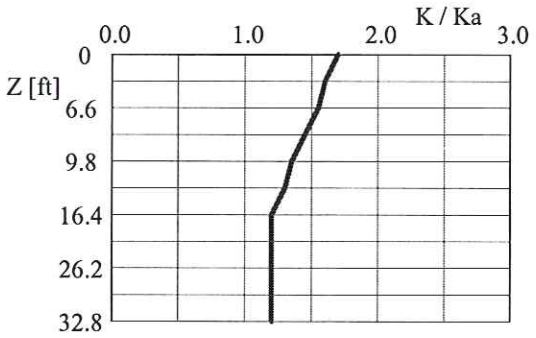
RKK RW6 & 16-12
JOS 1-30-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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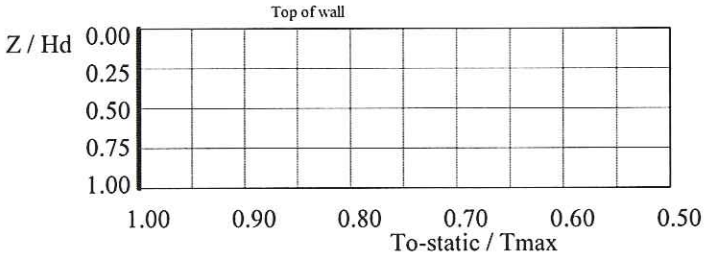
RKK RW6 & 16-13
1-30-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 152.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK RW6 & 16-14 JPT 1-30-09

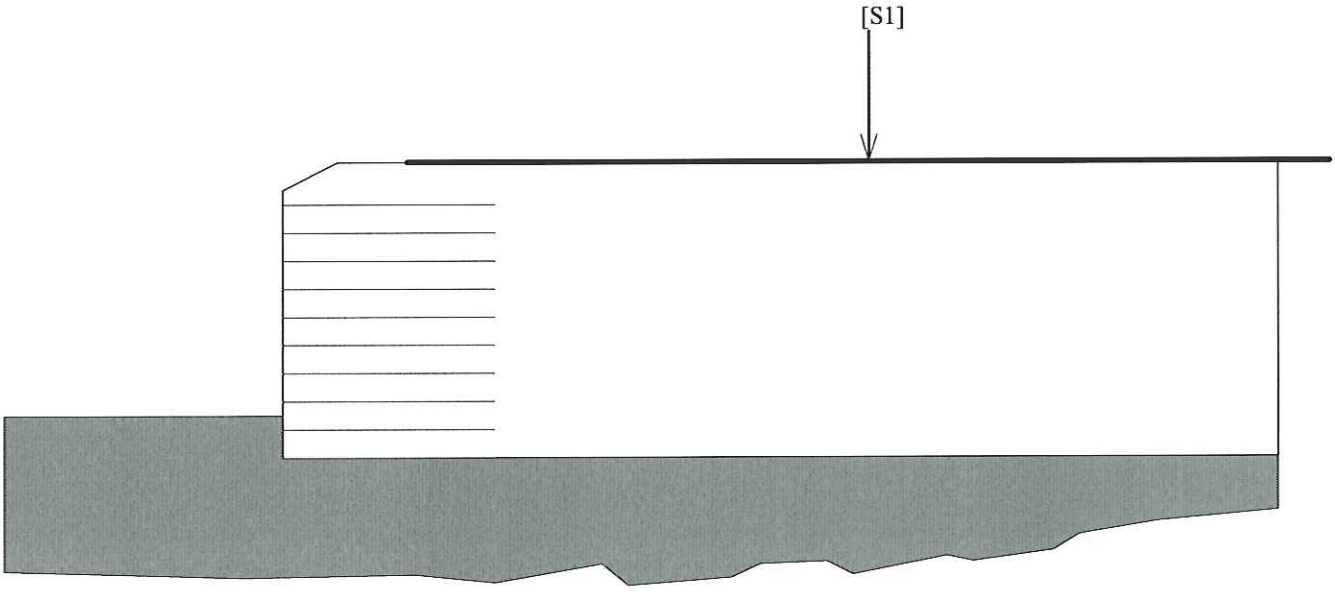
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	19.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 16.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	2.0	[ft]	Broken back equivalent angle, I = 3.01° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=66.0 [ft]. Distance of center of footing from wall face, d = 42.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10 [ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35		
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00		
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75		
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50		
Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35
Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:		$\gamma_{p\text{-}EH}$	1.50	
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):		$(\gamma_{p\text{-}EH})_{EQ}$	1.50	
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):		$\gamma_{p\text{-}EQ}$	1.00	

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00
Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
	ϕ_b	0.65		0.65

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RKK RW6 & 16-16 JPT 1-30-09

ANALYSIS: CALCULATED FACTORS (Static conditions) See p. 6

~~Bearing capacity, CDR = 0.98~~, Meyerhof stress = 4684 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.147, Eccentricity, e/L = 0.1639, CDR-overturning = 2.88

METAL STRIP				CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	15.20	1	N/A	2.86	3.18	3.181	2.161	1.733	0.1639	---
2	2.00	15.20	1	N/A	1.50	1.66	1.662	1.116	1.913	0.1323	---
3	4.00	15.20	1	N/A	1.62	1.80	1.800	1.145	2.129	0.1037	---
4	6.00	15.20	1	N/A	1.79	1.99	1.986	1.147	2.402	0.0780	---
5	8.00	15.20	1	N/A	1.99	2.21	2.211	1.108	2.757	0.0551	---
6	10.00	15.20	1	N/A	2.26	2.52	2.515	1.043	3.237	0.0350	---
7	12.00	15.20	1	N/A	2.68	2.98	2.976	1.069	3.922	0.0173	---
8	14.00	15.20	1	N/A	3.38	3.76	3.756	1.140	4.979	0.0014	---
9	16.00	15.20	1	N/A	4.72	5.24	5.239	1.226	6.822	-0.0144	---
10	18.00	15.20	1	N/A	7.99	8.88	8.882	1.339	10.830	-0.0370	---

CDR = 0.98 for MSE wall bearing directly on in situ soil. MSE will bear directly on 14½ ft of Select Fill. See page 6 for 2 layer analysis.

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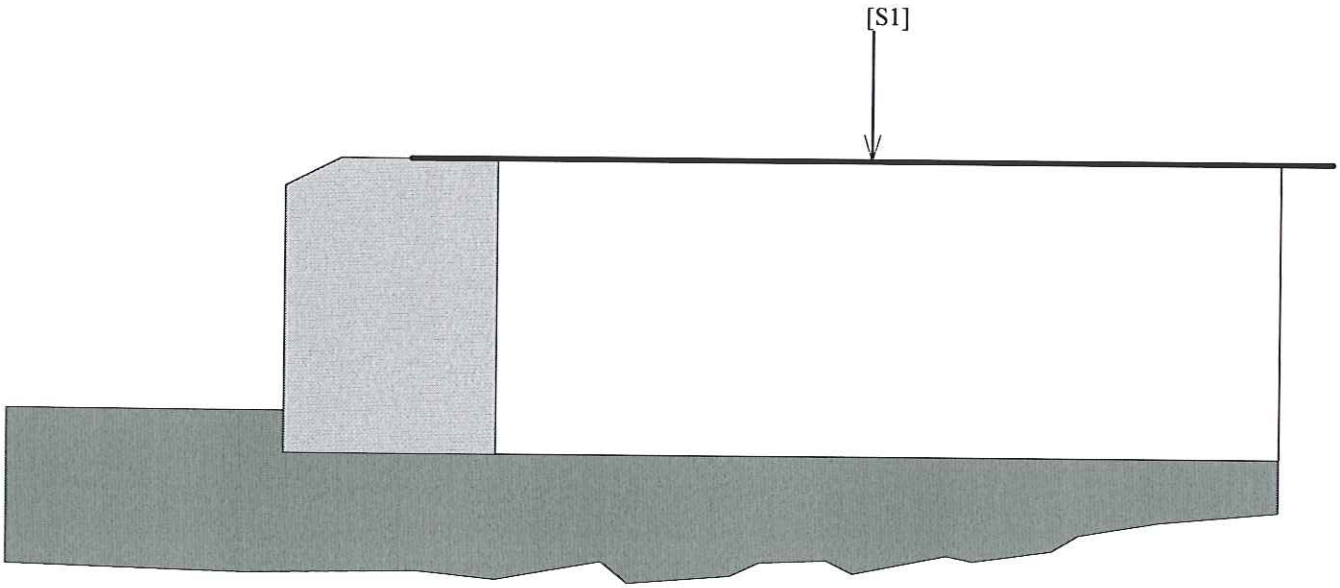
RKK RW6 & 16-17
JT 1-30-09

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Ultimate bearing capacity, q-ult	4604	N/A	[lb/ft ²]
Meyerhof stress, σ_v	4683.7	N/A	[lb/ft ²]
Eccentricity, e	1.83	N/A	[ft]
Eccentricity, e/L	0.120	N/A	
~~CDR calculated~~	~~0.98~~	~~N/A~~	
Base length	15.20	N/A	[ft]

See p. 6



SCALE:

0 2 4 6 8 10 [ft]

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RKK RW6 & 16-18
JBT 1-30-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.147

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	15.20	1.733	N/A	1	---
2	2.00	15.20	1.913	N/A	1	---
3	4.00	15.20	2.129	N/A	1	---
4	6.00	15.20	2.402	N/A	1	---
5	8.00	15.20	2.757	N/A	1	---
6	10.00	15.20	3.237	N/A	1	---
7	12.00	15.20	3.922	N/A	1	---
8	14.00	15.20	4.979	N/A	1	---
9	16.00	15.20	6.822	N/A	1	---
10	18.00	15.20	10.830	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1639; Overturning: CDR-static = 2.88

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	15.20	0.1639	N/A	1	---
2	2.00	15.20	0.1323	N/A	1	---
3	4.00	15.20	0.1037	N/A	1	---
4	6.00	15.20	0.0780	N/A	1	---
5	8.00	15.20	0.0551	N/A	1	---
6	10.00	15.20	0.0350	N/A	1	---
7	12.00	15.20	0.0173	N/A	1	---
8	14.00	15.20	0.0014	N/A	1	---
9	16.00	15.20	-0.0144	N/A	1	---
10	18.00	15.20	-0.0370	N/A	1	---

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Subject SR1/I-95 Interchange Page 16 of
RW6 - STA 1118+50 Analysis Cm. No. 103-059-27U
Prepared By SAB Date 12/18/08 Checked By JST Date 1-27-09
EMR 1/29/09

Ramp C
STA 1118+50 (see cross-section, p. 17)

RW 6 Height = 18' (assumed wall will be constructed on Select Borrow and height shortened to 6' below top of pavement of Ramp C, not into natural soil)

BOF EL = EL 79

Backslope: Rise = 11.5' @ 2(H):1(V) = 26.57°

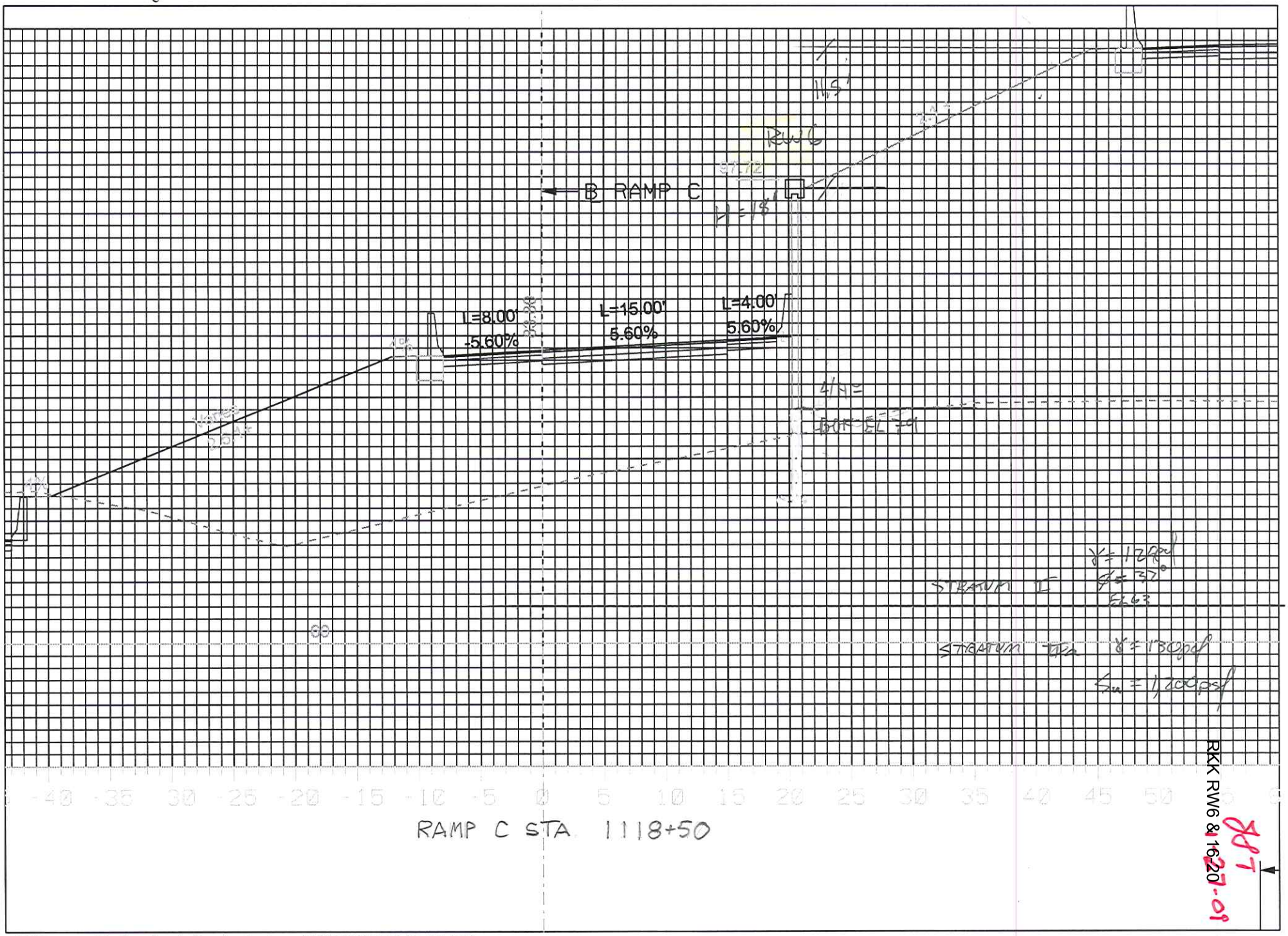
Embedment Depth, E = 3'

Soils: (see fence diagram, p. 5)

Soil	γ_t (pcf)	ϕ' (deg)	c' (psf)	S_u (psf)(1)	EL (Ft.)
Stratum I	125	32	-	-	79-63
Stratum IIa	130	24	-	1,200 psf	63-40
Stratum IIa	130	24	-	1,700 psf	40
Water	62.4				62

(1) Undrained shear strength from 10MT-20 near STA 1118+50.

SR1/I-95 Interchange 103-059-270 RW6 12/18/08



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RKK RW6 & I-95-01

17

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Subject SR1/I-95 Interchange
RW6 STA 1118+50 Analysis
Page 18 of
Cm. No. 103-059-27U
Prepared By SAB Date 12/18/08 Checked By JPT Date 1-27-09
AM 1/29/09

Check 2-layered foundation soil:

AASHTO 10.6.3.1.2c-2: If 2nd soil layer is < H_{crit} below footing, use 2-layer soil:

$$H_{crit} = \frac{3B\ln\left(\frac{q_1}{q_2}\right)}{2\left(1+B/L\right)}$$ as defined on p. 4.

from MSEW 3.0, q_1 = 12,217 psf, q_{2w} = 4,010 psf, q_{2pi} = 3,970 psf ← Governing case; B = 0.8H = 14.4', L = 176'

$$= \frac{3(14.4')\ln\left(\frac{12,217}{3,970}\right)}{2\left(1+14.4'/176'\right)} = 22.4'$$

→ CLAY is 16' below footing, so use 2-layer soil.

Per AASHTO 10.6.3.1.2f, if upper layer is cohesionless w/ 25° < φ' < 50°,

$$q_n = q_2 e^{0.67\left[1+\left(\frac{B}{L}\right)\right]\left(\frac{H}{B}\right)}$$ as defined on p. 6 with B = 14.4', L = 176', & H = 16'

$$= 3,970\, e^{0.67\left[1+\frac{14.4'}{176'}\right]\left(\frac{16'}{14.4'}\right)} = 3,970\, e^{0.8054} = \underline{8,883\ psf} = q_n$$

Per AASHTO LRFD, Table 11.5.6-1, ϕ_b = 0.65 for MSE walls.

$$\Rightarrow q_R = 0.65(8,883) = \boxed{5,774\ psf}$$ → check Vertical Stress from MSEW to get CDR

from MSEW, σ_v = 6,094 psf ⇒ CDR = 0.95 < 1.0 for L/H = 0.8 & conventional backfill.

REVISE:

Increasing reinforcement length does not increase CDR because due to 2-layer soil, a wider footing causes more influence on the weaker clay layer.

⇒ Use Select Fill for Retained Soil (including soil above wall & in retained wedge)

Now, $\underline{\sigma_v = 5,177\ psf}$ ⇒ $\underline{CDR = 1.12}$ > 1.0 ✓ OK

Sliding Resistance (Stratum I foundation soil): CDR = 1.52 > 1.0 ✓ OK

Overturning Resistance (" " " "): CDR = 2.46 > 1.0 ✓ OK

RW-6 REQUIRES SELECT FILL IN BACK FILL WEDGE BEHIND WALL

RKK RW6 & 16-22 JJT 1-27-09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: Ramp C STA 1118+50

Description:

Retaining Wall 6 DRAINED Analysis L/H = 0.8 Foundation Soil = Stratum I Used to calculate Meyerhof Stress and check Sliding and Overturning Resistance

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21217
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN..... .....RW 6 STA 1118+50.BEN
Original date and time of creating this file:

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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RKK RW6 & 16-23
12-27-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select Fill
Design value of internal angle of friction, ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select Fill
Design value of internal angle of friction, ϕ	34.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	125.0 lb/ft ^{3}	
Equivalent internal angle of friction, $\phi_{equiv.}$	32.0 °	Strata 1
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ^{2}	

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3239 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 35.49 N γ= 30.21

SEISMICITY

Not Applicable

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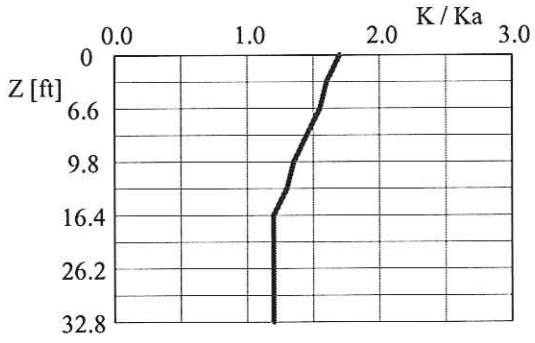
INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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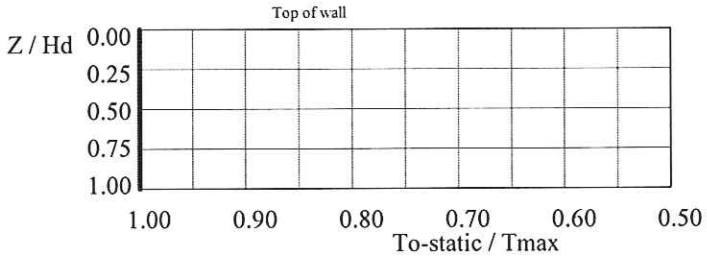
INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 152.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK RW6 & 16-26
1-27-09

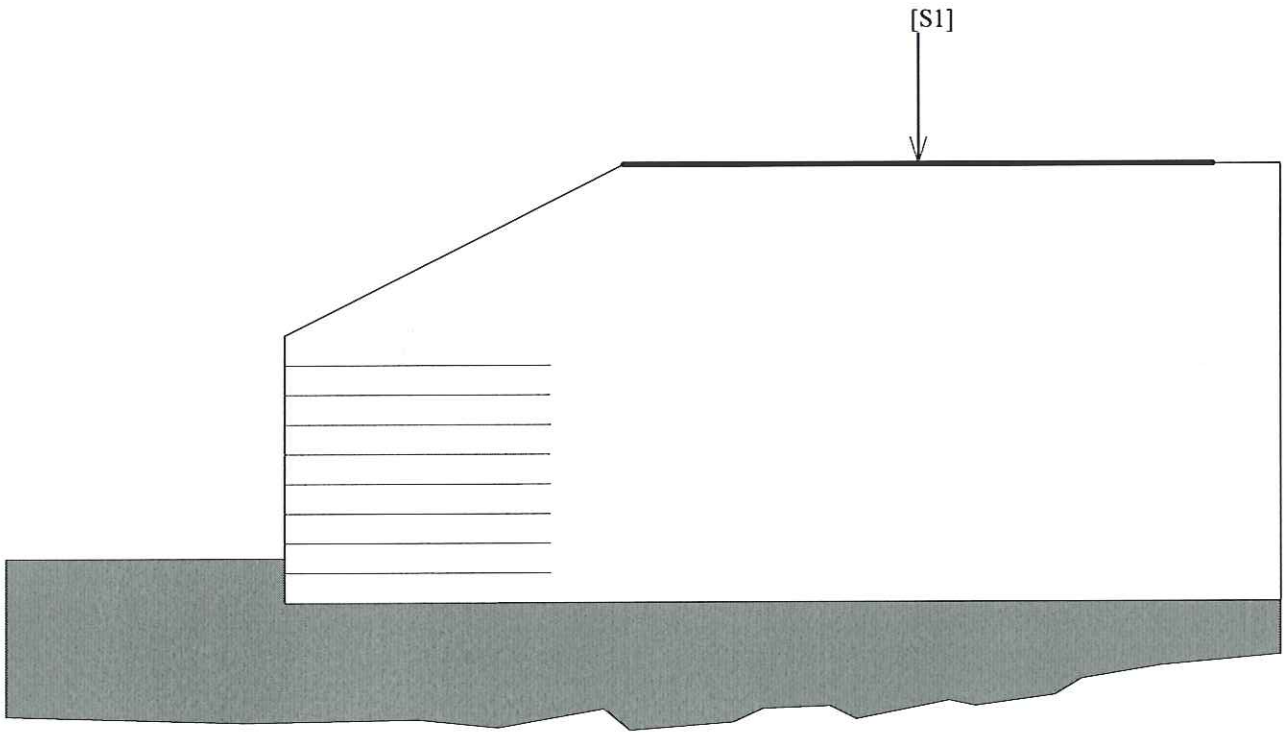
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	18.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 15.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	11.5	[ft]	Broken back equivalent angle, I = 17.72° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=40.0 [ft]. Distance of center of footing from wall face, d = 43.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10 [ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00

Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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RKK RW6 & 16-28
1-27-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 2.67, Meyerhof stress = 5177 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.520, Eccentricity, e/L = 0.1499, CDR-overturning = 2.46

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	14.40	1	N/A	2.74	3.04	3.041	2.223	1.641	0.1499	---
2	2.00	18.00	1	N/A	1.44	1.60	1.596	1.527	1.932	0.0734	---
3	4.00	18.00	1	N/A	1.56	1.73	1.734	1.616	2.045	0.0516	---
4	6.00	18.00	1	N/A	1.71	1.90	1.898	1.671	2.173	0.0302	---
5	8.00	18.00	1	N/A	1.89	2.10	2.095	1.695	2.317	0.0090	---
6	10.00	18.00	1	N/A	2.13	2.37	2.372	1.710	2.478	-0.0126	---
7	12.00	18.00	1	N/A	2.52	2.80	2.797	1.843	2.656	-0.0357	---
8	14.00	18.00	1	N/A	3.15	3.50	3.500	2.083	2.846	-0.0624	---
9	16.00	18.00	1	N/A	3.13	3.48	3.476	1.786	3.026	-0.0974	---

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BEARING CAPACITY for GIVEN LAYOUT

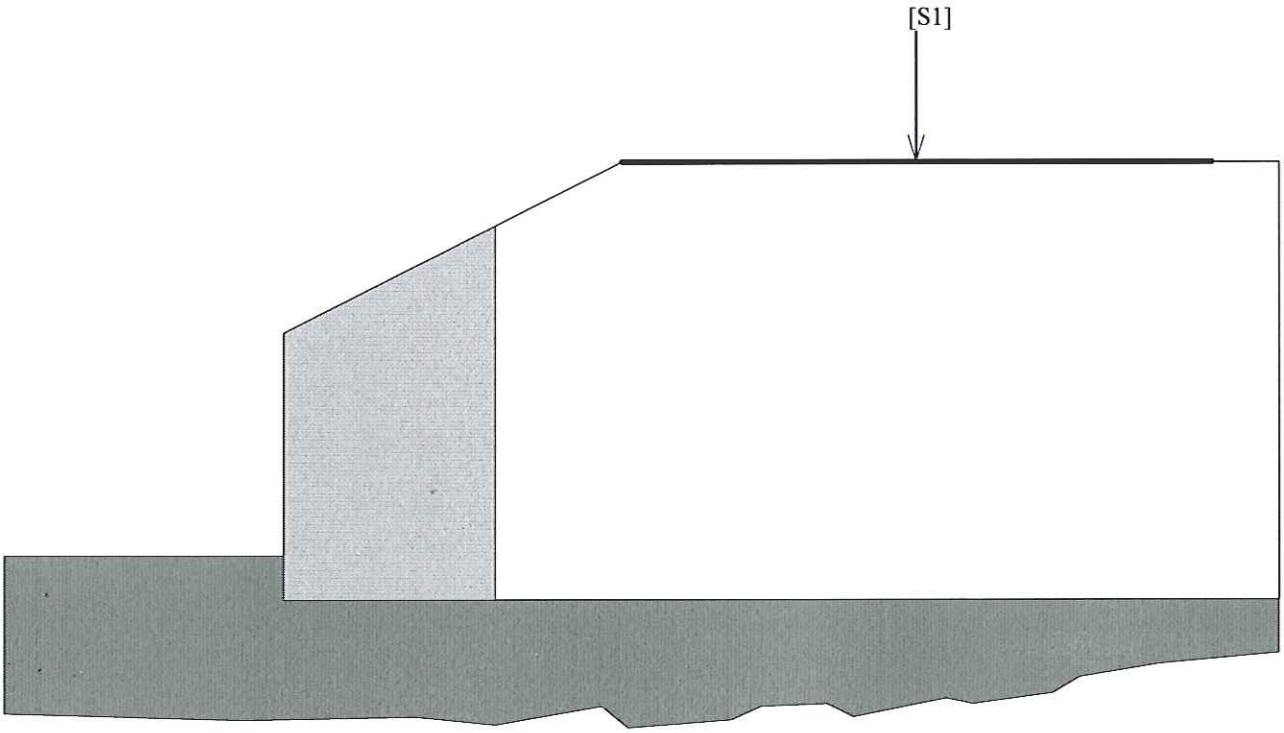
	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Ultimate bearing capacity, q-ult	13840	N/A	[lb/ft ²]
Meyerhof stress, σ_V	5176.8	N/A	[lb/ft ²]
Eccentricity, e	1.56	N/A	[ft]
Eccentricity, e/L	0.109	N/A	
CDR calculated	2.67	N/A	
Base length	14.40	N/A	[ft]

q_{ult} = 8973 psf from Pg 18 for 2 layer System

q_L for 2 layer system = 5832 psf

$CDR = \frac{5832}{5176} = 1.13 > 1 \therefore OK$

See Pg 18



SCALE:

0 2 4 6 8 10 [ft]

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RKK RW6 & 16-30 1-27-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.520

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	14.40	1.641	N/A	1	---
2	2.00	18.00	1.932	N/A	1	---
3	4.00	18.00	2.045	N/A	1	---
4	6.00	18.00	2.173	N/A	1	---
5	8.00	18.00	2.317	N/A	1	---
6	10.00	18.00	2.478	N/A	1	---
7	12.00	18.00	2.656	N/A	1	---
8	14.00	18.00	2.846	N/A	1	---
9	16.00	18.00	3.026	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1499; Overturning: CDR-static = 2.46

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	14.40	0.1499	N/A	1	---
2	2.00	18.00	0.0734	N/A	1	---
3	4.00	18.00	0.0516	N/A	1	---
4	6.00	18.00	0.0302	N/A	1	---
5	8.00	18.00	0.0090	N/A	1	---
6	10.00	18.00	-0.0126	N/A	1	---
7	12.00	18.00	-0.0357	N/A	1	---
8	14.00	18.00	-0.0624	N/A	1	---
9	16.00	18.00	-0.0974	N/A	1	---

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Subject SR1/I-95 Interchange
RW6 Analysis
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Cm. No. 103-059-27W
Prepared By SAG Date 12/19/08 Checked By SPT Date 1-27-09
EMC 1/29/09

Determine where transition must occur between common Borrow & Select Fill Retained Soil:

@ STA 1118+00, RW6: H = 19', Backslope Rise = 6'

Checking Meyerhof stress with MSEW 3.0 → σ_V = 5,797 psf (see p. 29-30)

→ From STA 1117+50 Analysis, σ_R = 5,754 psf (see p. 8 of 6)

5754 σV
5797 σR

⇒ C/R = 0.99 < 1.0 so use Select Fill in the retained soil & to construct backslope.

⇒ Retained Soil should be Select Fill from STA 1117+75 to end of wall @ STA 1119+25.

Summary

Start STA	End STA	L/H	Retained Soil & Wedge
1117+50 (Start Wall)	1117+75	0.8	Common Borrow
1117+75	1119+25	0.8	Select Fill

* Anywhere RW 6 is placed on Fill, Select Fill must be used.

RKK RW6 & 16-32
1-27-09

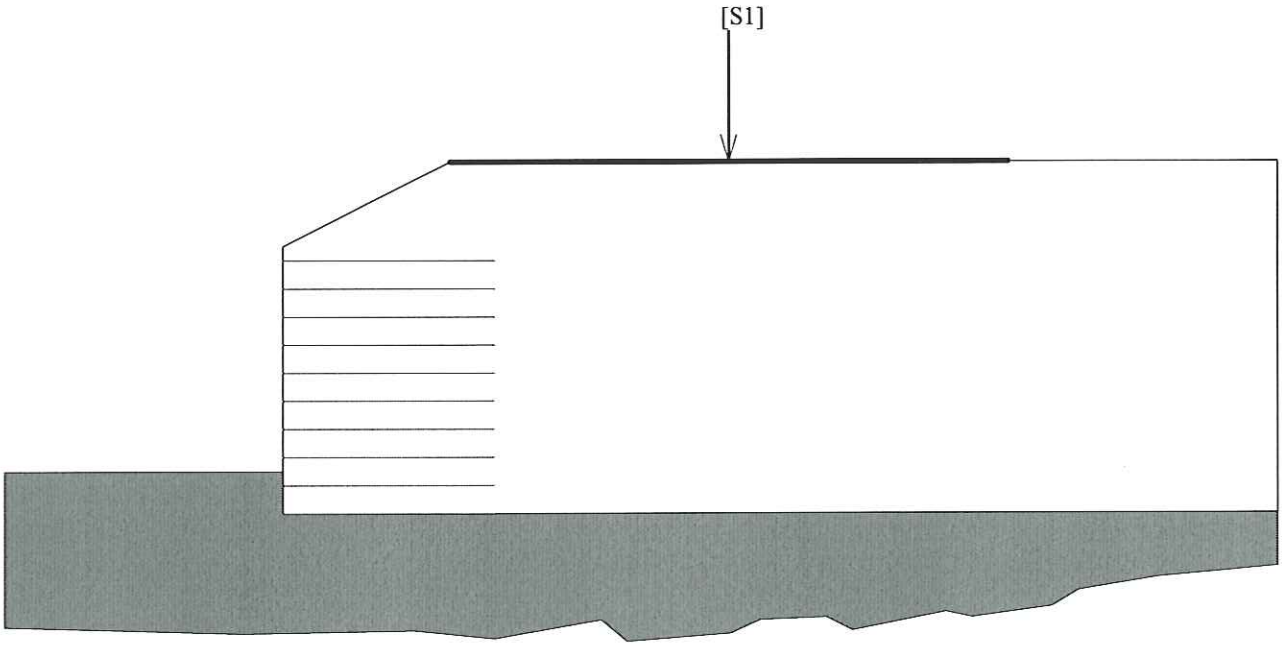
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	19.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 16.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	6.0	[ft]	Broken back equivalent angle, I = 8.97° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=40.0 [ft]. Distance of center of footing from wall face, d = 32.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

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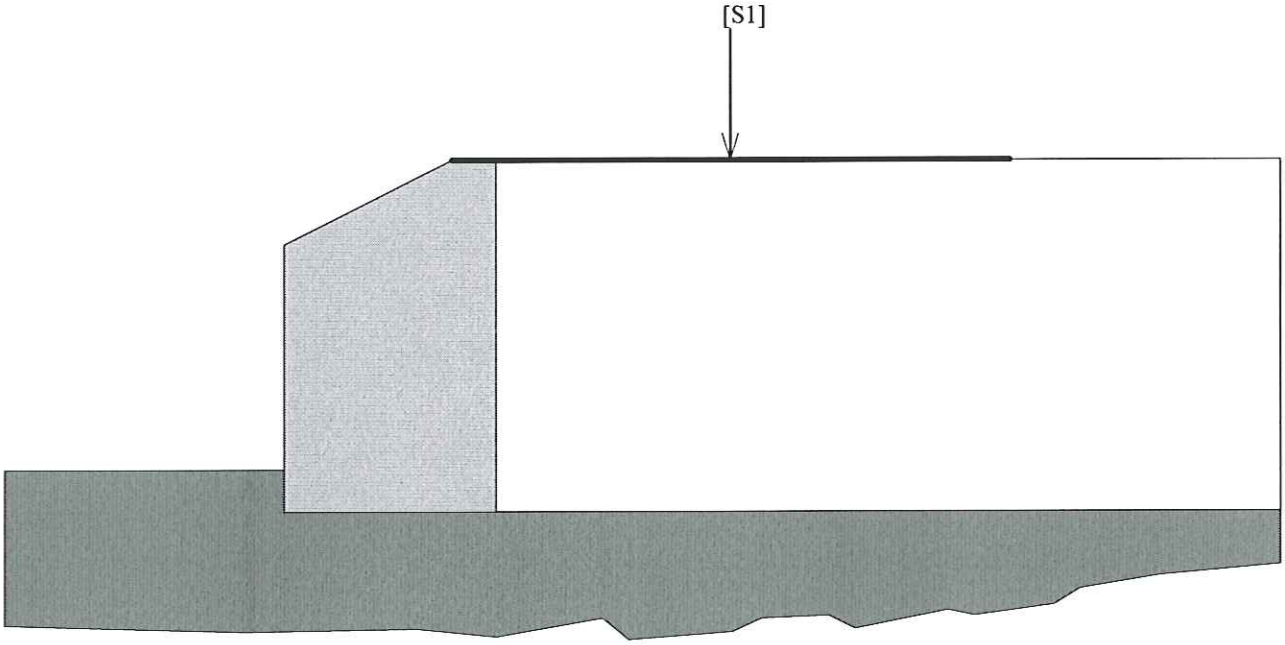
RKK RW6 & 16-33
1-27-09

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Ultimate bearing capacity, q-ult	4528	N/A	[lb/ft ²]
Meyerhof stress, σ_v	5797.1	N/A	[lb/ft ²]
Eccentricity, e	2.28	N/A	[ft]
Eccentricity, e/L	0.150	N/A	
CDR calculated	0.78	N/A	
Base length $= 0.8H$	15.20	N/A	[ft]



SCALE:

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Subject SR1/I-95 Interchange
RW 16 Foundation Soil
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Cm. No. 103-059-270
Prepared By SAB Date 11/26/08 Checked By JJT Date 1-27-09

From AASHTO LRFD 2008, 10.6.3.1.2d:

$$H_{crit} = \frac{3B \ln\left(\frac{g_1}{g_2}\right)}{2\left(1+\frac{B}{L}\right)}$$ (see p. 4 for symbol definitions)

From MSEW 3.0,

for Upper IIa, $S_u = 1,355$ psf, $g_1 = 4,528$ psf

for Lower IIa, $S_u = 2,800$ psf, $g_2 = 9,358$ psf

$B = 22.5'$ (assume $L/H = 1.0$ will be required) $L = 141'$ (RW-16 length)

$$\Rightarrow H_{crit} = \frac{3(22.5')\ln\left(\frac{4528}{9358}\right)}{2(1+22.5'/141')} = 21.13' >$$ depth below footing of Lower Stratum IIa (9.5'), so use 2-layer soil system.

Undrained condition: AASHTO LRFD 10.6.3.1.2e suggests modifying the bearing resistance using the following parameters:

c_1 = undrained shear strength of top soil layer C_2 = undrained strength of lower layer
$N_{cm} = N_m$, as specified below.
$N_{qm} = 1.0$

→ when bearing stratum overlies a stiffer layer, N_m is taken from Figure 2 (see p. 32)

$c_1/c_2 = \frac{2800}{1355} = 2.07 \approx 2$ $B/H = 22.5'/9.5' = 2.37$

⇒ From Figure 2, $N_m = 5.33$

AASHTO 10.6.3.1.2a: $q_n = c N_{cm} + \gamma D_f N_{qm} C_{wq} + 0.5 \gamma B N_{\gamma m} C_{w\gamma}$ ($C_{wq} = 1.0$; $C_{w\gamma} = 0$ (water table @ BOF = EL)) as defined on p. 33 & 33a

Table 2: $C_{wq} = 1.0$ [GW @ BOF = EL (D_f)]

$\Rightarrow q_n = 1,355(5.33) + 130(3')(1.0)(1.0) + 0 = 7,612$ psf

⇒ From Table 11.5.6-1, $\phi_b = 0.65$ for MSE walls

$\Rightarrow q_R = 0.65(7,612\text{ psf}) = 4,948$ psf

⇒ Use MSEW 3.0 to find Megabar stress to get CDR.

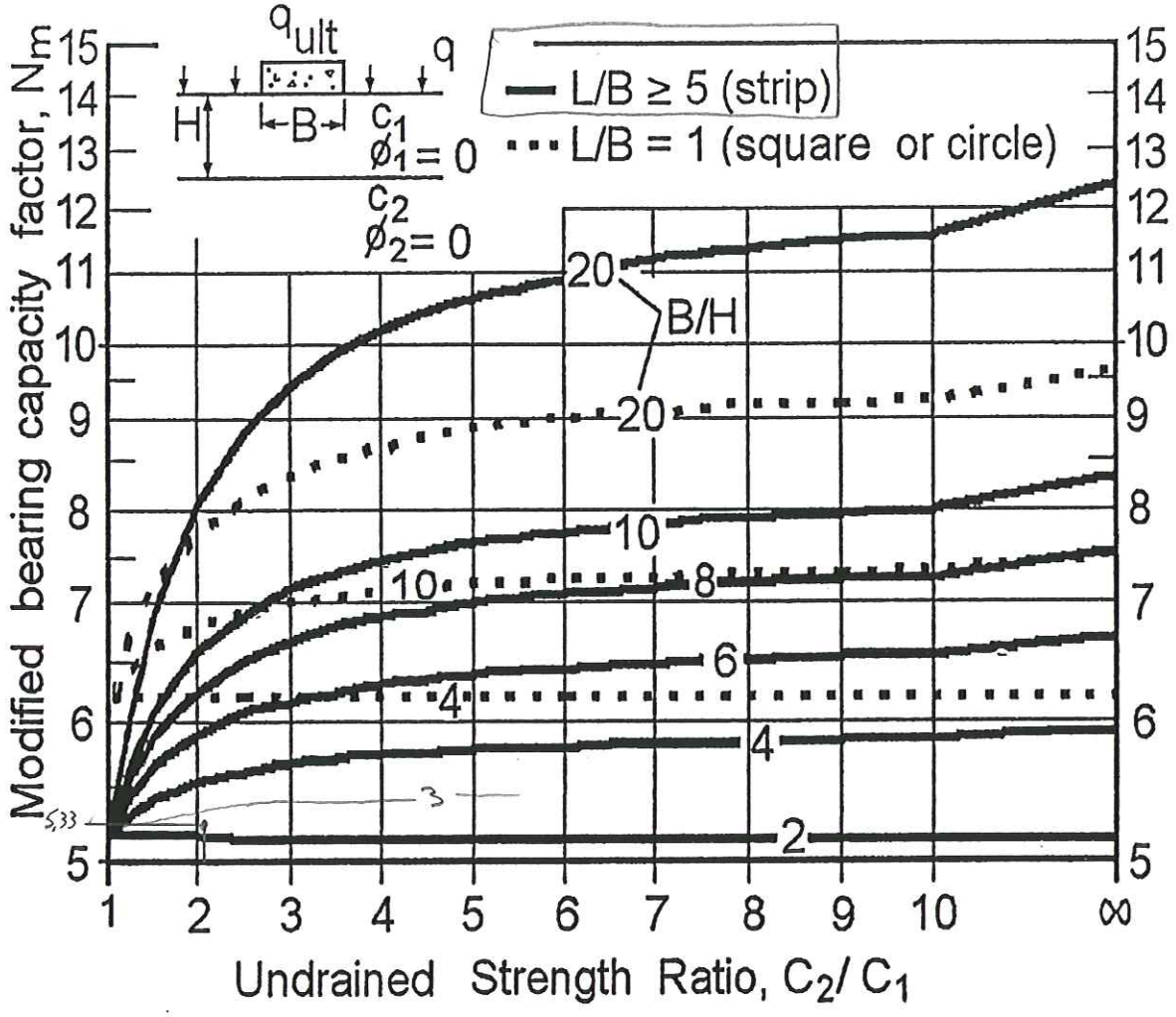

Figure 10.6.3.1.2e-2 Modified Bearing Factor for Two-Layer Cohesive Soil with Weaker Soil Overlying Stronger Soil (*EPRI, 1983*).

10.6.3.1.2f Two-Layered Soil System in Drained Loading

Where a footing supported on a two-layered soil system is subjected to a drained loading, the nominal bearing resistance, in ksf, may be taken as:

If t
equals 2

RKK RW6 & 16-36

Consideration should be given to the relative change in the computed nominal resistance based on effective versus gross footing dimensions for the size of footings typically used for bridges. Judgment should be used in deciding whether the use of gross footing dimensions for computing nominal bearing resistance at the strength limit state would result in a conservative design.

10.6.3.1.2 Theoretical Estimation

10.6.3.1.2a Basic Formulation

C10.6.3.1.2a

The nominal bearing resistance shall be estimated using accepted soil mechanics theories and should be based on measured soil parameters. The soil parameters used in the analyses shall be representative of the soil shear strength under the considered loading and subsurface conditions.

The nominal bearing resistance of spread footings on cohesionless soils shall be evaluated using effective stress analyses and drained soil strength parameters.

The nominal bearing resistance of spread footings on cohesive soils shall be evaluated for total stress analyses and undrained soil strength parameters. In cases where the cohesive soils may soften and lose strength with time, the bearing resistance of these soils shall also be evaluated for permanent loading conditions using effective stress analyses and drained soil strength parameters.

For spread footings bearing on compacted soils, the nominal bearing resistance shall be evaluated using the more critical of either total or effective stress analyses.

Except as noted below, the nominal bearing resistance of a soil layer, in ksf, should be taken as:

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + 0.5\gamma \quad BN_{\gamma m} C_{w\gamma} \qquad (10.6.3.1.2a\text{-}1)$$

in which:

$$N_{cm} = N_c s_c i_c \qquad (10.6.3.1.2a\text{-}2)$$

$$N_{qm} = N_q s_q d_q i_q \qquad (10.6.3.1.2a\text{-}3)$$

$$N_\gamma m = N_\gamma s_\gamma i_\gamma \qquad (10.6.3.1.2a\text{-}4)$$

The bearing resistance formulation provided in Eqs. 1 though 4 is the complete formulation as described in the Munfakh, et al. (*2001*). However, in practice, not all of the factors included in these equations have been routinely used.

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Subject SR1/I-95 Interchange
RW16 Analysis

Cm. No. 103-059-270

Prepared By SAB Date 11/26/08 Checked By JST Date 1-27-09

External Stability: Performed using MSEW 3.0 (see attached output, p. 35-43)
↳ see p. 25 for LRFD resistance factors used.

UNDRAINED
Analysis: Foundation Soil = Stratum IIa (This will generate conservative CDR's for sliding & overturning.)

Results: Bearing Capacity: Factored bearing resistance, from p. 31 ⇒ q_R = 4,948 psf

Maximum Stress, σ_v = 4,743 *

⇒ CDR = 1.04 > 1.0 √OK ← $\frac{q_R}{\sigma_v} = \frac{4948}{4743}$

* To get $\sigma_v < q_R$, No. 57 stone must be used in the reinforced soil zone & as the retained backfill (in a zone from the back of the bottom reinforced layer, extending upward at an angle = (45 + φ/2), where φ = 34°.

Sliding CDR = 1.84 > 1.0 √OK

Overturning CDR = 4.62 > 1.0 √OK

RKK RW6 & 16-38
1-27-09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: Ramp C STA 1117+50

Description:

Retaining Wall 16 UNDRAINED Analysis L/H = 1.0 Reinforced and Retained Soil = No. 57 Stone

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....\RW 16 UNDRAINED.BEN
Original date and time of creating this file:

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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License number MSEW-301874

RKK RW6 & 16-39
JRT 1-27-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ	105.0 lb/ft ^{3}	No 57 stone
Design value of internal angle of friction, ϕ	38.0 °	

RETAINED SOIL

Unit weight, γ	105.0 lb/ft ^{3}	No 57 stone
Design value of internal angle of friction, ϕ	38.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}	Strata IIa
Equivalent internal angle of friction, $\phi_{equiv.}$	0.0 °	
Equivalent cohesion, $c_{equiv.}$	1355.0 lb/ft ^{2}	

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2379 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2406 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 5.14 N γ= 0.00

SEISMICITY

Not Applicable

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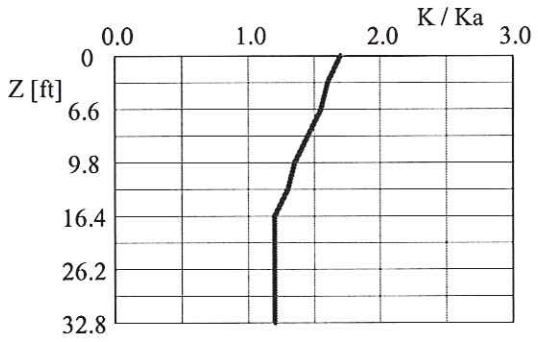
INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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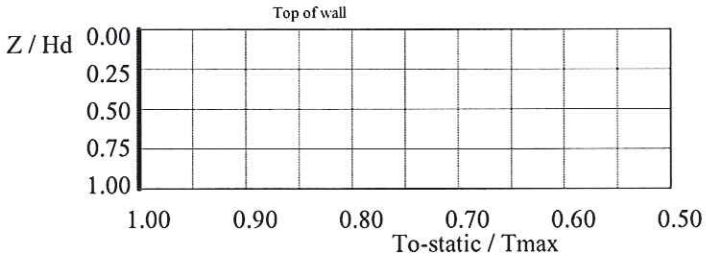
INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 152.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK RW6 & 16-42
JPT 1-27-09

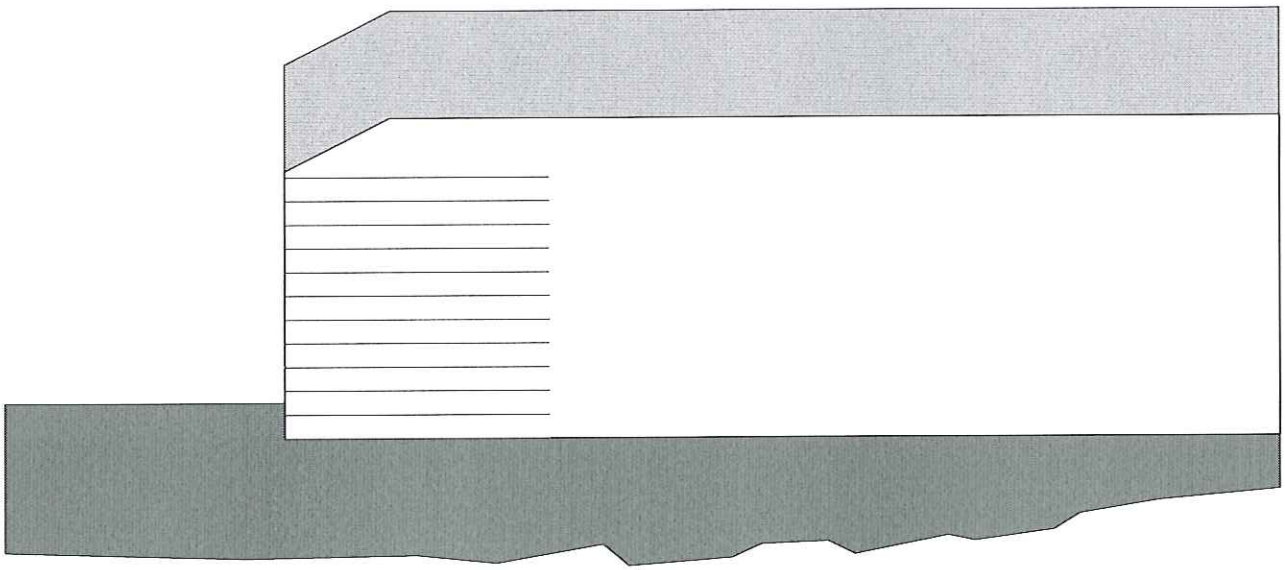
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	22.50	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 19.50 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	4.5	[ft]	Broken back equivalent angle, I = 5.71° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00

Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90		1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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RKK RW6 & 16-44
1-27-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 0.95, Meyerhof stress = 4743 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.840, Eccentricity, e/L = 0.0882, CDR-overturning = 4.62

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	22.50	1	N/A	2.98	3.31	3.313	3.307	2.953	0.0882	---
2	2.00	22.50	1	N/A	1.57	1.75	1.745	1.534	3.133	0.0740	---
3	4.00	22.50	1	N/A	1.65	1.84	1.837	1.569	3.346	0.0604	---
4	6.00	22.50	1	N/A	1.72	1.91	1.914	1.655	3.598	0.0475	---
5	8.00	22.50	1	N/A	1.83	2.04	2.036	1.720	3.877	0.0352	---
6	10.00	22.50	1	N/A	1.96	2.18	2.183	1.744	4.189	0.0233	---
7	12.00	22.50	1	N/A	2.11	2.34	2.344	1.713	4.556	0.0117	---
8	14.00	22.50	1	N/A	2.30	2.55	2.553	1.699	4.990	0.0000	---
9	16.00	22.50	1	N/A	2.56	2.85	2.850	1.753	5.509	-0.0123	---
10	18.00	22.50	1	N/A	2.97	3.30	3.296	1.799	6.132	-0.0264	---
11	20.00	22.50	1	N/A	3.55	3.94	3.940	1.802	6.874	-0.0448	---
12	22.00	22.50	1	N/A	5.72	6.35	6.351	2.223	7.685	-0.0752	---

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RKK RW6 & 16-45
1-27-09

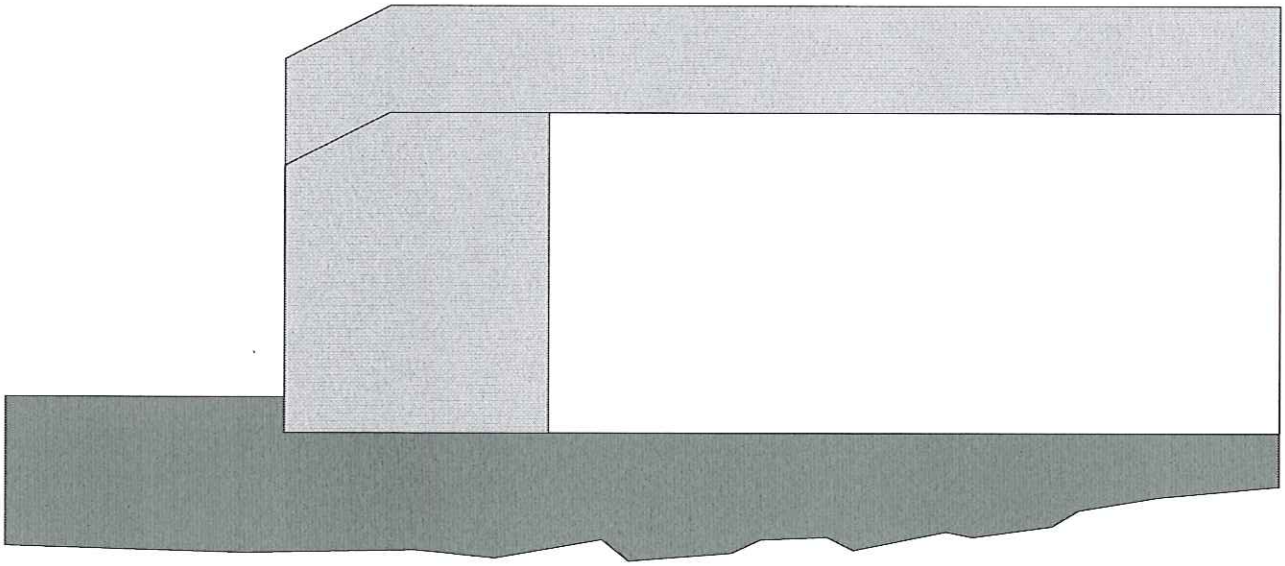
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	4528	N/A	[lb/ft ²]
Meyerhof stress, σ_V	4742.7	N/A	[lb/ft ²]
Eccentricity, e	1.26	N/A	[ft]
Eccentricity, e/L	0.056	N/A	
CDR calculated	0.95	N/A	
Base length	22.50	N/A	[ft]

q_{ult} = 4948 psf for 2 layer System

$\therefore$ CDR = $\frac{4948}{4742}$ $\frac{q_{ult}\ (2\ layer\ System)}{\sigma_V}$

CDR = 1.04 $\therefore$ ok



SCALE:

0 2 4 6 8 10[ft]

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DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.840

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	22.50	2.953	N/A	1	---
2	2.00	22.50	3.133	N/A	1	---
3	4.00	22.50	3.346	N/A	1	---
4	6.00	22.50	3.598	N/A	1	---
5	8.00	22.50	3.877	N/A	1	---
6	10.00	22.50	4.189	N/A	1	---
7	12.00	22.50	4.556	N/A	1	---
8	14.00	22.50	4.990	N/A	1	---
9	16.00	22.50	5.509	N/A	1	---
10	18.00	22.50	6.132	N/A	1	---
11	20.00	22.50	6.874	N/A	1	---
12	22.00	22.50	7.685	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0882; Overturning: CDR-static = 4.62

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	22.50	0.0882	N/A	1	---
2	2.00	22.50	0.0740	N/A	1	---
3	4.00	22.50	0.0604	N/A	1	---
4	6.00	22.50	0.0475	N/A	1	---
5	8.00	22.50	0.0352	N/A	1	---
6	10.00	22.50	0.0233	N/A	1	---
7	12.00	22.50	0.0117	N/A	1	---
8	14.00	22.50	0.0000	N/A	1	---
9	16.00	22.50	-0.0123	N/A	1	---
10	18.00	22.50	-0.0264	N/A	1	---
11	20.00	22.50	-0.0448	N/A	1	---
12	22.00	22.50	-0.0752	N/A	1	---

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RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject SR1/I-95 Interchange
RW 16 Analysis
Page 44 of
Cm. No. 103-054-290
Prepared By SAB Date 12/1/08 Checked By JFT Date 1-27-09

DRAINED condition: AASHTO 10.6.3.1.2f:

$$q_n = \left[q_{b2} + \left(\frac{1}{K}\right) c_1' \cot\phi_1'\right] e^{2\left[1+\frac{B}{L}\right] K \tan\phi_1' \left(\frac{H}{B}\right)} - \left(\frac{1}{K}\right) c_1' \cot\phi_1' \qquad \text{where: } K = \frac{1-\sin^2\phi_1'}{1+\sin^2\phi_1'}$$

c_1' = drained shear strength of top soil layer
q_{b2} = nominal bearing resistance of lower soil layer if top layer not present
ϕ_1' = effective stress friction angle of top soil

$$K = \frac{1-\sin^2(24°)}{1+\sin^2(24°)} = 0.716$$

From MSEW, $q_{R2} = 1,549$ psf (See p.)

So, $q_{n2} = q_R/\phi_b = 1548/0.65 = 2,382$ psf

$$\left(\frac{1}{K}\right) c_1' \cot\phi_1' = \frac{1}{0.716}(0 \text{ psf}) \cot 24° = 0$$

$$e^{2\left[1+\frac{B}{L}\right] K \tan\phi_1' \left(\frac{H}{B}\right)} = e^{2\left[1+\frac{22.5}{141}\right](0.716)\tan 24°\left(\frac{9.5'}{22.5'}\right)} = e^{0.43597} = 1.546$$

$$\Rightarrow q_n = [2382 + 0](1.546) = 3684 \text{ psf}$$

$\Rightarrow$ From Table 11.5.6-1, $\phi_b = 0.65$ for MSE walls.

$$\Rightarrow q_R = 0.65(3,684) = \boxed{2,395 \text{ psf}}$$

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Subject SR 1/I-95 Interchange
RW 16 Analysis
Page 45 of
Cm. No. 103-059-270
Prepared By SAB Date 12/3/08 Checked By JPT Date 1-27-09

Drained Stability: Performed using MSEW 3.0 (see attached output, p. 46-54)
↳ See p. 36 for LRFD resistance factors used.

L/H = 1.0

Foundation Soil) $\gamma = 130$ pcf $\phi' = 17°$ $c' = 0$ used in MSEW.

Results: Bearing capacity: Factored bearing resistance from p. 44 => q_R = 2,395 psf

* To reduce Maximum Stress to less than q_R, the following conditions are required:

Reinforced Soil Zone:	$\gamma_t = 45$ pcf	$\phi = 38°$
Retained Soil:	$\gamma_t = 40$ pcf	$\phi = 38°$

∴ LWEF

with these conditions, σ_V = 2,358 psf (from p. 52)

CDR = 1.02 > 1.0 ✓OK

Sliding Resistance: (using $\phi' = 17°$ → conservative; $c' = 0$)

CDR = 1.03 > 1.0 ✓OK

Overturning Resistance: (using $\phi' = 17°$, $c' = 0$)

CDR = 3.79 > 1.0 ✓OK.

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RKK RW6 & 16-49 JLT 12-3-09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: Ramp C STA 1117+50

Description:

Retaining Wall 16 DRAINED Analysis L/H = 1.0 Reinforced Soil Zone = 45-pcf Retained Soil = 40-pcf LWEF

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN..... .....gn\RW 16 DRAINED.BEN
Original date and time of creating this file: Mon Dec 01 14:58:44 2008

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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License number MSEW-301874

SOIL DATA

REINFORCED SOIL

Unit weight,	γ	45.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	38.0 °

RETAINED SOIL

Unit weight,	γ	40.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	38.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight,	$\gamma_{equiv.}$	130.0 lb/ft ^{3}
Equivalent internal angle of friction,	$\phi_{equiv.}$	17.0 °
Equivalent cohesion, c	$_{equiv.}$	0.0 lb/ft ^{2}

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2379 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2406 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 12.34 N γ= 3.53

SEISMICITY

Not Applicable

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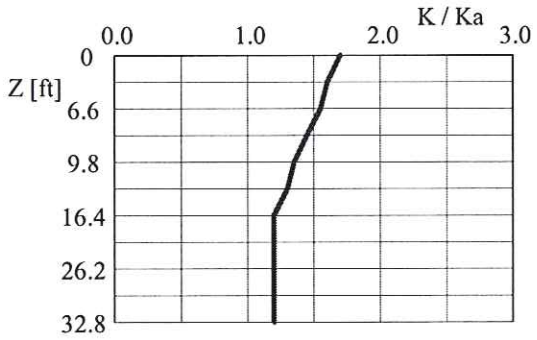
RKK RW6 & 16-51
JLT 1-27-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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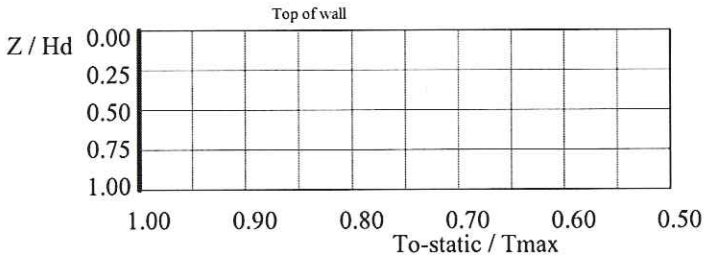
RKK RW6 & 16-52
1-27-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 152.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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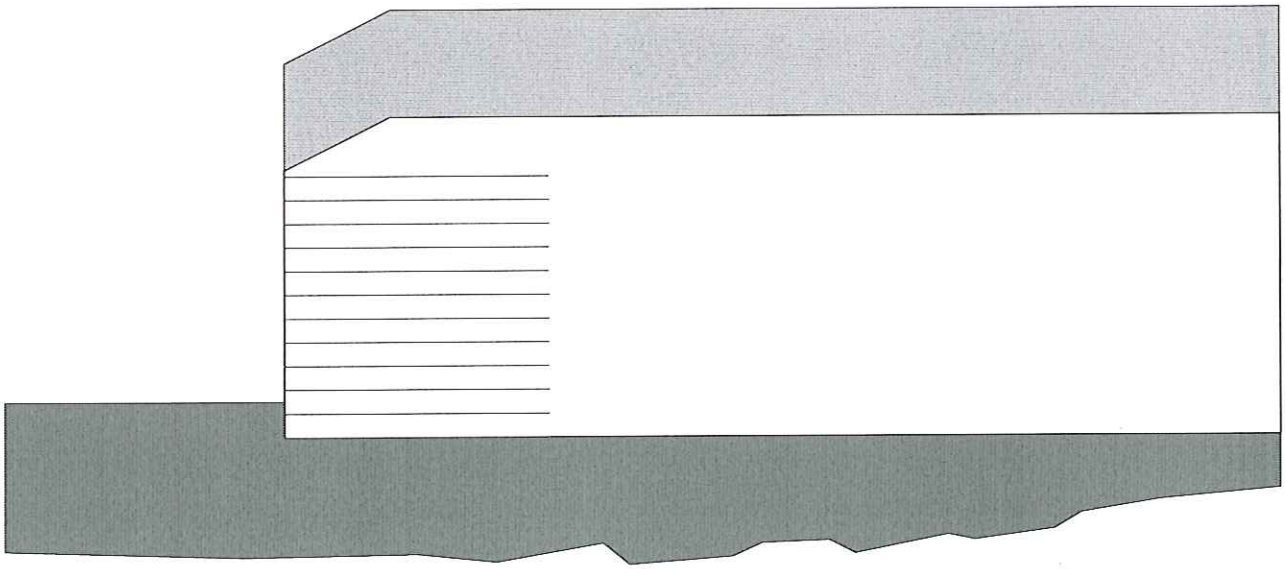
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	22.50	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 19.50 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	4.5	[ft]	Broken back equivalent angle, I = 5.71° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35		
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00		
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75		
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50		
Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35
Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:		$\gamma_{p\text{-}EH}$	1.50	
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):		$(\gamma_{p\text{-}EH})_{EQ}$	1.50	
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):		$\gamma_{p\text{-}EQ}$	1.00	
Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00
Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
	ϕ_b	0.65		0.65

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ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 0.65, Meyerhof stress = 2358 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.033, Eccentricity, e/L = 0.1121, CDR-overturning = 3.79

METAL STRIP #	Elevation [ft]	Length [ft]	Type #	CONNECTION CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	22.50	1	N/A	6.07	6.75	6.748	2.887	2.610	0.1121	---
2	2.00	22.50	1	N/A	3.18	3.53	3.530	1.330	2.731	0.0967	---
3	4.00	22.50	1	N/A	3.31	3.68	3.675	1.346	2.871	0.0818	---
4	6.00	22.50	1	N/A	3.40	3.78	3.782	1.401	3.033	0.0675	---
5	8.00	22.50	1	N/A	3.57	3.97	3.965	1.435	3.203	0.0536	---
6	10.00	22.50	1	N/A	3.76	4.18	4.179	1.430	3.381	0.0401	---
7	12.00	22.50	1	N/A	3.95	4.39	4.393	1.376	3.578	0.0267	---
8	14.00	22.50	1	N/A	4.19	4.66	4.659	1.329	3.795	0.0131	---
9	16.00	22.50	1	N/A	4.53	5.03	5.030	1.326	4.032	-0.0011	---
10	18.00	22.50	1	N/A	5.01	5.57	5.568	1.302	4.282	-0.0173	---
11	20.00	22.50	1	N/A	5.63	6.26	6.260	1.227	4.526	-0.0378	---
12	22.00	22.50	1	N/A	8.42	9.35	9.353	1.403	4.691	-0.0705	---

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1-27-09

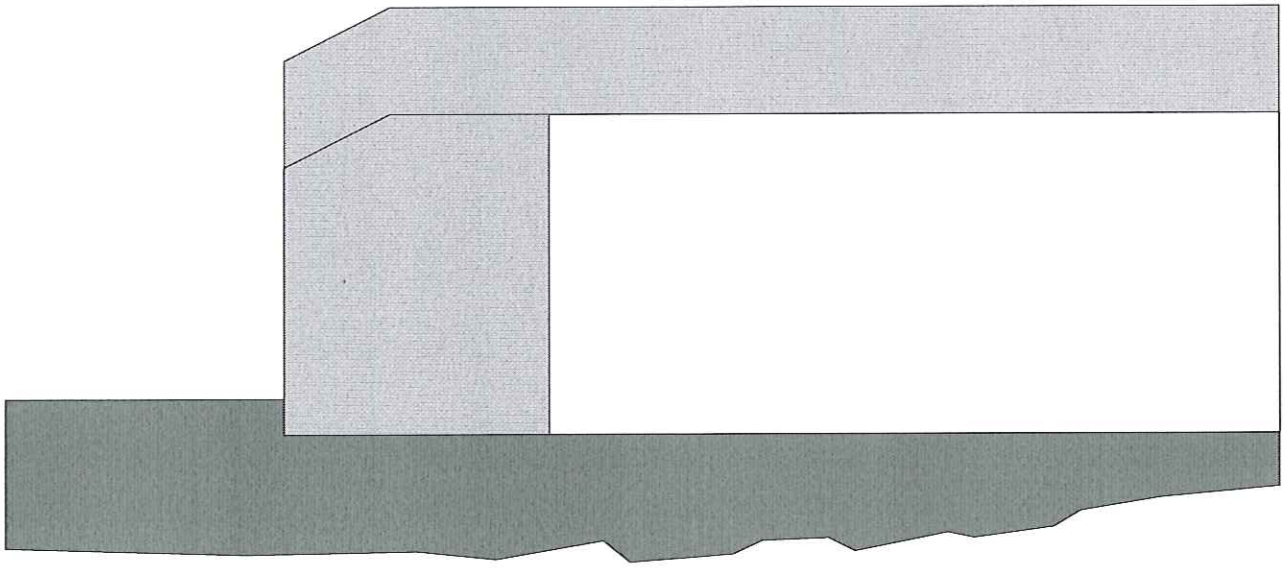
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	~~1522~~	N/A	[lb/ft ²]
Meyerhof stress, σ_V	2357.8	N/A	[lb/ft ²]
Eccentricity, e	1.43	N/A	[ft]
Eccentricity, e/L	0.063	N/A	
CDR calculated	~~0.65~~	N/A	
Base length	22.50	N/A	[ft]

q_{ult} for 2 layer system = 2395 psf (Pg 45)

CDR for 2 layer system = $\frac{2395}{2358} = 1.02$

∴ OK



SCALE:

0 2 4 6 8 10[ft]

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DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.033

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	22.50	2.610	N/A	1	---
2	2.00	22.50	2.731	N/A	1	---
3	4.00	22.50	2.871	N/A	1	---
4	6.00	22.50	3.033	N/A	1	---
5	8.00	22.50	3.203	N/A	1	---
6	10.00	22.50	3.381	N/A	1	---
7	12.00	22.50	3.578	N/A	1	---
8	14.00	22.50	3.795	N/A	1	---
9	16.00	22.50	4.032	N/A	1	---
10	18.00	22.50	4.282	N/A	1	---
11	20.00	22.50	4.526	N/A	1	---
12	22.00	22.50	4.691	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1121; Overturning: CDR-static = 3.79

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	22.50	0.1121	N/A	1	---
2	2.00	22.50	0.0967	N/A	1	---
3	4.00	22.50	0.0818	N/A	1	---
4	6.00	22.50	0.0675	N/A	1	---
5	8.00	22.50	0.0536	N/A	1	---
6	10.00	22.50	0.0401	N/A	1	---
7	12.00	22.50	0.0267	N/A	1	---
8	14.00	22.50	0.0131	N/A	1	---
9	16.00	22.50	-0.0011	N/A	1	---
10	18.00	22.50	-0.0173	N/A	1	---
11	20.00	22.50	-0.0378	N/A	1	---
12	22.00	22.50	-0.0705	N/A	1	---

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Subject I-95/SR1 Interchange — Page 1 of 69
Retng Walls 6&16 Global Stability — Cm. No. 103-059-270
Prepared By SAB Date 9/30/08 Checked By JJ Date 1-27-09
REV 12/8/08

Global Stability Analysis: Performed using Slope/W.

→ Check global stability of: 1) RW 6 only 2) RW 6 & 16 as a system
→ Morgenstern-Price method used for analysis.

→ STA 1117+50 (Ramp C) chosen for global stability analysis. - This station is where the walls are proposed to be a 2 tiered wall system with the greatest heights.
- See attached cross-section, p. 2 (Ramp C Baseline) & p. 2a (Ramp A Baseline)

Soils: (See attached fence diagram, p. 3)

Soil	γ_T (pcf)	ϕ' (deg)	c' (psf)	Su (psf)	EL (ft.)
Water	62.4				62
Reinforced Soil (CLSM)	145	0	10,000	—	
Retained Soil (CLSM)	145	0	10,000	—	
Select Fill (DelDOT B)	125	34	0	— (1)	
Stratum IIa (upper)	130	(see p. 4)	0	1,350	62.5-53
Stratum IIa (lower)	130		0	2,500	53-15
Stratum IIb	130	34	—	—	15-9
Common Borrow (DelDOT F)	130	28	-	-	

1) From Unconsolidated Undrained Triaxial Test, Boring IRW-97 U-1 (see test results, p. 7 & 7a)

→ Check UNDRAINED & DRAINED cases. FS required for walls ≥ 1.538

→ Check with & without LL between walls. (Use LL above RW 6 in all cases; neglect LL below RW 16 in all cases.)

All FS > 1.538 OK

Summary:

Wall	Case	LL b/t Walls?	Global FS	Pages
RW 6	Undrained	No	2.02	8
RW 6	Drained	No	2.02	9-30
RW 6 & 16	Undrained	Yes	1.82	31
RW 6 & 16	Undrained	No	1.83	32-51
RW 6 & 16	Drained	Yes	1.66	52 ← Critical
RW 6 & 16	Drained	No	1.66	53-69 ← Cooks

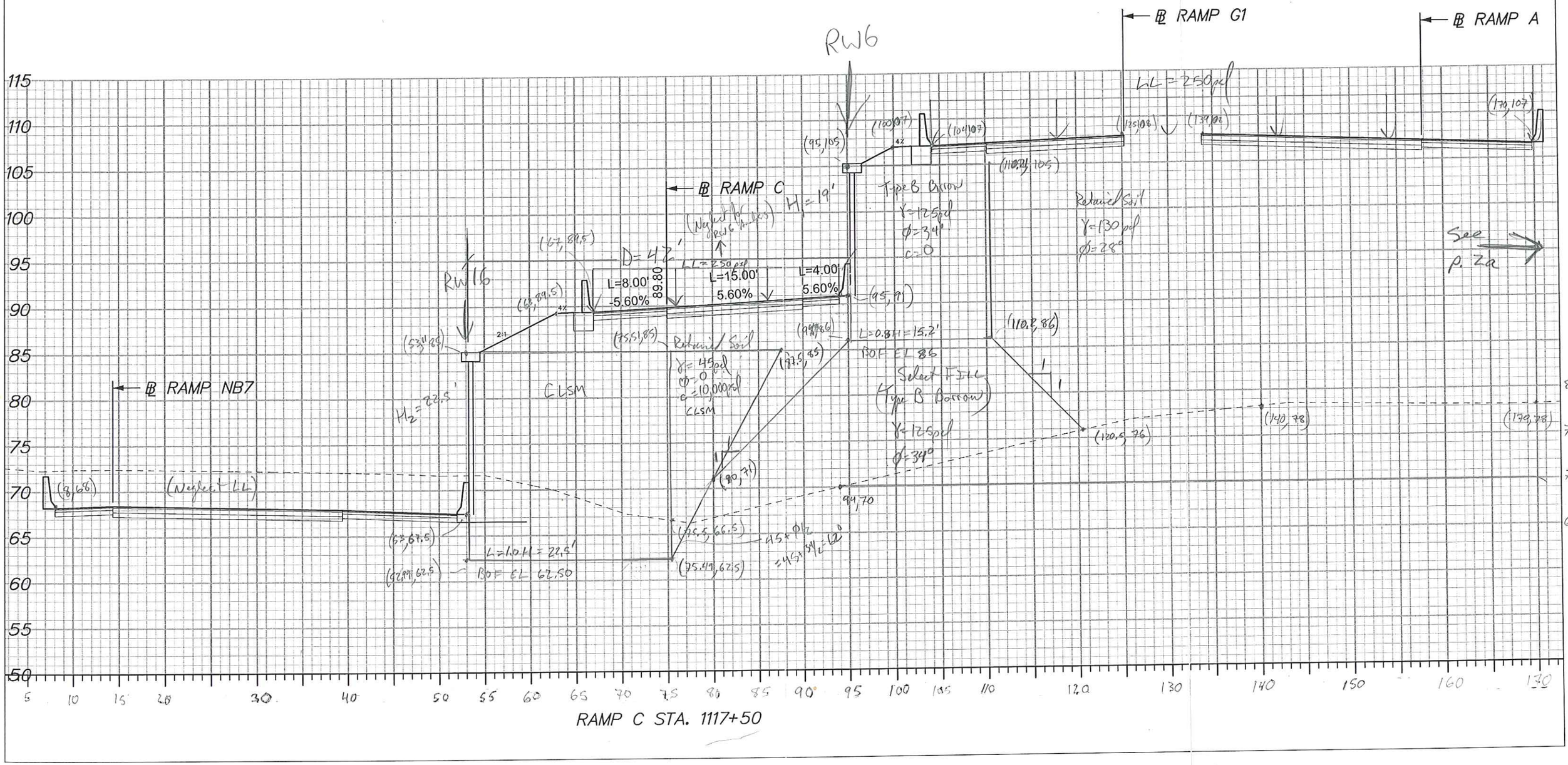
I-95/SR1 ~~Interchange~~ 103-059-270 9/29/08
REV: 12/16/09

RW 6 & 16

SST 1-27-09

2

RKK RW6 & 16-59



RAMP C STA. 1117+50

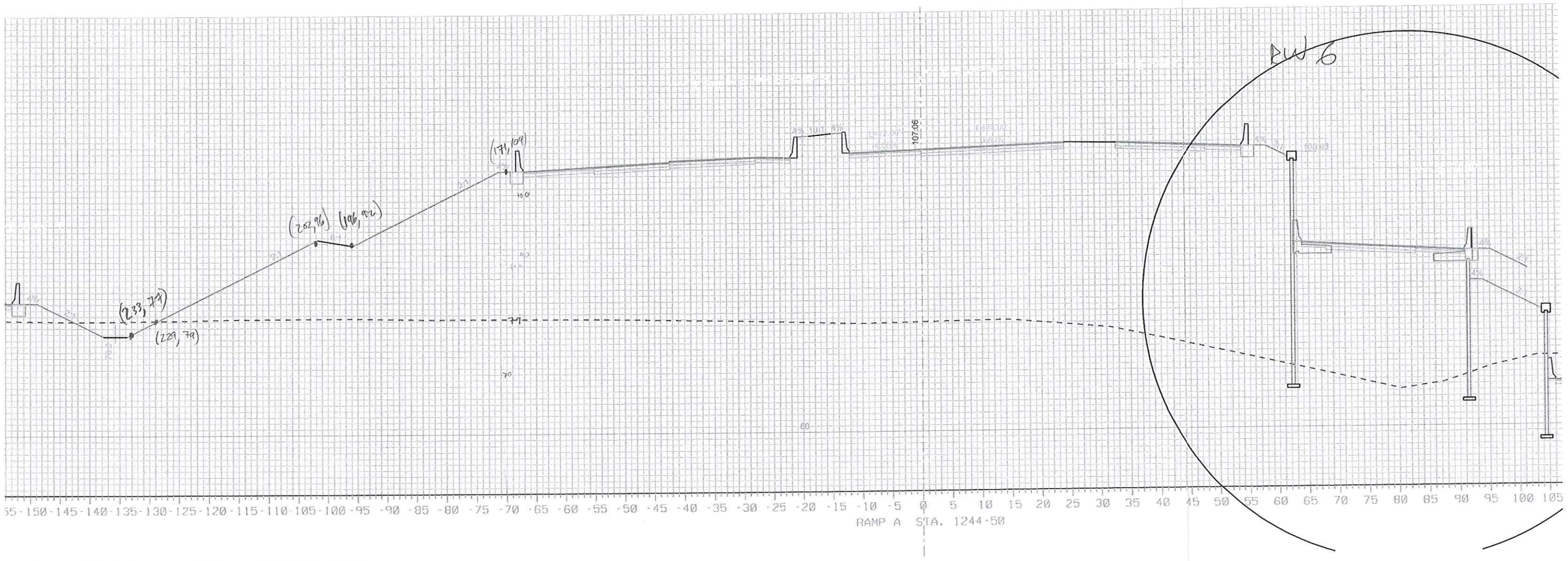
SR1 /I-95 Interchange
RW 6 & 16 Global Stability

103-059-270
12/9/08

JJT 1-27-09

Za

RKK RW6 & 16-60



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SR1 / I-95 Interchange 103-059-27U

11/25/08 RW6 & 16 Analysis

JST 1-27-09

RKK-RW6 & 16-61

STA 1117+50

RW 6 BOF EL 86

RW 16 BOF EL 66.50

Ramp C ~STA 1117+10

IBR-31
N612621, E432392.5
EL 68.0

SPT N or REC, RQD

	NMC	AASHTO
	16.2%	(A-6) LL=33 PI=14
	21.9%	(A-6) LL=29
	18.6%	(A-4)
50/5"		
50/5"		

100.5'

Ramp C STA 1117+60

IRW-43
N612649.3, E432456.1
EL 78.0

	NMC	AASHTO
	9.7%	(A-2-4) NP
	23.5%	(A-7-5) LL=48 PI=26
	22.0%	(A-2-4) NP
	26.2%	(A-7-5) LL=62 PI=33

46.5'

IRW-97
N612677.17, E432386.32
EL 71.0

	NMC	AASHTO
	13.5%	(A-2-4)
	8.5%	(A-1-b)
	21.3%	(A-6(14))
	19.9%	(A-6(11))
	23.8%	(A-7-6(18))
	28.4%	(A-7-5(32))
	25.8%	(A-7-6(24))
	24.0%	(A-7-6(24))
	21.6%	(A-7-6(21))
	19.8%	(A-6(12))
	19.8%	(A-4(7))
	35.4%	(A-4(4))
	16.1%	(A-4(0))
	16.7%	(A-6(11))
	25.2%	(A-7-6(34))
	23.3%	(A-6(15))
	30.5%	(A-7-5(17)) LL=46 PI=15
	22.5%	(A-4(0)) NP LL=21
50/6"	23.0%	(A-2-4) NP LL=14

60.0'

Ramp C ~STA 1118+35

IBR-18C
N612737.5, E432441.6
EL 71.0

	NMC	AASHTO
	31.9%	(A-7-5) LL=42 PI=17
	13.8%	(A-6) LL=32 PI=12
	25.0%	(A-7-6) LL=62 PI=30
	20.0%	(A-2-4) NP
	14.1%	(A-4) LL=23 PI=8
50/4"	13.2%	(A-2-4) NP
50/5"		
50/5"		
50/5"		

100.5'

Ramp C ~STA 1118+50

IDMT-20
N612744, E432489
EL 79.0

S_u/Phi Ko/OCR

46.6'

IBR-18A
N612787, E432515.4
EL 80.0

	NMC	AASHTO
	20.7%	(A-6)
	20.1%	(A-7-5)
	18.2%	(A-4)
50/5"		
50/3"		
50/5"	13.6%	(A-2-4)

79.9'

~STA 1119+35

IBR-18B
N612836.2, E432480.3
EL 78.0

	NMC	AASHTO
	17.8%	(A-6) LL=35 PI=15
	16.9%	(A-2-4) NP
	20.4%	(A-6) LL=37 PI=16
	25.2%	(A-7-5) LL=67 PI=37
	19.6%	(A-4)
	15.8%	(A-2-4)
	15.5%	(A-2-4)
50/5"		
50/5"		
50/5"		

100.5'

U=1355psf
γ_d = 103.3pcf
NMC = 23.7%
γ_T = 127.7pcf
LL=54
PI=30

D.S.: φ'=17°
c'=338psf
γ_d=103.8pcf
NMC=22.2%
γ_T=126.8pcf
ε=1537

EL 67 EL 53 EL 15 EL 9 EL 63

(Wet Sample)

Zone labels: I, IIa, IIb, IIb, IIa, IIb, IIa, IIb

AASHTO SOIL KEY

A	A-1-a	5	A-2-5	A-5	A-8
B	A-1-b		A-2-6	A-6	Asphalt
	A-3	7	A-2-7	A-7-5	FILL
	A-2-4	+ + + + + +	A-4	A-7-6	Decomposed Rock

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Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
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Title: Summary of Boring Data
Retaining Wall 6 & 16

Figure No.

Drawn: SAB | Approved: | Date: 11/25/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 11/25/08

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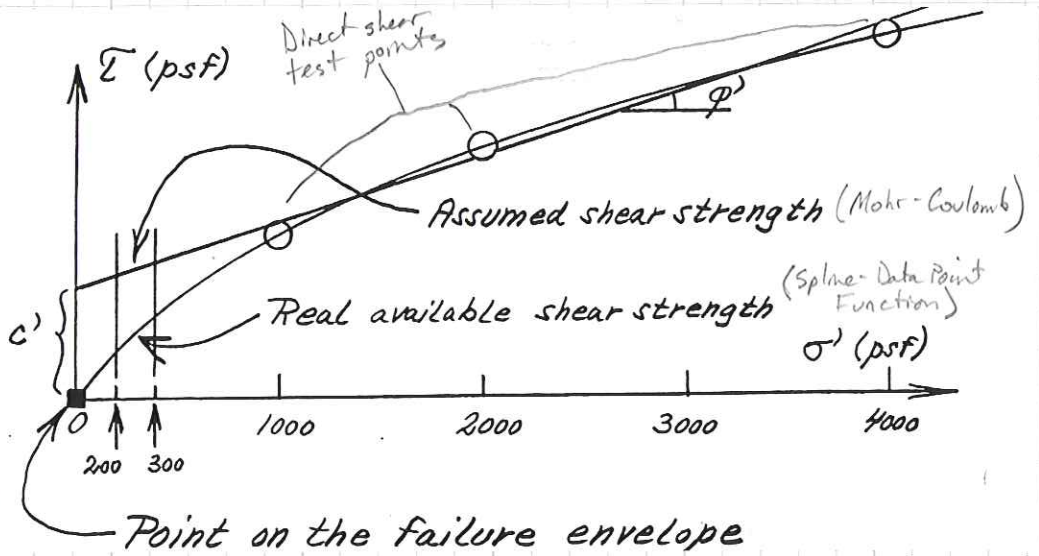
Subject SR1/I-95 Interchange
RW 6 & 16 Global Stability
Page ____ of ____
Cm. No. 103-059-270
Prepared By SAB Date 12/10/08 Checked By SPT Date 1-27-09

Drained soil parameters are defined using a spline-data point function.
(Reference: Dr. Paul Ladde's Class Notes)

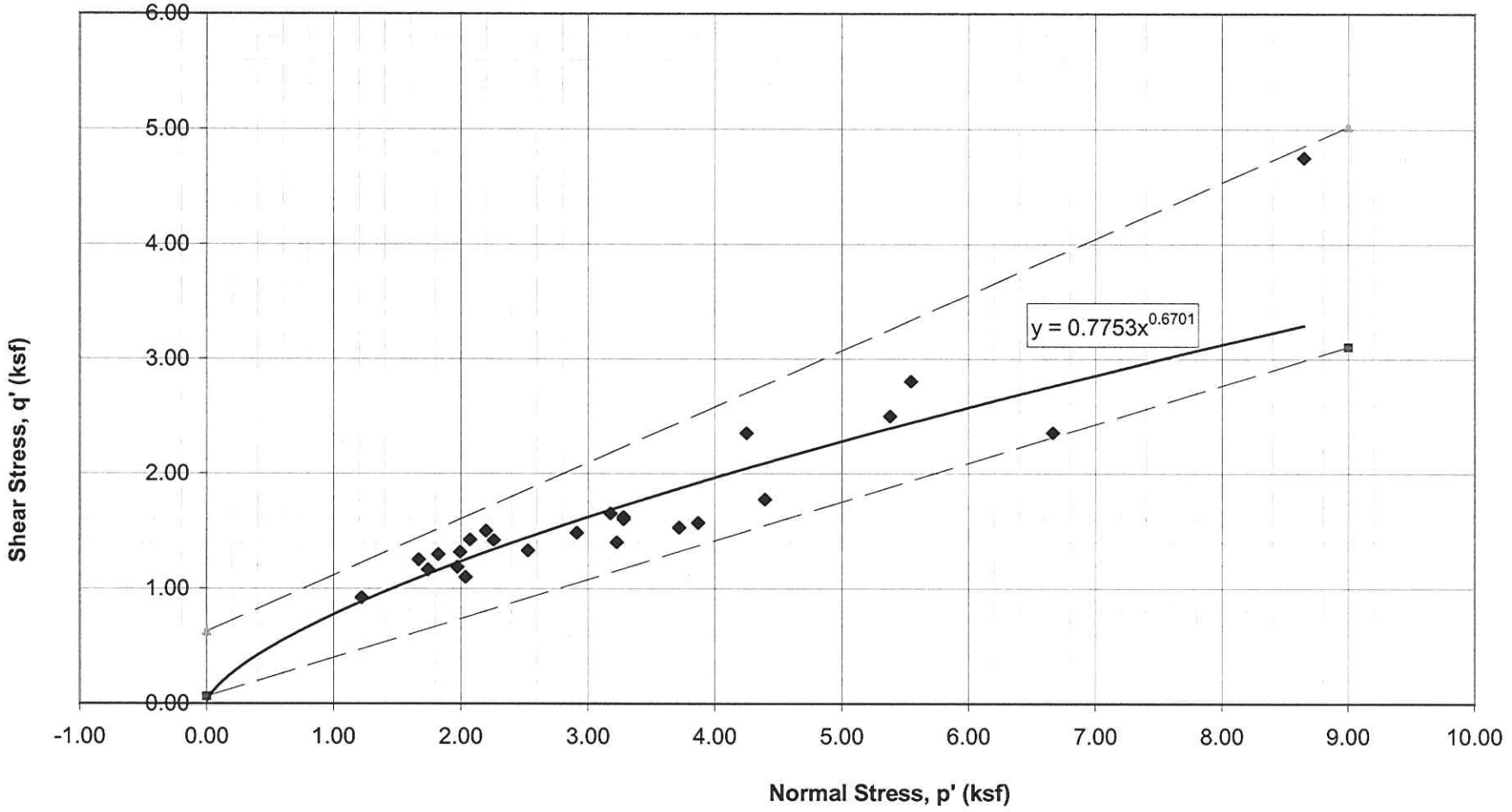
This method develops a realistic shear strength envelope based on direct shear test results. At relatively shallow depths, the Mohr-Coulomb failure criterion overestimates the shear strength of a soil, as direct shear test are generally not performed for low effective normal stresses. This method uses an exponential function that passes through the origin to estimate the real available shear strength. See graph below.



→ Spline-Data Function for Stratum IIa (above EL 53) was defined using the equation developed from Figure C-2a (see p. 5), which summarizes the CU tests for the site above EL 40.

→ Spline-Data Function for Stratum IIa (EL 15-53) was defined using the direct shear test from this stratum (Boring RW-97, U-2). See p. 6.

Figure C-2a
Summary of CU with Pore Pressure
Effective Stress - Strata IIa
EL 40 & Above



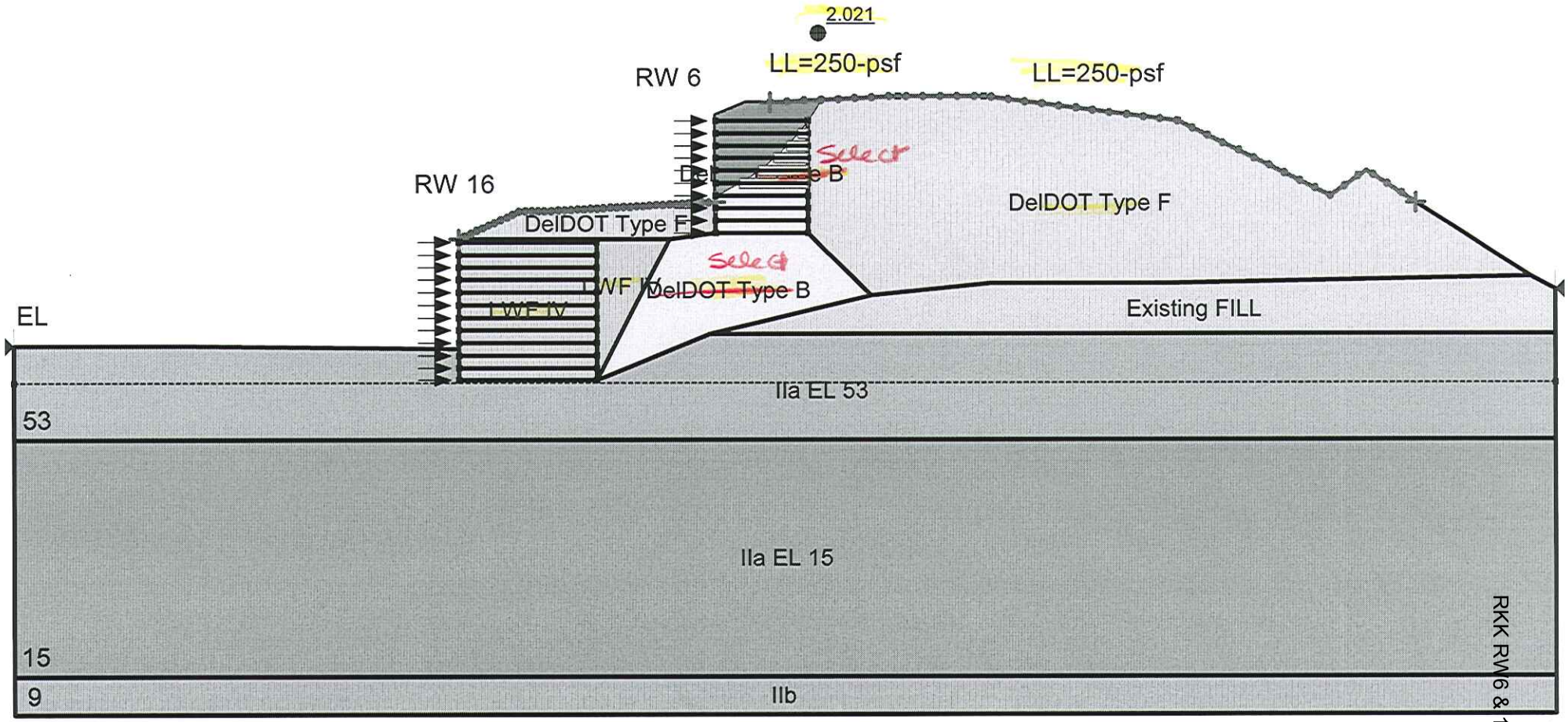
— — — = 95% confidence interval

RKK RW6 & 16-63

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\CICU Plots(Revised).xls\CU Effect Plot EL 40&Above (SP)

12/9/2008

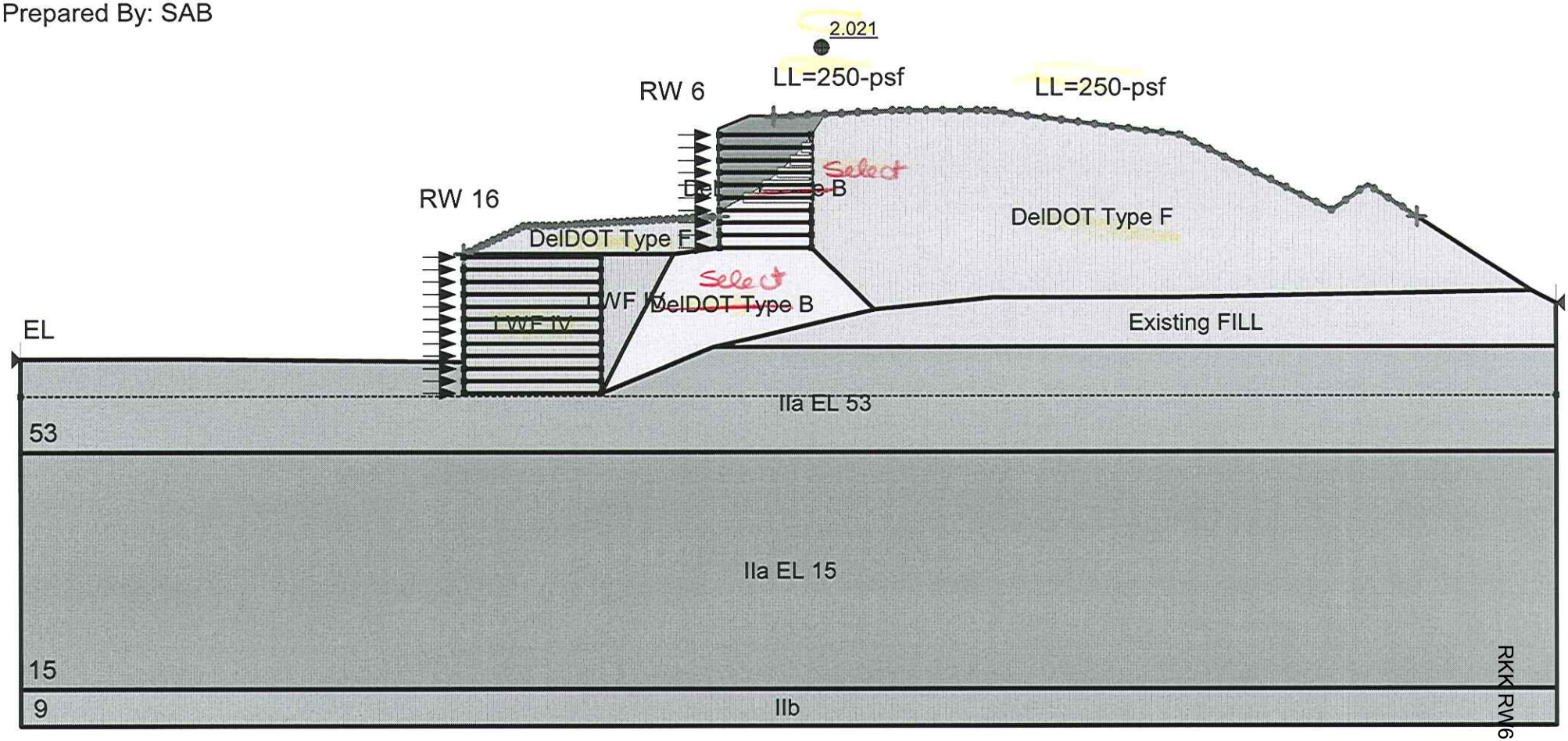
SR 1/I-95 Interchange 103-059-27U 12/10/08
RW 6 Global Stability Analysis - Undrained
Prepared By: SAB



* Printed only this page (no report) to show that critical failure surface does not extend to foundation soil, and therefore is not affected by undrained/drained conditions. (See p. 9)

SBT 1-27-09

SR 1/I-95 Interchange 103-059-27U 12/9/08
RW 6 Global Stability Analysis - Drained
Prepared By: SAB



RKK RW6 & 16-65

DOT 1-27-09

JPT 1-27-09

RKK RW6 & 16-66

SR1/I-95 Interchange 103-059-27U Retaining Wall 6 Global Stability

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File Information

Revision Number: 50
Date: 12/9/2008
Time: 4:06:23 PM
File Name: RW 6 Drained.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 6 and 16\Final Design\
Last Solved Date: 12/9/2008
Last Solved Time: 4:07:17 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SR1/I-95 Interchange 103-059-27U Retaining Wall 6 Global Stability

Description: Ramp C STA 117+50
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- **Apply Phreatic Correction:** Yes
- **Side Function**
  - **Interslice force function option:** Half-Sine
- **PWP Conditions Source:** Piezometric Line
- **Use Staged Rapid Drawdown:** No

SlipSurface
- **Direction of movement:** Right to Left
- **Allow Passive Mode:** No
- **Slip Surface Option:** Entry and Exit
- **Critical slip surfaces saved:** 1

Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 40
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 32
Ending Optimization Points: 64
Complete Passes per Insertion: 1

Materials

DelDOT Type B Select Fill

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

DelDOT Type F Borrow

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

LWF IV

Model: Mohr-Coulomb
Unit Weight: 42 pcf
Cohesion: 17280 psf = 120 psi
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Existing FILL

Model: Mohr-Coulomb

Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa EL 53

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: CU Tests
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa EL 15

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: IRW-97 U-2
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIb

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (53, 85) ft
Left-Zone Right Coordinate: (95, 91) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (104, 107) ft
Right-Zone Right Coordinate: (210.08094, 90.912001) ft
Right-Zone Increment: 40
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (-20, 68) ft

Right Coordinate: (233, 77) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-20	62
	233	62

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	104	107
	125	108

1' : 1.05

Surcharge Load 2

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	139	108
	171	104

Reinforcements → 1-10 = RW6, 11-22 = RW16 > Fabric used to model steel straps (not an option in Slope/w)

Reinforcement 1

Type: Fabric
Outside Point: (95, 86) ft
Inside Point: (110.2, 86) ft
Slip Surface Intersection: (0, 0) ft

Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 17 ° → From AASHTO LRFD Table 3.11.5.3-1 for steel on SAND
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (95, 88) ft
Inside Point: (110.2, 88) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 17 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (95, 90) ft

Inside Point: (110.2, 90) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (95, 92) ft
Inside Point: (110.2, 92) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (95, 94) ft
Inside Point: (110.2, 94) ft
Slip Surface Intersection: (98.989, 94) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 2195.1 lbs
Resisting Force Used: 195.8 lbs/ft
Available Bond Length: 11.211 ft
Required Bond Length: 11.211 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (95, 96) ft
Inside Point: (110.2, 96) ft
Slip Surface Intersection: (102.08, 96) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 1397.9 lbs
Resisting Force Used: 172.22 lbs/ft
Available Bond Length: 8.1169 ft

Required Bond Length: 8.1169 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (95, 98) ft
Inside Point: (110.2, 98) ft
Slip Surface Intersection: (104.61, 98) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 600.76 lbs
Resisting Force Used: 107.56 lbs/ft
Available Bond Length: 5.5855 ft
Required Bond Length: 5.5855 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (95, 100) ft
Inside Point: (110.2, 100) ft
Slip Surface Intersection: (106.75, 100) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 259.68 lbs

Resisting Force Used: 75.245 lbs/ft
Available Bond Length: 3.4512 ft
Required Bond Length: 3.4512 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (95, 102) ft
Inside Point: (110.2, 102) ft
Slip Surface Intersection: (108.58, 102) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 73.117 lbs
Resisting Force Used: 45.027 lbs/ft
Available Bond Length: 1.6239 ft
Required Bond Length: 1.6239 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (95, 104) ft
Inside Point: (110.2, 104) ft
Slip Surface Intersection: (110.16, 104) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0

Applied Load: 5000 lbs
Fabric Load Used: 0.83564 lbs
Resisting Force Used: 19.14 lbs/ft
Available Bond Length: 0.043659 ft
Required Bond Length: 0.043659 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (53, 62.5) ft
Inside Point: (75.5, 62.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 ° → AASHTO Table 3.11.5.3-1 for steel on silty SAND (more conservative)
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 12

Type: Fabric
Outside Point: (53, 64.5) ft
Inside Point: (75.5, 64.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs

Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 13

Type: Fabric
Outside Point: (53, 66.5) ft
Inside Point: (75.5, 66.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 14

Type: Fabric
Outside Point: (53, 68.5) ft
Inside Point: (75.5, 68.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs

Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 15

Type: Fabric
Outside Point: (53, 70.5) ft
Inside Point: (75.5, 70.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 16

Type: Fabric
Outside Point: (53, 72.5) ft
Inside Point: (75.5, 72.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1

Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 17

Type: Fabric
Outside Point: (53, 74.5) ft
Inside Point: (75.5, 74.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 18

Type: Fabric
Outside Point: (53, 76.5) ft
Inside Point: (75.5, 76.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf

Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 19

Type: Fabric
Outside Point: (53, 78.5) ft
Inside Point: (75.5, 78.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 20

Type: Fabric
Outside Point: (53, 80.5) ft
Inside Point: (75.5, 80.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable

F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 21

Type: Fabric
Outside Point: (53, 82.5) ft
Inside Point: (75.5, 82.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 22

Type: Fabric
Outside Point: (53, 84.5) ft
Inside Point: (75.5, 84.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 22.5 ft

Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Shear/Normal Strength Functions

IRW-97 U-2

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
- Curve Fit to Data: 100 %
- Segment Curvature: 100 %

Y-Intercept: 1139.0648
Data Points: Normal Stress (psf), Shear Stress (psf)
- Data Point: (2250, 1252)
- Data Point: (4500, 1460)
- Data Point: (9000, 2972)
- Data Point: (12000, 4134)

Estimation Properties
- Intact Rock Param.: 10
- Geological Strength: 100
- Disturbance Factor: 0
- SigmaC: 600000 psf
- Sigma3: 300000 psf
- Num. Points: 20

CU Tests

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
- Curve Fit to Data: 100 %
- Segment Curvature: 100 %

Y-Intercept: 188.17854

Data Points: Normal Stress (psf), Shear Stress (psf)
- Data Point: (500, 487)
- Data Point: (1000, 775)
- Data Point: (1500, 1017)
- Data Point: (2000, 1234)
- Data Point: (2500, 1433)
- Data Point: (3000, 1619)
- Data Point: (3500, 1795)
- Data Point: (4000, 1963)
- Data Point: (4500, 2124)
- Data Point: (5000, 2280)
- Data Point: (5500, 2430)
- Data Point: (6000, 2576)
- Data Point: (6500, 2718)
- Data Point: (7000, 2856)
- Data Point: (7500, 2991)
- Data Point: (8000, 3123)
- Data Point: (8500, 3253)
- Data Point: (9000, 3380)
- Data Point: (9500, 3505)
- Data Point: (10000, 3627)

Estimation Properties
- Intact Rock Param.: 10
- Geological Strength: 100
- Disturbance Factor: 0
- SigmaC: 600000 psf
- Sigma3: 300000 psf
- Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	IIb	34,36,35,33	1518
Region 2	IIa EL 15	33,32,31,35	9614
Region 3	IIa EL 53	30,29,28,4,3,2,1,32,31	3905.625
Region 4	LWF IV	3,5,27,28,4	506.25
Region 5	LWF IV	28,25,26,27	134.625
Region 6	DelDOT Type B	9,26,25,28,29,21,19	508
Region 7	DelDOT Type F	5,6,7,8,9,26,27	183.75
Region 8	Existing FILL	29,21,22,23,24,18,30	989.5
Region 9	DelDOT Type B	19,9,8,10,20	288.8
Region 10	DelDOT Type F	10,11,12,13,14,15,17,16,24,23,22,21,19,20	2592.7

Points

	X (ft)	Y (ft)
Point 1	-20	68
Point 2	8	68
Point 3	53	67.5
Point 4	53	62.5
Point 5	53	85
Point 6	63	89.5
Point 7	67	89.5
Point 8	95	91
Point 9	95	86
Point 10	95	105
Point 11	100	107
Point 12	104	107
Point 13	125	108
Point 14	139	108
Point 15	171	104
Point 16	202	96
Point 17	196	92
Point 18	233	77
Point 19	110.2	86
Point 20	110.2	105
Point 21	120.5	76
Point 22	140	78
Point 23	170	78
Point 24	229	79
Point 25	80	71
Point 26	87.5	85
Point 27	75.5	85
Point 28	75.5	62.5
Point 29	94	70
Point 30	233	70
Point 31	233	53
Point 32	-20	53
Point 33	-20	15

← Toe of Wall 16 ⇒ Wall Height = Point 5 - Point 4

← Top of Wall 16 = EL 89.5 - EL 62.5

H = 22.5'

← Toe of Wall 6

← Top of Wall 6 ⇒ Wall Height = Point 10 - Point 9

= EL 105 - EL 86

H = 19'

Point 34	-20	9
Point 35	233	15
Point 36	233	9

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	4118	2.021	(80.774, 125.577)	36.454	(112.373, 107.399)	(95, 105)

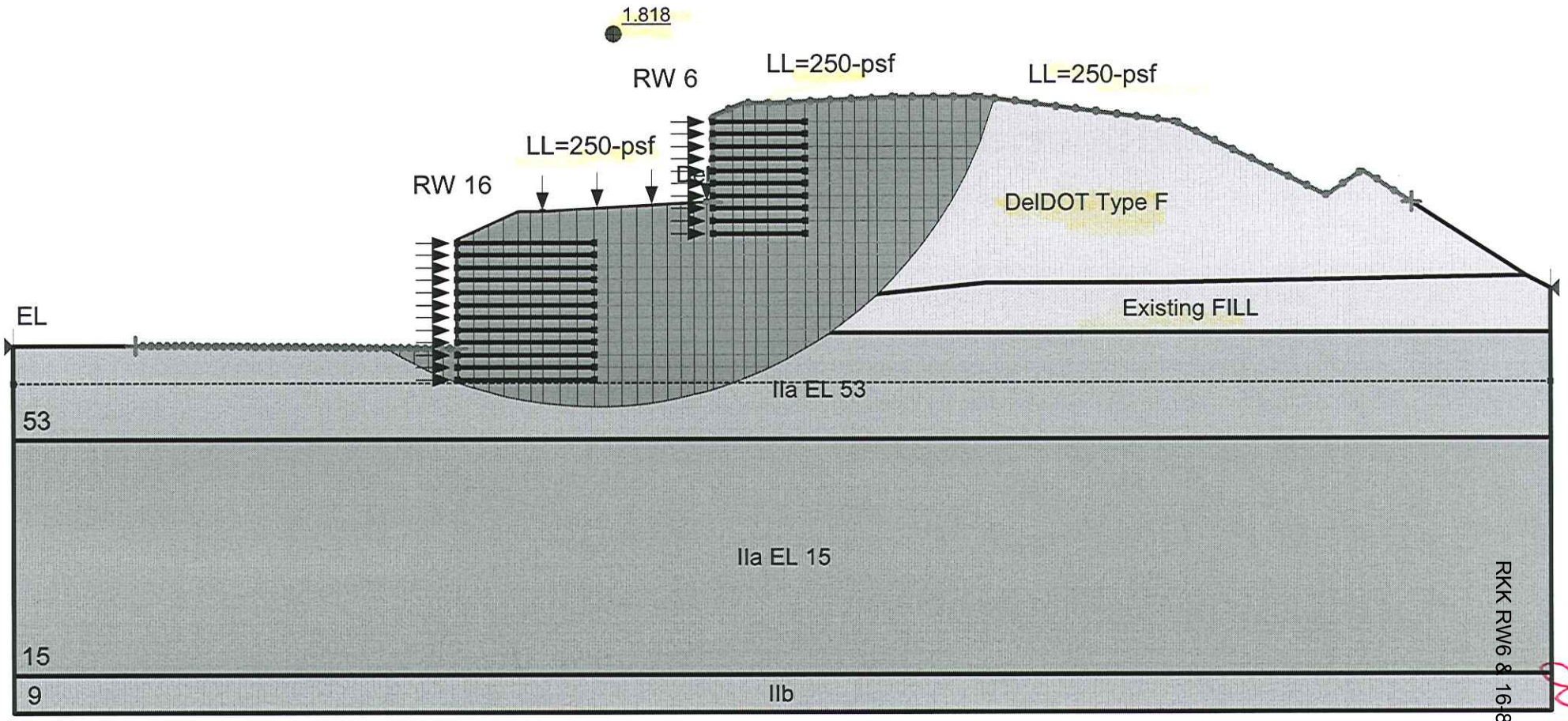
Slices of Slip Surface: 4118

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohe Stren (ps
1	4118	95.208335	92.102485	-1878.3979	1413.3879	953.34219	(
2	4118	95.625	92.285255	-1889.7973	1393.9011	940.19818	(
3	4118	96.041665	92.47428	-1901.6022	1371.8212	925.30505	(
4	4118	96.458335	92.66967	-1913.7768	1347.4757	908.88381	(
5	4118	96.875	92.87153	-1926.3904	1321.2093	891.16694	(
6	4118	97.291665	93.079985	-1939.4012	1293.4048	872.41257	(
7	4118	97.708335	93.29517	-1952.8285	1264.4588	852.88824	(
8	4118	98.125	93.51721	-1966.6674	1234.7605	832.85645	(
9	4118	98.541665	93.74625	-1980.9713	1204.6688	812.55936	(
10	4118	98.958335	93.98245	-1995.7051	2879.4448	1942.21	(
11	4118	99.375	94.22597	-2010.8924	1264.6382	853.00922	(
12	4118	99.791665	94.476975	-2026.5706	1223.5346	825.28449	(

13	4118	100.2222	94.744545	-2043.2926	1173.3946	791.46466	(
14	4118	100.66665	95.02943	-2060.9915	1115.2281	752.23086	(
15	4118	101.1111	95.323525	-2079.4299	1059.3403	714.53406	(
16	4118	101.55555	95.627105	-2098.3087	1005.9718	678.53654	(
17	4118	102	95.94046	-2117.8794	2227.9989	1502.8042	(
18	4118	102.44445	96.263905	-2138.0082	927.35675	625.51003	(
19	4118	102.8889	96.59778	-2158.9109	874.9581	590.16669	(
20	4118	103.33335	96.942445	-2180.4243	825.58143	556.86171	(
21	4118	103.7778	97.29829	-2202.5501	779.19204	525.57166	(
22	4118	104.22145	97.665075	-2225.518	572.37239	386.07005	(
23	4118	104.6643	98.04322	-2249.0935	1042.9197	703.45822	(
24	4118	105.10715	98.433855	-2273.511	488.17773	329.28003	(
25	4118	105.55	98.83753	-2298.6667	450.75598	304.03875	(
26	4118	105.99285	99.25485	-2324.7521	415.02483	279.93778	(
27	4118	106.4357	99.686475	-2351.5861	380.69938	256.78498	(
28	4118	106.87855	100.13313	-2379.5797	522.89916	352.69994	(
29	4118	107.32145	100.5956	-2408.4398	306.22343	206.55031	(
30	4118	107.7643	101.07485	-2438.2807	273.12083	184.22232	(
31	4118	108.20715	101.57185	-2469.275	239.90896	161.82064	(
32	4118	108.65	102.08765	-2501.4827	241.4181	162.83857	(
33	4118	109.09285	102.6236	-	167.84693	113.21418	(

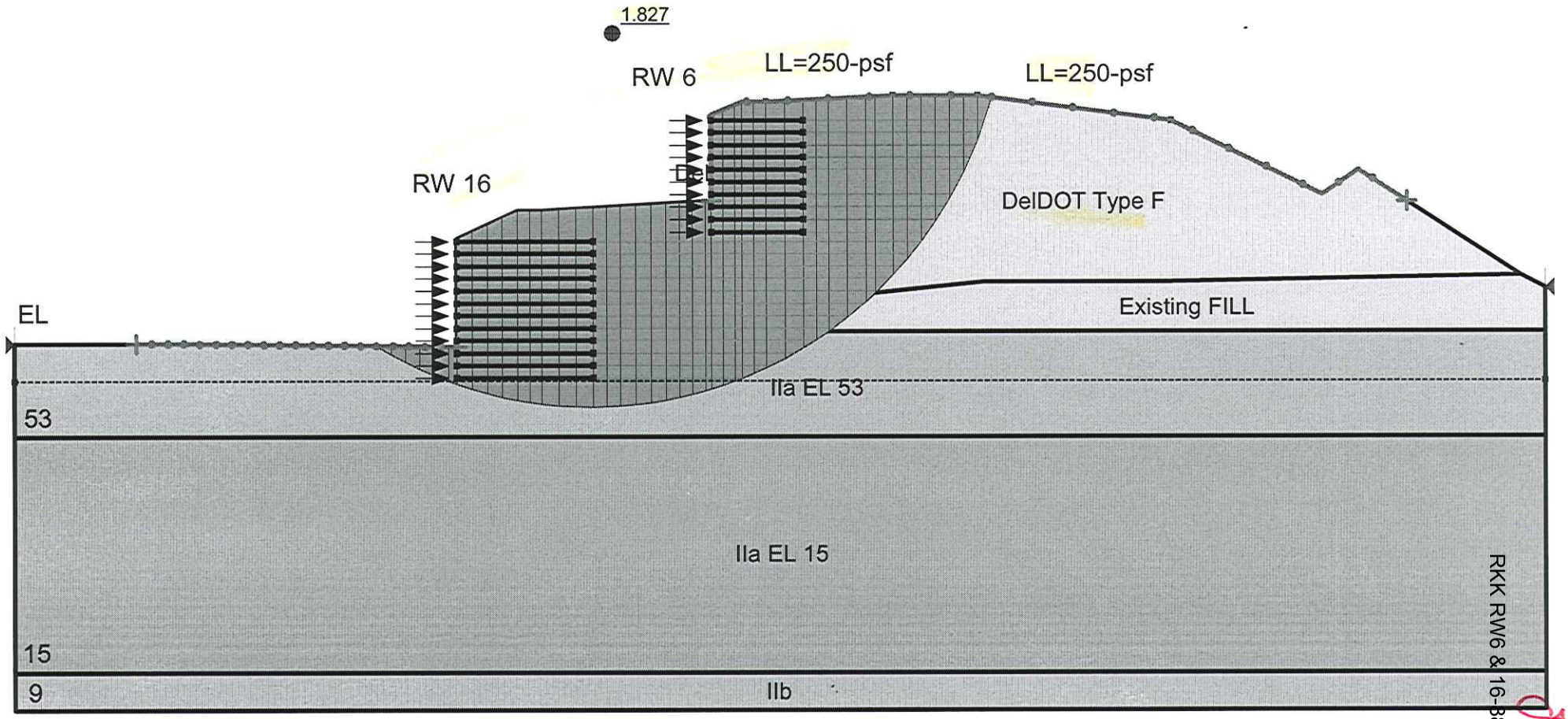
				2534.9791			
34	4118	109.5357	103.1812	-2569.6848	130.99941	88.360215	(
35	4118	109.97855	103.762	-2605.8843	92.068093	62.100713	(
36	4118	110.4173	104.36205	-2643.3726	3.7245332	1.9803694	(
37	4118	110.85185	104.98305	-2682.1021	3.1889857	1.6956138	(
38	4118	111.2864	105.6328	-2722.6333	2.6235484	1.3949654	(
39	4118	111.721	106.3143	-2765.1942	2.0641676	1.0975374	(
40	4118	112.15555	107.03105	-2809.9487	1.5527832	0.82562948	(

SR 1/I-95 Interchange 103-059-27U 12/10/08
RW 6 and 16 Global Stability Analysis - Undrained – Liveload b/t Walls
Prepared By: SAB



1-27-09

SR 1/I-95 Interchange 103-059-27U 12/10/08
RW 6 and 16 Global Stability Analysis - Undrained
Prepared By: SAB



1-27-09

SJT 1-27-09

RKK RW6 & 16-89

SR1/I-95 Interchange 103-059-27U Retaining Wall 6 & 16 Global Stability

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File Information

Revision Number: 46
Last Edited By: sberkheimer
Date: 12/10/2008
Time: 7:10:33 AM
File Name: RW 6 and 16 Undrained.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 6 and 16\Final Design\
Last Solved Date: 12/10/2008
Last Solved Time: 7:10:45 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SR1/I-95 Interchange 103-059-27U Retaining Wall 6 & 16 Global Stability

Description: Ramp C STA 117+50 Undrained
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- **Apply Phreatic Correction:** Yes
- **Side Function**
  - **Interslice force function option:** Half-Sine
- **PWP Conditions Source:** Piezometric Line
- **Use Staged Rapid Drawdown:** No

SlipSurface
- **Direction of movement:** Right to Left

Allow Passive Mode: No
Slip Surface Option: Entry and Exit
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 40
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 16
Ending Optimization Points: 32
Complete Passes per Insertion: 1

Materials

~~DelDOT Type B~~ Select Fill

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

DelDOT Type F Borrow

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

LWF IV

Model: Mohr-Coulomb
Unit Weight: 42 pcf
Cohesion: 17280 psf
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Existing FILL

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa EL 53

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 1350 psf
Pore Water Pressure
Piezometric Line: 1

IIa EL 15

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 2500 psf
Pore Water Pressure
Piezometric Line: 1

IIb

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0, 68) ft
Left-Zone Right Coordinate: (53, 67.5) ft
Left-Zone Increment: 20
Right Projection: Range
Right-Zone Left Coordinate: (95, 91) ft
Right-Zone Right Coordinate: (210.08094, 90.912003) ft
Right-Zone Increment: 20
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (-20, 68) ft

Right Coordinate: (233, 77) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-20	62
	233	62

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	104	107
	125	108

Surcharge Load 2

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	139	108
	171	104

Reinforcements

=> 1-10 = RW 6
11-22 = RW 16
> Fabric used to model metal straps (not an option in Slope/W)

Reinforcement 1

Type: Fabric
Outside Point: (95, 86) ft
Inside Point: (110.2, 86) ft
Slip Surface Intersection: (130.74, 86) ft

Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 17 ° ← AASHTO LRFD Table 3.11.5.3-1 for Steel on Sand
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 474.87 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (95, 88) ft
Inside Point: (110.2, 88) ft
Slip Surface Intersection: (132.17, 88) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 17 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 400.48 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (95, 90) ft

Inside Point: (110.2, 90) ft
Slip Surface Intersection: (133.45, 90) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 326.6 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (95, 92) ft
Inside Point: (110.2, 92) ft
Slip Surface Intersection: (134.68, 92) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 256.71 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (95, 94) ft
Inside Point: (110.2, 94) ft
Slip Surface Intersection: (135.77, 94) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 256.71 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (95, 96) ft
Inside Point: (110.2, 96) ft
Slip Surface Intersection: (136.84, 96) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 173.6 lbs/ft
Available Bond Length: 0 ft

Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (95, 98) ft
Inside Point: (110.2, 98) ft
Slip Surface Intersection: (137.74, 98) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 173.6 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (95, 100) ft
Inside Point: (110.2, 100) ft
Slip Surface Intersection: (138.65, 100) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 173.6 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (95, 102) ft
Inside Point: (110.2, 102) ft
Slip Surface Intersection: (139.43, 102) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (95, 104) ft
Inside Point: (110.2, 104) ft
Slip Surface Intersection: (140.11, 104) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0

Applied Load: 5000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (53, 62.5) ft
Inside Point: (75.5, 62.5) ft
Slip Surface Intersection: (100.21, 62.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 ° ← AASHTO Table 3.11.5.3-1 for Steel on Silty SAND (conservative)
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 759.5 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 12

Type: Fabric
Outside Point: (53, 64.5) ft
Inside Point: (75.5, 64.5) ft
Slip Surface Intersection: (104.8, 64.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs

Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 688.53 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 13

Type: Fabric
Outside Point: (53, 66.5) ft
Inside Point: (75.5, 66.5) ft
Slip Surface Intersection: (108.67, 66.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 660.28 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 14

Type: Fabric
Outside Point: (53, 68.5) ft
Inside Point: (75.5, 68.5) ft
Slip Surface Intersection: (112.07, 68.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs

Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 293.57 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 15

Type: Fabric
Outside Point: (53, 70.5) ft
Inside Point: (75.5, 70.5) ft
Slip Surface Intersection: (115.03, 70.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 161.88 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 16

Type: Fabric
Outside Point: (53, 72.5) ft
Inside Point: (75.5, 72.5) ft
Slip Surface Intersection: (117.72, 72.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1

Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 69.047 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 17

Type: Fabric
Outside Point: (53, 74.5) ft
Inside Point: (75.5, 74.5) ft
Slip Surface Intersection: (120.15, 74.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 69.047 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 18

Type: Fabric
Outside Point: (53, 76.5) ft
Inside Point: (75.5, 76.5) ft
Slip Surface Intersection: (122.36, 76.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf

Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 19

Type: Fabric
Outside Point: (53, 78.5) ft
Inside Point: (75.5, 78.5) ft
Slip Surface Intersection: (124.39, 78.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 20

Type: Fabric
Outside Point: (53, 80.5) ft
Inside Point: (75.5, 80.5) ft
Slip Surface Intersection: (126.27, 80.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable

F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 488.97 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 21

Type: Fabric
Outside Point: (53, 82.5) ft
Inside Point: (75.5, 82.5) ft
Slip Surface Intersection: (128.01, 82.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 440.92 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 22

Type: Fabric
Outside Point: (53, 84.5) ft
Inside Point: (75.5, 84.5) ft
Slip Surface Intersection: (129.65, 84.5) ft
Total Length: 22.5 ft

Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 440.92 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Regions

	Material	Points	Area (ft²)
Region 1	IIb	34,36,35,33	1518
Region 2	IIa EL 15	33,32,31,35	9614
Region 3	IIa EL 53	30,29,28,4,3,2,1,32,31	3905.625
Region 4	LWF IV	3,5,27,28,4	506.25
Region 5	LWF IV	28,25,26,27	134.625
Region 6	DelDOT Type B	9,26,25,28,29,21,19	508
Region 7	DelDOT Type F	5,6,7,8,9,26,27	183.75
Region 8	Existing FILL	29,21,22,23,24,18,30	989.5
Region 9	DelDOT Type B	19,9,8,10,20	288.8
Region 10	DelDOT Type F	10,11,12,13,14,15,17,16,24,23,22,21,19,20	2592.7

Points

	X (ft)	Y (ft)
Point 1	-20	68
Point 2	8	68
Point 3	53	67.5
Point 4	53	EL 62.5 ← Toe of RW 16
Point 5	53	EL 85 ← Top of RW 16

→ Wall Height = Point 5 - Point 4
= 85 - 62.5
H = 22.5'

Point 6	63	89.5
Point 7	67	89.5
Point 8	95	91
Point 9	95	EL 86
Point 10	95	EL 105
Point 11	100	107
Point 12	104	107
Point 13	125	108
Point 14	139	108
Point 15	171	104
Point 16	202	96
Point 17	196	92
Point 18	233	77
Point 19	110.2	86
Point 20	110.2	105
Point 21	120.5	76
Point 22	140	78
Point 23	170	78
Point 24	229	79
Point 25	80	71
Point 26	87.5	85
Point 27	75.5	85
Point 28	75.5	62.5
Point 29	94	70
Point 30	233	70
Point 31	233	53
Point 32	-20	53
Point 33	-20	15
Point 34	-20	9
Point 35	233	15
Point 36	233	9

← Toe of RW6

← Top of RW6

Wall Height = Point 10 - Point 9

= 105 - 86

H = 19'

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)

FOS

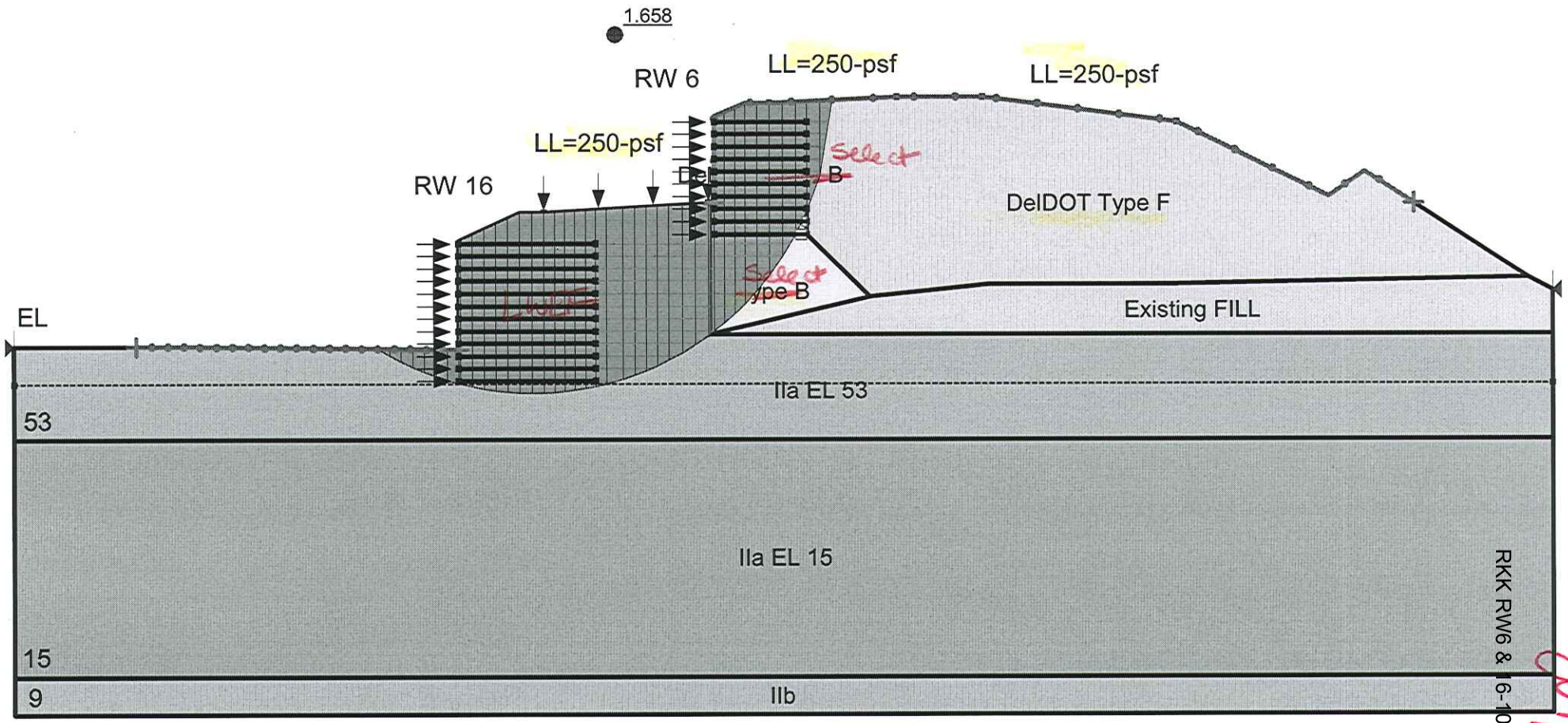
1	1624	1.827	(75.224, 126.616)	68.816	(141.39, 107.701)	(39.7501, 67.6472)

Slices of Slip Surface: 1624

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)
1	1624	40.930075	66.96882	-310.05351	538.58302	0
2	1624	43.28998	65.672145	-229.14167	723.8443	0
3	1624	45.649885	64.49216	-155.50984	899.00718	0
4	1624	48.009795	63.422315	-88.751271	1061.9095	0
5	1624	50.3697	62.45709	-28.522364	1210.533	0
6	1624	52.274825	61.74347	16.007301	1319.9231	0
7	1624	54.25	61.086855	56.980567	1809.8006	0
8	1624	56.75	60.33836	103.68755	2079.6078	0
9	1624	59.25	59.6916	144.04575	2326.4889	0
10	1624	61.75	59.143635	178.23703	2548.524	0
11	1624	64	58.728695	204.12905	2665.7143	0
12	1624	66	58.4281	222.88518	2684.1058	0
13	1624	68.416665	58.15198	240.11494	2694.2338	0
14	1624	71.25	57.929175	254.02113	2687.9877	0
15	1624	74.083335	57.823735	260.60063	2653.2233	0
16	1624	76.625	57.82317	260.63479	2778.0012	0
17	1624	78.875	57.90587	255.47505	3063.4105	0
18	1624	81.25	58.075555	244.88324	3338.1215	0
19	1624	83.75	58.341565	228.28676	3600.473	0
20	1624	86.25	58.700615	205.88029	3839.053	0
21	1624	88.583335	59.11798	179.8389	3885.0925	0
22	1624	90.75	59.583325	150.79853	3748.8754	0
23	1624	92.916665	60.12251	117.15581	3606.0635	0
24	1624	94.5	60.55667	90.063886	3498.4953	0
25	1624	95.974405	61.01077	61.727912	4986.3746	0
26	1624	97.923215	61.659485	21.248047	4912.3755	0
27	1624	99.44881	62.20731	-12.936268	4852.7986	0
28	1624	101	62.818655	-51.083064	4743.9241	0
29	1624	103	63.66392	-103.82744	4570.5665	0

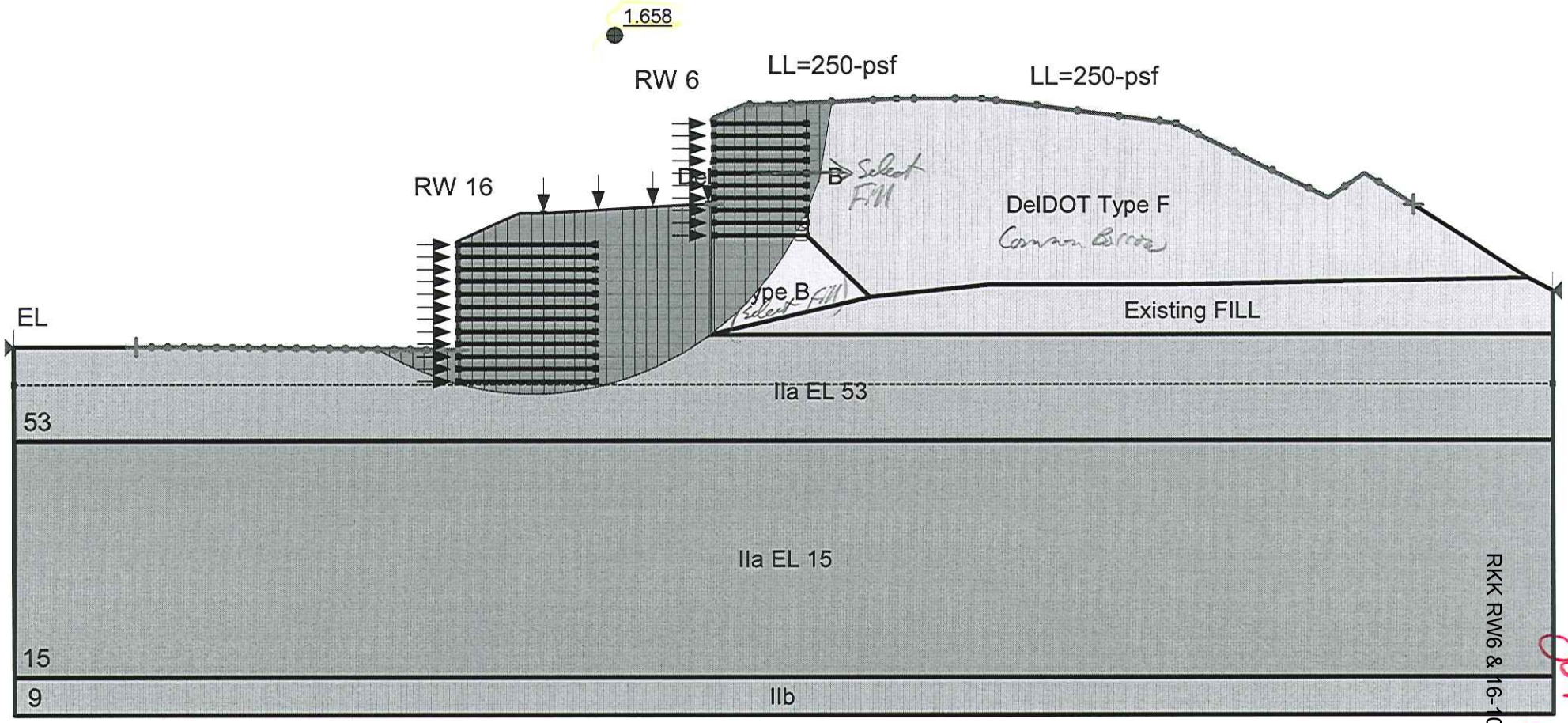
30	1624	105.55	64.86638	-178.86149	4121.1138	0
31	1624	108.65	66.4893	-280.13128	3847.3716	0
32	1624	111.2357	67.98717	-373.59842	1481.65	0
33	1624	113.30715	69.311675	-456.26025	1067.3145	0
34	1624	115.88215	71.12789	-569.57244	748.92304	398.20945
35	1624	118.9607	73.523825	-719.09258	219.75672	116.84672
36	1624	121.2574	75.47362	-840.74062	-100.60429	-53.492251
37	1624	123.5074	77.62645	-975.09627	-195.35805	-103.87372
38	1624	126.16665	80.38305	-1147.0963	2317.7526	1232.3709
39	1624	128.5	83.0968	-1316.447	2053.2018	1091.7067
40	1624	130.83335	86.1274	-1505.5538	1770.7531	941.52613
41	1624	133.16665	89.553725	-1719.3418	1463.5639	778.19073
42	1624	135.5	93.50127	-1965.6738	1122.0365	596.59736
43	1624	137.83335	98.19493	-2258.4768	732.26447	389.35193
44	1624	140.1948	104.23315	-2635.3597	1.3813352e-008	7.3446896e-009

SR 1/I-95 Interchange 103-059-27U 12/9/08
RW 6 and 16 Global Stability Analysis – Drained – LL between walls
Prepared By: SAB



1-27-09

SR 1/I-95 Interchange 103-059-27U 12/9/08
RW 6 and 16 Global Stability Analysis
Prepared By: SAB



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SLT 1-27-09

RKK RW6 & 16-110

SR1/I-95 Interchange 103-059-27U Retaining Wall 6 & 16 Global Stability

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Revision Number: 41
Date: 12/9/2008
Time: 4:13:02 PM
File Name: RW 6 and 16 Drained.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 6 and 16\Final Design\

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SR1/I-95 Interchange 103-059-27U Retaining Wall 6 & 16 Global Stability

Description: Ramp C STA 117+50
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- **Apply Phreatic Correction:** Yes
- **Side Function**
  - **Interslice force function option:** Half-Sine
- **PWP Conditions Source:** Piezometric Line
- **Use Staged Rapid Drawdown:** No

SlipSurface
- **Direction of movement:** Right to Left
- **Allow Passive Mode:** No
- **Slip Surface Option:** Entry and Exit
- **Critical slip surfaces saved:** 1

Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 40
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 16
Ending Optimization Points: 32
Complete Passes per Insertion: 1

Materials

~~DelDOT Type B~~ Select Fill

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

DelDOT Type F Borrow

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

LWF IV

Model: Mohr-Coulomb
Unit Weight: 42 pcf
Cohesion: 17280 psf
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Existing FILL

Model: Mohr-Coulomb

Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa EL 53

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: CU Tests
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa EL 15

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: IRW-97 U-2
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIb

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0, 68) ft
Left-Zone Right Coordinate: (53, 67.5) ft
Left-Zone Increment: 20
Right Projection: Range
Right-Zone Left Coordinate: (95, 91) ft
Right-Zone Right Coordinate: (210.08094, 90.912003) ft
Right-Zone Increment: 20
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (-20, 68) ft

Right Coordinate: (233, 77) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-20	62
	233	62

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	104	107
	125	108

Surcharge Load 2

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	139	108
	171	104

Reinforcements

1-10 for RW 6
11-22 for RW 16

→ Fabric used to model metal straps (not an option in Slope/W

Reinforcement 1

Type: Fabric
Outside Point: (95, 86) ft
Inside Point: (110.2, 86) ft
Total Length: 15.2 ft

Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 17 ° → AASHTO LRFD Table 3.11.5.3-1 for Steel on Sand
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs

Reinforcement 2

Type: Fabric
Outside Point: (95, 88) ft
Inside Point: (110.2, 88) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 17 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs

Reinforcement 3

Type: Fabric
Outside Point: (95, 90) ft
Inside Point: (110.2, 90) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs

Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs

Reinforcement 4

Type: Fabric
Outside Point: (95, 92) ft
Inside Point: (110.2, 92) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs

Reinforcement 5

Type: Fabric
Outside Point: (95, 94) ft
Inside Point: (110.2, 94) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs

Reinforcement 6

Type: Fabric
Outside Point: (95, 96) ft
Inside Point: (110.2, 96) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °

Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs

Reinforcement 7

Type: Fabric
Outside Point: (95, 98) ft
Inside Point: (110.2, 98) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs

Reinforcement 8

Type: Fabric
Outside Point: (95, 100) ft
Inside Point: (110.2, 100) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice

Load Orientation: 0
Applied Load: 5000 lbs

Reinforcement 9

Type: Fabric
Outside Point: (95, 102) ft
Inside Point: (110.2, 102) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs

Reinforcement 10

Type: Fabric
Outside Point: (95, 104) ft
Inside Point: (110.2, 104) ft
Total Length: 15.2 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 5000 lbs
Fabric Safety Factor: 1
Fabric Load: 5000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 5000 lbs

Reinforcement 11

Type: Fabric
Outside Point: (53, 62.5) ft
Inside Point: (75.5, 62.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable

F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 ° ← AASHTO Table 3.11.5.3-1 for Steel on Silty Sand (conservative)
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs

Reinforcement 12

Type: Fabric
Outside Point: (53, 64.5) ft
Inside Point: (75.5, 64.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs

Reinforcement 13

Type: Fabric
Outside Point: (53, 66.5) ft
Inside Point: (75.5, 66.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0

Applied Load: 6000 lbs

Reinforcement 14

Type: Fabric
Outside Point: (53, 68.5) ft
Inside Point: (75.5, 68.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs

Reinforcement 15

Type: Fabric
Outside Point: (53, 70.5) ft
Inside Point: (75.5, 70.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs

Reinforcement 16

Type: Fabric
Outside Point: (53, 72.5) ft
Inside Point: (75.5, 72.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs

Reinforcement 17

Type: Fabric
Outside Point: (53, 74.5) ft
Inside Point: (75.5, 74.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs

Reinforcement 18

Type: Fabric
Outside Point: (53, 76.5) ft
Inside Point: (75.5, 76.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs

Reinforcement 19

Type: Fabric
Outside Point: (53, 78.5) ft
Inside Point: (75.5, 78.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs

Reinforcement 20

Type: Fabric
Outside Point: (53, 80.5) ft
Inside Point: (75.5, 80.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs

Reinforcement 21

Type: Fabric
Outside Point: (53, 82.5) ft
Inside Point: (75.5, 82.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf

Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs

Reinforcement 22

Type: Fabric
Outside Point: (53, 84.5) ft
Inside Point: (75.5, 84.5) ft
Total Length: 22.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs

Shear/Normal Strength Functions

IRW-97 U-2

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
    Curve Fit to Data: 100 %
    Segment Curvature: 100 %
Y-Intercept: 1139.0648
Data Points: Normal Stress (psf), Shear Stress (psf)
    Data Point: (2250, 1252)
    Data Point: (4500, 1460)
    Data Point: (9000, 2972)
    Data Point: (12000, 4134)
Estimation Properties
    Intact Rock Param.: 10
    Geological Strength: 100
    Disturbance Factor: 0

SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

CU Tests

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 100 %
Y-Intercept: 188.17854
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (500, 487)
Data Point: (1000, 775)
Data Point: (1500, 1017)
Data Point: (2000, 1234)
Data Point: (2500, 1433)
Data Point: (3000, 1619)
Data Point: (3500, 1795)
Data Point: (4000, 1963)
Data Point: (4500, 2124)
Data Point: (5000, 2280)
Data Point: (5500, 2430)
Data Point: (6000, 2576)
Data Point: (6500, 2718)
Data Point: (7000, 2856)
Data Point: (7500, 2991)
Data Point: (8000, 3123)
Data Point: (8500, 3253)
Data Point: (9000, 3380)
Data Point: (9500, 3505)
Data Point: (10000, 3627)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	IIb	34,36,35,33	1518
Region 2	IIa EL 15	33,32,31,35	9614
Region 3	IIa EL 53	30,29,28,4,3,2,1,32,31	3905.625
Region 4	LWF IV	3,5,27,28,4	506.25

Region 5	LWF IV	28,25,26,27	134.625
Region 6	DelDOT Type B	9,26,25,28,29,21,19	508
Region 7	DelDOT Type F	5,6,7,8,9,26,27	183.75
Region 8	Existing FILL	29,21,22,23,24,18,30	989.5
Region 9	DelDOT Type B	19,9,8,10,20	288.8
Region 10	DelDOT Type F	10,11,12,13,14,15,17,16,24,23,22,21,19,20	2592.7

Points

	X (ft)	Y (ft)
Point 1	-20	68
Point 2	8	68
Point 3	53	67.5
Point 4	53	62.5
Point 5	53	85
Point 6	63	89.5
Point 7	67	89.5
Point 8	95	91
Point 9	95	86
Point 10	95	105
Point 11	100	107
Point 12	104	107
Point 13	125	108
Point 14	139	108
Point 15	171	104
Point 16	202	96
Point 17	196	92
Point 18	233	77
Point 19	110.2	86
Point 20	110.2	105
Point 21	120.5	76
Point 22	140	78
Point 23	170	78
Point 24	229	79
Point 25	80	71
Point 26	87.5	85

Point 27	75.5	85
Point 28	75.5	62.5
Point 29	94	70
Point 30	233	70
Point 31	233	53
Point 32	-20	53
Point 33	-20	15
Point 34	-20	9
Point 35	233	15
Point 36	233	9

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	1605	1.658	(65.261, 109.692)	49.179	(114.39, 107.495)	(39.7501, 67.6472)

Slices of Slip Surface: 1605

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesiv Strengt (psf)
1	1605	40.69654	67.10137	-318.32454	182.54567	109.09561	188.1
2	1605	42.58938	66.063715	-253.57792	368.53931	220.25184	188.1
3	1605	44.48222	65.130605	-195.35045	544.88789	325.35997	188.4
4	1605	46.37506	64.29557	-143.24151	708.54942	415.47078	195.3
5	1605	48.2679	63.553275	-96.924599	855.96651	483.39547	212.4
6	1605	50.16074	62.8993	-56.114895	984.28572	528.2782	238.3
7	1605	52.05358	62.329975	-20.590762	1091.5211	557.23803	265.4
8	1605	53.12977	62.03303	-2.061182	1520.2907	684.36231	341.7
9	1605	54.233585	61.77584	13.987896	1643.9104	721.66973	353.4
10	1605	56.181675	61.368675	39.395069	1843.2259	776.2179	374.8
11	1605	58.12977	61.042895	59.723461	2014.0606	818.51907	396.4
12	1605	60.077865	60.79687	75.073787	2155.5319	850.92597	416.2
13	1605	62.025955	60.6294	85.523846	2267.6087	876.66165	431.7
14	1605	64	60.53953	91.135017	2286.7976	880.11441	433.7
15	1605	66	60.528915	91.794627	2217.7994	862.45987	423.2
16	1605	67.85	60.58877	88.060001	2143.1987	844.46652	412.2
17	1605	69.55	60.70802	80.620918	2067.7349	827.11504	401.5
18	1605	71.25	60.886765	69.467109	1980.9044	806.95101	389.9
19	1605	72.95	61.125655	54.55924	1884.3523	783.8345	378.3
20	1605	74.65	61.42558	35.843976	1779.5246	757.993	367.0
21	1605	76.380965	61.795465	12.763221	1799.2681	771.0175	372.5
22	1605	78.630965	62.386945	-24.145119	1966.1291	821.64335	398.2
23	1605	80.9375	63.089255	-67.969336	2109.5971	858.33467	420.7
24	1605	82.8125	63.762885	-110.00639	2204.6116	882.40665	434.9
25	1605	84.6875	64.524375	-157.52009	2285.1706	902.87201	446.5

26	1605	86.5625	65.37826	-210.80233	2352.9779	920.22751	455.8
27	1605	88.583335	66.412715	-275.35296	2276.7376	900.8267	445.2
28	1605	90.75	67.653365	-352.77031	2066.1607	847.52065	413.7
29	1605	92.916665	69.047355	-439.77253	1854.9434	791.35346	381.6
30	1605	94.148455	69.892245	-492.48113	1726.1098	752.75593	364.6
31	1605	94.363115	70.048605	-502.2321	1742.1484	926.31674	0
32	1605	94.71466	70.310615	-518.58455	1663.9722	1122.3634	0
33	1605	95.833335	71.18566	-573.186	2787.4095	1880.1314	0
34	1605	97.5	72.571045	-659.61853	2654.6011	1790.551	0
35	1605	99.166665	74.08839	-754.32889	2519.9043	1699.6969	0
36	1605	101	75.940895	-869.91508	2333.4253	1573.9153	0
37	1605	103	78.19811	-1010.7644	2094.7948	1412.957	0
38	1605	105.0891	80.903175	-1179.5631	1679.7882	1133.0314	0
39	1605	107.26735	84.204965	-1385.5973	1412.2452	952.57141	0
40	1605	109.27825	87.85833	-1613.5653	1086.4684	732.83221	0
41	1605	111.2476	92.52256	-1904.621	-0.12214682	-0.064946619	0
42	1605	113.3428	101.41163	-2459.2946	-0.064519526	-0.03430564	0

RKK RW6 & 16-128

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject I-95/SR 1 Interchange — Page 1 of
Retaining Wall 6 & 16 Settlement — Cm. No. 103-059-270

Prepared By SAB Date 12/19/08 Checked By [illegible] Date 1-27-09

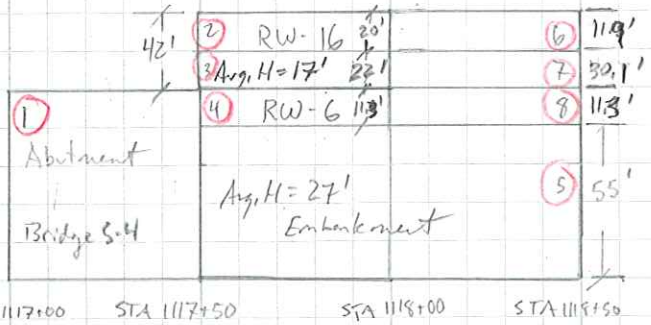
Objective: To estimate the settlement anticipated to occur from the construction of Retaining Wall 6 & 16 and the associated embankment.

Wall Details: (See p. 2 for cross-section)

Retaining Wall 6 is 177' long.
Retaining Wall 16 is 141' long.

→ 40' High bridge abutment @ STA 1117+50 @ termination of RW6 for Bridge 5-4

Layout (plan view): (NTS)



(#) Footing #

MSE W Analysis (see p. 3-6)

Rep't STA	Height RW16	Backslope Height	Height RW6	Backslope Height	Avg. H RW6 for Model	Avg. H RW6 for Model	B' RW16	B' RW6	Neigh. Ftg Stress (RW16)	Neigh. Ftg Stress (RW6)
1117+50	22.5'	4.5'	19'	2'	⇒ 21.75'	> 21'	20.0'	11.3'	1,625 psf	3,866 psf
1118+00	13.5'	10.5'	19'	6'	⇒ 12.25'	> 23'	11.9'	11.4'	1,187 psf	4,743 psf
1118+50	0'	11.5'	18'	11.5'						

* For average height to model RWs as in software, take the average of H + (½ BH) between the stations.
→ Walls modeled as rectangular footings with a uniform surcharge pressure.

Embankment: $\Delta\sigma$ = 27'(130pcf) = 3,510psf, Assume B=55' (Common Borrow)

Fill b/t walls: $\Delta\sigma$ = 17'(125pcf) = 2125psf, B=22'/30.7' (Select Fill)

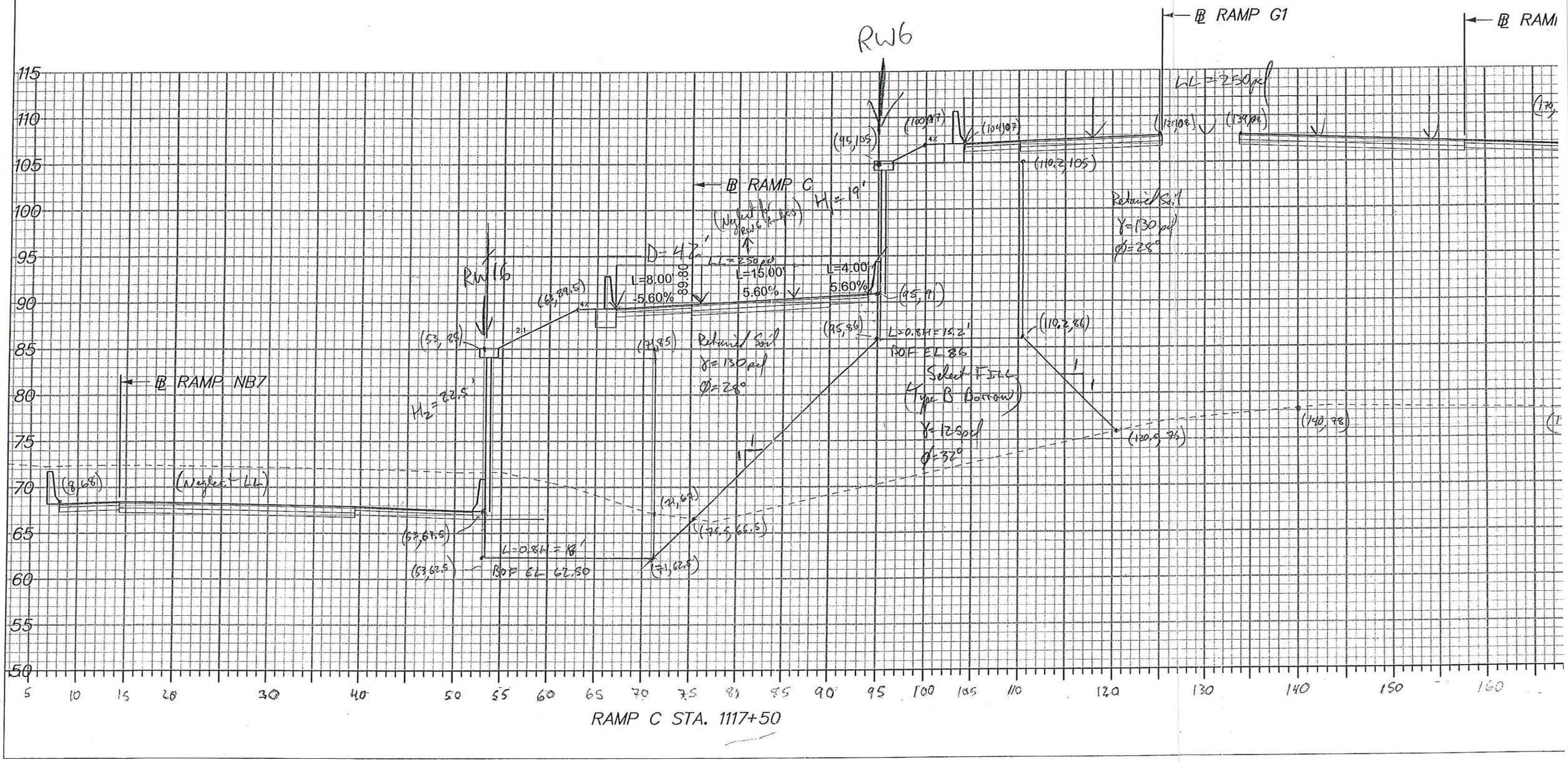
Abutment: From URS: Bearing Stress = 2.34tsf = 4,680psf, B=33'

I-95/SR 1 Interchange

RW 6 & 16

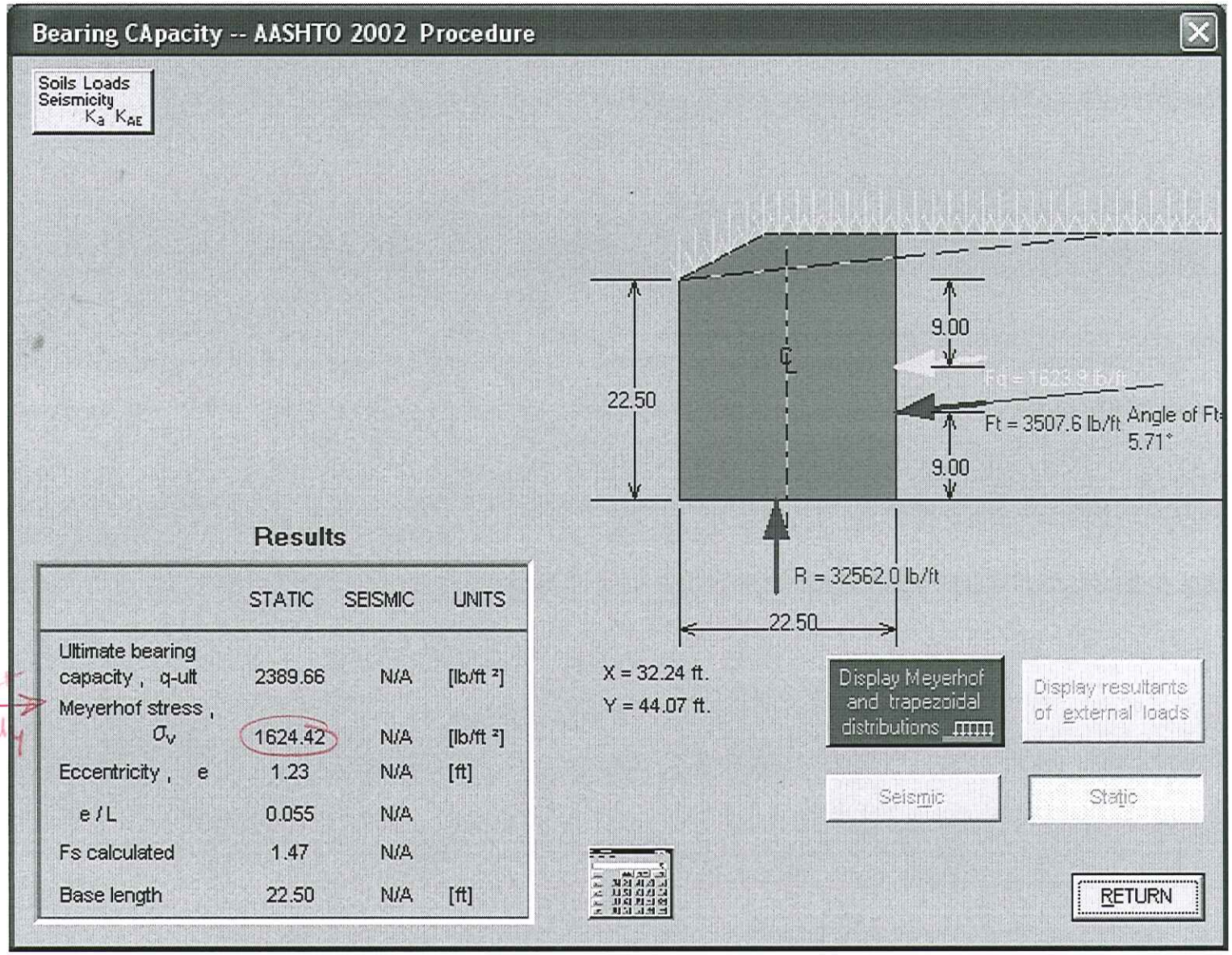
JYT 1-27-09

RKK RW6 & 16-129



RAMP C STA. 1117+50

SR 1/I-95 Interchange 103-059-27U
RW 16 STA 1117+50 Service Loads



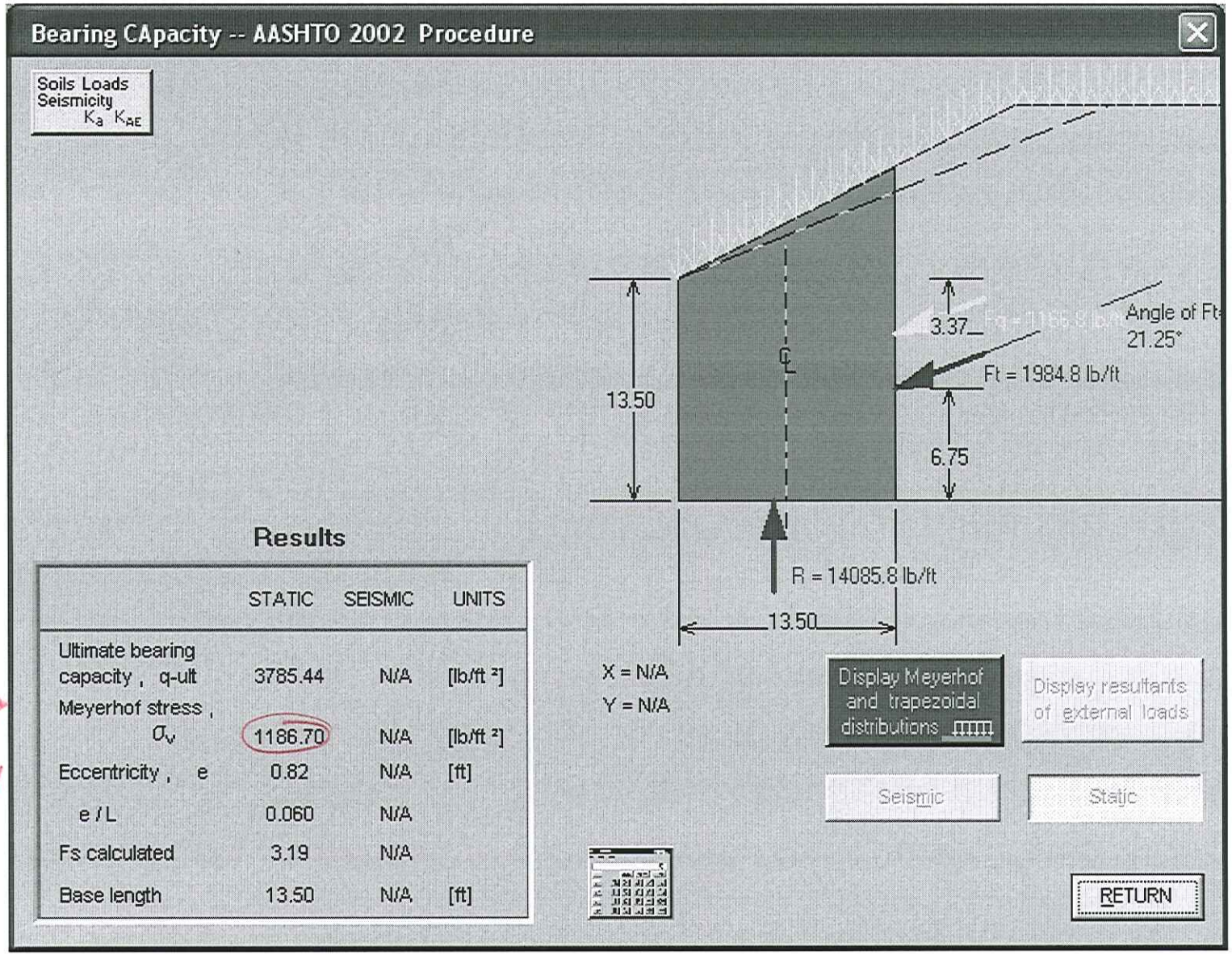
Results

	STATIC	SEISMIC	UNITS
Ultimate bearing capacity , q-ult	2389.66	N/A	[lb/ft ²]
Meyerhof stress , σ_v	1624.42	N/A	[lb/ft ²]
Eccentricity , e	1.23	N/A	[ft]
e / L	0.055	N/A	
Fs calculated	1.47	N/A	
Base length	22.50	N/A	[ft]

For settlement analysis only →

RKK RW6 & 16-130-09

SR 1/I-95 Interchange 103-059-27U
RW 16 STA 1118+00 Service Loads



Results

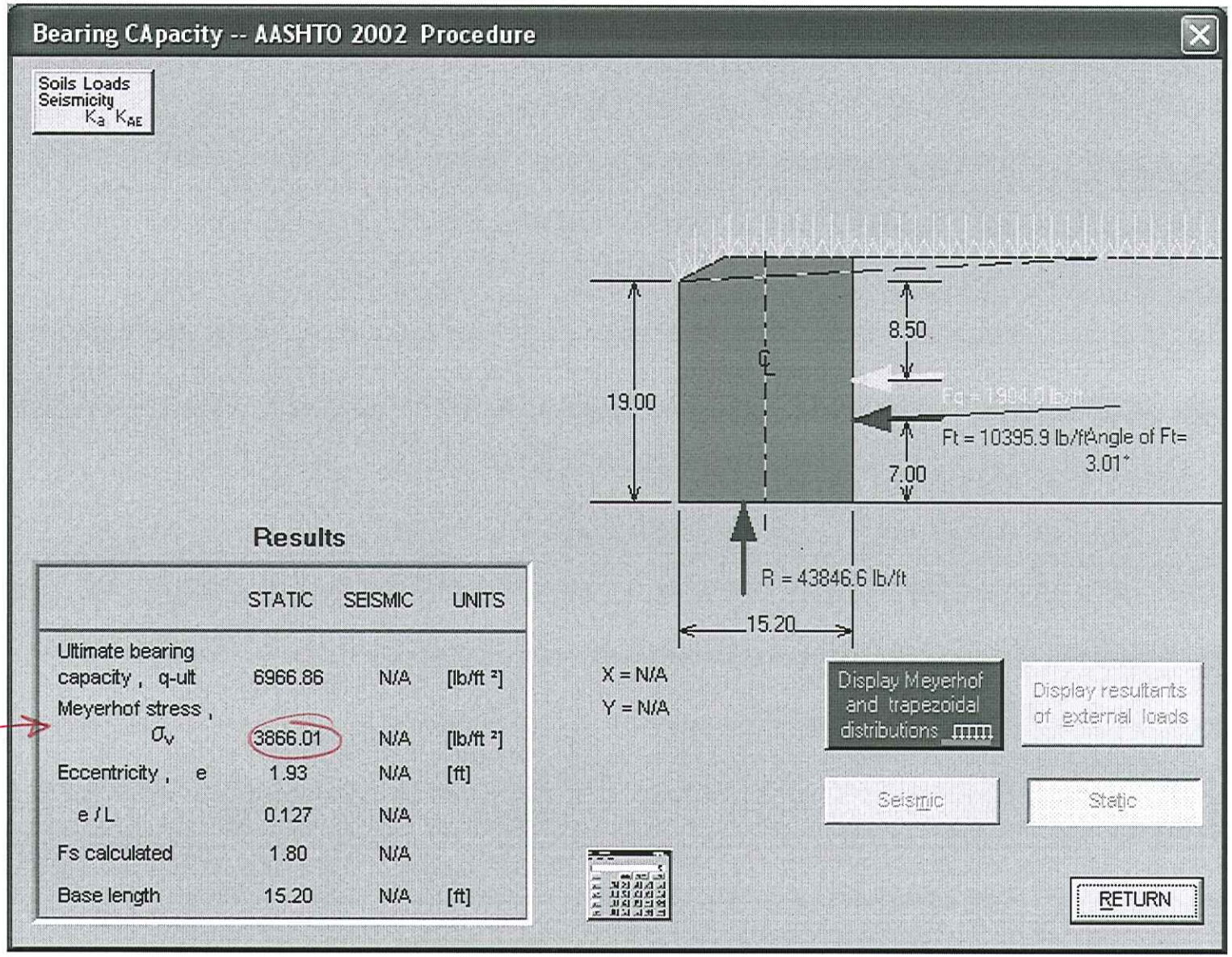
	STATIC	SEISMIC	UNITS
Ultimate bearing capacity , q-ult	3785.44	N/A	[lb/ft ²]
Meyerhof stress , σ_v	1186.70	N/A	[lb/ft ²]
Eccentricity , e	0.82	N/A	[ft]
e / L	0.060	N/A	
Fs calculated	3.19	N/A	
Base length	13.50	N/A	[ft]

For Settlement analysis only →

RKK RW6 & 16-131

RFT 1-27-09

SR 1/I-95 Interchange 103-059-27U
RW 6 STA 1117+50 Service Loads



Results

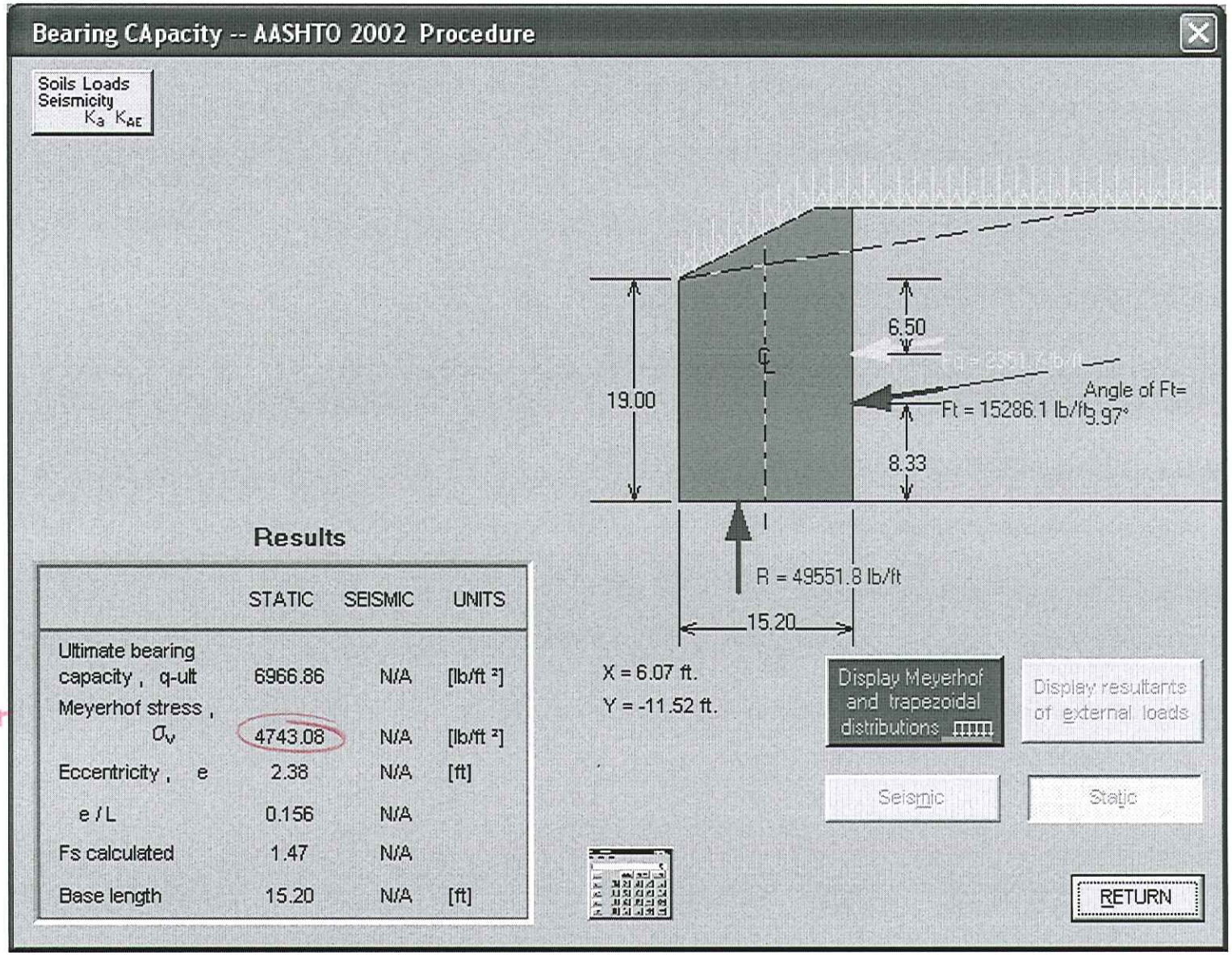
	STATIC	SEISMIC	UNITS
Ultimate bearing capacity , q-ult	6966.86	N/A	[lb/ft ²]
Meyerhof stress , σ_v	3866.01	N/A	[lb/ft ²]
Eccentricity , e	1.93	N/A	[ft]
e / L	0.127	N/A	
Fs calculated	1.80	N/A	
Base length	15.20	N/A	[ft]

For Settlements Only

RKK RW6 & 16-132

JPT 1-27-09

SR 1/I-95 Interchange 103-059-27U
RW 6 STA 1118+00 Service Loads



Results

	STATIC	SEISMIC	UNITS
Ultimate bearing capacity , q-ult	6966.86	N/A	[lb/ft ²]
Meyerhof stress , σ_v	4743.08	N/A	[lb/ft ²]
Eccentricity , e	2.38	N/A	[ft]
e / L	0.156	N/A	
Fs calculated	1.47	N/A	
Base length	15.20	N/A	[ft]

For Settlement Only

RKK RW6 & 16-133

1-27-09 OPT

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject I-95/SR1 Interchange
RW 6 & 16 Settlement
Page 7 of
Cm. No. 103-059-270
Prepared By SAB Date 12/18/08 Checked By [illegible] Date 1-27-09

Soils: (see attached fence, p. 8) → Assume BOF EL (for bottom wall, RW 16) = EL 62.5

Stratum	EL	γ_T (pcf)	μ	E (ksf) (2)	C_c (1)	C_r (1)	e_o (1)	C_v (ft²/day) (1)	OCR (1)	P_c (psf) (1)	P_o @ Bottom (3)	$P_c - P_o$ (psf)
1. IIa	62.5-50	130	0.4	545	0.16	0.016	0.633	–	3.7	8,000	939	7,061
2. IIa	50-20	130	0.4	818	0.16	0.016	0.654	–	2.7	9,500	2,967	6,533
3. IIa	20-0	130	0.4	1,364	0.16	0.016	0.654	–	2.0	9,500	4,319	5,181
4. IIa	0-20	130	0.4	1,364	0.16	0.016	0.654	–	–	9,500	5,671	3,829
5. IIb	Below -20	130	0.3	1,364	–	–	–	–	–	–	–	–
Water	61	62.4										

*(1): Consolidation parameters from general site parameters from lab testing, see page 9.

* Use $C_c = C_r$ in analysis since $\Delta\sigma < P_c$; use C_r = 10% of C_c w/ min. C_c = 0.015

*(2): E-values based on calculations with settlement plate data @ Ramps A, B, C, & G1.

*(3): P_o: 1. 1.5'(130) + 11'(130 - 62.4) = 939 psf
2. 939 + 30'(67.6 pcf) = 2,967 psf
3. 2,967 + 20'(67.6) = 4,319 psf
4. 4,319 + 20'(67.6) = 5,671 psf

SR1 / I-95 Interchange 103-059-27U

11/25/08 RW6 & 16 Analysis

JT 1-27-09

8

RKK RW6 & 16135

STA 1117+50

RW 6 BOF EL 86

Rep C ~STA 1117+10

IBR-31
N612621, E432392.5
EL 68.0

IRW-97
N612677.17, E432386.32
EL 71.0

RW 16 BOF EL 66.50

Rep C STA 1117+60

IRW-43
N612649.3, E432456.1
EL 78.0

Rep C ~STA 1118+35

IBR-18C
N612737.5, E432441.6
EL 71.0

Rep C ~STA 1118+50

IDMT-20
N612744, E432489
EL 79.0

BOF EL 79

RW6 STA 1118+50

Rep C ~STA 1119+35

IBR-18A
N612787, E432515.4
EL 80.0

IBR-18B
N612836.2, E432480.3
EL 78.0

SPT N or REC, RQD | NMC | AASHTO | Su/Phi | Ko/OCR

IBR-31: 16.2% (A-6) LL=33 PI=14; 21.9% (A-6); 18.6% (A-4); 50/5"; 100.5'

IRW-97: 13.5% (A-2-4); 8.5% (A-1-b); 21.3% (A-6(14)); 19.9% (A-6(11)); 23.8% (A-7-6(18)); 28.4% (A-7-5(32)); 25.8% (A-7-6(24)); 24.0% (A-7-6(24)); 21.6% (A-7-6(21)); 19.8% (A-6(12)); 19.8% (A-4(7)); 35.4% (A-4(4)); 16.1% (A-4(0)); 16.7% (A-6(11)); 25.2% (A-7-6(34)); 23.3% (A-6(15)); 30.5% (A-7-5(17)) LL=46 PI=13; 22.5% (A-4(0)) NP LL=21; 23.0% (A-2-4) NP LL=14; 50/6"; 60.0'

IRW-43: 9.7% (A-2-4) NP; 23.5% (A-7-5) LL=48 PI=26; 22.0% (A-2-4) NP; 26.2% (A-7-5) LL=62 PI=33; 46.5'

IBR-18C: 31.9% (A-7-5) LL=42 PI=17; 13.8% (A-6) LL=32 PI=12; 25.0% (A-7-6) LL=62 PI=30; 20.0% (A-2-4) NP; 14.1% (A-4) LL=23 PI=8; 13.2% (A-2-4) NP; 50/4"; 50/5"; 100.5'

IBR-18A: 20.7% (A-6); 20.1% (A-7-5); 18.2% (A-4); 50/5"; 50/3"; 13.6% (A-2-4); 79.9'

IBR-18B: 17.8% (A-6) LL=35 PI=15; 16.9% (A-2-4) NP; 20.4% (A-6) LL=37 PI=16; 25.2% (A-7-5)CH LL=67 PI=37; 19.6% (A-4); 15.8% (A-2-4); 15.5% (A-2-4); 50/6"; 50/5"; 100.5'

U-1, U-2, S-15, EL 15, EL 9, EL -10, EL 53, EL 63, I, IIa, IIb, Su=1200psf, Su=1700psf, γ=130pcf, γ=130pcf, UU=1,355psf, γ=103.3pcf, NMC=23.7%, γT=127.7pcf, LL=54, PI=30, D.S.: φ'=17°, C'=338psf, γ=103.8pcf, NMC=22.2%, γT=126.4pcf, φ'=37°

AASHTO SOIL KEY

A-1-a	A-2-5	A-5	A-8
A-1-b	A-2-6	A-6	Asphalt
A-3	A-2-7	A-7-5	FILL
A-2-4	A-4	A-7-6	Decomposed Rock

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data
Retaining Wall 6 & 16

Figure No.

Drawn: SAB | Approved: | Date: 11/25/08

Comm. No 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 11/25/08

SR 1/I-95 Interchange - Consolidation Soil Parameters - Stratum 2a																										
PointID	Sample	GS EL	GWL (ft)	Depth (ft)	Sample EL	γ_T (pcf)	NMC (%)	LL	PL	PI	LI	P_0 (tsf)	$Pc_{Casagrande}$ (tsf)	$Pc_{Work\ Energy}$ (tsf)	OCR_C	$OCR_{W.E.}$	FINAL P_c (tsf)	FINAL OCR	e_0	c_c	c_r	$C_{v(Max)}$ (ft^2/d)	$C_{v(Min)}$ (ft^2/d)	cr/cc	CC	CR
IEB-15	U-1	83	52.0	12	71	129.5	26.7	49	26	23	0.03	0.78	3.53	6.00	4.5	7.7	3.53	4.5	0.669	0.19	0.05	3.17	0.02	26	11.384	0.030
IBR-61	U-1	84	24.0	14	70	123.6	30.7	34	21	13	0.75	0.87	2.91	1.85	3.4	2.1	2.91	3.4	0.748	0.24	0.05	2.64	0.03	21	13.730	0.029
IEB-13A	T-1	84	9.6	15	69	77.8	18.7	33	19	14	-0.02	0.82	2.95	3.30	3.6	4.0	3.13	3.8	0.554	0.12	0.02	0.23		17	7.722	0.013
IBR-60	U-1	86	11.4	18	68	133.3	20.5	30	19	11	0.14	0.94	1.97	1.83	2.1	2.0	1.97	2.1	0.521	0.13	0.03	2.10	0.01	23	8.547	0.020
ICPT-15A	T-1	80.19	3.0	19	61.19	101.5	24.4	49	23	26	0.05	0.69	2.30	3.10	3.3	4.5	2.7	3.9	0.666	0.12	0.03	0.19	0.09	25	7.203	0.018
IRW-33A	T-1	80	15.0	24	56	107.8	23.3	42	21	21	0.11	1.10	1.25	0.90	1.1	0.8	1.08	1.0	0.685	0.19	0.07	0.41	0.01	37	11.276	0.042
IRW-44	T-1	81	10.0	25	56	103.6	20.1	40	19	21	0.05	1.11	2.91	3.93	2.6	3.5	3.42	3.1	0.657	0.17	0.05	0.11	0	29	10.260	0.030
URS-4	U-1	77	14.0	22	55	123.9	34.7	53	28	25	0.27	1.12	1.78	3.10	1.6	2.8	3.1	2.8	0.851	0.25	0.09	2.50	0.01	36	13.506	0.049
IRW-51	T-1	80	10.7	25	55	105.8	21.6	38	19	19	0.14	1.17	1.94	2.75	1.7	2.4	2.35	2.0	0.64	0.23	0.09	0.2	0.03	39	14.024	0.055
IRW-32	T-1	79	13.4	25	54	114.2	19.5	39	19	20	0.03	1.24	6.50	4.60	5.3	3.7	NV	NV	0.545	0.14	0.04	0.24	0.05	29	9.061	0.026
ICPT-16A	T-1	84.87	14.4	31	53.87	134.1	16.4	34	19	15	-0.17	1.90	3.90	5.00	2.1	2.6	4.45	2.3	0.474	0.07	0.01	2.27	0.29	14	4.749	0.007
IRW-52	T-2	88	15.2	35	53	108.3	22.3	44	19	25	0.13	1.63	2.56	2.60	1.6	1.6	2.58	1.6	0.628	0.16	0.05	0.47	0.24	31	9.828	0.031
IRW-50	T-1	77.69	5.2	25	52.69	111.2	19.9	NP	NP	NP		1.02	8.28	5.25	8.1	5.2	NV	NV	0.563	0.19	0.03	1.0	0	16	12.156	0.019
IEB-15	U-2	83	52.0	31	52	132.8	22.6	36	20	16	0.16	2.02	5.29	1.91	2.6	0.9	5.29	2.6	0.527	0.17	0.05	1.10	0.01	29	11.133	0.033
IRW-33	T-1	79	DRY	27	52	100.5	26.1	47	22	25	0.16	1.30	1.12	1.40	0.9	1.1	1.26	1.0	0.801	0.20	0.07	0.16	0.02	35	11.105	0.039
ICPT-15A	T-2	80.19	3.0	29	51.19	72.3	36.7	50	24	26	0.49	1.00	11.00	12.00	11.0	12.0	11.5	11.5	1.333	0.15	0.02	6.74	2.36	13	6.429	0.009
IBR-15	T-1	70	2.0	19.5	50.5	96.9	24.6	42	20	22	0.21	0.72	1.63	2.30	2.3	3.2	1.97	2.7	0.772	0.22	0.06	0.15	0.03	27	12.415	0.034
URS-1	U-1	73	6.0	24	49	126.0	33.5	48	24	24	0.40	0.95	0.67	0.70	0.7	0.7	NV	NV	0.792	0.23	0.07	0.17	0.03	30	12.835	0.039
IEB-13B	T-2	81.64	7.0	33	48.64	115.9	16.1	28	17	11	-0.08	1.40	5.70	7.25	4.1	5.2	6.48	4.6	0.454	0.04	0.01	6.87	2.47	25	2.751	0.007
IRW-53	T-1	63.39	18.5	15	48.39	107.6	19.9	39	17	22	0.13	0.96	1.96	4.00	2.0	4.2	NV	NV	0.539	0.15	0.04	0.32	0.04	27	9.747	0.026
URS-3	U-1	82	6.0	35	47	132.3	26.1	40	22	18	0.23	1.33	2.59	2.40	1.9	1.8	2.59	1.9	0.614	0.20	0.07	1.92	0.02	35	12.392	0.043
IBR-04	T-1	65	2.0	18	47	115.5	12.6	22	17	5	-0.88	0.67	3.00	2.75	4.5	4.1	2.88	4.3	0.487	0.05	0.01	1.5	0	20	3.362	0.007
IRW-49	T-2	77	2.6	30	47	113.4	20.7	60	19	41	0.04	1.12	5.11	4.00	4.5	3.6	4.56	4.1	0.475	0.09	0.03	0.3	0.08	33	6.102	0.020
IRW-42	T-2	75	1.0	30	45	114.7	26.1	44	22	22	0.19	1.18	3.96	4.38	3.4	3.7	4.17	3.5	0.541	0.18	0.04	0.22	0.01	22	11.681	0.026
IEB-13B	T-3	81.64	7.0	39	42.64	116.9	15.5	27	14	13	0.12	1.63	10.00	7.25	6.1	4.5	8.63	5.3	0.447	0.05	0.03	4.99	1.59		3.455	0.021
IBR-52	U-1	57	11.5	16	41	126.9	29.8	43	23	20	0.34	0.88	1.10	3.75	1.3	4.3	3.75	4.3	0.678	0.18	0.07	0.22	0.02	39	10.727	0.042
IBR-60	U-2	86	11.4	46	40	132.3	24.2	36	21	15	0.21	1.90	1.23	2.00	0.6	1.1	2.00	1.1	0.602	0.16	0.04	1.11	0.01	25	9.988	0.025
URS-4	U-2	77	14.0	37	40	131.2	26.9	42	22	20	0.25	1.64	1.01	1.12	0.6	0.7	NV	NV	0.458	0.20	0.06	2.35	0.01	30	13.717	0.041
														Above EL 40 Averages:			3.75	3.37	0.639	0.16	0.05	1.56	0.28	27	9.689	0.028
ICPT-16A	T-2	84.87	14.4	45	39.87	134.1	16.7	41	18	23	-0.06	2.45	4.20	3.90	1.7	1.6	4.05	1.7	0.304	0.07	0.01	0.99	0.23	14	5.368	0.008
IBR-32	T-3	89		50	39	132.7	16.7	31	18	13	-0.10	2.11	3.00	3.38	1.4	1.6	3.19	1.5	0.519	0.16	0.05	0.02		31	10.533	0.033
IRW-23	T-2	60	36.7	24.5	35.5	108.7	18.4	36	21	15	-0.17	0.81	4.96	3.63	6.1	4.5	4.29	5.3	0.522	0.13	0.03	0.38	0.06	23	8.541	0.020
ICPT-15A	T-3	80.19	3.0	45	35.19	97.3	22.3	53	22	31	0.01	1.47	3.50	2.20	2.4	1.5	2.85	1.9	0.739	0.12	0.04	0.09	0.05	33	6.901	0.023
IBR-05	T-2	66	38.0	31.5	34.5	119.0	16.0	21	18	3	-0.67	1.17	4.75	2.70	4.1	2.3	NV	NV	0.661	0.15	0.02	1.0		13	9.031	0.012
URS-3	U-2	82	6.0	50	32	117.0	42.8	51	24	27	0.70	1.74	0.84	1.20	0.5	0.7	NV	NV	0.987	0.27	0.08	0.33	0.01	30	13.588	0.040
ICPT-16A	T-3	84.87	14.4	55	29.87	134.1	13.2	64	26	38	-0.34	3.39	5.00	5.40	1.5	1.6	5.20	1.5	0.872	0.19	0.04	1.08	0.08	21	10.150	0.021
URS-5	U-1	63	4.0	35.5	27.5	121.5	34.5	55	29	26	0.21	1.24	2.01	1.60	1.6	1.3	2.01	1.6	0.786	0.23	0.09	1.61	0.01	39	12.878	0.050
IEB-15	U-3	83	52.0	56	27	132.8	25.5	47	25	22	0.02	3.56	2.40	4.05	0.7	1.1	4.05	1.1	0.582	0.20	0.06	1.70	0.01	30	12.642	0.038
IBR-61	U-2	84	24.0	59	25	123.3	33.3	46	24	22	0.42	2.55	0.69	2.50	0.3	1.0	2.50	1.0	0.839	0.22	0.06	0.56	0.01	27	11.963	0.033
IRW-09	T-2	59	DRY	35	24	110.9	17.5	23	18	5	-0.10	1.39	3.92	2.30	2.8	1.7	NV	NV	0.536	0.11	0.03	2.8	0.2	27	7.161	0.020
IEB-13B	T-4	81.64	7.0	59	22.64	104.1	22.1	NP	NP	NP		2.13	8.00	9.60	3.8	4.5	8.8	4.1	0.505	0.04	0.01	1.76	0.34	25	2.658	0.007
														EL 40 to 20 Averages:			4.10	2.2	0.654	0.16	0.04	1.03	0.10	26	9.285	0.025
														Total Average:			3.85	3.0	0.639	0.16	0.05	1.40	0.23	27	9.567	0.027

$10\%C_c = 0.016$

RKK RW6 & 16-136

1-27-09

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject I-95/SR1 Interchange
RW 6 & 16 Settlement
Page 10 of
Cm. No. 103-059-27U
Prepared By SAB Date 12/18/08 Checked By JST Date 1-27-09

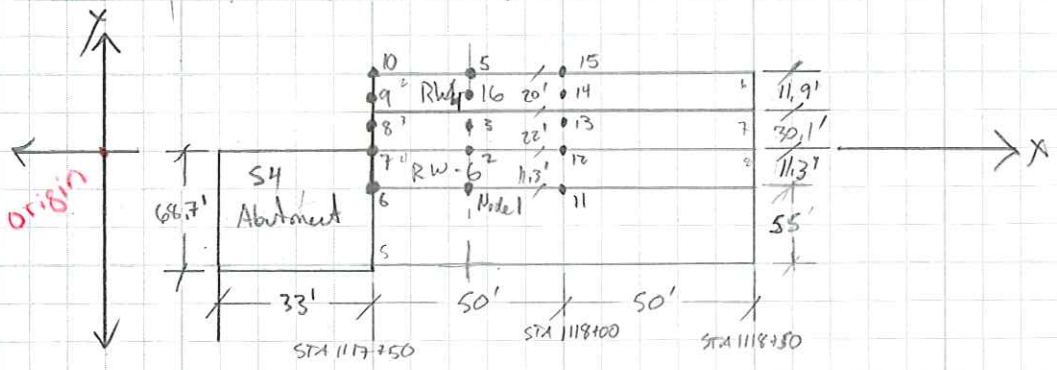
Analysis: Performed using FoSSA (See attached output, p. 11-22)

→ Calculate Elastic settlement to a depth of 4B below the BOF EL. (BOF EL = 62.5)
Assume NO elastic settlement in Clay (only consolidation).
→ Use full "footing" width for both walls as B: 42' + 11.3' = 53.3', 4B = 213.2'

EL 62.5 - 213.2 = EL -150.7

⇒ Check settlements for tallest wall section, STA 1117+50 to 1118+00.

Plan View of Settlement Points: (NTS)



Summary: (see p. 23)

Maximum Elastic Settlement = 0.13' = 1.5" @ Nodes 1 & 11

Maximum Consolidation Settlement = 0.32' = 3.8" @ Nodes 6 & 11

Maximum Total Settlement = 0.45' = 5.4" @ Node 11

→ Based on our interpretation of the settlement plate data, it is anticipated that the consolidation settlement will occur within less than a month of construction completion.

⇒ See p. 23 for differential settlement. (AASHTO Tolerance = 1/100)

RKK RW6 & 16-138 27-09

SR 1/I-95 Interchange

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PROJECT IDENTIFICATION

Title:	SR 1/I-95 Interchange
Project Number:	103-059 - 27U
Client:	DelDOT
Designer:	SAB
Station Number:	1117+50

Description:
Retaining Walls 6 and 16

Company's information:

Name:	RK&K Engineers, LLP
Street:	81 Mosher Street Baltimore, MD 21217
Telephone #:	410-728-2900
Fax #:	410-728-0282
E-Mail:	

Original file path and name: M:\project ..... and 16\Final Design\For Settlement\RW6 and 16.2ST
Original date and time of creating this file: Mon Jan 19 14:38:38 2009

GEOMETRY: Analysis of a Multiple Footings

12

RKK RW6 & 16-139

1-27-09

INPUT DATA – FOUNDATION LAYERS – 5 layers

	Wet Unit Weight, γ [lb/ft^3]	Poisson's Ratio μ	Description of Soil
1	130.00	0.40	IIa EL 62.5 to 50
2	130.00	0.40	IIa EL 50 to 20
3	130.00	0.40	IIa EL 20 to 0
4	130.00	0.40	IIa EL 0 to -20
5	130.00	0.30	IIb

INPUT DATA – MULTIPLE FOOTINGS – 8 footings

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	0.00	361.00
2	100.00	361.00
3	150.00	361.00
4	200.00	361.00
5	300.00	361.00

Actual EL = Z - 300

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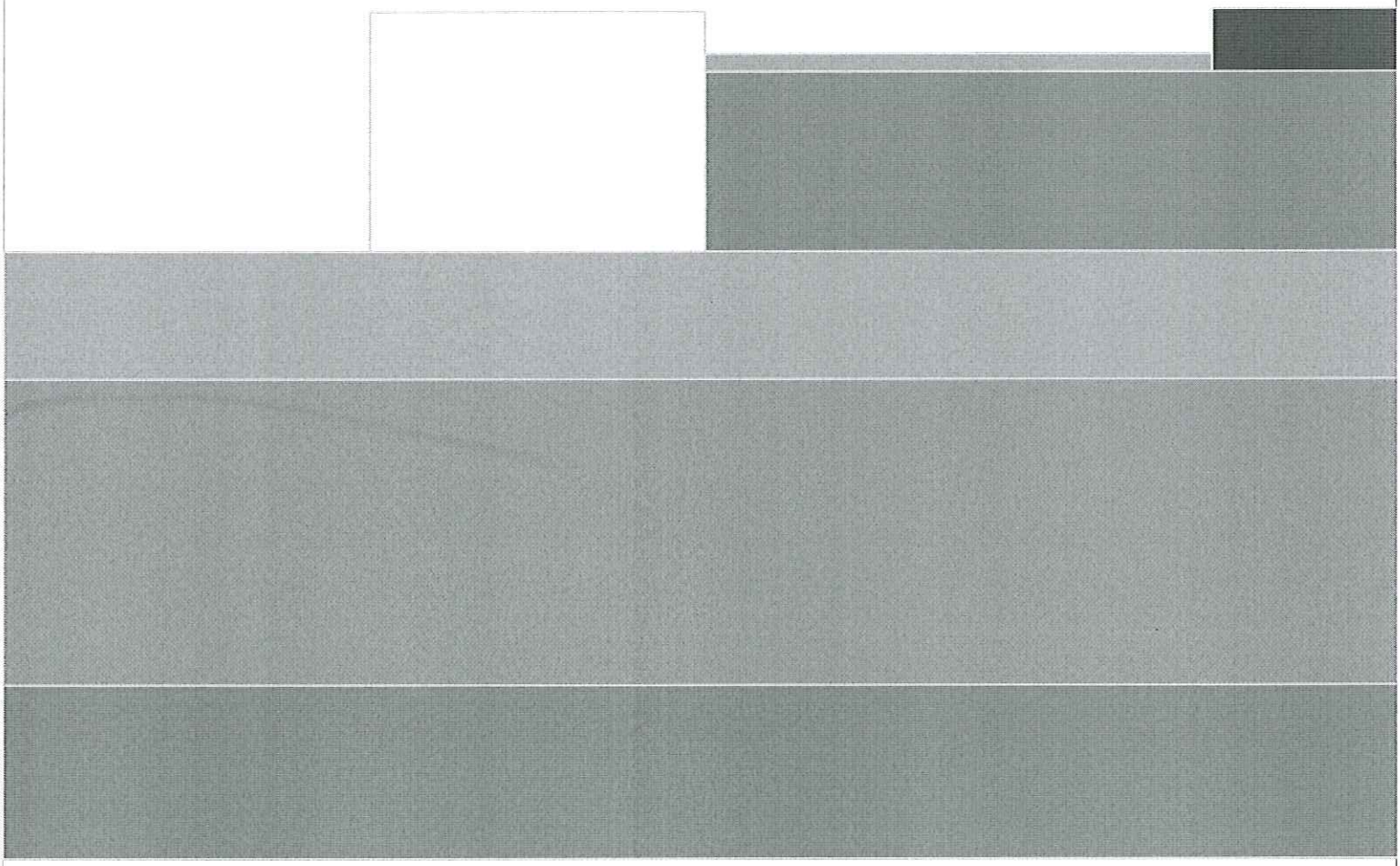
RKK RW6 & 16-140

JVP 1-27-09

DRAWING OF SPECIFIED GEOMETRY



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RKK RW6 & 16-141
JBP 1-27-09

INPUT DATA FOR CONSOLIDATION -- $\alpha = 1/6$

Layer # Undergoing Consolidation [Yes/No]		$(\sigma'_p - \sigma'_o)$ given at layer's boundaries in [lb/ft²] at Top	Bottom	Cc	Cr	e0	Cv [ft²/day]	Drains at :
1	Yes	8000.0	7061.0	0.02	0.02	0.63	0.0973	Top
2	Yes	7061.0	6533.0	0.02	0.02	0.65	0.5900	Bottom
3	Yes	6533.0	5181.0	0.02	0.02	0.65	0.5900	Bottom
4	Yes	5181.0	3829.0	0.02	0.02	0.65	0.5900	Bottom
5	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	362.50	IIa EL 62.5 to 50
	2	100.00	362.50	
	3	150.00	362.50	
	4	200.00	362.50	
	5	300.00	362.50	
2	1	0.00	350.00	IIa EL 50 to 20
	2	100.00	350.00	
	3	150.00	350.00	
	4	200.00	350.00	
	5	300.00	350.00	
3	1	0.00	320.00	IIa EL 20 to 0
	2	100.00	320.00	
	3	150.00	320.00	
	4	200.00	320.00	
	5	300.00	320.00	
4	1	0.00	300.00	IIa EL 0 to -20
	2	100.00	300.00	
	3	150.00	300.00	
	4	200.00	300.00	
	5	300.00	300.00	
5	1	0.00	280.00	IIb
	2	100.00	280.00	
	3	150.00	280.00	
	4	200.00	280.00	
	5	300.00	280.00	

Actual EL = Z - 300

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RKK RW6 & 16-143
JSW 1-27-09

TABULATED GEOMETRY: INPUT OF MULTIPLE FOOTINGS – 8 footings

Footing #	L (in X direction) [ft]	B (in Y direction) [ft]	X of center [ft]	Y of center [ft]	q [ft]l [lb/ft²]	
1	33.00	68.70	133.50	-34.50	4680.00	STR A abut
2	50.00	20.00	175.00	32.00	1625.00	RW-16
3	50.00	22.00	175.00	11.00	2125.00	BTW RW6+RW16
4	50.00	11.30	175.00	-5.65	3866.00	RW 16
5	100.00	55.00	200.00	-38.80	3510.00	Emb
6	50.00	11.90	225.00	36.05	1187.00	RW 16 STA 1118+00 to 1118+50
7	50.00	30.10	225.00	15.05	2125.00	BTW RW 6+16
8	50.00	11.30	225.00	-5.65	4743.00	RW16 STA 1118+00 to 1118+50

(#) See pg 1 and 2 for locations of footings. Footing #'s Circled

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	175.00	-11.30	1	545000	0.4000	0.0358	362.50	362.20	0.30
			2	818000	0.4000	0.0773			
			3	1364000	0.4000	0.0295			
			4	1364000	0.4000	0.0249			
			5	1364000	0.3000	0.1281			= 1.5"
2	175.00	2.02	1	545000	0.4000	0.0209	362.50	362.25	0.25
			2	818000	0.4000	0.0618			
			3	1364000	0.4000	0.0252			
			4	1364000	0.4000	0.0220			
			5	1364000	0.3000	0.1226			= 1.5"
3	175.00	15.35	1	545000	0.4000	0.0185	362.50	362.29	0.21
			2	818000	0.4000	0.0448			
			3	1364000	0.4000	0.0195			
			4	1364000	0.4000	0.0180			
			5	1364000	0.3000	0.1141			= 1.4"
4	175.00	28.67	1	545000	0.4000	0.0149	362.50	362.32	0.18
			2	818000	0.4000	0.0312			
			3	1364000	0.4000	0.0137			
			4	1364000	0.4000	0.0136			
			5	1364000	0.3000	0.1038			= 1.2"
5	175.00	42.00	1	545000	0.4000	0.0058	362.50	362.37	0.13
			2	818000	0.4000	0.0142			
			3	1364000	0.4000	0.0084			
			4	1364000	0.4000	0.0095			
			5	1364000	0.3000	0.0927			

actual @ = 2.305" = 1.1"

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

Ignore elastic Settlement in Strata IIa

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RKK RW6 & 16-145
JGT 1-27-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	175.00	-11.30	362.50	0.31	362.19
2	175.00	2.02	362.50	0.28	362.22
3	175.00	15.35	362.50	0.24	362.26
4	175.00	28.67	362.50	0.20	362.30
5	175.00	42.00	362.50	0.14	362.36

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

Actual EL = Z - 350

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
16	150.00	-11.30	1	545000	0.4000	0.0460	362.50	362.20	0.30
			2	818000	0.4000	0.0828			
			3	1364000	0.4000	0.0273			
			4	1364000	0.4000	0.0222			
			5	1364000	0.3000	0.1197'			= 1.4"
17	150.00	2.02	1	545000	0.4000	0.0118	362.50	362.28	0.22
			2	818000	0.4000	0.0526			
			3	1364000	0.4000	0.0216			
			4	1364000	0.4000	0.0189			
			5	1364000	0.3000	0.1141'			= 1.4"
18	150.00	15.35	1	545000	0.4000	0.0058	362.50	362.33	0.17
			2	818000	0.4000	0.0265			
			3	1364000	0.4000	0.0152			
			4	1364000	0.4000	0.0149			
			5	1364000	0.3000	0.1060'			= 1.3"
19	150.00	28.67	1	545000	0.4000	0.0054	362.50	362.36	0.14
			2	818000	0.4000	0.0146			
			3	1364000	0.4000	0.0097			
			4	1364000	0.4000	0.0108			
			5	1364000	0.3000	0.0964'			= 1.2"
10	150.00	42.00	1	545000	0.4000	0.0016	362.50	362.39	0.11
			2	818000	0.4000	0.0050			
			3	1364000	0.4000	0.0055			
			4	1364000	0.4000	0.0073			
			5	1364000	0.3000	0.0861'			= 1.0"

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

actual El = Z - 300

Ignore elastic settlement in strata IIa

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
~~6~~	150.00	-11.30	362.50	0.32	362.18
~~7~~	150.00	2.02	362.50	0.24	362.26
~~8~~	150.00	15.35	362.50	0.18	362.32
~~9~~	150.00	28.67	362.50	0.14	362.36
~~10~~	150.00	42.00	362.50	0.09	362.41

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

actual EL = Z - 300

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	200.00	-11.30	1	545000	0.4000	0.0398	362.50	362.20	0.30
			2	818000	0.4000	0.0806			
			3	1364000	0.4000	0.0295			
			4	1364000	0.4000	0.0246			
			5	1364000	0.3000	0.1272			= 1.5"
2	200.00	2.02	1	545000	0.4000	0.0229	362.50	362.24	0.26
			2	818000	0.4000	0.0662			
			3	1364000	0.4000	0.0259			
			4	1364000	0.4000	0.0221			
			5	1364000	0.3000	0.1221			= 1.5"
3	200.00	15.35	1	545000	0.4000	0.0191	362.50	362.28	0.22
			2	818000	0.4000	0.0483			
			3	1364000	0.4000	0.0206			
			4	1364000	0.4000	0.0185			
			5	1364000	0.3000	0.1141			= 1.4"
4	200.00	28.67	1	545000	0.4000	0.0169	362.50	362.32	0.18
			2	818000	0.4000	0.0334			
			3	1364000	0.4000	0.0148			
			4	1364000	0.4000	0.0142			
			5	1364000	0.3000	0.1041			= 1.2"
5	200.00	42.00	1	545000	0.4000	0.0045	362.50	362.37	0.13
			2	818000	0.4000	0.0144			
			3	1364000	0.4000	0.0092			
			4	1364000	0.4000	0.0101			
			5	1364000	0.3000	0.0931			= 1.1"

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

actual ZZ = Z - 350

Ignore elastic Settlement in Strata IIa

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RKK RW6 & 16-149
1-27-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	200.00	-11.30	362.50	0.32	362.18
2	200.00	2.02	362.50	0.28	362.22
3	200.00	15.35	362.50	0.25	362.25
4	200.00	28.67	362.50	0.21	362.29
5	200.00	42.00	362.50	0.14	362.36

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

actual EL = Z - 300

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SR 1/I-95 Interchange 103-059-27U 1/19/2009
Retaining Wall 6 and 16 Settlement Results

	Settlement (ft)		
Point	Elastic	Consolidation	Total
1	0.13	0.31	0.44
2	0.12	0.28	0.40
3	0.11	0.24	0.35
4	0.10	0.20	0.30
5	0.09	0.14	0.23
6	0.12	0.32	0.44
7	0.11	0.24	0.35
8	0.11	0.18	0.29
9	0.10	0.14	0.24
10	0.09	0.09	0.18
11	0.13	0.32	0.45
12	0.12	0.28	0.40
13	0.11	0.25	0.36
14	0.10	0.21	0.31
15	0.09	0.14	0.23

	Settlement (in)		
Point	Elastic	Consolidation	Total
1	1.5	3.7	5.3
2	1.5	3.4	4.8
3	1.4	2.9	4.2
4	1.2	2.4	3.6
5	1.1	1.7	2.8
6	1.4	3.8	5.3
7	1.4	2.9	4.2
8	1.3	2.2	3.4
9	1.2	1.7	2.8
10	1.0	1.1	2.1
11	1.5	3.8	5.4
12	1.5	3.4	4.8
13	1.4	3.0	4.4
14	1.2	2.5	3.8
15	1.1	1.7	2.8

Max = 5.4"
Min = 2.1"

	RW 6 and 16 Differential Settlement							
	Front RW 16		Near Back RW 16		Front RW 6		Back RW 6	
	10 to 5	5 to 15	9 to 4	4 to 14	7 to 2	2 to 12	6 to 1	1 to 11
Inches	0.7	0.0	0.8	0.1	0.6	0.0	0.0	0.1
Ratio	1/442	0	1/371	1/2427	13/6701	0	0	3/8242

All differential settlements meet the AASHTO tolerance of 1/100.

For pt locations see PS 10

RKK RW6 & 16-150

1-27-09

CALCULATION CHECKLIST

Project: **SR 1/I-95 Interchange** Comm. No.: **103-059-27U**

Title of Calculation Set: RW 7 & 8 Analysis

Project Manager: **EMK/JLT**

Calculations Prepared By: **SAB**

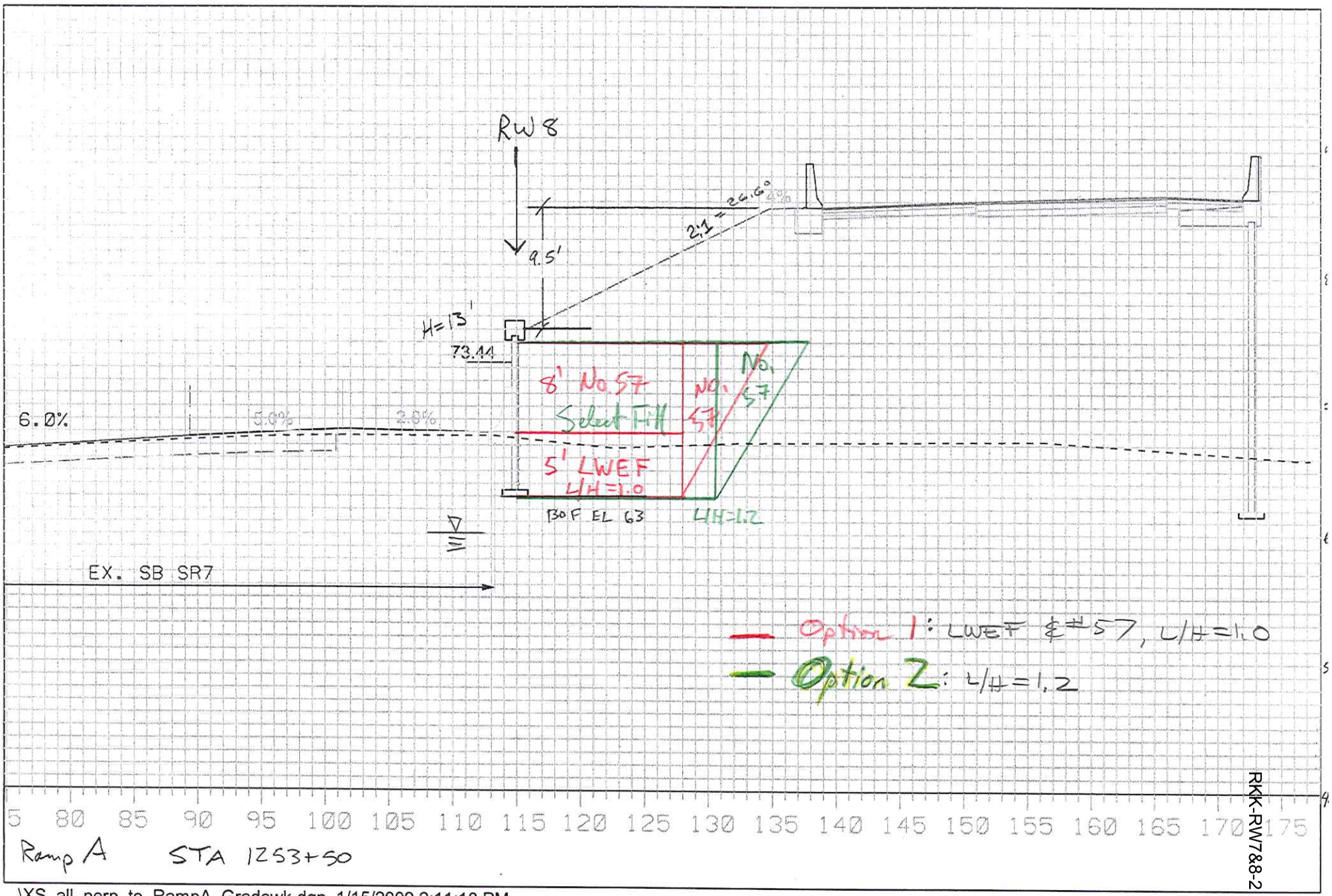
Calculation Checked By:

Computer Programs / Files: **Slope/W**, MSEW 3.0, FoSSA 2.0

Initial	Date	
		Subsurface Characterization approved by Project Manager
SAB	1/19/09	Calculations are neat, legible and understandable.
SAB	1/19/09	Table of Contents is provided.
SAB	1/19/09	Heading on each page filled out
SAB	1/19/09	The first page contains purpose of the calculation.
SAB	1/19/09	Symbols are defined.
SAB	1/19/09	References for data, methods, formulas and computer program names and version numbers are given.
SAB	1/19/09	Assumptions are listed and those that need to be verified later are Flagged.
SAB	1/19/09	Headings on front sheet of each set of computer input and output.
SAB	1/19/09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JLT	1-19-09	All calculations checked and each calculation sheet initialed by checker.
EMK	2/9/09	Calculation set reviewed by Project Manager.
		Has this calculation been superseded? Reference new calculation, if applicable.

This sheet is to be prepared by the originator of the calculation and attached to the front of the calculation set.

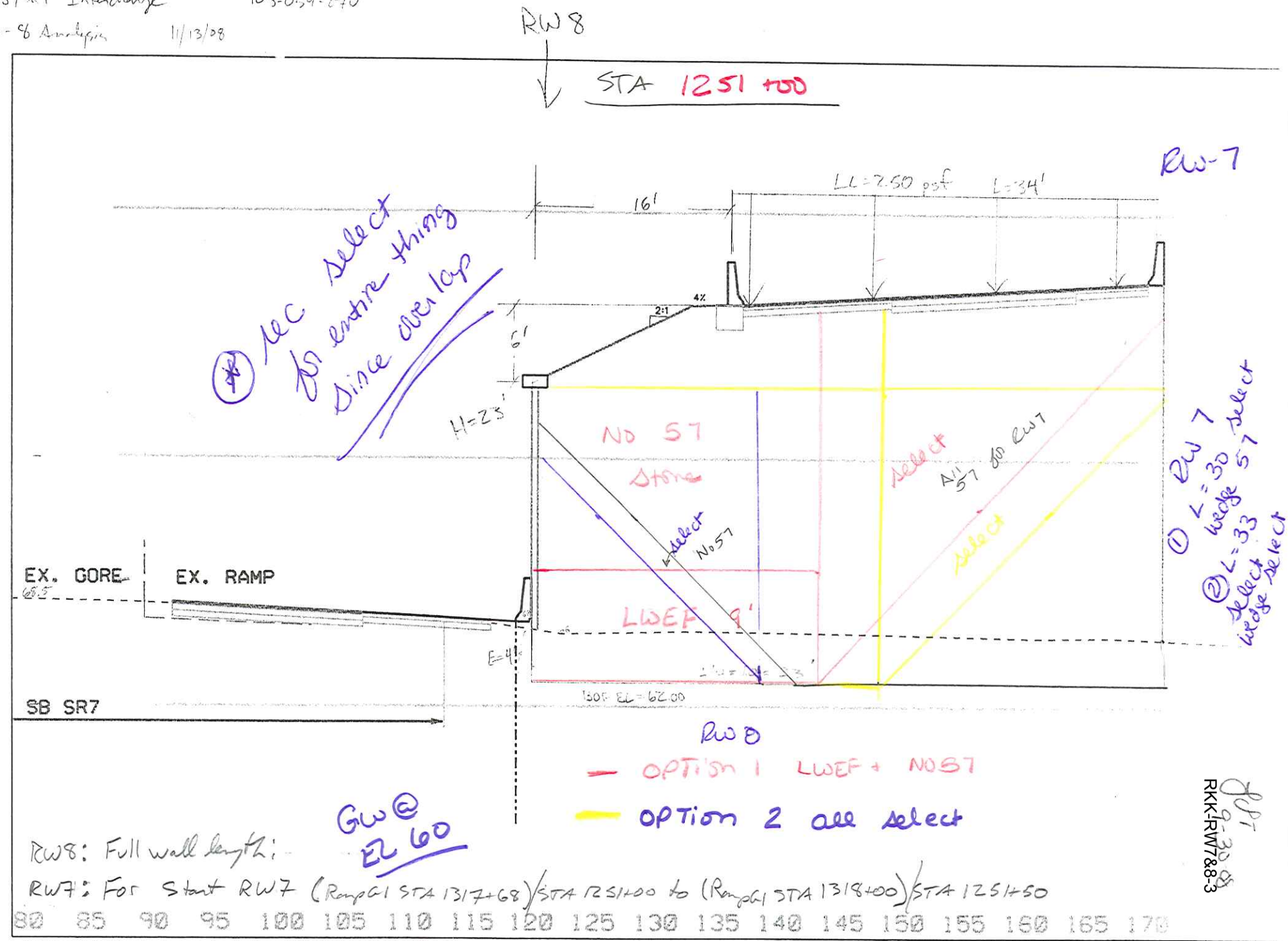
RW 8 Analysis " 103-059-270 1/15/09



...\XS_all_perp_to_RampA_Gradewk.dgn 1/15/2009 2:11:18 PM

I-45/SR1 Interchange 103-059-270

RW-8 Analysis 11/13/08



(*) Rec select for entire thing since overlap

GW @ EL 60

RW8: Full wall length:

RW7: For Start RW7 (Ramp C1 STA 1317+68)/STA 1251+00 to (Ramp C1 STA 1318+00)/STA 1251+50

80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170

...\InRoads\XS_study_geotech.dgn 9/18/2008 7:54:03 AM

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject I-95/SR1 Interchange
Ramp C1 Retaining Wall 7 Analysis
Cm. No. 103-054-27U

Prepared By SAB Date 9/17/08 Checked By SJT Date 9-30-08
REV 11/13/08 SJT 1-11-09
EMK 2/9/09

Objective: To evaluate the external and global stability of Ramp C1 Retaining Wall 7. This wall is proposed to be a mechanically stabilized earth (MSE) wall.

References: 1) AASHTO LRFD Bridge Design Specifications, 4th ed.
2) FHWA Publication No. FHWA-NHI-00-043 "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines."

Summary: STA 1251+50

UNDRAINED ANALYSIS
Foundation Soil
γ = 130 pcf, ϕ = 0°, S_u = 2,000 psf

Bearing Resistance, q_R = 6,684 psf CDR = 1.13

Sliding Resistance, CDR = 1.89

Option 1

* L/H = 1.0 must be used. = 30 ft
* No. 57 Stone must be used in reinforcement zone.

Option 2 (Recommended Option)

* L/H = 1.1 must be used = 33 ft
* ~~Type B Borrow~~ Select Borrow in reinforced soil zone

DRAINED ANALYSIS
Foundation Soil
γ = 130 pcf, ϕ' = 24°,

Bearing Resistance, q_R = 7,739 psf

Sliding Resistance, CDR = 1.31

w/ Cohesion in Bearing
Soil ϕ = 24°
c = 190 psf

w/o cohesion: (c' = 0)

Option 1:

Foundation Soil: γ = 130 pcf, ϕ' = 24°, c' = 0 psf

Bearing Resistance, q_R = 5,188 psf

Meyerhof Stress, σ_v = 5,112 psf

CDR = 1.01

Sliding Resistance, CDR = 1.33

Option 2

Bearing Resistance, q_R = 6,054 psf

Meyerhof Stress, σ_v = 5,734 psf

CDR = 1.06

Sliding Resistance, CDR = 1.74

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Subject SR1/I-95 RW 7 Analysis
Page 1a of
Cm. No. 103-059-274
Prepared By JST Date 1-11-09 Checked By EMK Date 2/9/09

* Dewatering will be required during Construction as GW is anticipated to be @ Leveling Pad EL.

* Global stability to be checked
* Check Settlement

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Subject I-95/SR1 Interchange
RW 7 Analysis

Page 2 of 30

Cm. No. 103-059-27U

Prepared By SAB Date 9/17/08 Checked By JJT Date 9-30-08
REV 11/13/08 JJT 1-11-09
EMK, 2/9/09

Wall Details: (See attached cross-section, p. 2a)

→ Ramp A STA 1251+50 (Ramp G STA ~1317+80) chosen for analysis (Tallest wall section)

H = 30' Embedment Depth, E = 3' (assumed - minimum on plans)

Reinforcement Length, L = 24' (used; assumed L/H = 0.8 - minimum on plans)

Traffic (LL) Surcharge = 250 psf

BOF EL = EL 62.5

⇒ Check if RW 7 & RW 8 should be analyzed as back-to-back walls:

Per FHWA (Ref 2), p. 178 Eqn. 55, reduce the active thrust if $D < H_1 \tan(45° - \phi/2)$

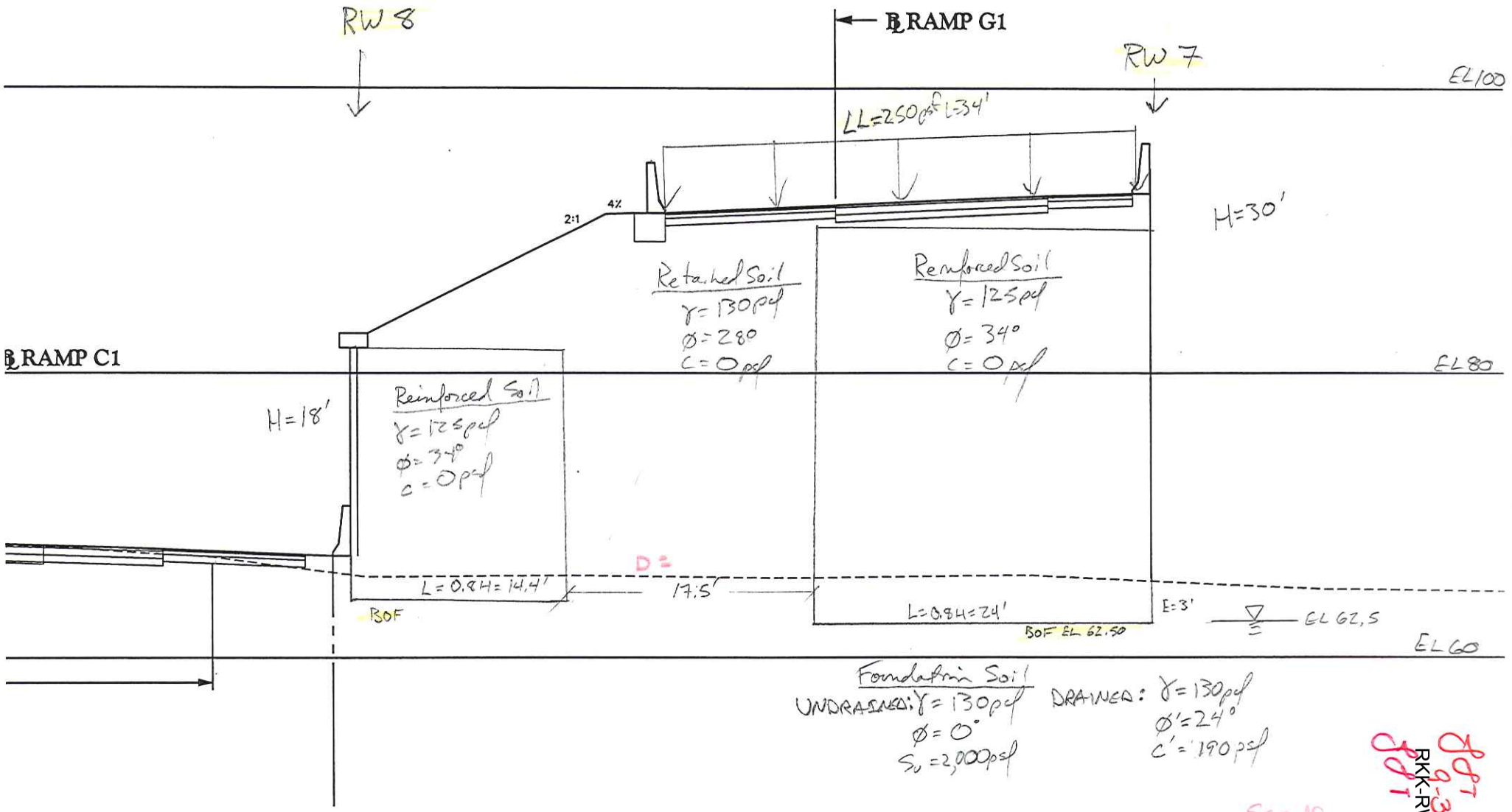
D = distance bt walls H_1 = Wall height (Max), ϕ = Retained soil friction angle

→ Actual D = 17.5' (assuming L/H = 0.8 for both walls)

$H_1 \tan(45 - \phi/2) = 30' \tan(45 - 28/2) = 18' \approx 17.5'$,

→ Do not analyze as back-to-back walls (active thrust not reduced).
WALLS TO BE ANALYZED AS INDEPENDANT WALLS W/ FULL ACTIVE K_a. DUE TO DIFFERENCE IN WALL HEIGHTS, THERE COULD BE SOME OVERLAP, BUT IT WILL BE MINOR, SO TREAT AS INDEPENDANT WALLS.

I-95/SR1 Interchange 103-059-27U 9/17/08
REV 11/13/08



RKK-RW7&8-7
9-30-08
1-11-09

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Subject I-95/SR1 Interchange — RW 7 Analysis
Page 3 of 30
Cm. No. 103-059-270
Prepared By SAB Date 9/17/08 Checked By JST Date 9-30-08
REV 11/13/08 JST 1-11-09
EMK 2/9/09

Soils: (See attached fence diagram, p. 3a

Soil	γ_T (pcf)	DRAINED ϕ' (deg)	DRAINED c' (psf)	UNDRAINED S_u (psf)	EL (ft)	
Reinforced Soil	125	34	0	-		Select Borrow
Retained Soil	130	28	0	-		TYPE F BORROW
Foundation Soil (IIa) *1	130	24	190	2,000	62.5 - 39	
IIb	130	34	0	-	39 - 29	
IIa	130	18	0	2,500	29 - 19	
IIb	130	34	0	-	19 ...	
Water	62.4				62.5	

*, This stratum was modified from the general site soil parameters based on laboratory testing within this stratum from Boring IBR-04:

UU Test: S_u = 2,013 psf (U-1) DS Test: ϕ' = 24°, c' = 760 psf

* GW ≈ @ EL of Leveling Pad *

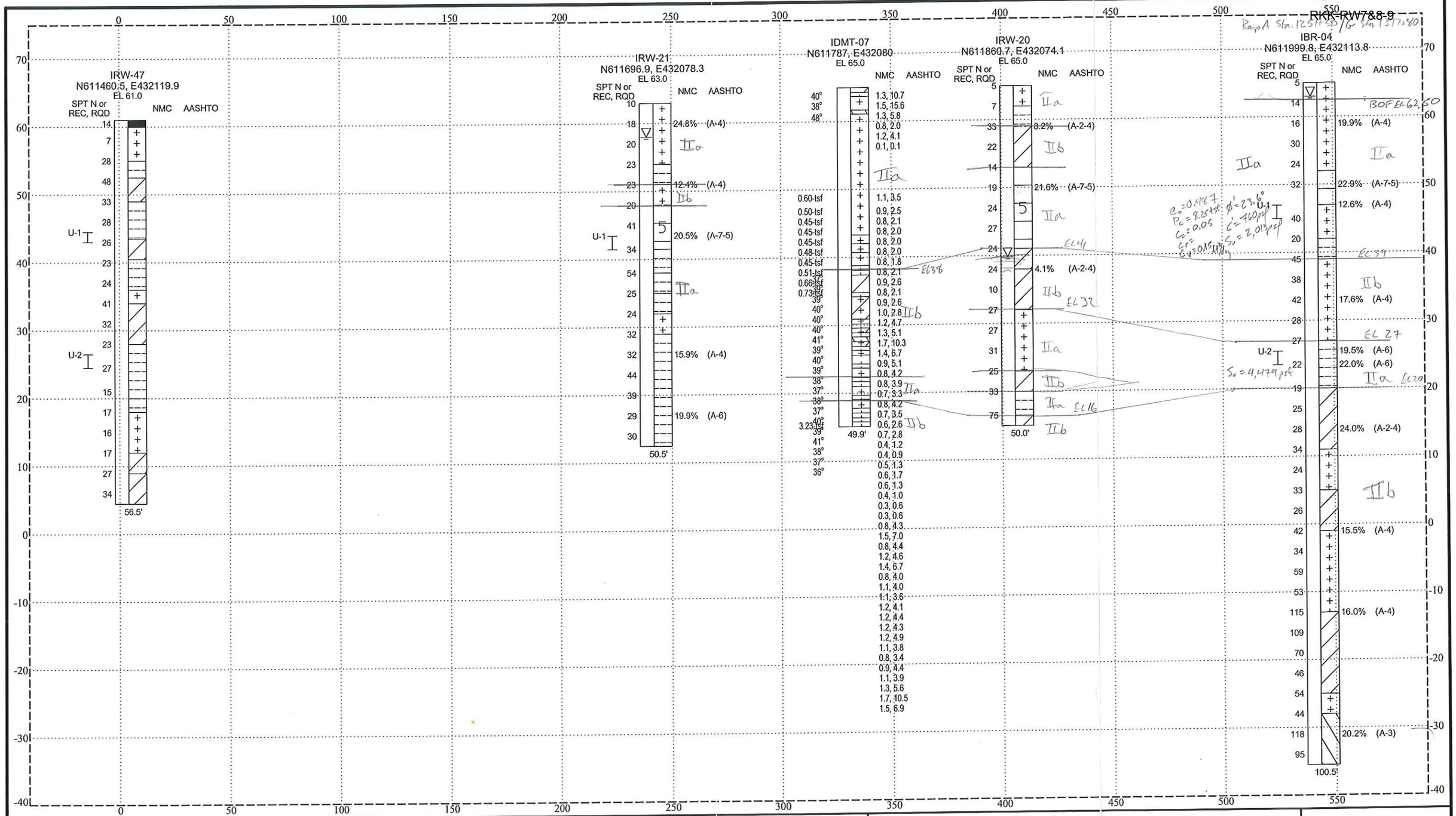
SR1/I-95 Interchange 103-059-270

11/13/08

3a

SPT 1-11-09

RKK-RW7&8-9



AASHTO SOIL KEY

A-1-a	A-2-5	A-5	A-8
A-1-b	A-2-6	A-6	Asphalt
A-3	A-2-7	A-7-5	FILL
A-2-4	A-4	A-7-6	Decomposed Rock

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data

Retaining Wall 7

Figure No.

Drawn: SAB | Approved: | Date: 9/17/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 9/17/08

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject SR1/I-95 Interchange — RW 7 Analysis
Page 4 of
Cm. No. 103-059-270
Prepared By SAB Date 11/13/08 Checked By JST Date 1-11-09

External Stability: Performed using MSEW 3.0 (See attached MSEW output, p. 5-22)
* See p. 10 for LRFD Resistance Factors used.

Undrained: (p. 5-13)
From Analysis: To get a Capacity to Demand Ratio (CDR) > 1.0, L/H must be increased to L/H = 1.0 = 30'. (for bearing resistance)

Results: Bearing Capacity: Factored bearing resistance, q_R = 6,684 psf
Meyerhof Stress = 5,896 psf => CDR = 1.13 > 1.0 ✓OK

Sliding: CDR = 1.89 > 1.0 ✓OK

Overturning: CDR = 5.30 > 1.0 ✓OK

Drained: (See p. 19 for LRFD Resistance Factors used) (p. 14-22)
Analysis: L/H must be 1.0 for Undrained case → evaluate for Drained conditions.

Results: Bearing Capacity: Factored bearing resistance, q_R = 7,739 psf
Meyerhof Stress = 5,896 psf => CDR = 1.31 ✓OK
Sliding: CDR = 1.76 > 1.0 ✓OK
Overturning: CDR = 5.30 > 1.0 ✓OK

w/o cohesion: Option 1 * Need 57 stone in reinforcement zone w/ L/H = 1.0 * (see p. 23-31)

Bearing Capacity: q_R = 5,188 psf, σ_v = 5,112 psf > CDR = 1.01 > 1.0 ✓OK

Sliding Resistance: CDR = 1.33 > 1.0 ✓OK
Overturning Resistance: CDR = 4.45 > 1.0 ✓OK

More cost effective. ← Option 2 * DelDOT SELECT Borrow in reinforcement zone w/ L/H extended to L/H = 1.1 (see p. 32-40)

Bearing Capacity: q_R = 6,054 psf, σ_v = 5,734 psf > CDR = 1.06 > 1.0 ✓OK

Sliding Resistance: CDR = 1.74 > 1.0 ✓OK
Overturning Resistance: CDR = 6.42 > 1.0 ✓OK

5

RKK-RW7&8-11

JJT 1-11-09

EMK 2/9/09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: Ramp A STA 1251+50

Description:

Retaining Wall 7 - Ramp G1 UNDRAINED Analysis H = 30' L/H = 1.0

Company's information:

BC COR=1.13

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....gn\RW7 UNDRAINED.BEN
Original date and time of creating this file:

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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License number MSEW-301874

6

RKK-RW7&8-12
GT 1-11-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select Borrow
Design value of internal angle of friction, ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ	130.0 lb/ft ^{3}	Common Borrow
Design value of internal angle of friction, ϕ	28.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}	
Equivalent internal angle of friction, $\phi_{equiv.}$	0.0 °	Strata IIa
Equivalent cohesion, $c_{equiv.}$	2000.0 lb/ft ^{2}	

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3610 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 5.14 N γ= 0.00

SEISMICITY

Not Applicable

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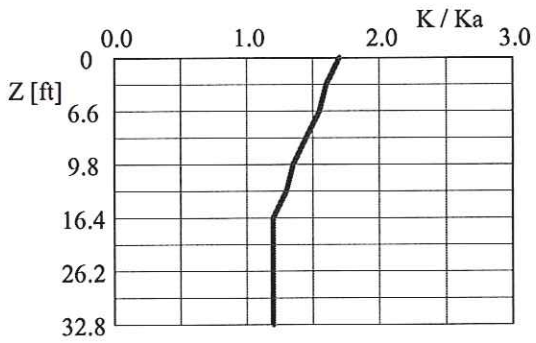
INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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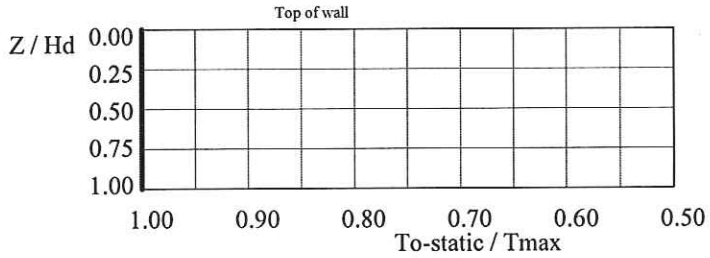
RKK-RW7&8-14 JLT 1-11-09

8

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK-RW7&8-15
1-11-09

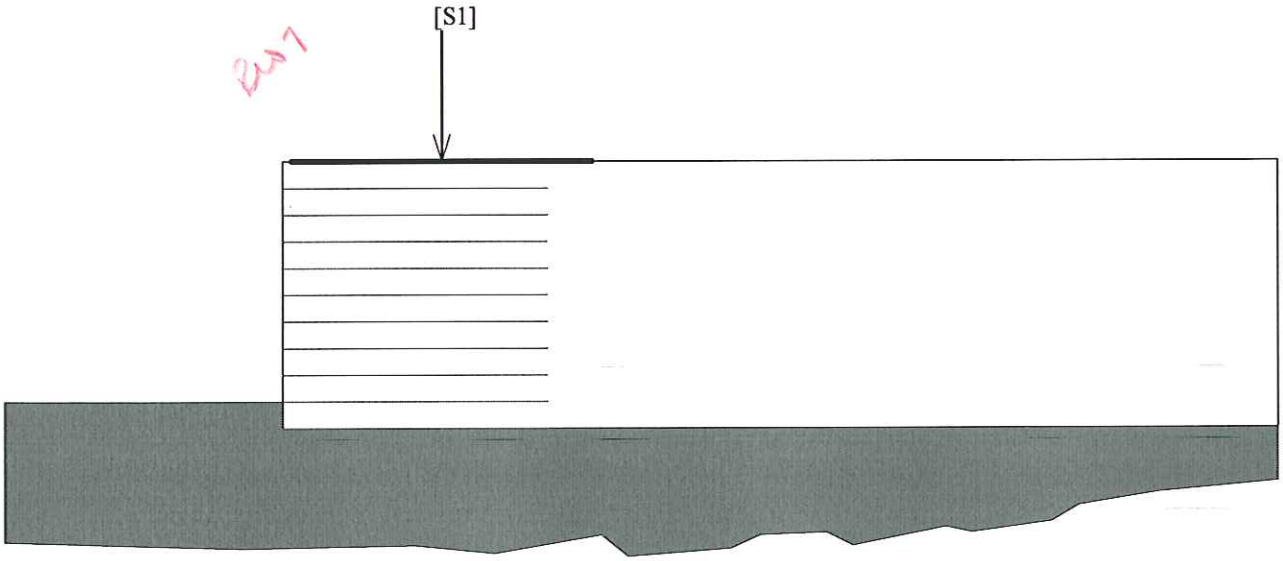
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	30.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 27.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=34.0 [ft]. Distance of center of footing from wall face, d = 18.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35		
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00		
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75		
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50		
Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00
Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
	ϕ_b	0.65		0.65

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RKK-RW7&8-17 JBT 1-11-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.13, Meyerhof stress = 5896 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.890, Eccentricity, e/L = 0.0943, CDR-overturning = 5.30

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	30.00	1	N/A	1.36	1.51	1.508	2.746	2.380	0.0943	---
2	3.00	30.00	1	N/A	0.73	0.82	0.816	1.258	2.644	0.0764	---
3	6.00	30.00	1	N/A	0.83	0.92	0.918	1.177	2.973	0.0604	---
4	9.00	30.00	1	N/A	0.94	1.05	1.047	1.094	3.396	0.0463	---
5	12.00	30.00	1	N/A	1.06	1.18	1.176	1.135	3.974	0.0341	---
6	15.00	30.00	1	N/A	1.20	1.33	1.335	1.233	4.764	0.0237	---
7	18.00	30.00	1	N/A	1.43	1.59	1.590	1.409	5.943	0.0152	---
8	21.00	30.00	1	N/A	1.79	1.99	1.991	1.542	7.899	0.0086	---
9	24.00	30.00	1	N/A	2.55	2.83	2.829	1.668	11.768	0.0039	---
10	27.00	30.00	1	N/A	4.32	4.80	4.804	1.593	23.053	0.0010	---

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RKK-RW7&8-18

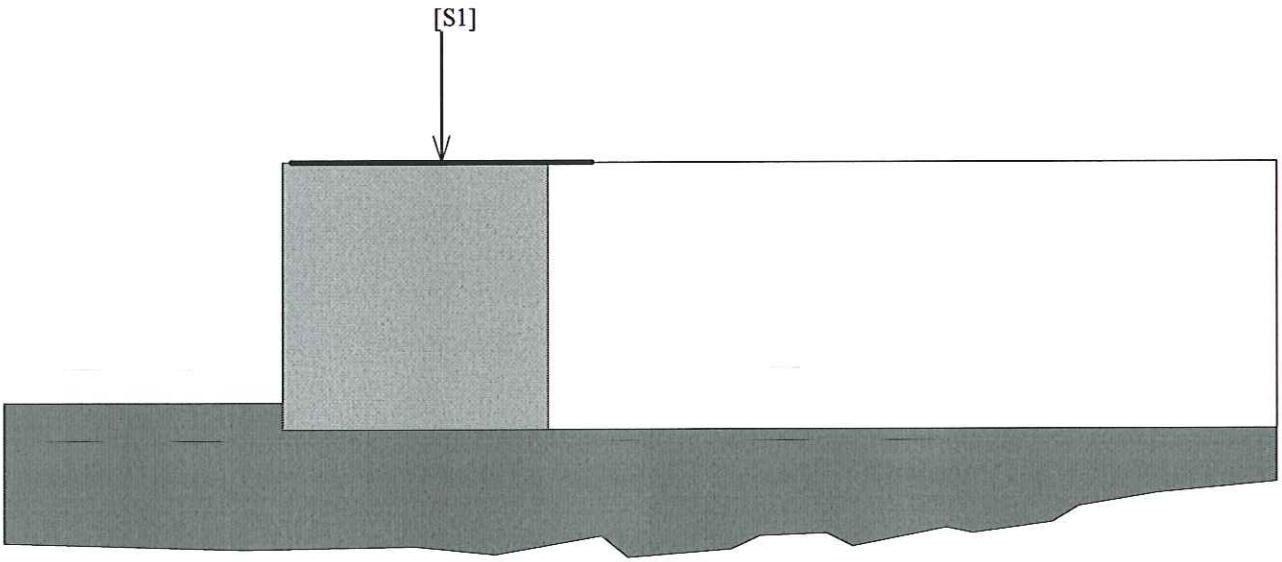
GJT 1-11-09

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	6684	N/A	[lb/ft ²]
Meyerhof stress, σ_V	5896.0	N/A	[lb/ft ²]
Eccentricity, e	2.09	N/A	[ft]
Eccentricity, e/L	0.070	N/A	
CDR calculated	1.13	N/A	
Base length	30.00	N/A	[ft]

$q_{ult} > \sigma_V$ ∴ ok

w/ $L/H = 1.0 = 30'$



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW7&8-19
JPT 1-11-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.890

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	30.00	2.380	N/A	1	---
2	3.00	30.00	2.644	N/A	1	---
3	6.00	30.00	2.973	N/A	1	---
4	9.00	30.00	3.396	N/A	1	---
5	12.00	30.00	3.974	N/A	1	---
6	15.00	30.00	4.764	N/A	1	---
7	18.00	30.00	5.943	N/A	1	---
8	21.00	30.00	7.899	N/A	1	---
9	24.00	30.00	11.768	N/A	1	---
10	27.00	30.00	23.053	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0943; Overturning: CDR-static = 5.30

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	30.00	0.0943	N/A	1	---
2	3.00	30.00	0.0764	N/A	1	---
3	6.00	30.00	0.0604	N/A	1	---
4	9.00	30.00	0.0463	N/A	1	---
5	12.00	30.00	0.0341	N/A	1	---
6	15.00	30.00	0.0237	N/A	1	---
7	18.00	30.00	0.0152	N/A	1	---
8	21.00	30.00	0.0086	N/A	1	---
9	24.00	30.00	0.0039	N/A	1	---
10	27.00	30.00	0.0010	N/A	1	---

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14

RKK-RW7&8-20
1-11-09
EM 2/9/09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: Ramp A STA 1251+50

Description: (w/ cohesion)

Retaining Wall 7 - Ramp G1 DRAINED Analysis H = 30' L/H = 1.0

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....\RW7 DRAINED L=H.BEN
Original date and time of creating this file:

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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RKK-RW7&8-21

SLT 1-11-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select Fill
Design value of internal angle of friction, ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ	130.0 lb/ft ^{3}	Common Borrow
Design value of internal angle of friction, ϕ	28.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}	Strata IIa
Equivalent internal angle of friction, $\phi_{equiv.}$	24.0 °	
Equivalent cohesion, $c_{equiv.}$	190.0 lb/ft ^{2}	

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3610 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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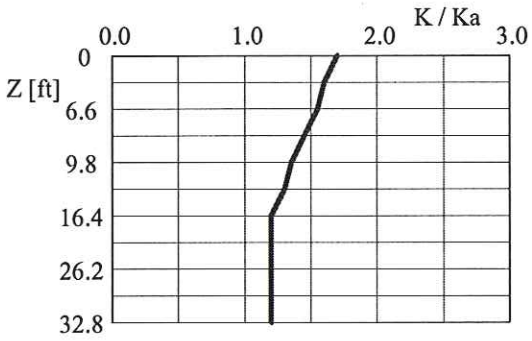
RKK-RW7&8-22

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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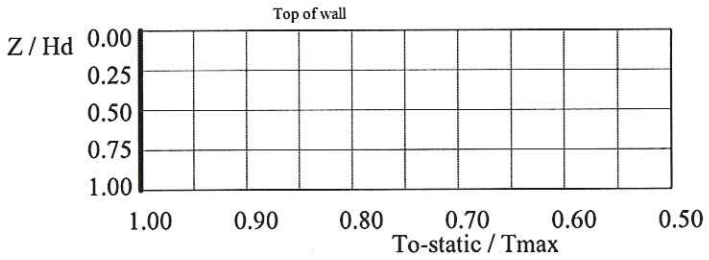
RKK-RW7&8-23 JDT 1-11-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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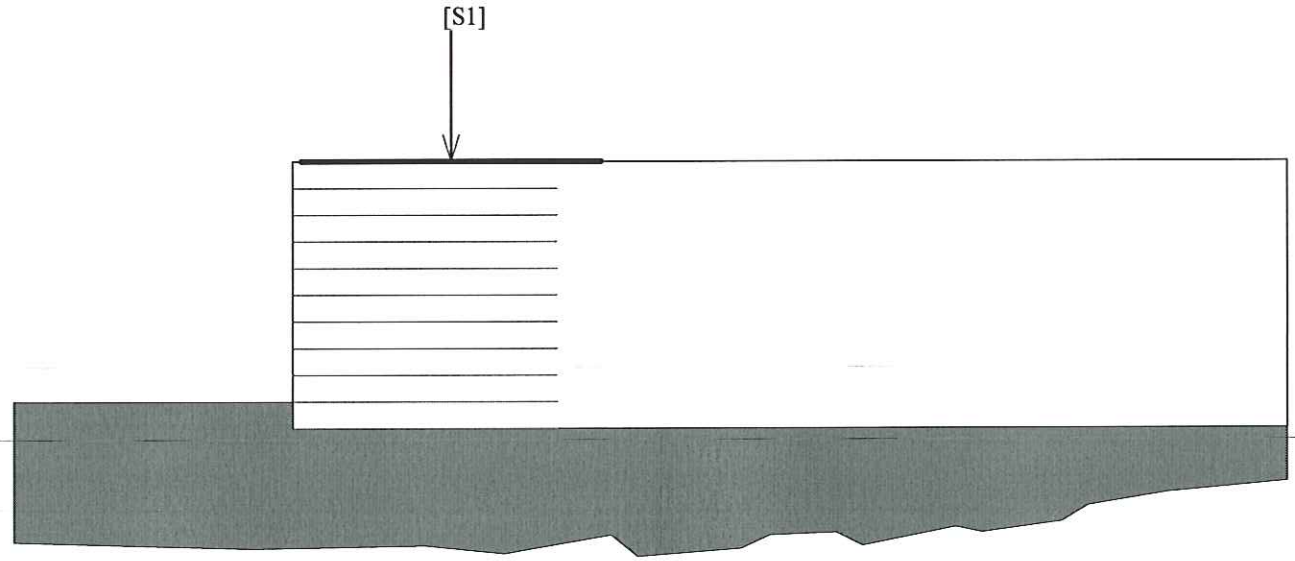
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	30.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 27.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=34.0 [ft]. Distance of center of footing from wall face, d = 18.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW7&8-25 SDT 1-11-09

AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35		
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00		
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75		
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50		
Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35
Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:		$\gamma_{p\text{-}EH}$	1.50	
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):		$(\gamma_{p\text{-}EH})_{EQ}$	1.50	
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):		$\gamma_{p\text{-}EQ}$	1.00	
Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00
Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
	ϕ_b	0.65		0.65

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RKK-RW7&8-26 JDT 1-11-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.31, Meyerhof stress = 5896 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.757, Eccentricity, e/L = 0.0943, CDR-overturning = 5.30

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	30.00	1	N/A	1.36	1.51	1.508	2.746	2.380	0.0943	---
2	3.00	30.00	1	N/A	0.73	0.82	0.816	1.258	2.644	0.0764	---
3	6.00	30.00	1	N/A	0.83	0.92	0.918	1.177	2.973	0.0604	---
4	9.00	30.00	1	N/A	0.94	1.05	1.047	1.094	3.396	0.0463	---
5	12.00	30.00	1	N/A	1.06	1.18	1.176	1.135	3.974	0.0341	---
6	15.00	30.00	1	N/A	1.20	1.33	1.335	1.233	4.764	0.0237	---
7	18.00	30.00	1	N/A	1.43	1.59	1.590	1.409	5.943	0.0152	---
8	21.00	30.00	1	N/A	1.79	1.99	1.991	1.542	7.899	0.0086	---
9	24.00	30.00	1	N/A	2.55	2.83	2.829	1.668	11.768	0.0039	---
10	27.00	30.00	1	N/A	4.32	4.80	4.804	1.593	23.053	0.0010	---

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RKK-RW7&8-27

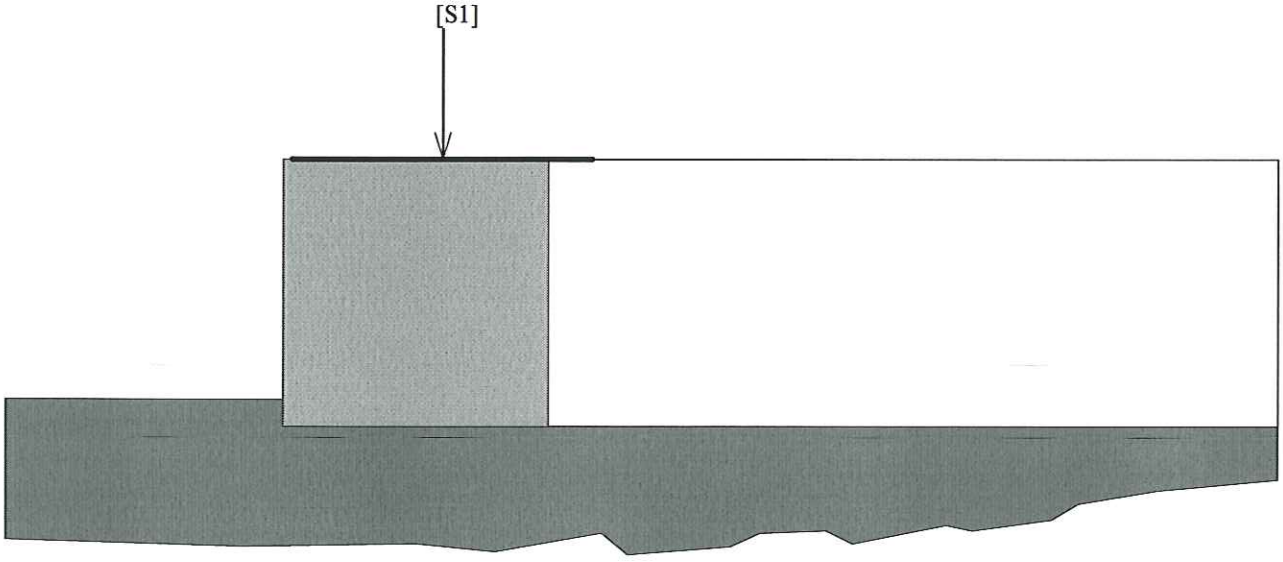
1-11-09

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	7739	N/A	[lb/ft ²]
Meyerhof stress, σ_V	5896.0	N/A	[lb/ft ²]
Eccentricity, e	2.09	N/A	[ft]
Eccentricity, e/L	0.070	N/A	
CDR calculated	1.31	N/A	
Base length	30.00	N/A	[ft]

$q_{ult} > \sigma_V$ ∴ OK

CDR > 1 ∴ OK



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW7&8-28 EPT 1-11-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.757

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	30.00	2.380	N/A	1	---
2	3.00	30.00	2.644	N/A	1	---
3	6.00	30.00	2.973	N/A	1	---
4	9.00	30.00	3.396	N/A	1	---
5	12.00	30.00	3.974	N/A	1	---
6	15.00	30.00	4.764	N/A	1	---
7	18.00	30.00	5.943	N/A	1	---
8	21.00	30.00	7.899	N/A	1	---
9	24.00	30.00	11.768	N/A	1	---
10	27.00	30.00	23.053	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0943; Overturning: CDR-static = 5.30

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	30.00	0.0943	N/A	1	---
2	3.00	30.00	0.0764	N/A	1	---
3	6.00	30.00	0.0604	N/A	1	---
4	9.00	30.00	0.0463	N/A	1	---
5	12.00	30.00	0.0341	N/A	1	---
6	15.00	30.00	0.0237	N/A	1	---
7	18.00	30.00	0.0152	N/A	1	---
8	21.00	30.00	0.0086	N/A	1	---
9	24.00	30.00	0.0039	N/A	1	---
10	27.00	30.00	0.0010	N/A	1	---

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RKK-RW7&8-29

1-11-09

EMIC 2/9/09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: Ramp A STA 1251+50

Description: (Option 1 - No. 57 reinforced soil)

Retaining Wall 7 - Ramp G1 DRAINED Analysis H = 30' L/H = 1.0 Reinforcement Zone = No. 57

Company's information:

$\gamma_{pn} = 1.01$

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN..... .....DRAINED L=H No57.BEN
Original date and time of creating this file: Thu Dec 04 08:48:45 2008

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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RKK-RW7&8-308 1-11-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ		105.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	38.0 °

No 57 Stone

RETAINED SOIL

Unit weight, γ		130.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	28.0 °

Common Borrow

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight,	$\gamma_{equiv.}$	130.0 lb/ft ^{3}
Equivalent internal angle of friction,	$\phi_{equiv.}$	24.0 °
Equivalent cohesion,	$c_{equiv.}$	0.0 lb/ft ^{2}

Strata IIa

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2379 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3610 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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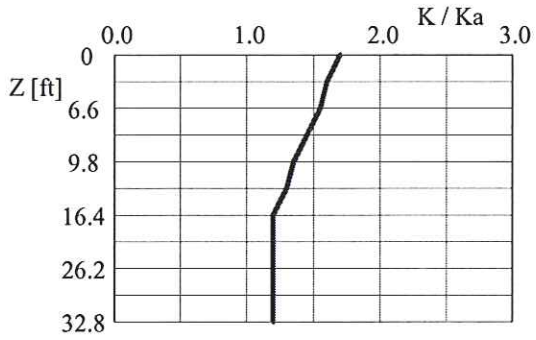
INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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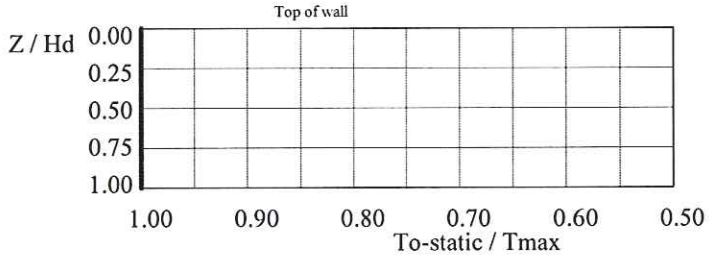
INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK-RW7&8-33
JBT 1-11-09

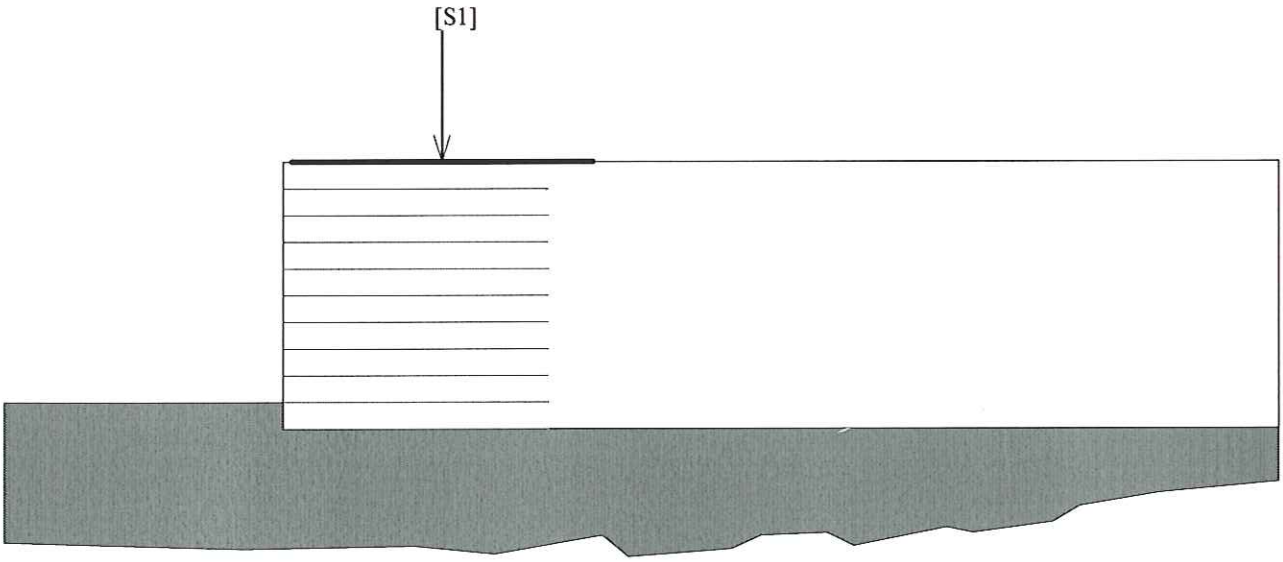
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	30.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 27.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=34.0 [ft]. Distance of center of footing from wall face, d = 18.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35		
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00		
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75		
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50		
Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00
Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
	ϕ_b	0.65		0.65

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RKK-RW7&8-35 PPT 1-11-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.01, Meyerhof stress = 5112 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.325, Eccentricity, e/L = 0.1122, CDR-overturning = 4.45

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	30.00	1	N/A	1.92	2.13	2.132	3.262	2.300	0.1122	---
2	3.00	30.00	1	N/A	1.04	1.15	1.155	1.495	2.555	0.0910	---
3	6.00	30.00	1	N/A	1.17	1.30	1.299	1.399	2.873	0.0719	---
4	9.00	30.00	1	N/A	1.33	1.48	1.480	1.300	3.281	0.0551	---
5	12.00	30.00	1	N/A	1.50	1.66	1.663	1.348	3.841	0.0406	---
6	15.00	30.00	1	N/A	1.70	1.89	1.887	1.465	4.635	0.0282	---
7	18.00	30.00	1	N/A	2.02	2.25	2.247	1.672	5.783	0.0181	---
8	21.00	30.00	1	N/A	2.53	2.81	2.814	1.830	7.685	0.0103	---
9	24.00	30.00	1	N/A	3.59	3.99	3.994	1.978	11.450	0.0046	---
10	27.00	30.00	1	N/A	6.08	6.76	6.755	1.881	22.430	0.0012	---

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RKK-RW7&8-36

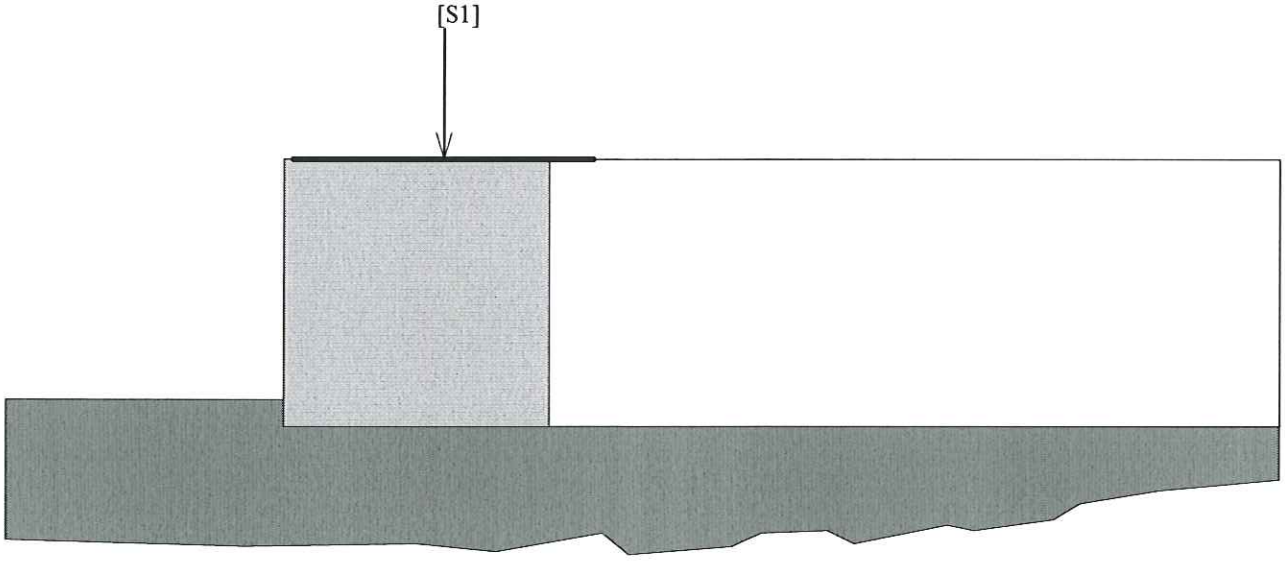
JSP 1-11-09

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	5188	N/A	[lb/ft ²]
Meyerhof stress, σ_V	5112.0	N/A	[lb/ft ²]
Eccentricity, e	2.49	N/A	[ft]
Eccentricity, e/L	0.083	N/A	
CDR calculated	1.01	N/A	
Base length	30.00	N/A	[ft]

$q_{ult} > \sigma_V$ ok

CDR > 1 ok



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW7&8-37 dlf 1-11-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.325

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	30.00	2.300	N/A	1	---
2	3.00	30.00	2.555	N/A	1	---
3	6.00	30.00	2.873	N/A	1	---
4	9.00	30.00	3.281	N/A	1	---
5	12.00	30.00	3.841	N/A	1	---
6	15.00	30.00	4.635	N/A	1	---
7	18.00	30.00	5.783	N/A	1	---
8	21.00	30.00	7.685	N/A	1	---
9	24.00	30.00	11.450	N/A	1	---
10	27.00	30.00	22.430	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1122; Overturning: CDR-static = 4.45

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	30.00	0.1122	N/A	1	---
2	3.00	30.00	0.0910	N/A	1	---
3	6.00	30.00	0.0719	N/A	1	---
4	9.00	30.00	0.0551	N/A	1	---
5	12.00	30.00	0.0406	N/A	1	---
6	15.00	30.00	0.0282	N/A	1	---
7	18.00	30.00	0.0181	N/A	1	---
8	21.00	30.00	0.0103	N/A	1	---
9	24.00	30.00	0.0046	N/A	1	---
10	27.00	30.00	0.0012	N/A	1	---

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RKK-RW7&8-38

1-11-09

EMK 2/9/09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: Ramp A STA 1251+50

Description: (Option 2 Select Soil in reinforced Zone,

Retaining Wall 7 - Ramp G1 DRAINED Analysis H = 30' L/H = 1.1

CDR = 1.06

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....7 DRAINED L=1.1H.BEN
Original date and time of creating this file: Fri Dec 12 07:16:19 2008

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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RKK-RW7&8-39 JPT 1-11-09

SOIL DATA

REINFORCED SOIL

Unit weight,	γ	125.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	34.0 °

Select Soil

RETAINED SOIL

Unit weight,	γ	130.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	28.0 °

Common Borrow

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight,	$\gamma_{equiv.}$	130.0 lb/ft ^{3}
Equivalent internal angle of friction,	$\phi_{equiv.}$	24.0 °
Equivalent cohesion,	$c_{equiv.}$	0.0 lb/ft ^{2}

Strata IIa

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3610 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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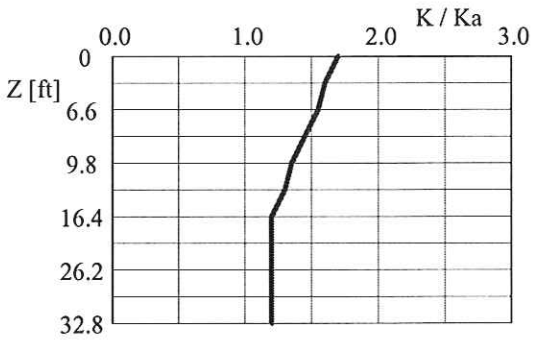
RKK-RW7&8-40 BBT 1-11-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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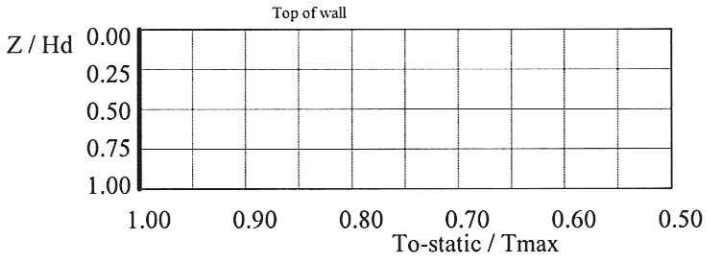
INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK-RW7&8-42 JBT 1-11-09

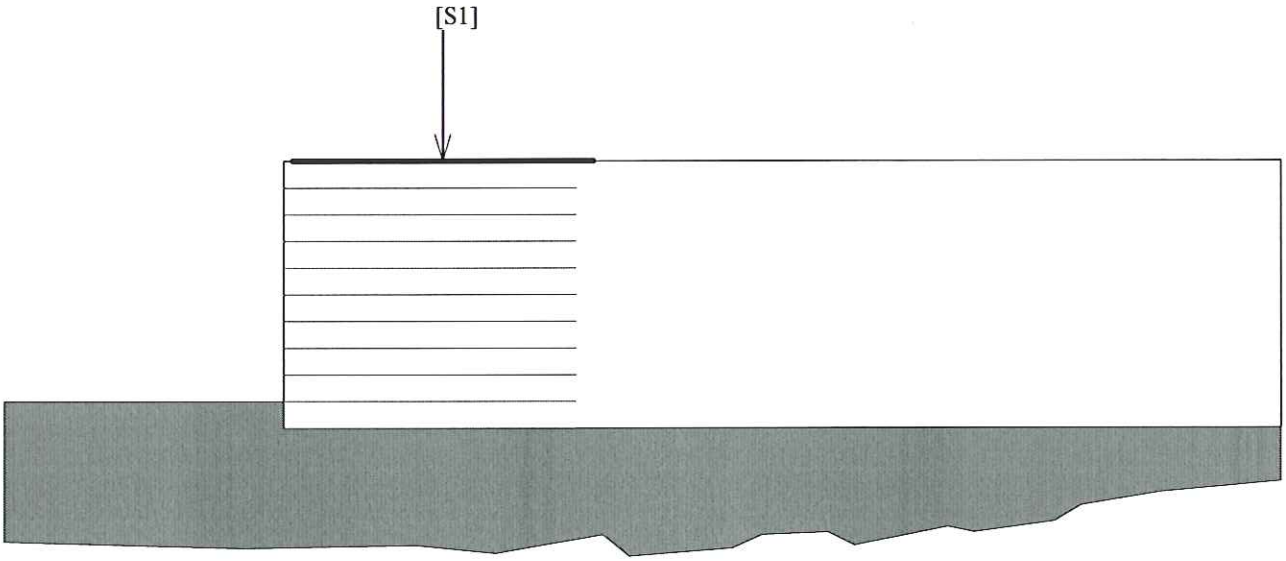
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	30.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 27.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=34.0 [ft]. Distance of center of footing from wall face, d = 18.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35		
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00		
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75		
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50		
Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35
Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50		
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50		
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00		

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00
Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
	ϕ_b	0.65		0.65

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RKK-RW7&8-44 BBT 1-11-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.06, Meyerhof stress = 5734 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.737, Eccentricity, e/L = 0.0778, CDR-overturning = 6.42

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	33.00	1	N/A	1.36	1.51	1.508	3.020	2.620	0.0778	---
2	3.00	33.00	1	N/A	0.73	0.82	0.816	1.392	2.911	0.0631	---
3	6.00	33.00	1	N/A	0.83	0.92	0.918	1.311	3.273	0.0499	---
4	9.00	33.00	1	N/A	0.94	1.05	1.047	1.228	3.739	0.0382	---
5	12.00	33.00	1	N/A	1.06	1.18	1.176	1.284	4.378	0.0281	---
6	15.00	33.00	1	N/A	1.20	1.33	1.335	1.410	5.248	0.0196	---
7	18.00	33.00	1	N/A	1.43	1.59	1.590	1.610	6.551	0.0125	---
8	21.00	33.00	1	N/A	1.79	1.99	1.991	1.763	8.711	0.0071	---
9	24.00	33.00	1	N/A	2.55	2.83	2.829	1.906	12.990	0.0032	---
10	27.00	33.00	1	N/A	4.32	4.80	4.804	1.820	25.486	0.0008	---

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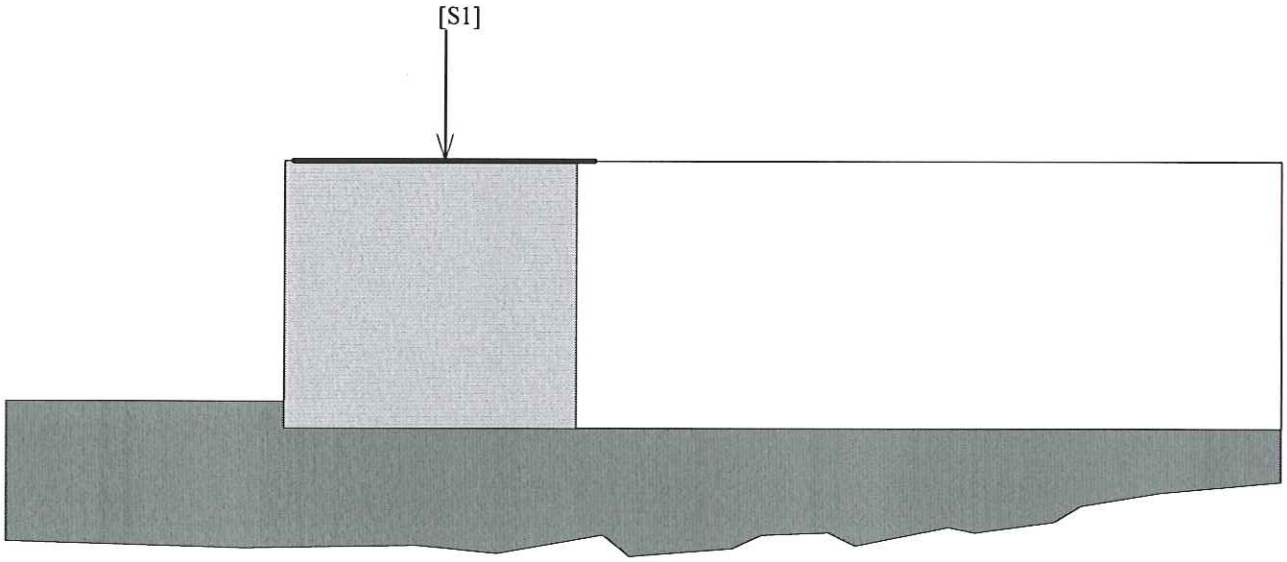
RKK-RW7&8-45 SBT 1-11-09

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	6054	N/A	[lb/ft ²]
Meyerhof stress, σ_V	5734.1	N/A	[lb/ft ²]
Eccentricity, e	1.90	N/A	[ft]
Eccentricity, e/L	0.057	N/A	
CDR calculated	1.06	N/A	
Base length	33.00	N/A	[ft]

$q_{ult} > \sigma_V$ ∴ OK

CDR > 1 ∴ OK



SCALE:

0 2 4 6 8 10[ft]

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DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.737

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	33.00	2.620	N/A	1	---
2	3.00	33.00	2.911	N/A	1	---
3	6.00	33.00	3.273	N/A	1	---
4	9.00	33.00	3.739	N/A	1	---
5	12.00	33.00	4.378	N/A	1	---
6	15.00	33.00	5.248	N/A	1	---
7	18.00	33.00	6.551	N/A	1	---
8	21.00	33.00	8.711	N/A	1	---
9	24.00	33.00	12.990	N/A	1	---
10	27.00	33.00	25.486	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0778; Overturning: CDR-static = 6.42

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	33.00	0.0778	N/A	1	---
2	3.00	33.00	0.0631	N/A	1	---
3	6.00	33.00	0.0499	N/A	1	---
4	9.00	33.00	0.0382	N/A	1	---
5	12.00	33.00	0.0281	N/A	1	---
6	15.00	33.00	0.0196	N/A	1	---
7	18.00	33.00	0.0125	N/A	1	---
8	21.00	33.00	0.0071	N/A	1	---
9	24.00	33.00	0.0032	N/A	1	---
10	27.00	33.00	0.0008	N/A	1	---

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Subject I-95/SR1 Interchange
Ramp G1 - Retaining Wall 8 Analysis
Prepared By SAB Date 9/17/08 RGV 11/13/08 Checked By JJT Date 9-30-08
JJT 1-11-09
EMM 2/9/09

Cm. No. 103-059-270

Objective: To evaluate the external and global stability of Ramp G1 Retaining Wall 8. This wall is proposed to be a mechanically stabilized earth (MSE) wall.

References: 1) AASHTO LRFD Bridge Design Specifications, 4th ed.
2) FHWA Publication No. FHWA-NHI-00-043 "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines."

Summary: Option 1: (L/H=1.0, CLSM) (see p. 1a for Option 2 → Recommended Option)

Ramp A
STA 1251+00 (Ramp C1 STA 1816+00)

Drained case Governs

UNDRAINED ANALYSIS
Foundation Soil
γ = 130 pcf, ϕ = 0°, S_u = 2,000 psf

Bearing Resistance, q_R = 6,084 psf

Sliding Resistance, CDR = 1.17

DRAINED ANALYSIS
Foundation Soil
γ = 130 pcf ϕ' = 24°, c' = ~~100~~ psf / 0 psf

Bearing Resistance, q_R = 3,859 psf ← Governs

Sliding Resistance, CDR = 1.05

⇒ Reinforcement Length extended to L/H = 1.0 for both cases. *
* Reinforced zone = 80 pcf (9' CLSM @ 40 pcf, 14' No. 57 stone @ 105 pcf); Retained Soil = Select Fill *

Ramp A
STA 1253+50 (SR7 SB-STA 1614+50)

Drained Case Governs

Undrained
Foundation Soil
γ = 130 pcf, S_u = 1,500 psf

Bearing Resistance, q_R = 5,013 psf

Sliding Resistance, CDR = 1.11

Drained
Foundation Soil
γ = 130 pcf ϕ' = 24°, c' = ~~100~~ psf / 0 psf

Bearing Resistance, q_R = 2,334 psf ← GOVERNS

Sliding Resistance, CDR = 1.13

* No. 57 stone must be used in the Retained Fill zone.

* 5' CLSM + 8' No. 57 stone must be used in the reinforced zone.

* L/H must be lengthened to L = 1.0H = 13'

Summary: Option 2: (L/H = 1.2, Reinforcement Zone = Select Fill, Retained Wedge = No. 57/Select Fill) ⇐ Recommended Option

STA 1251+00 (Ramp C1 STA 1816+00)

DRAINED ANALYSIS

Foundation Soil
γ = 130 pcf ϕ' = 24° c' = 0 psf

Bearing Resistance, q_R = 5,350 psf

Meyerhof Stress, σ_v = 5,119 psf

→ CDR = 1.05

L = 27.6'

Sliding CDR = 1.93
Overturning CDR = 6.57

* Retained wedge must be Select Fill

STA 1253+50 (SR 7 SB STA ~1614+50)

DRAINED ANALYSIS

Foundation Soil
γ = 130 pcf ϕ' = 24° c' = 0 psf

Bearing Resistance, q_R = 3,150 psf
σ_v = 3,143 psf

⇒ CDR = 1.00

L = 15.6-ft
L/H = 1.20

Sliding Resistance: CDR = 1.81
Overturning Resistance: CDR = 5.30

⇒ RETAINED WEDGE MATERIAL: Ramp C1 STA 1815+60 to 1817+00: Select Fill
Ramp C1 STA 1817+00 to SR 7 SB STA 1616+00: No. 57

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Subject I-95/SR1 Interchange
RW 8 Analysis

Cm. No. 103-059-270

Prepared By SAB Date 9/17/08 Checked By JJT Date 9-30-08
REV: 11/13/08 JJT 1-11-09
AM 2/9/09

Wall Details:

1) Ramp A STA 1251+00 chosen for analysis (Tallest wall section) → See cross-section, p.2a

H = 23' Embedment Depth, E = 4' H includes Pavement for Ramp.

Reinforcement Length, L = 18.4' (Using assumed L/H = 0.8 minimum on plans)

Traffic LL = 250psf

BOF EL = 62.00

⇒ See RW 7 calculations for back-to-back wall analysis check.
(Do not analyze as back-to-back walls)

2) Ramp A STA 1253+50 - check due to combined wall height & backslope rise = 22.5'

H = 13' Embedment Depth, E = 4'

Backslope Rise = 9.5' from top of wall @ 2(H):1(V) = 26.6°

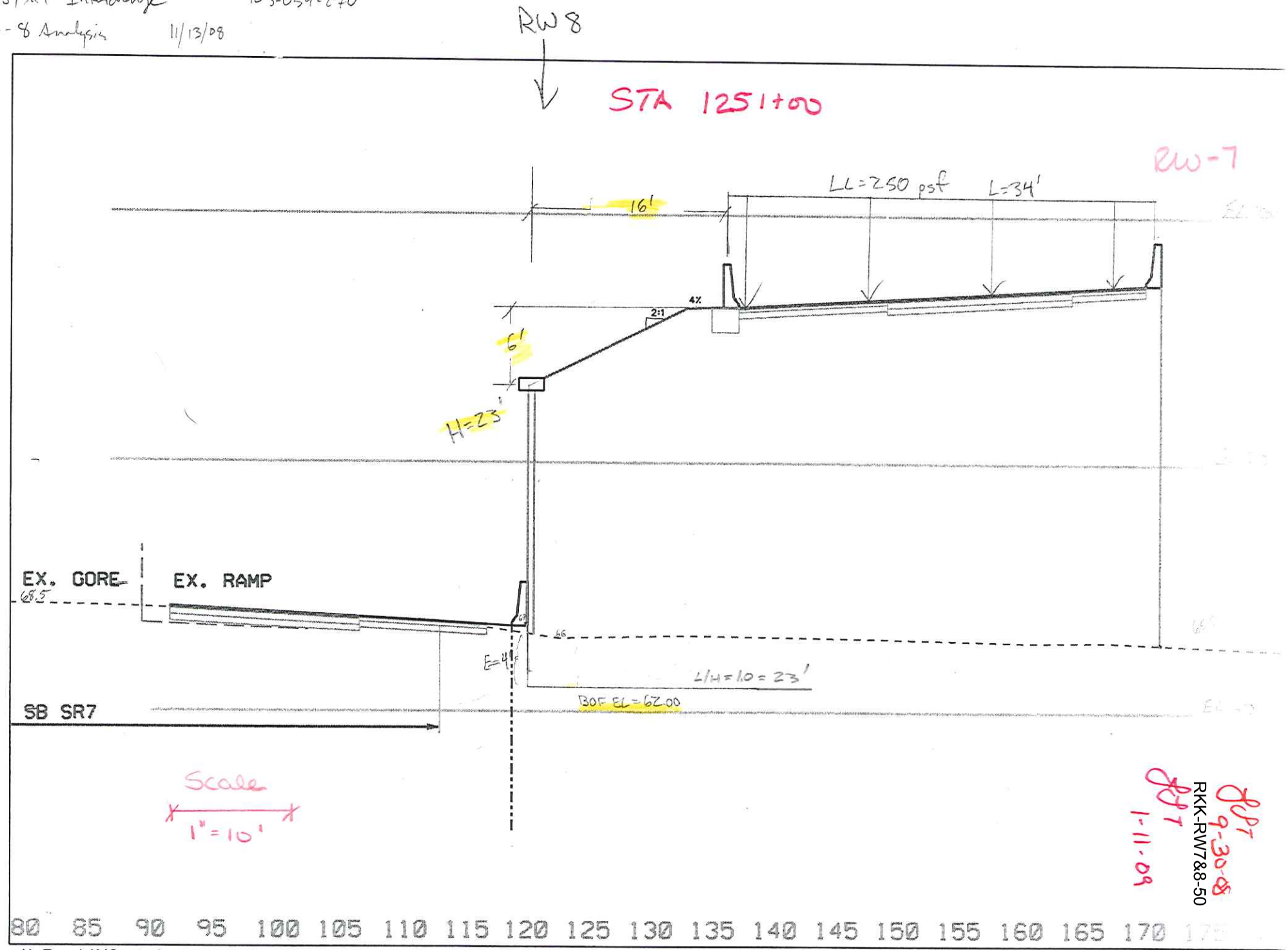
Reinforcement Length, L/H = 0.8 ⇒ 10.4'

Traffic LL = 250 psf

BOF EL = 63.00

I-45/SR1 Interchange 103-059-270

RW-8 Analysis 11/13/08



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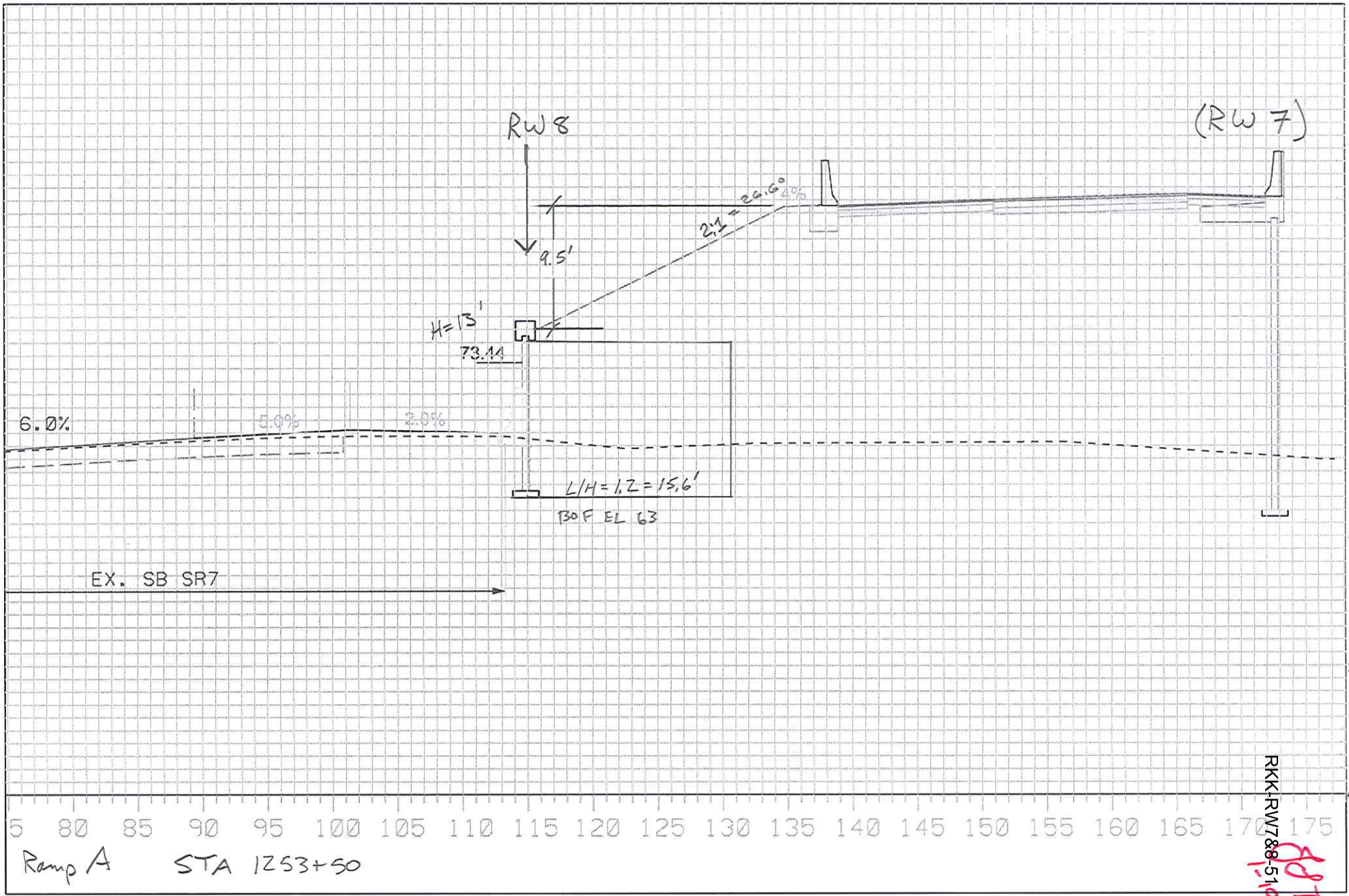
RKK-RW7&8-50

2a

SR1/I-95 Interchange 103-059-270 1/15/09
RW 8 Analysis



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RKK-RW7&8-5

1-19-09

20

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Subject I-95/SR1 Interchange
RW 8 Analysis
Cm. No. 103-059-270

Prepared By SAB Date 9/19/08 Checked By JST Date 9-30-08
REV: 11/13/08 JST 1-11-09
EM 2/9/09

Soils: (See attached fence diagram, p. 3a)

STA 1251+00

Soil STA 1251	γ_t (pcf)	ϕ' (deg)	c' (psf)	S_u (psf)	EL (ft)	
Reinforced Soil	125	34	0	-		Select Fill Common Borrow
Retained Soil	130	28	0	-		
Foundation Soil (IIA) *1	130	24	190	2,000	62-12	
IIb	130	34	0	-	12..	
Water	62.4				60	

*1. This stratum was modified from the general site soil parameters based on laboratory testing from adjacent borings for RW 7.

UU Test: S_u = 2,013 psf. DS Test: ϕ' = 24° c' = 760 psf

IBL-04-U1

STA 1253+50

Same as STA 1251+00, except:

	γ_t (pcf)	ϕ' (deg)	c' (psf)	S_u (psf)	
Retained Soil (~~Select Fill Common Borrow~~)	125	34°	-	-	Select Soil
IIa (Foundation Soil)	130	24	190	1,500	

SR1/I-95 Interchange
RW 8 Analysis

103-059-27U
11/13/08

3a

JDT 1-11-09

RKK-RW7&8-53

RAMP A STA 1256+00
IRW-17
N611512, E432139.2
EL 62.0
SPT N or REC, RQD | STA 1656+90 | NMC | AASHTO
EL 61.50 BOF
14.0% (A-4) LL=27 PI=10
22.6% (A-7-5) LL=46 PI=21
16.6% (A-6) LL=28 PI=11
20.3% (A-4) LL=26 PI=8 EL 12
50.5'
U-1 U-2
IIa IIb

Ramp A STA 1254+20
IRW-18
N611681, E432109.3
EL 63.0
SPT N or STA 1658+20 | NMC | AASHTO
BOF EL 62
20.1% (A-4) LL=24 PI=5
15.2% (A-4) LL=21 PI=6
22.6% (A-6) LL=37 PI=15
18.7% (A-6) LL=40 PI=18
12.4% (A-4) LL=25 PI=8
49.5'
Ramp A STA 1254+00
IIa IIb
γ=130pcf
$S_u = N/7.5$
Lowest N=16 bpf
$S_u = 16/7.5 = 2{,}100$psf

Ramp A STA 1253+40
IDMT-07
N611787, E432080
EL 65.0
STA 1654+70 (Offset)
NMC | AASHTO
0.60-tsf 1.1, 3.5
0.50-tsf 0.9, 2.5
0.45-tsf 0.8, 2.1
0.45-tsf 0.8, 2.0
0.45-tsf 0.8, 2.0
0.48-tsf 0.8, 2.0
0.45-tsf 0.8, 1.8
0.51-tsf 0.8, 2.1
0.66-tsf 0.9, 2.6
0.73-tsf 0.8, 2.1
0.9, 2.6
1.0, 2.8
1.2, 4.7
1.3, 5.1
1.7, 10.3
1.4, 6.7
0.9, 5.1
0.8, 4.2
0.8, 3.9
0.7, 3.3
0.8, 4.2
0.7, 3.5
0.6, 2.6
0.7, 2.8
0.4, 1.2
0.4, 0.9
0.5, 1.3
0.6, 1.7
0.6, 1.3
0.4, 1.0
0.3, 0.6
0.3, 0.6
0.8, 4.3
1.5, 7.0
0.8, 4.4
1.2, 4.6
1.4, 6.7
0.8, 4.0
1.1, 4.0
1.1, 3.6
1.2, 4.1
1.2, 4.4
1.2, 4.3
1.2, 4.9
1.1, 3.8
0.8, 3.4
0.9, 4.4
1.1, 3.9
1.3, 5.6
1.7, 10.5
1.5, 6.9
40° 38° 46° 41° 39° 40° 40° 41° 39° 40° 39° 38° 37° 38° 37° 40° 39° 41° 38° 37° 36°
3.23-tsf
49.9'
IIa IIb
EL38
UC: S_u=3,512 psf
CIUC: ϕ'=8.3° c'=570psf ϕ_r=7.5° c=430psf

IRW-19 STA 1253+00
N611805.2, E432119.9
EL 67.0
SPT N or STA 1654+00 | NMC | AASHTO
15.3% (A-1-a)
28.6% (A-7-5) LL=48 PI=21
19.1% (A-6) LL=39 PI=17
15.3% (A-4) LL=26 PI=8
18.6% (A-6)
22.0% (A-7-5)
16.4% (A-4)
49.5'
U-1 U-2
IIb IIa

Ramp A STA 1252+25
IBR-05
N611992.6, E432150.8
EL 66.0
SPT N or STA 1656+00 | NMC | AASHTO
BOF EL 62.00
19.7% (A-7-5) LL=46 PI=23
26.6% (A-7-5) LL=58 PI=29 EL 42
17.5% (A-6) LL=36 PI=14
16.0% (A-4)
20.8% (A-4) LL=21 PI=5
17.7% (A-4)
18.7% (A-4)
18.8% (A-4)
23.1% (A-2-4)
99.5'
U-1 U-2
IIa IIb
use lab tests from IBR-04
UC: S_u=2,042 psf
DS: ϕ'=15.6° c'=955psf
e_o=0.661
P_c=1.7tsf
C_c=0.15
C_r=
Expan=25t/sq
Comp=17t/sq

AASHTO SOIL KEY
A-1-a A-1-b A-3 A-2-4 A-2-5 A-2-6 A-2-7 A-4 A-5 A-6 A-7-5 A-7-6 A-8 Asphalt FILL Decomposed Rock

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data
Retaining Wall 8

Figure No.

Drawn: SAB | Approved: | Date: 9/18/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 9/18/08

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Subject SR1/I-95 Interchange — RW 8 Analysis
Page 4 of
Cm. No. 103-059-270
Prepared By SAB Date 11/13/08 Checked By JBT Date 11-11-09

STA 1251+00

External Stability: Performed using MSEW 3.0

Undrained: See attached MSEW output p. 5 - 13.
→ See p. 10 for LRFD Resistance Factors used.

Results: * Reinforcement Length must be extended to L/H = 1.0. ⇒ L = 23'
Bearing Capacity: Factored bearing resistance, q_R = 6,684 psf
Meyerhof Stress, σ_v = 5,714 psf
⇒ CDR = 1.17 ✓ OK

Sliding: CDR = 1.52 > 1.0 ✓ OK

Overturning: CDR = 3.51 > 1.0 ✓ OK

Drained: See attached MSEW output, p. 14 - 22.

Analysis: L/H must be 1.0 for undrained case → evaluate Drained condition.

Results: Bearing Capacity: Factored bearing resistance, q_R = 6,396 psf
Meyerhof Stress, σ_v = 5,714 psf
→ CDR = 1.12 ✓ OK

w/ Cohesion = 190 psf for Strata IIa

Sliding: CDR = 1.36 > 1.0 ✓ OK
Overturning: CDR = 3.51 > 1.0 ✓ OK

⇒ w/o cohesion: * γ = 80 pcf (9' CLSM @ 40 pcf; 14' No. 57 stone @ 105 pcf) for reinforced zone
(see p. 23 - 31) * Retained soil must be DelDOT Type B: γ_t = 125 pcf, ϕ = 34°.
* L/H = 1.0

Bearing Capacity: Factored Bearing Resistance, q_R = 3,859 psf ← Governs ⇐
(see p. 29)
Meyerhof Stress, σ_v = 3824 psf ⇒ CDR = 1.01 > 1.0 ✓ OK

Sliding: CDR = 1.05 > 1.0 ✓ OK
Overturning: CDR = 3.05 > 1.0 ✓ OK

5

RKK-RW7&8-55

EMC 2/9/08

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1816+00 (Ramp A STA 1251+00)

Description:

Retaining Wall 8 - Ramp G1 UNDRAINED Analysis H=23' L/H=1.0

CDR=1.17

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....251+00 UNDRAINED.BEN
Original date and time of creating this file:

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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RKK-RW7&8-56

1-11-08

SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select Fill
Design value of internal angle of friction, ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ	130.0 lb/ft ^{3}	Common Borrow
Design value of internal angle of friction, ϕ	28.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}	
Equivalent internal angle of friction, $\phi_{equiv.}$	0.0 °	IIa
Equivalent cohesion, $c_{equiv.}$	2000.0 lb/ft ^{2}	

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3713 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 5.14 N γ= 0.00

SEISMICITY

Not Applicable

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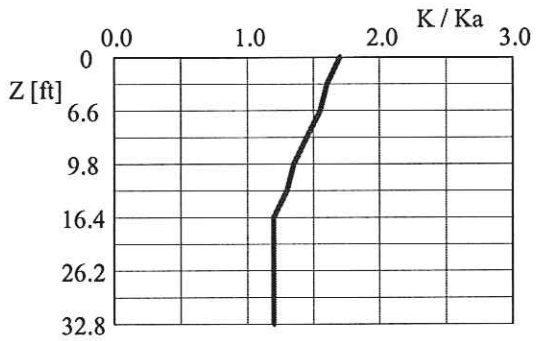
INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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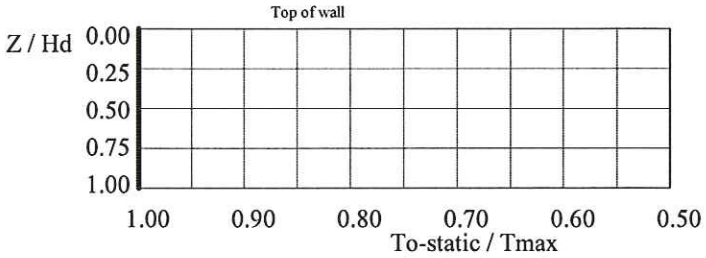
RKK-RW7&8-58 JLT 1-11-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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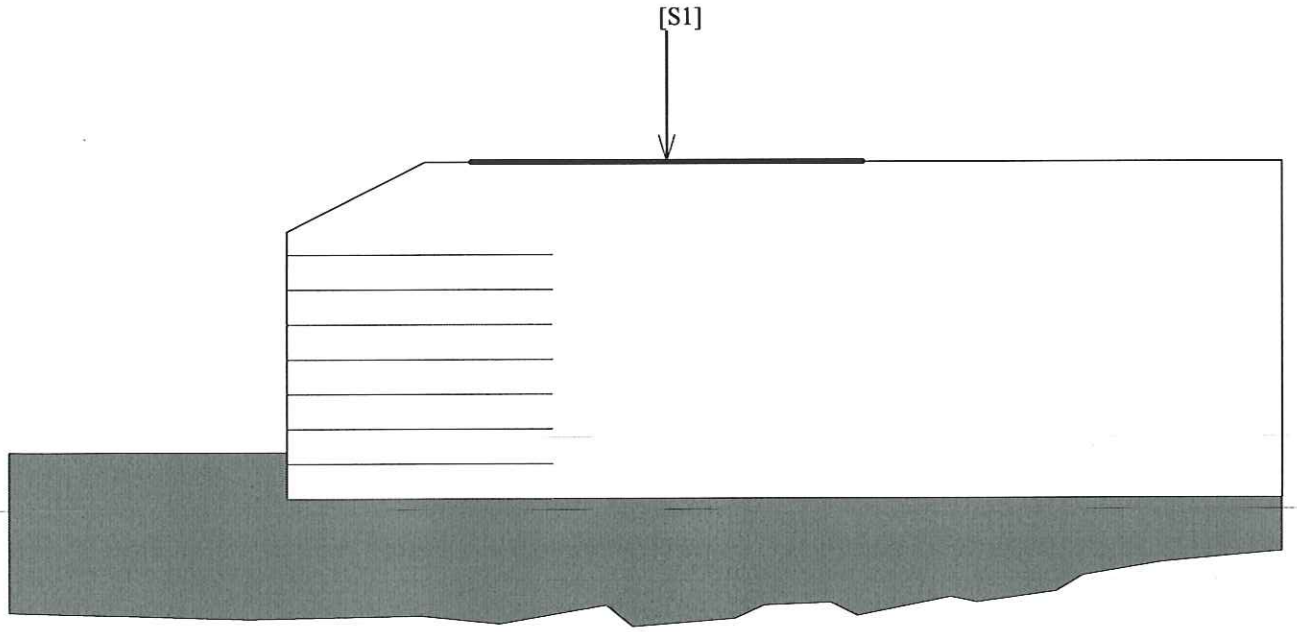
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	23.00	[ft]	{ Embedded depth is E = 4.00 ft, and height above top of finished bottom grade is H = 19.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	6.0	[ft]	Broken back equivalent angle, I = 7.43° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=34.0 [ft]. Distance of center of footing from wall face, d = 33.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW7&8-60

JDT 1-11-09

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00

Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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RKK-RW7&8-61
1-11-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.17, Meyerhof stress = 5714 lb/ft².
Foundation Interface: Direct sliding, CDR = 1.518, Eccentricity, e/L = 0.1126, CDR-overturning = 3.51

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	23.00	1	N/A	1.53	1.70	1.698	2.168	1.836	0.1126	---
2	3.00	23.00	1	N/A	0.82	0.92	0.917	0.974	2.024	0.0838	---
3	6.00	23.00	1	N/A	0.90	1.00	1.003	1.094	2.266	0.0573	---
4	9.00	23.00	1	N/A	1.00	1.11	1.114	1.188	2.564	0.0327	---
5	12.00	23.00	1	N/A	1.15	1.27	1.273	1.241	2.953	0.0096	---
6	15.00	23.00	1	N/A	1.35	1.50	1.502	1.318	3.486	-0.0131	---
7	18.00	23.00	1	N/A	1.73	1.93	1.926	1.501	4.254	-0.0378	---
8	21.00	23.00	1	N/A	2.27	2.52	2.524	1.588	5.437	-0.0716	---

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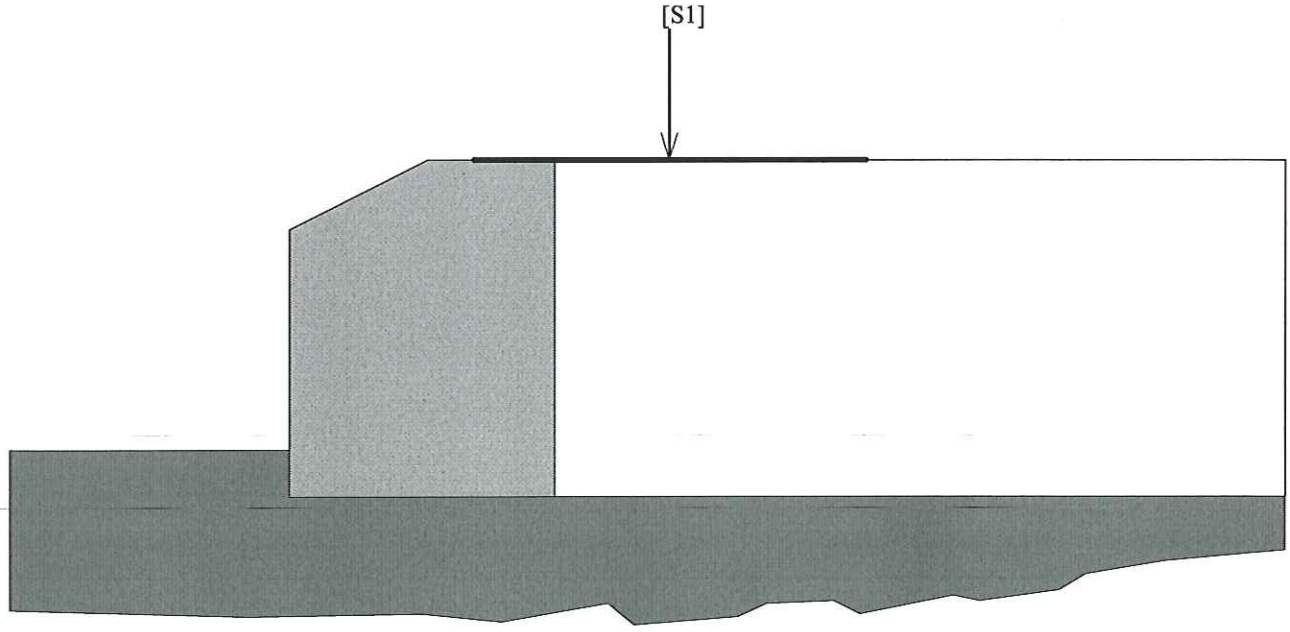
RKK-RW7&8-62
1-11-09

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	6684	N/A	[lb/ft ²]
Meyerhof stress, σ_V	5713.6	N/A	[lb/ft ²]
Eccentricity, e	1.83	N/A	[ft]
Eccentricity, e/L	0.079	N/A	
CDR calculated	1.17	N/A	
Base length	23.00	N/A	[ft]

$q_{ult} > \sigma_V$ ∴ OK

CDR > 1 ∴ OK



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW7&8-63
JLT 1-11-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.518

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	23.00	1.836	N/A	1	---
2	3.00	23.00	2.024	N/A	1	---
3	6.00	23.00	2.266	N/A	1	---
4	9.00	23.00	2.564	N/A	1	---
5	12.00	23.00	2.953	N/A	1	---
6	15.00	23.00	3.486	N/A	1	---
7	18.00	23.00	4.254	N/A	1	---
8	21.00	23.00	5.437	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1126; Overturning: CDR-static = 3.51

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	23.00	0.1126	N/A	1	---
2	3.00	23.00	0.0838	N/A	1	---
3	6.00	23.00	0.0573	N/A	1	---
4	9.00	23.00	0.0327	N/A	1	---
5	12.00	23.00	0.0096	N/A	1	---
6	15.00	23.00	-0.0131	N/A	1	---
7	18.00	23.00	-0.0378	N/A	1	---
8	21.00	23.00	-0.0716	N/A	1	---

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RKK-RW7&8-64 JBT 1-11-09
EMIC 2/9/09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1816+00 (Ramp A STA 1251+00)

Description:

Retaining Wall 8 - Ramp G1 DRAINED Analysis H=23' L/H=1.0 COV=1.12

Lyf Cohesion for Strata IIa

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....1+00 DRAINED L=H.BEN
Original date and time of creating this file: Mon Oct 20 10:17:53 2008

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select
Design value of internal angle of friction, ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ	130.0 lb/ft ^{3}	Common Borrow
Design value of internal angle of friction, ϕ	28.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}	IIa
Equivalent internal angle of friction, $\phi_{equiv.}$	24.0 °	
Equivalent cohesion, $c_{equiv.}$	190.0 lb/ft ^{2} (*)	

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3713 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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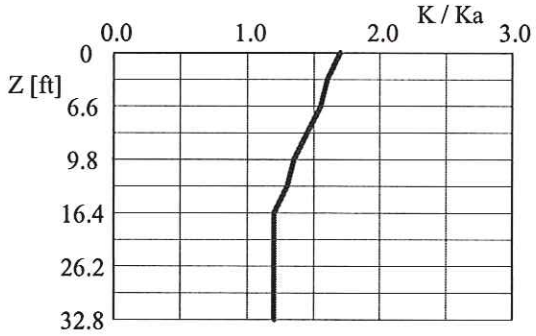
INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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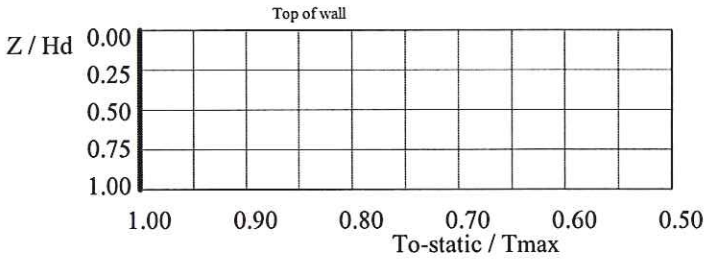
INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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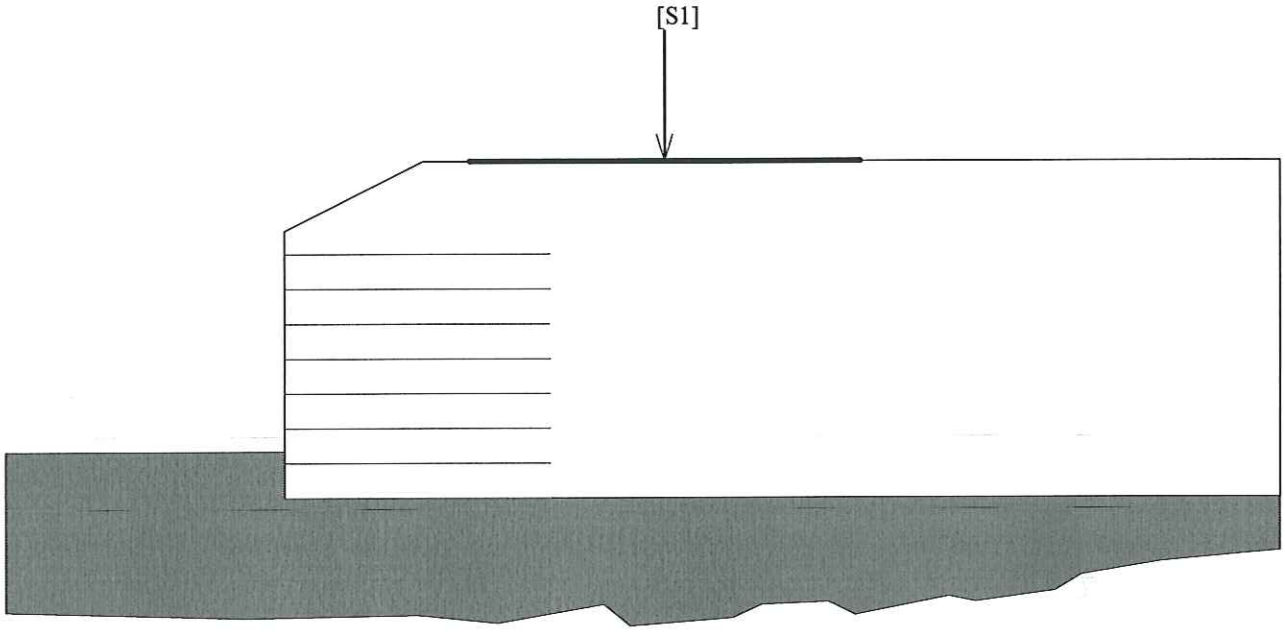
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	23.00	[ft]	{ Embedded depth is E = 4.00 ft, and height above top of finished bottom grade is H = 19.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	6.0	[ft]	Broken back equivalent angle, I = 7.43° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=34.0 [ft]. Distance of center of footing from wall face, d = 33.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.12, Meyerhof stress = 5714 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.361, Eccentricity, e/L = 0.1126, CDR-overturning = 3.51

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	23.00	1	N/A	1.53	1.70	1.698	2.168	1.836	0.1126	---
2	3.00	23.00	1	N/A	0.82	0.92	0.917	0.974	2.024	0.0838	---
3	6.00	23.00	1	N/A	0.90	1.00	1.003	1.094	2.266	0.0573	---
4	9.00	23.00	1	N/A	1.00	1.11	1.114	1.188	2.564	0.0327	---
5	12.00	23.00	1	N/A	1.15	1.27	1.273	1.241	2.953	0.0096	---
6	15.00	23.00	1	N/A	1.35	1.50	1.502	1.318	3.486	-0.0131	---
7	18.00	23.00	1	N/A	1.73	1.93	1.926	1.501	4.254	-0.0378	---
8	21.00	23.00	1	N/A	2.27	2.52	2.524	1.588	5.437	-0.0716	---

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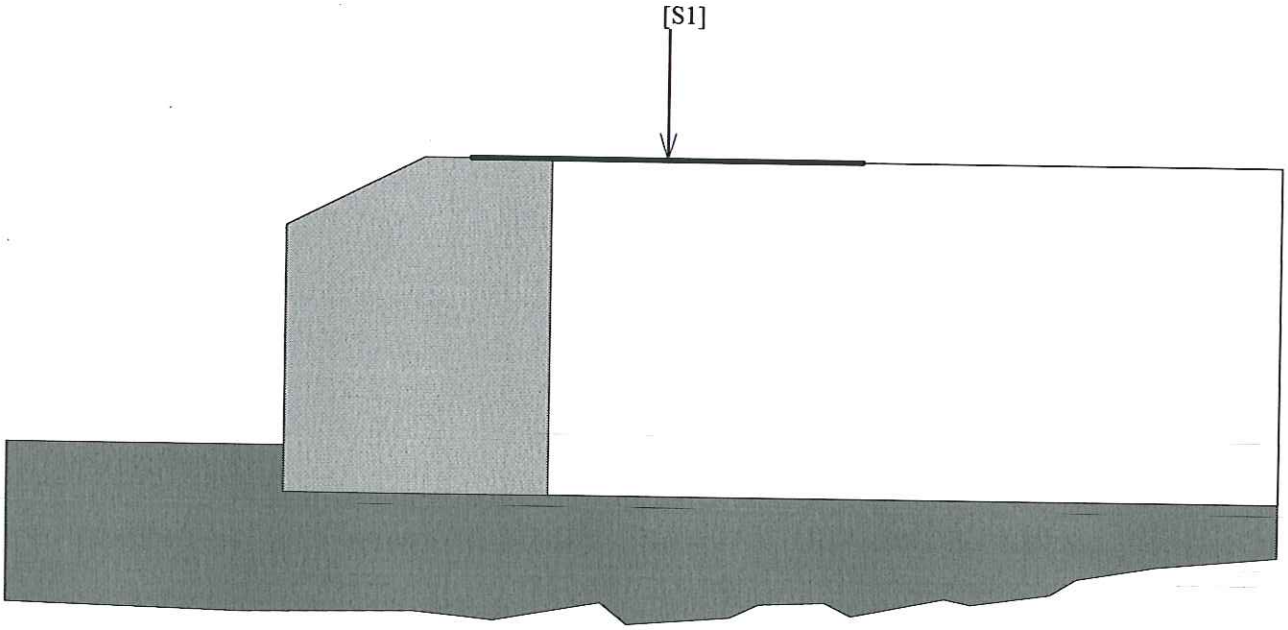
OK 1-11-09

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	6396	N/A	[lb/ft ²]
Meyerhof stress, σ_v	5713.6	N/A	[lb/ft ²]
Eccentricity, e	1.83	N/A	[ft]
Eccentricity, e/L	0.079	N/A	
CDR calculated	1.12	N/A	
Base length	23.00	N/A	[ft]

$q_{ult} > \sigma_V$; OK

CDR > 1 ; OK



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW7&8-72 1-11-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.361

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	23.00	1.836	N/A	1	---
2	3.00	23.00	2.024	N/A	1	---
3	6.00	23.00	2.266	N/A	1	---
4	9.00	23.00	2.564	N/A	1	---
5	12.00	23.00	2.953	N/A	1	---
6	15.00	23.00	3.486	N/A	1	---
7	18.00	23.00	4.254	N/A	1	---
8	21.00	23.00	5.437	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1126; Overturning: CDR-static = 3.51

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	23.00	0.1126	N/A	1	---
2	3.00	23.00	0.0838	N/A	1	---
3	6.00	23.00	0.0573	N/A	1	---
4	9.00	23.00	0.0327	N/A	1	---
5	12.00	23.00	0.0096	N/A	1	---
6	15.00	23.00	-0.0131	N/A	1	---
7	18.00	23.00	-0.0378	N/A	1	---
8	21.00	23.00	-0.0716	N/A	1	---

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RKK-RW7&8-73

JGT 1-11-09
EMK
2/9/09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1816+00 (Ramp A STA 1251+00)

Description:

Retaining Wall 8 - Ramp G1 DRAINED Analysis H=23' L/H=1.0 Reinforc
d Zone: 9' CLSM, 14' No. 57 Retained Soil: ~~DelDOT Type B Borrow~~ Select Borrow
CDR=1.01

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....RAINED L=H No c'.BEN
Original date and time of creating this file: Mon Oct 20 10:17:53 2008

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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SOIL DATA

REINFORCED SOIL

Unit weight,	γ	80.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	38.0 °

9' CLSM @ 40pcf + 14' No. 57 @ 105pcf
9'(40pcf) + 14'(105pcf) = 23'(required pcf)
360 + 1470 = 23'(x)
x = 80pcf ✓

RETAINED SOIL

Unit weight,	γ	125.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	34.0 °

2 Select Borrow

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight,	$\gamma_{equiv.}$	130.0 lb/ft ^{3}
Equivalent internal angle of friction,	$\phi_{equiv.}$	24.0 °
Equivalent cohesion, c	$_{equiv.}$	0.0 lb/ft ^{2}

Strata IIa

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2379 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2890 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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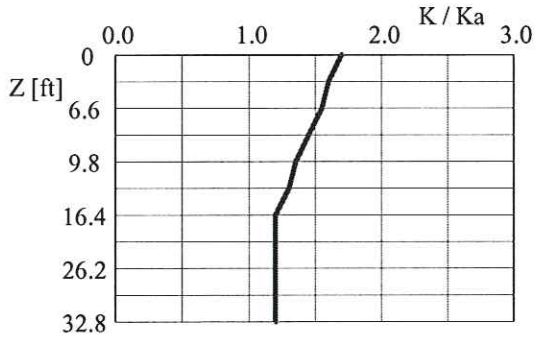
INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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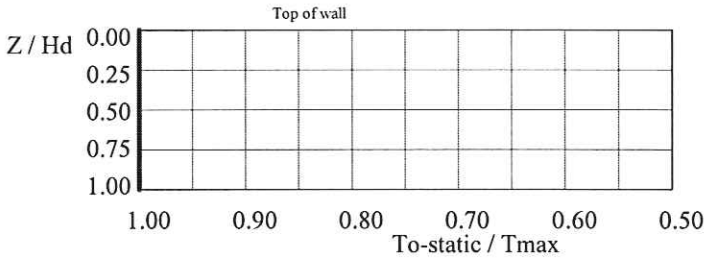
INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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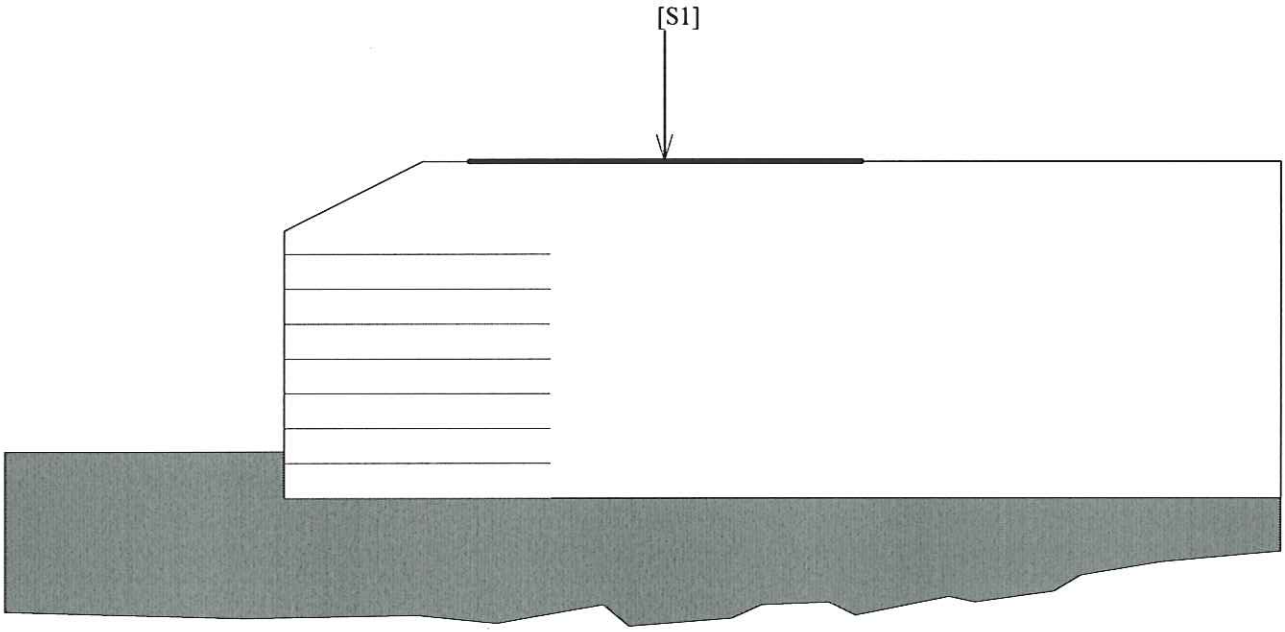
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	23.00	[ft]	{ Embedded depth is E = 4.00 ft, and height above top of finished bottom grade is H = 19.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	6.0	[ft]	Broken back equivalent angle, I = 7.43° (see Fig. 25 in DEMO 82)

U N I F O R M S U R C H A R G E
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=34.0 [ft]. Distance of center of footing from wall face, d = 33.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00

Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90		1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.01, Meyerhof stress = 3824 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.049, Eccentricity, e/L = 0.1337, CDR-overturning = 3.05

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	23.00	1	N/A	2.84	3.15	3.153	2.576	1.821	0.1337	---
2	3.00	23.00	1	N/A	1.53	1.70	1.702	1.157	2.005	0.1007	---
3	6.00	23.00	1	N/A	1.68	1.86	1.863	1.301	2.250	0.0704	---
4	9.00	23.00	1	N/A	1.86	2.07	2.069	1.412	2.553	0.0425	---
5	12.00	23.00	1	N/A	2.13	2.36	2.364	1.475	2.939	0.0166	---
6	15.00	23.00	1	N/A	2.51	2.79	2.789	1.567	3.467	-0.0085	---
7	18.00	23.00	1	N/A	3.22	3.58	3.577	1.784	4.227	-0.0351	---
8	21.00	23.00	1	N/A	4.22	4.69	4.688	1.887	5.397	-0.0703	---

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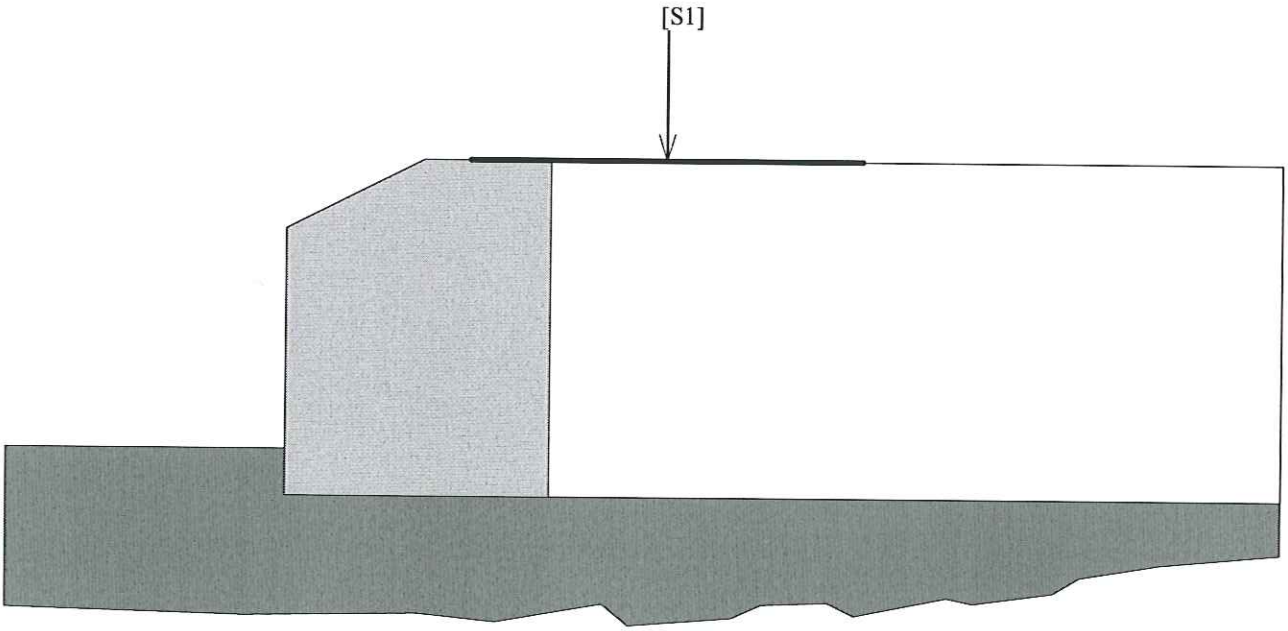
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	3859	N/A	[lb/ft ²]
Meyerhof stress, σ_V	3824.2	N/A	[lb/ft ²]
Eccentricity, e	2.19	N/A	[ft]
Eccentricity, e/L	0.095	N/A	
CDR calculated	1.01	N/A	
Base length	23.00	N/A	[ft]

qult > σV ∴ OK

CDR > 1 ∴ OK



SCALE:

0 2 4 6 8 10[ft]

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DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.049

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	23.00	1.821	N/A	1	---
2	3.00	23.00	2.005	N/A	1	---
3	6.00	23.00	2.250	N/A	1	---
4	9.00	23.00	2.553	N/A	1	---
5	12.00	23.00	2.939	N/A	1	---
6	15.00	23.00	3.467	N/A	1	---
7	18.00	23.00	4.227	N/A	1	---
8	21.00	23.00	5.397	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1337; Overturning: CDR-static = 3.05

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	23.00	0.1337	N/A	1	---
2	3.00	23.00	0.1007	N/A	1	---
3	6.00	23.00	0.0704	N/A	1	---
4	9.00	23.00	0.0425	N/A	1	---
5	12.00	23.00	0.0166	N/A	1	---
6	15.00	23.00	-0.0085	N/A	1	---
7	18.00	23.00	-0.0351	N/A	1	---
8	21.00	23.00	-0.0703	N/A	1	---

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"A Tradition Of Excellence" since 1923

Subject SR1/I-95 Interchange RW 8 Analysis | Page 32 of ____ | Cm. No. 103-059-27U
Prepared By SAB Date 11/14/08 Checked By JPT Date 1-11-09

STA 1253+50

External Stability: Performed using MSEW 3.0

Undrained: See attached MSEW output, p. 33-41
↳ see p. 38 for LRFD resistance factors used.

Results:

Bearing Capacity: Factored Bearing Resistance, $q_R = 5,013$ psf

Meyerhof Stress, $\sigma_v = 4,455$ psf

$\Rightarrow$ CDR = 1.13 > 1.0 ✓OK L = 10.4 JPT

Sliding: CDR = 1.11 > 1.0 ✓ OK

Overturning: CDR = 1.94 > 1.0 ✓OK

Drained: See attached MSEW output, p. 42-50
↳ see p. 47 for LRFD factors used.

Results: *Reinforcement length must be extended to L/H = 0.9 = 11.7'

Bearing Capacity: Factored Bearing Resistance, $q_R = 4,302$ psf ← Drained Case Governs

Meyerhof Stress, $\sigma_v = 4,134$ psf $\Rightarrow$ CDR = 1.03 > 1.0 ✓OK

Sliding: CDR = 1.00 ≥ 1.0 ✓OK

Overturning: CDR = 2.21 > 1.0 ✓OK

(See p. 51 for analysis without cohesion)

33

RKK-RW7&8-83

JJT 1-19-09

BMK 2/9/09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title:	SR 1/I-95 Interchange
Project Number:	103-059-27U
Client:	DelDOT
Designer:	SAB
Station Number:	Ramp A STA 1253+50

Description:

Retaining Wall 8 - Ramp G1 UNDRAINED Analysis H=13' L/H=0.8

COV=1.13

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....253+50 UNDRAINED.BEN

Original date and time of creating this file: Thu Nov 20 15:54:50 2008

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select
Design value of internal angle of friction, ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ	130.0 lb/ft ^{3}	Common Borrow
Design value of internal angle of friction, ϕ	28.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}	Strata IIa
Equivalent internal angle of friction, $\phi_{equiv.}$	0.0 °	
Equivalent cohesion, $c_{equiv.}$	1500.0 lb/ft ^{2}	

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.4615 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 5.14 N γ= 0.00

SEISMICITY

Not Applicable

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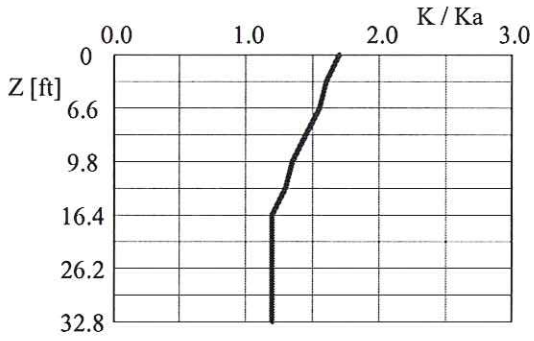
RKK-RW7&8-85
BJT 1-19-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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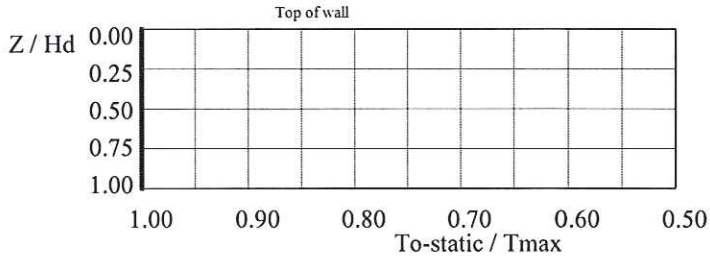
RKK-RW7&8-86
JJT
1-19-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK-RW7&8-87

JJT 1-19-09

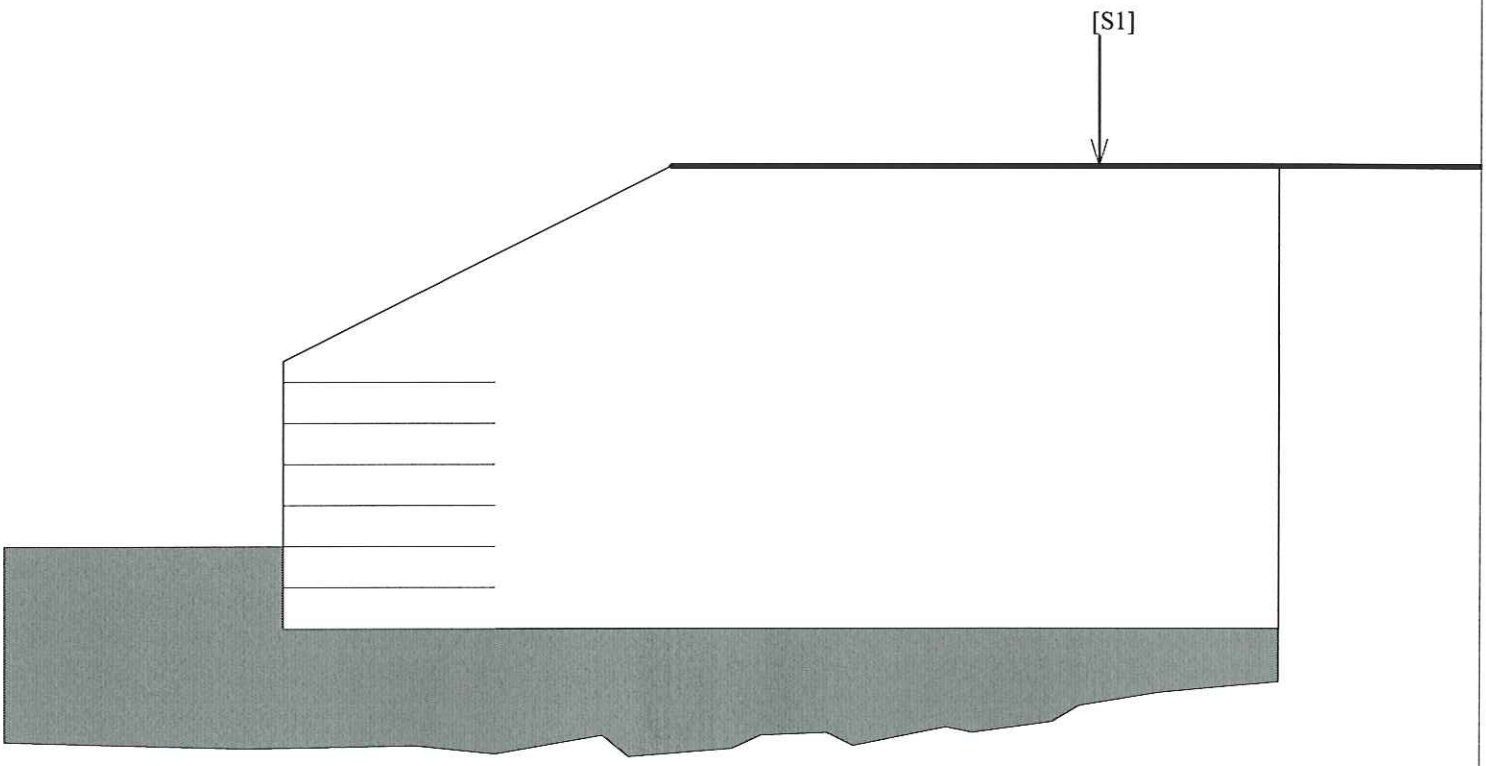
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	13.00	[ft]	{ Embedded depth is E = 4.00 ft, and height above top of finished bottom grade is H = 9.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	9.5	[ft]	Broken back equivalent angle, I = 20.07° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=42.0 [ft]. Distance of center of footing from wall face, d = 40.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 [ft]

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RKK-RW7&8-88

887
1-19-09

AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00

Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90		1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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RKK-RW7&8-89
JBT 1-19-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.13, Meyerhof stress = 4455 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.113, Eccentricity, e/L = 0.1987, CDR-overturning = 1.94

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	10.40	1	N/A	3.54	3.93	3.932	2.118	1.222	0.1987	---
2	2.00	10.40	1	N/A	1.91	2.12	2.120	1.006	1.320	0.1458	---
3	4.00	10.40	1	N/A	2.15	2.39	2.394	0.957	1.439	0.0966	---
4	6.00	10.40	1	N/A	2.52	2.80	2.802	0.897	1.584	0.0506	---
5	8.00	10.40	1	N/A	3.13	3.48	3.477	0.861	1.762	0.0062	---
6	10.00	10.40	1	N/A	4.21	4.68	4.683	0.966	1.974	-0.0403	---
7	12.00	10.40	1	N/A	6.58	7.31	7.311	1.139	2.189	-0.1019	---

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RKK-RW7&8-90

JPT 1-19-09

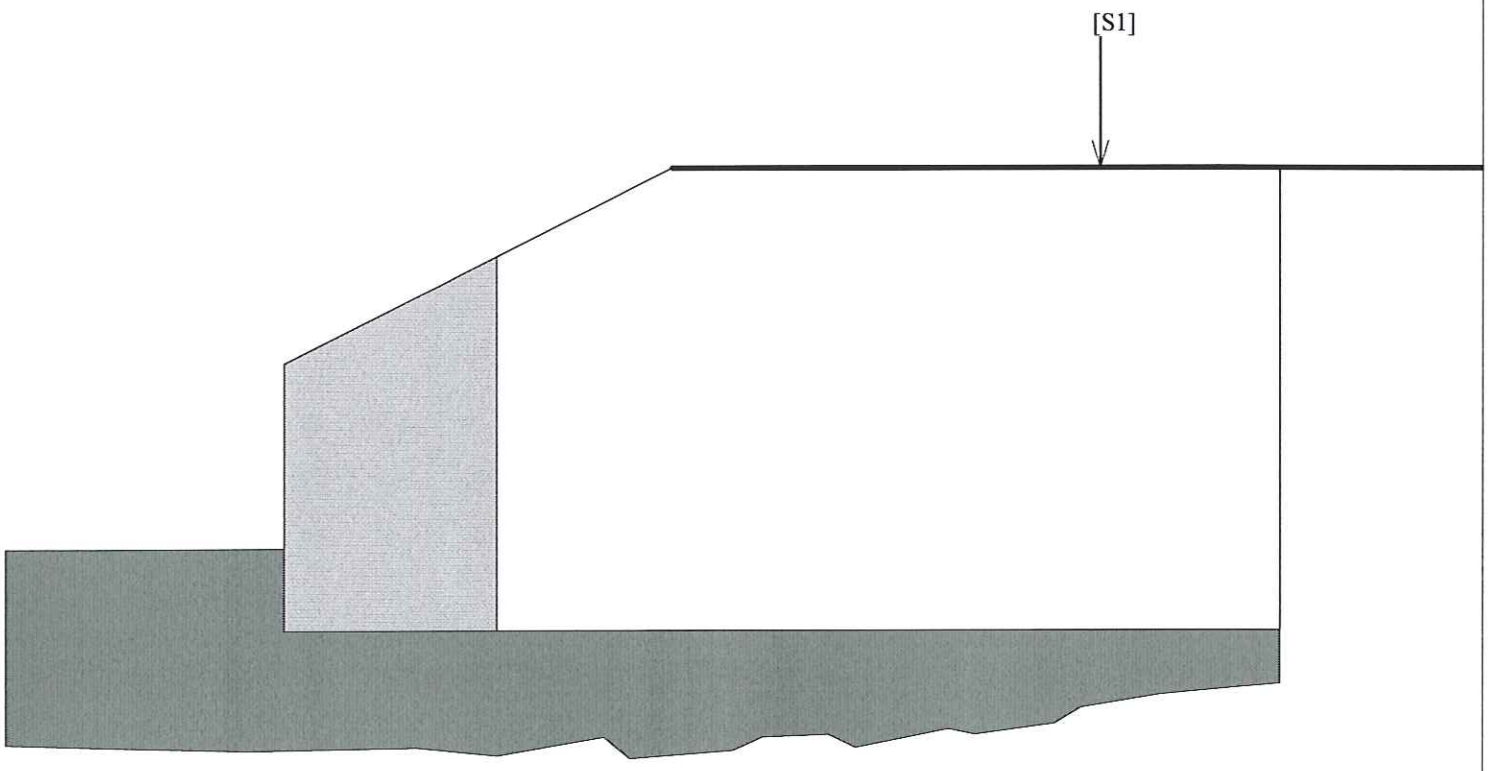
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	5013	N/A	[lb/ft ²]
Meyerhof stress, σ_V	4455.0	N/A	[lb/ft ²]
Eccentricity, e	1.55	N/A	[ft]
Eccentricity, e/L	0.149	N/A	
CDR calculated	1.13	N/A	
Base length	10.40	N/A	[ft]

$q_R > \sigma_V$

$q_{ult} > \sigma_V$ ∴ OK

CDR > 1 ∴ OK



SCALE:

0 2 4 6 [ft]

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DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.113

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	10.40	1.222	N/A	1	---
2	2.00	10.40	1.320	N/A	1	---
3	4.00	10.40	1.439	N/A	1	---
4	6.00	10.40	1.584	N/A	1	---
5	8.00	10.40	1.762	N/A	1	---
6	10.00	10.40	1.974	N/A	1	---
7	12.00	10.40	2.189	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1987; Overturning: CDR-static = 1.94

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	10.40	0.1987	N/A	1	---
2	2.00	10.40	0.1458	N/A	1	---
3	4.00	10.40	0.0966	N/A	1	---
4	6.00	10.40	0.0506	N/A	1	---
5	8.00	10.40	0.0062	N/A	1	---
6	10.00	10.40	-0.0403	N/A	1	---
7	12.00	10.40	-0.1019	N/A	1	---

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RKK-RW7&8-92

1-19-09

EMR 2/9/09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title:	SR 1/I-95 Interchange
Project Number:	103-059-27U
Client:	DelDOT
Designer:	SAB
Station Number:	Ramp A STA 1253+50

Description:

Retaining Wall 8 - Ramp G1 DRAINED Analysis H=13' L/H=0.9

CDR = 1,103

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN..... ..... 1253+50 DRAINED.BEN

Original date and time of creating this file: Thu Nov 20 15:54:50 2008

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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JJT 1-19-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select
Design value of internal angle of friction, ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ	130.0 lb/ft ^{3}	Common Borrow
Design value of internal angle of friction, ϕ	28.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}	
Equivalent internal angle of friction, $\phi_{equiv.}$	24.0 °	Strata IIa w/ Cohesion
Equivalent cohesion, $c_{equiv.}$	190.0 lb/ft ^{2}	

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.4615 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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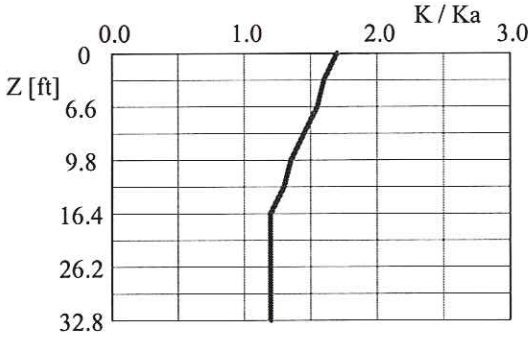
INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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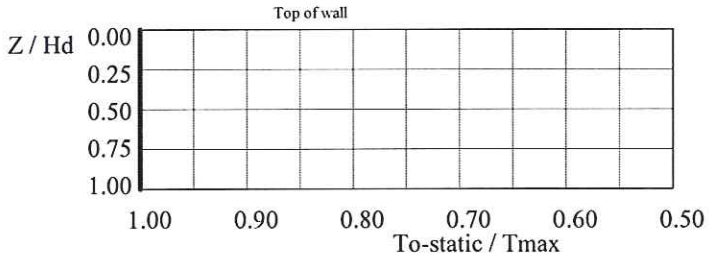
INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK-RW7&8-96
JJ 1-19-09

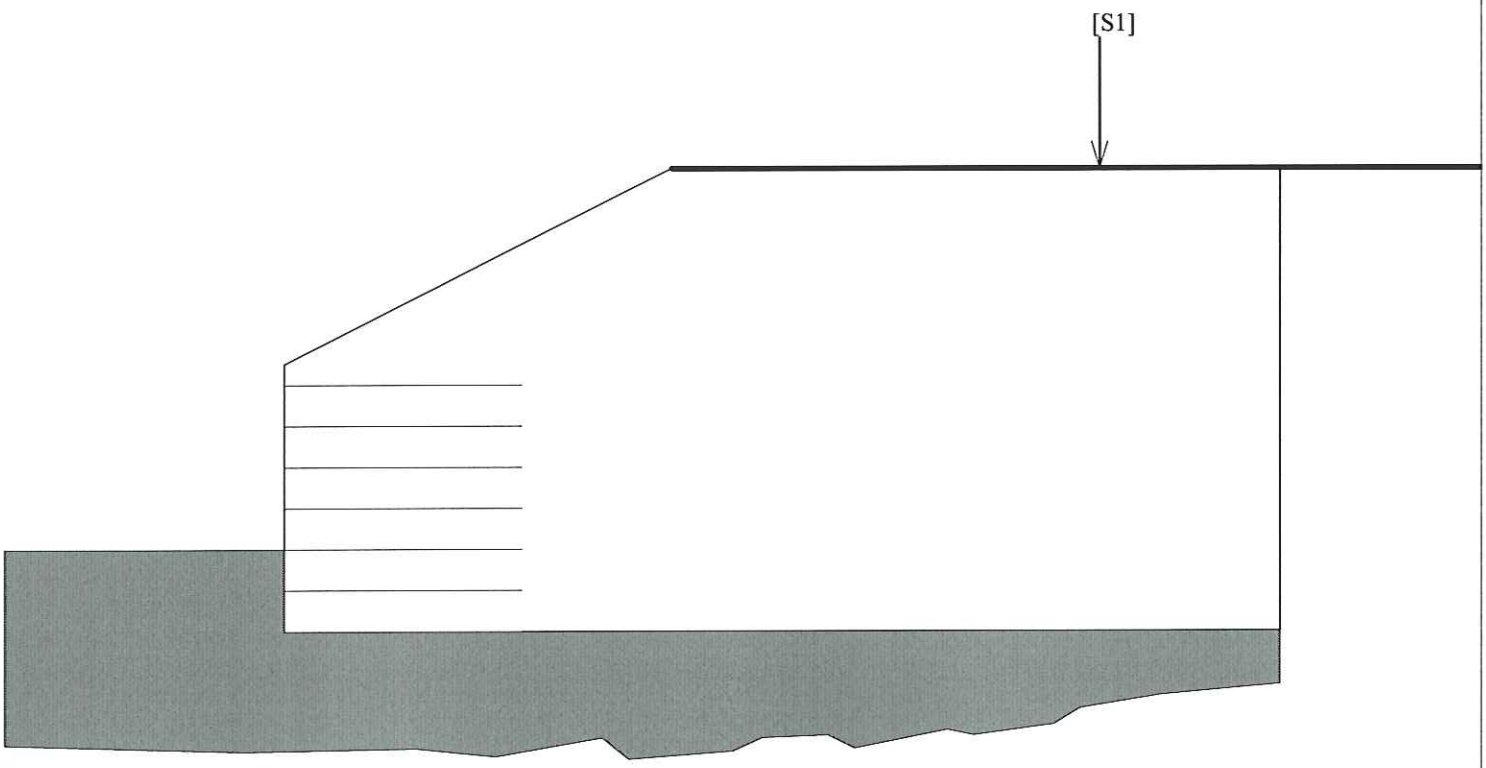
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	13.00	[ft]	{ Embedded depth is E = 4.00 ft, and height above top of finished bottom grade is H = 9.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	9.5	[ft]	Broken back equivalent angle, I = 20.07° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=42.0 [ft]. Distance of center of footing from wall face, d = 40.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 [ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00

Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static		Combined Static/Seismic
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:	Static	Combined Static/Seismic
ϕ_b	0.65	0.65

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RKK-RW7&8-98
1-19-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.03, Meyerhof stress = 4134 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.000, Eccentricity, e/L = 0.1603, CDR-overturning = 2.21

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	11.70	1	N/A	3.54	3.93	3.932	2.433	1.291	0.1603	---
2	2.00	11.70	1	N/A	1.91	2.12	2.120	1.174	1.389	0.1154	---
3	4.00	11.70	1	N/A	2.15	2.39	2.394	1.142	1.507	0.0733	---
4	6.00	11.70	1	N/A	2.52	2.80	2.802	1.102	1.648	0.0332	---
5	8.00	11.70	1	N/A	3.13	3.48	3.477	1.093	1.817	-0.0062	---
6	10.00	11.70	1	N/A	4.21	4.68	4.683	1.239	2.012	-0.0489	---
7	12.00	11.70	1	N/A	6.58	7.31	7.311	1.490	2.198	-0.1065	---

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RKK-RW7&8-99

1-19-09

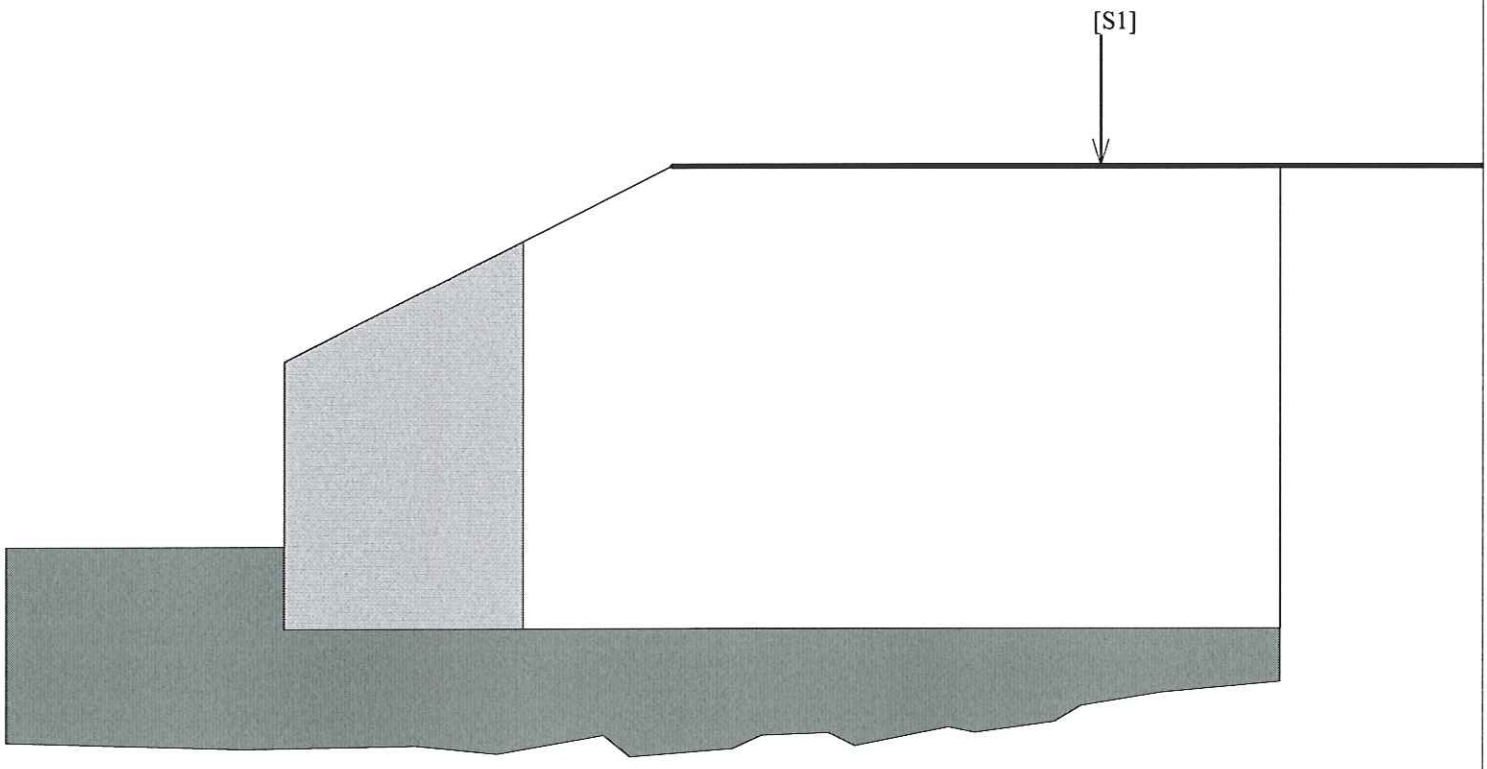
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	4239	N/A	[lb/ft ²]
Meyerhof stress, σ_V	4134.3	N/A	[lb/ft ²]
Eccentricity, e	1.38	N/A	[ft]
Eccentricity, e/L	0.118	N/A	
CDR calculated	1.03	N/A	
Base length	11.70	N/A	[ft]

$q_{ult} = q_n > \sigma_V$ ∴ OK

4239 > 4134

CDR > 1 ∴ OK



SCALE:

0 2 4 6 [ft]

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DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.000

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	11.70	1.291	N/A	1	---
2	2.00	11.70	1.389	N/A	1	---
3	4.00	11.70	1.507	N/A	1	---
4	6.00	11.70	1.648	N/A	1	---
5	8.00	11.70	1.817	N/A	1	---
6	10.00	11.70	2.012	N/A	1	---
7	12.00	11.70	2.198	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1603; Overturning: CDR-static = 2.21

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	11.70	0.1603	N/A	1	---
2	2.00	11.70	0.1154	N/A	1	---
3	4.00	11.70	0.0733	N/A	1	---
4	6.00	11.70	0.0332	N/A	1	---
5	8.00	11.70	-0.0062	N/A	1	---
6	10.00	11.70	-0.0489	N/A	1	---
7	12.00	11.70	-0.1065	N/A	1	---

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RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject SR1/I-95 Interchange
RW 8 Analysis
Page 51 of
Cm. No. 103-059.240
Prepared By SAG Date 12/4/08 Checked By JST Date 1-11-09
2M 2/9/09

STA 1253+50

Drained Analysis w/o cohesion: See MSEW output, p. 52-60,
↳ see p. 57 for LRFD factors used.

Results: * Reinforcement length must be extended to L/H = 1.0 = 13'; *
* Reinforcement zone must be: 5' CLSM @ 40-pcf max. & 8' No. 57 stone @ 105pcf
* Retained soil must be No. 57 stone

Bearing Capacity: Factored Bearing Resistance, $q_R = 2,334$ psf

Meyerhof Stress, $\sigma_v = 2,280$ psf

$\Rightarrow$ CDR = 1.02 $\geq$ 1.0 ✓OK

Sliding Resistance: CDR = 1.13 $\geq$ 1.0 ✓OK

Overturning Resistance: CDR = 3.04 $\geq$ 1.0 ✓OK

RKK-RW7&8-102

1-19-09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title:	SR 1/I-95 Interchange
Project Number:	103-059-27U
Client:	DelDOT
Designer:	SAB
Station Number:	Ramp A STA 1253+50

Description:

Retaining Wall 8 - Ramp G1 DRAINED Analysis H=13' L/H=1.0 Reinforc
d Zone: 5' CLSM, 8' No. 57 Retained Soil: No. 57

EDR=1.02

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....50 DRAINED No c'.BEN

Original date and time of creating this file: Thu Nov 20 15:54:50 2008

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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RKK-RW7&8-103

SOIL DATA

REINFORCED SOIL

Unit weight, γ	80.0 lb/ft ^{3}	Average LWEF + No. 57
Design value of internal angle of friction, ϕ	38.0 °	

RETAINED SOIL

Unit weight, γ	105.0 lb/ft ^{3}	No 57
Design value of internal angle of friction, ϕ	38.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}	Strata IIa
Equivalent internal angle of friction, $\phi_{equiv.}$	24.0 °	
Equivalent cohesion, c $_{equiv.}$	0.0 lb/ft ^{2}	

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2379 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2773 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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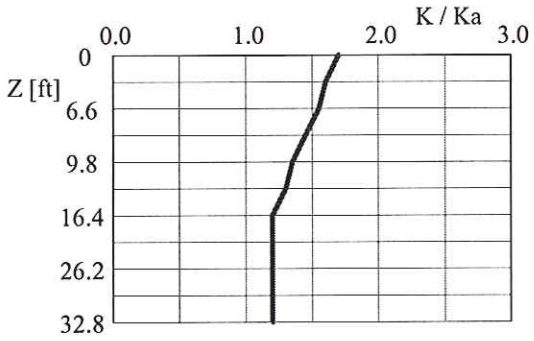
INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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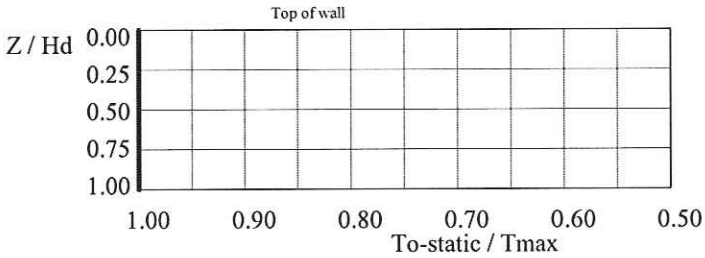
RKK-RW7&8-105
8/9
1-19-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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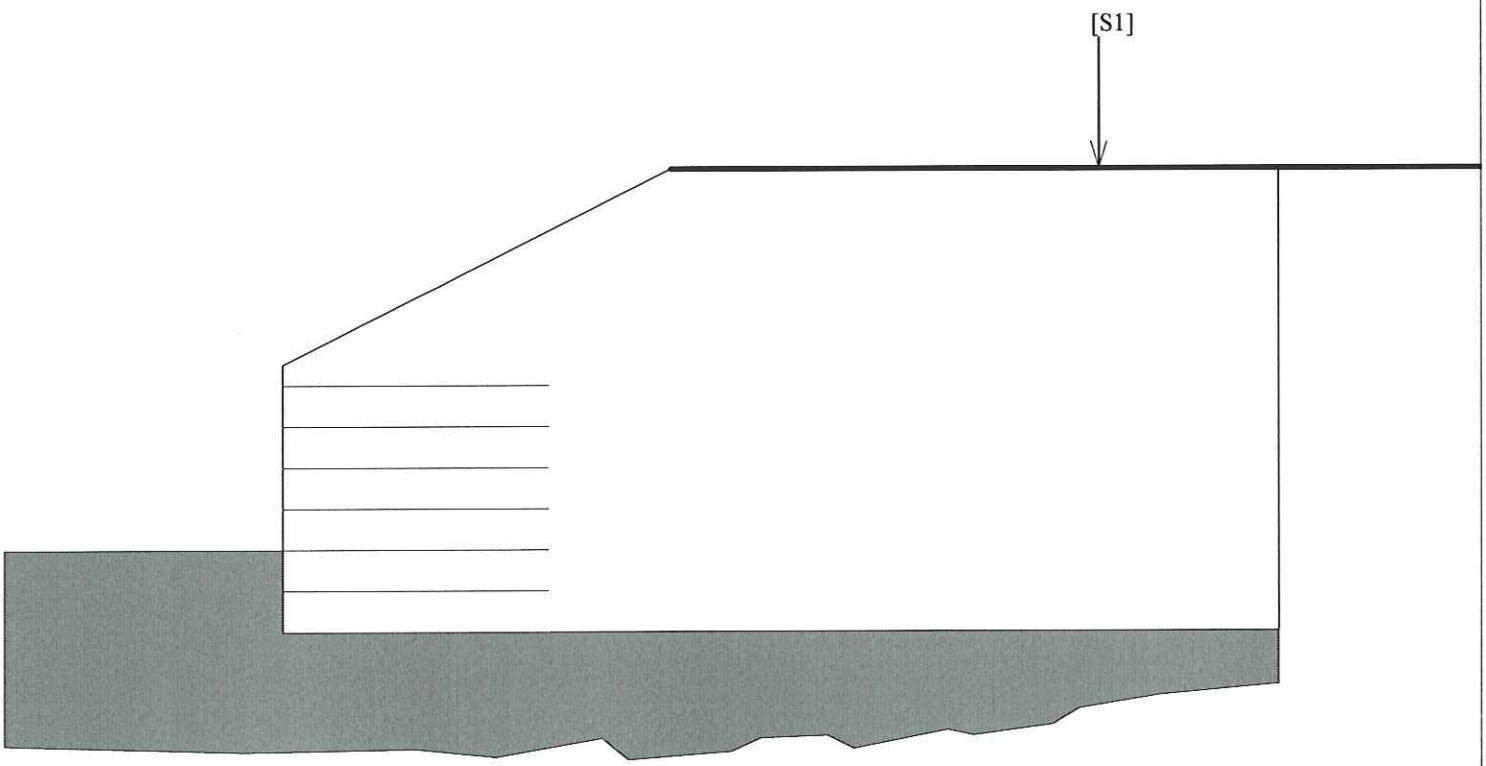
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	13.00	[ft]	{ Embedded depth is E = 4.00 ft, and height above top of finished bottom grade is H = 9.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	9.5	[ft]	Broken back equivalent angle, I = 20.07° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=42.0 [ft]. Distance of center of footing from wall face, d = 40.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 [ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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RKK-RW7&8-108

1-19-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.02, Meyerhof stress = 2280 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.125, Eccentricity, e/L = 0.0970, CDR-overturning = 3.04

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	13.00	1	N/A	6.57	7.30	7.302	3.279	1.974	0.0970	---
2	2.00	13.00	1	N/A	3.54	3.94	3.937	1.605	2.124	0.0649	---
3	4.00	13.00	1	N/A	4.00	4.45	4.445	1.588	2.300	0.0341	---
4	6.00	13.00	1	N/A	4.68	5.20	5.204	1.565	2.508	0.0040	---
5	8.00	13.00	1	N/A	5.81	6.46	6.456	1.592	2.752	-0.0271	---
6	10.00	13.00	1	N/A	7.83	8.70	8.696	1.822	3.027	-0.0628	---
7	12.00	13.00	1	N/A	12.22	13.58	13.576	2.228	3.278	-0.1141	---

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RKK-RW7&8-109

JJT 1-19-09

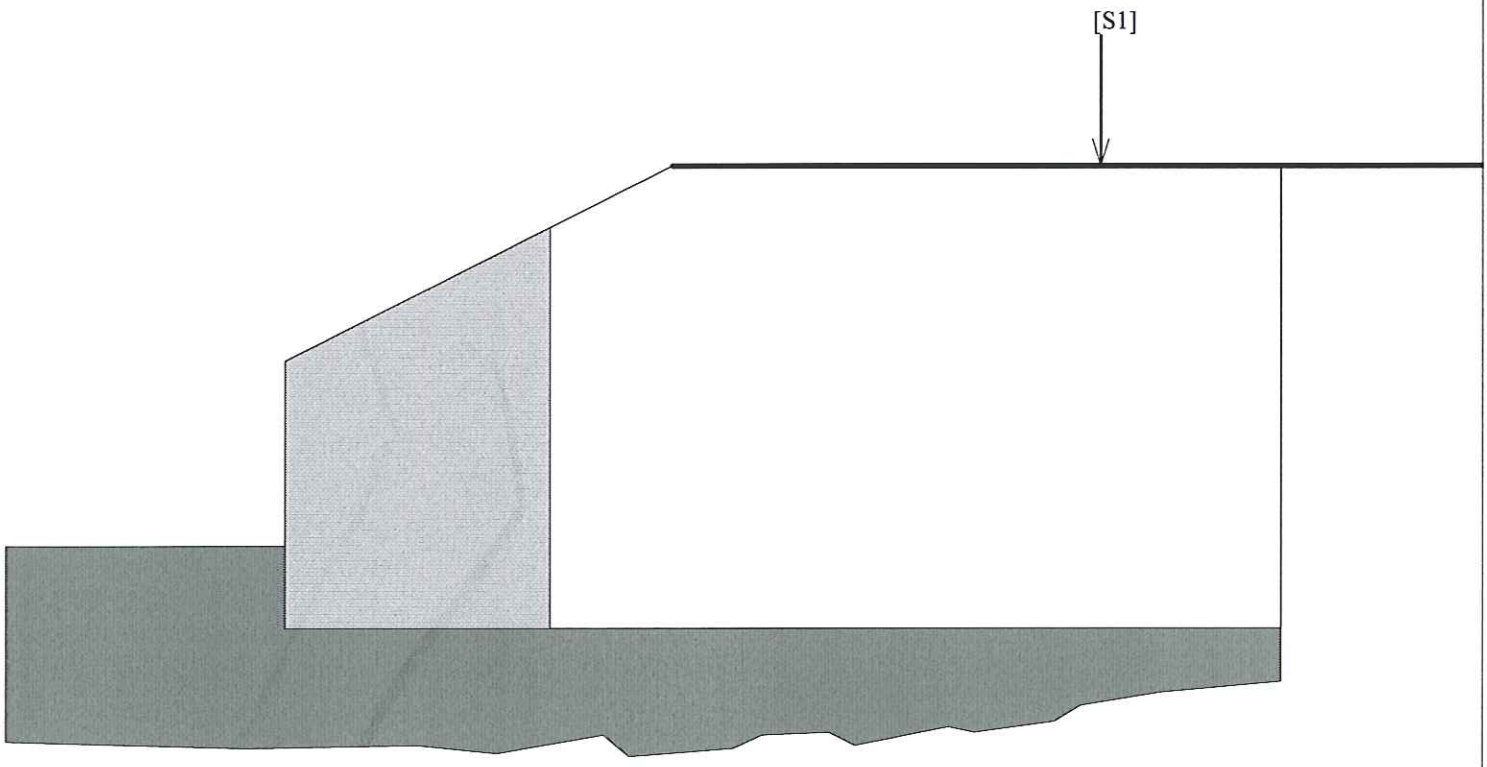
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	2334	N/A	[lb/ft ²]
Meyerhof stress, σ_V	2280.4	N/A	[lb/ft ²]
Eccentricity, e	0.87	N/A	[ft]
Eccentricity, e/L	0.067	N/A	
CDR calculated	1.02	N/A	
Base length	13.00	N/A	[ft]

CDR > 1 ∴ OK

$q_{ult} = q_R > \sigma_V$ ∴ OK

2334 > 2280.4



SCALE:

0 2 4 6 [ft]

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DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.125

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	13.00	1.974	N/A	1	---
2	2.00	13.00	2.124	N/A	1	---
3	4.00	13.00	2.300	N/A	1	---
4	6.00	13.00	2.508	N/A	1	---
5	8.00	13.00	2.752	N/A	1	---
6	10.00	13.00	3.027	N/A	1	---
7	12.00	13.00	3.278	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0970; Overturning: CDR-static = 3.04

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	13.00	0.0970	N/A	1	---
2	2.00	13.00	0.0649	N/A	1	---
3	4.00	13.00	0.0341	N/A	1	---
4	6.00	13.00	0.0040	N/A	1	---
5	8.00	13.00	-0.0271	N/A	1	---
6	10.00	13.00	-0.0628	N/A	1	---
7	12.00	13.00	-0.1141	N/A	1	---

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Option 2 → extend Reinforcement straps to L/H = 1.2 to avoid using CLSM.

STA 1251+00 → check Drained case (governing case requiring CLSM)

Drained: See attached MSEW 3.0 output p. 62-70.

Results: * Reinforced Soil + Retained Soil must be ~~DELOT Type D Backfill~~ Select *
* L/H = 1.2 *

Bearing Capacity: q_R = 5,350 psf
σ_V = 5,119 psf
⇒ CDR = 1.05 > 1.0 ✓OK L = 27.6'

Sliding Resistance: CDR = 1.93 > 1.0 ✓OK
Overturning Resistance: CDR = 6.57 > 1.0 ✓OK

STA 1253+50 → Undrained case OK with L/H=1.0 & Select Backfill in Reinforced & Retained Soil. ⇒ Check Drained case for L/H = 1.2 to avoid using CLSM.

Drained: See attached MSEW 3.0 output, p. 71-79.

Results: * Reinforced Soil must be Select Fill
* Retained Soil must be No. 57 Stone *
* L/H = 1.2 *

L = 15.6 - 6+

Bearing Capacity: q_R = 3,150 psf
σ_V = 3,143 psf
⇒ CDR = 1.00 > 1.0 ✓OK

Sliding Resistance: CDR = 1.81 > 1.0 ✓OK
Overturning Resistance: CDR = 5.30 > 1.0 ✓OK

⇒ From examining wall heights & backslope heights, Select Fill should be used as the retained Fill from the start of the wall (STA 1251+00) to near STA 1252+50. No. 57 stone should be used in the retained wedge from near STA 1252+50 to the end of the wall (SR 7 SB STA 1616+00).
(Ramp C1 STA 1615+60)
[2] This is approx. Ramp C1 STA 1817+00

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RKK-RW7&8-112

SLT 1-11-09

EMK 2/9/09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1816+00 (Ramp A STA 1251+00)

Description:

Retaining Wall 8 - Ramp G1 DRAINED Analysis H=23' L/H=1.2 Retained
Soil = ~~DelDOT Type B Borrow~~ Select Borrow

CDR=1.05

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....0 DRAINED L=1.2H.BEN
Original date and time of creating this file: Mon Oct 20 10:17:53 2008

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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SOIL DATA

REINFORCED SOIL

Unit weight,	γ	125.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	34.0 °

> Select

RETAINED SOIL

Unit weight,	γ	125.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	34.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight,	$\gamma_{equiv.}$	130.0 lb/ft ^{3}
Equivalent internal angle of friction,	$\phi_{equiv.}$	24.0 °
Equivalent cohesion,	$c_{equiv.}$	0.0 lb/ft ^{2}

IIa

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2890 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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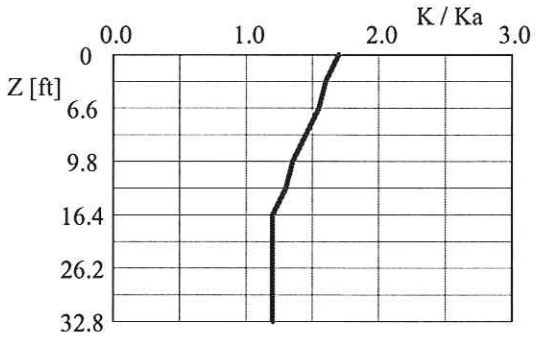
INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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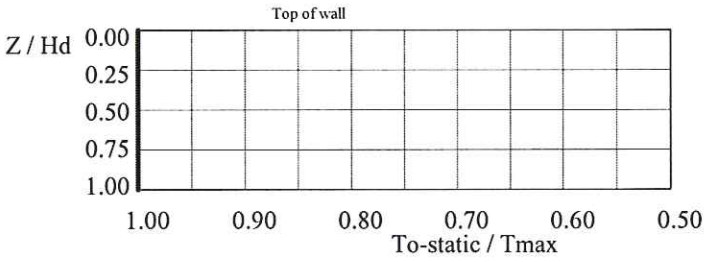
INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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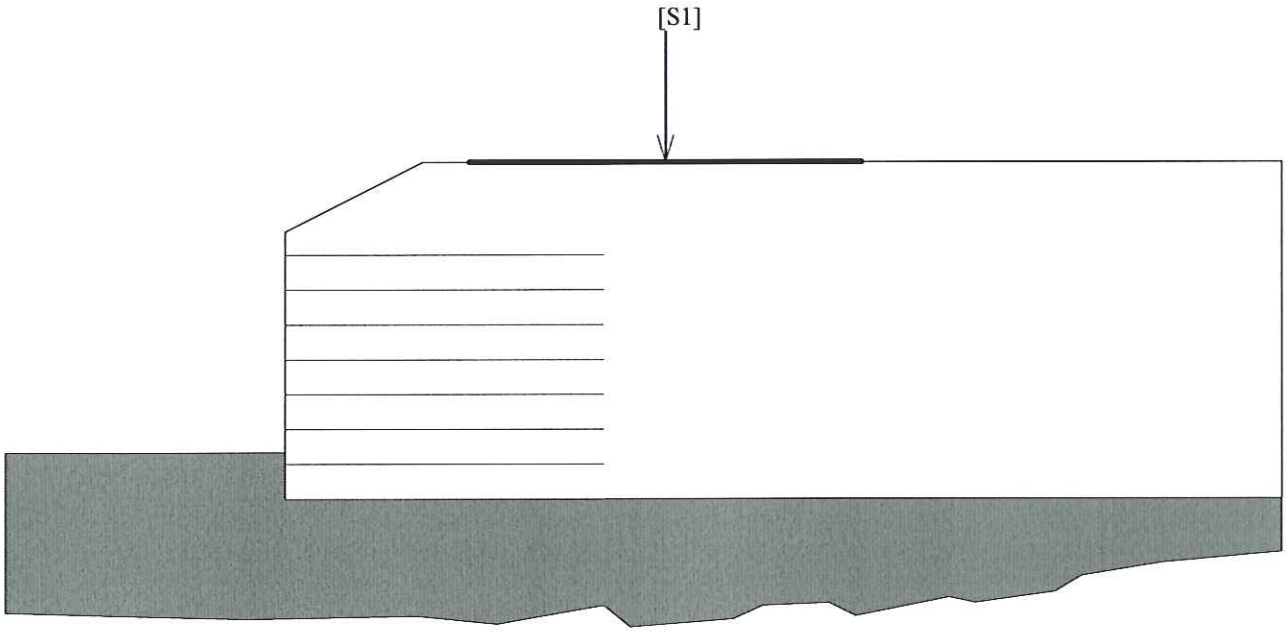
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	23.00	[ft]	{ Embedded depth is E = 4.00 ft, and height above top of finished bottom grade is H = 19.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	6.0	[ft]	Broken back equivalent angle, I = 7.43° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=34.0 [ft]. Distance of center of footing from wall face, d = 33.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35		
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00		
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75		
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50		
Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35
Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:		$\gamma_{p\text{-}EH}$	1.50	
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):		$(\gamma_{p\text{-}EH})_{EQ}$	1.50	
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):		$\gamma_{p\text{-}EQ}$	1.00	
Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00
Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
	ϕ_b	0.65		0.65

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ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.05, Meyerhof stress = 5119 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.934, Eccentricity, e/L = 0.0496, CDR-overturning = 6.57

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	27.60	1	N/A	1.53	1.70	1.698	2.627	2.918	0.0496	---
2	3.00	27.60	1	N/A	0.82	0.92	0.917	1.196	3.226	0.0338	---
3	6.00	27.60	1	N/A	0.90	1.00	1.003	1.364	3.623	0.0189	---
4	9.00	27.60	1	N/A	1.00	1.11	1.114	1.509	4.113	0.0048	---
5	12.00	27.60	1	N/A	1.15	1.27	1.273	1.610	4.760	-0.0090	---
6	15.00	27.60	1	N/A	1.35	1.50	1.502	1.734	5.650	-0.0234	---
7	18.00	27.60	1	N/A	1.73	1.93	1.926	1.976	6.951	-0.0405	---
8	21.00	27.60	1	N/A	2.27	2.52	2.524	2.094	9.008	-0.0661	---

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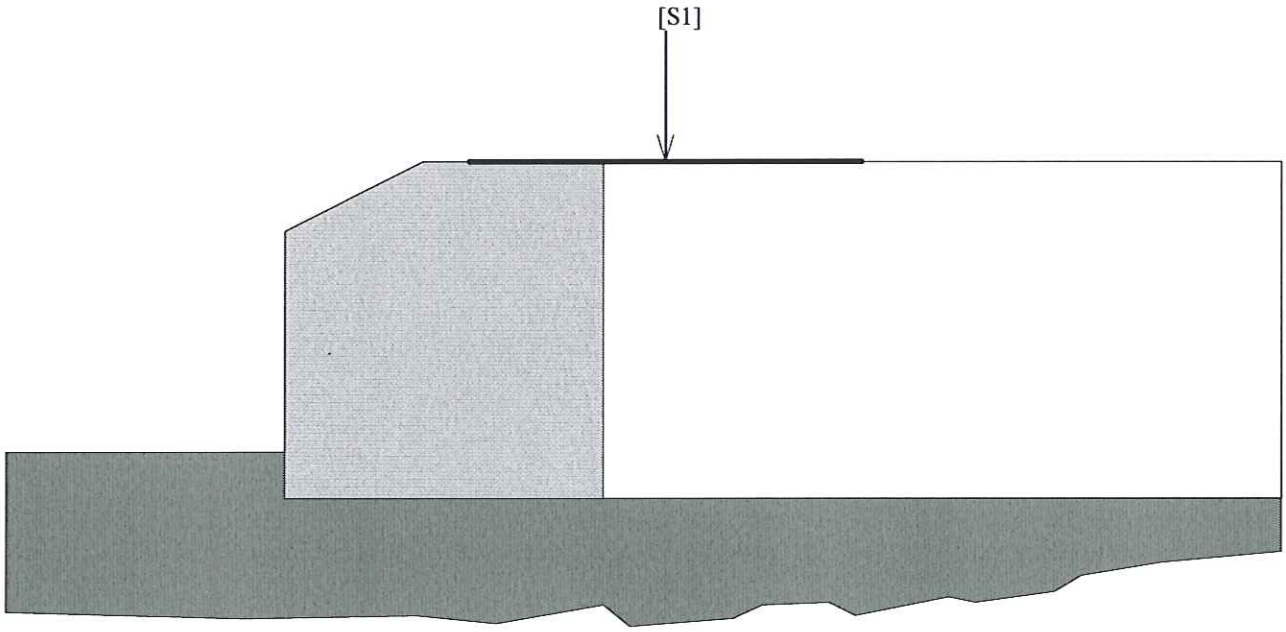
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	5350	N/A	[lb/ft ²]
Meyerhof stress, σ_V	5118.5	N/A	[lb/ft ²]
Eccentricity, e	0.90	N/A	[ft]
Eccentricity, e/L	0.032	N/A	
CDR calculated	1.05	N/A	
Base length	27.60	N/A	[ft]

$q_{ult} > \sigma_V$ ∴ ok

CDR > 1 ∴ ok



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW7&8-120 1-11-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.934

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	27.60	2.918	N/A	1	---
2	3.00	27.60	3.226	N/A	1	---
3	6.00	27.60	3.623	N/A	1	---
4	9.00	27.60	4.113	N/A	1	---
5	12.00	27.60	4.760	N/A	1	---
6	15.00	27.60	5.650	N/A	1	---
7	18.00	27.60	6.951	N/A	1	---
8	21.00	27.60	9.008	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0496; Overturning: CDR-static = 6.57

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	27.60	0.0496	N/A	1	---
2	3.00	27.60	0.0338	N/A	1	---
3	6.00	27.60	0.0189	N/A	1	---
4	9.00	27.60	0.0048	N/A	1	---
5	12.00	27.60	-0.0090	N/A	1	---
6	15.00	27.60	-0.0234	N/A	1	---
7	18.00	27.60	-0.0405	N/A	1	---
8	21.00	27.60	-0.0661	N/A	1	---

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RKK-RW7&8-121

1-19-09

2/9/09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: Ramp A STA 1253+50

Description:

Retaining Wall 8 - Ramp G1 DRAINED Analysis H=13' L/H=1.2 Reinforc
d Zone: Select Fill Retained Soil: No. 57 Stone

$\gamma_{DN} = 1.00$

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....0 DRAINED L=1.2H.BEN
Original date and time of creating this file: Fri Dec 12 09:26:29 2008

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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RKK-RW7&8-122
JGT 1-19-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select
Design value of internal angle of friction, ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ	105.0 lb/ft ^{3}	No. 57
Design value of internal angle of friction, ϕ	38.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}	Strata IIa
Equivalent internal angle of friction, $\phi_{equiv.}$	24.0 °	
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ^{2}	

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2773 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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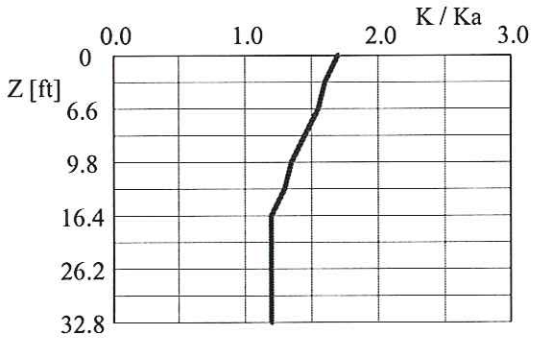
INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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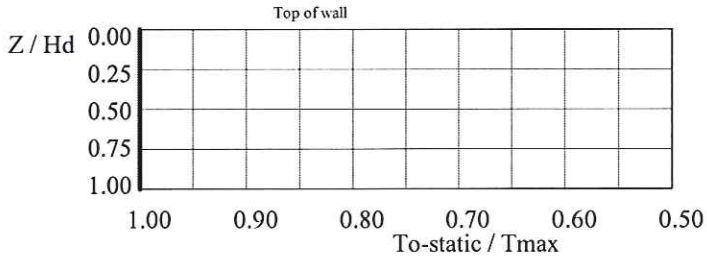
RKK-RW7&8-124
JJ 1-19-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK-RW7&8-125
1-19-09

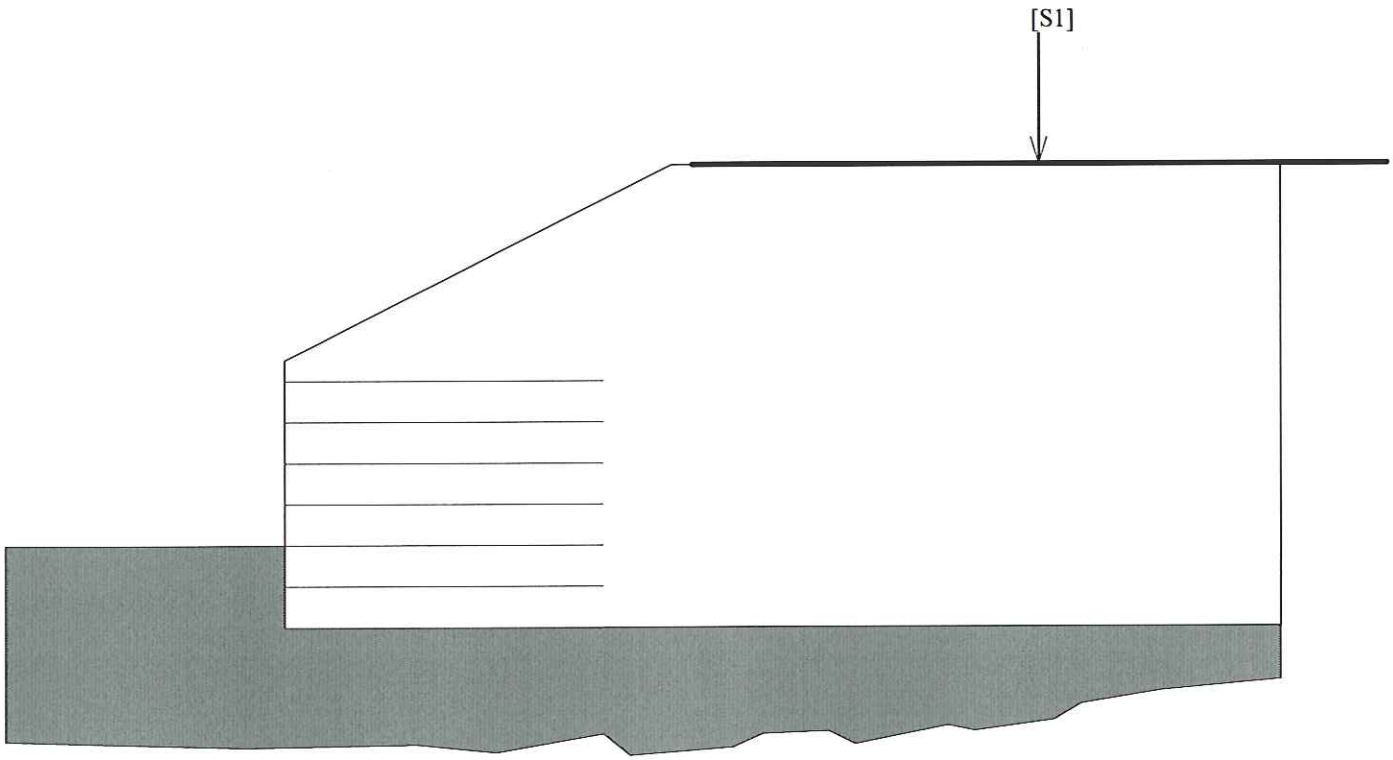
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	13.00	[ft]	{ Embedded depth is E = 4.00 ft, and height above top of finished bottom grade is H = 9.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	9.5	[ft]	Broken back equivalent angle, I = 20.07° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=34.0 [ft]. Distance of center of footing from wall face, d = 37.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6[ft]

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RKK-RW7&8-126
JBP
1-19-09

AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00

Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static		Combined Static/Seismic
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:	Static	Combined Static/Seismic
ϕ_b	0.65	0.65

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RKK-RW7&8-127

1-19-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.00, Meyerhof stress = 3143 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.810, Eccentricity, e/L = 0.0294, CDR-overturning = 5.30

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	15.60	1	N/A	3.54	3.93	3.932	3.443	2.742	0.0294	---
2	2.00	15.60	1	N/A	1.91	2.12	2.120	1.721	2.939	0.0103	---
3	4.00	15.60	1	N/A	2.15	2.39	2.394	1.748	3.165	-0.0089	---
4	6.00	15.60	1	N/A	2.52	2.80	2.802	1.779	3.424	-0.0291	---
5	8.00	15.60	1	N/A	3.13	3.48	3.477	1.874	3.715	-0.0518	---
6	10.00	15.60	1	N/A	4.21	4.68	4.683	2.183	4.025	-0.0804	---
7	12.00	15.60	1	N/A	6.58	7.31	7.311	2.750	4.292	-0.1243	---

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RKK-RW7&8-128

BGJ 1-9-09

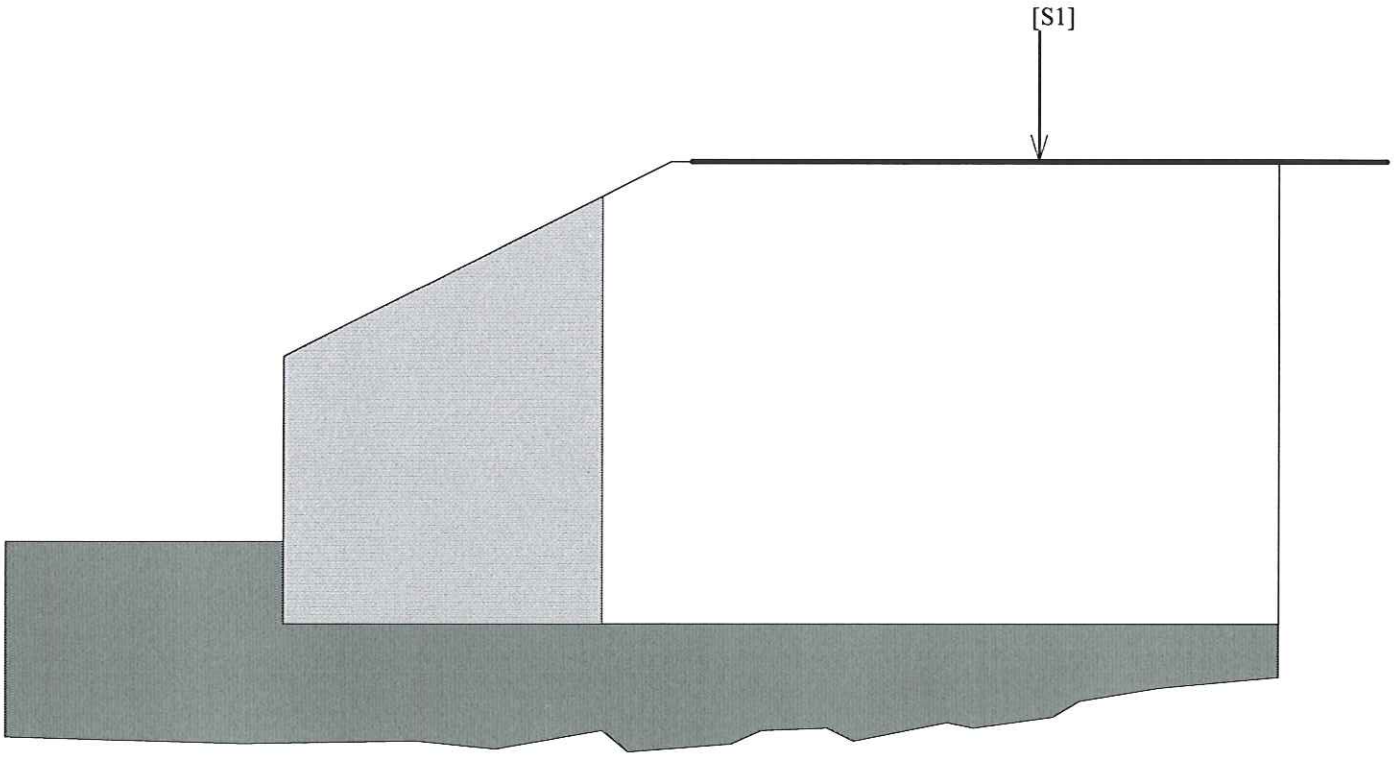
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	3150	N/A	[lb/ft ²]
Meyerhof stress, σ_V	3142.6	N/A	[lb/ft ²]
Eccentricity, e	0.20	N/A	[ft]
Eccentricity, e/L	0.013	N/A	
CDR calculated	1.00	N/A	
Base length	15.60	N/A	[ft]

$q_R = q_{ult} > \sigma_V$ ∴ OK

3150 > 3142.6

CDR > 1 ∴ OK



SCALE:

0 2 4 6 [ft]

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RKK-RW7&8-129
1-19-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.810

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	15.60	2.742	N/A	1	---
2	2.00	15.60	2.939	N/A	1	---
3	4.00	15.60	3.165	N/A	1	---
4	6.00	15.60	3.424	N/A	1	---
5	8.00	15.60	3.715	N/A	1	---
6	10.00	15.60	4.025	N/A	1	---
7	12.00	15.60	4.292	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0294; Overturning: CDR-static = 5.30

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	15.60	0.0294	N/A	1	---
2	2.00	15.60	0.0103	N/A	1	---
3	4.00	15.60	-0.0089	N/A	1	---
4	6.00	15.60	-0.0291	N/A	1	---
5	8.00	15.60	-0.0518	N/A	1	---
6	10.00	15.60	-0.0804	N/A	1	---
7	12.00	15.60	-0.1243	N/A	1	---

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RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject SR1/I-95 Interchange
RW 7 & 8 Back-to-back Analysis

Cm. No. 103-059-27U

Prepared By SAB Date 12/12/08 Checked By JGT Date 1-18-09
amc 2/9/09

Objective: To check the external stability of Retaining Wall 7 & 8 as back-to-back walls, near the start of the walls where the height is greatest.

References: 1) AASHTO LRFD Bridge Design Specifications, 4th ed.
2) FHWA Publication No. FHWA-NHI-00-043 "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines."

SUMMARY: STA 1251+00 (Ramp A)

Undrained Analysis
Foundation Soil
$\gamma = 130$ pcf $\phi = 0°$; $S_u = 2{,}000$ psf

Bearing Capacity: FS = 2.69

Weighted Stress: $\sigma_v = 3{,}820$ psf

→ So allowable bearing capacity = 3,900 psf

Sliding: FS ≫ 1.5

GOVERNS

Drained Analysis
Foundation Soil
$\gamma = 130$ pcf $\phi = 24°$ $c' = 0$ psf

Bearing Capacity: FS = 2.13

Weighted Stress: $\sigma_v = 3{,}420$ psf

→ So allowable bearing capacity = 3,900 psf

Sliding: FS ≫ 1.5

(Ramp G1 STA 1317+68)

⇒ So use: $L = 0.9H$ for RW 7 from STA 1251+00 (wall start) to STA 1251+50, then $L = 1.1H$

$L = 1.2H$ for full length of RW 8; No. 57 stone must be used behind Reinforced Soil zone (when not part of RW 7 reinforced soil)

Wall Details: (See attached cross-section, p. 3)

Ramp A STA 1251+00 (Ramp C1 STA 1816+00) analyzed → least distance between wall faces & greatest wall heights.

→ RW 7: H = 30.5' (Embedment depth, E = 3')

RW 8: H = 20', (Embedment depth, E = 3'), Backslope rise = 10' @ 2(H):1(V) Slope

⇒ Since MSEW 3.0 requires symmetry to analyze a back-to-back wall, use H = 30.5' for both walls.

overdesign for RW 8

Ramp C1 at top of walls → LL = 250 psf

Bottom of Landing Pad EL = 62.5

Per FHWA, (Ref 2), p. 178 Eqn. 55, reduce active thrust if $D < H_1 \tan(45 - \phi/2)$

D = distance between walls H_1 = Wall Height ϕ = Retained Soil Friction Angle

→ Actual D = 4' if L/H = 0.9 for both walls

$H_1(\tan 45 - \phi/2) = 30.5'(\tan 45 - 34/2) = 16.2' > 4'$ so active thrust is reduced.

In MSEW 3.0, maximum reinforcement length = Distance b/t wall Faces/2. = 25.5'

→ use L = 25.5 for both walls for analysis. This means for design!

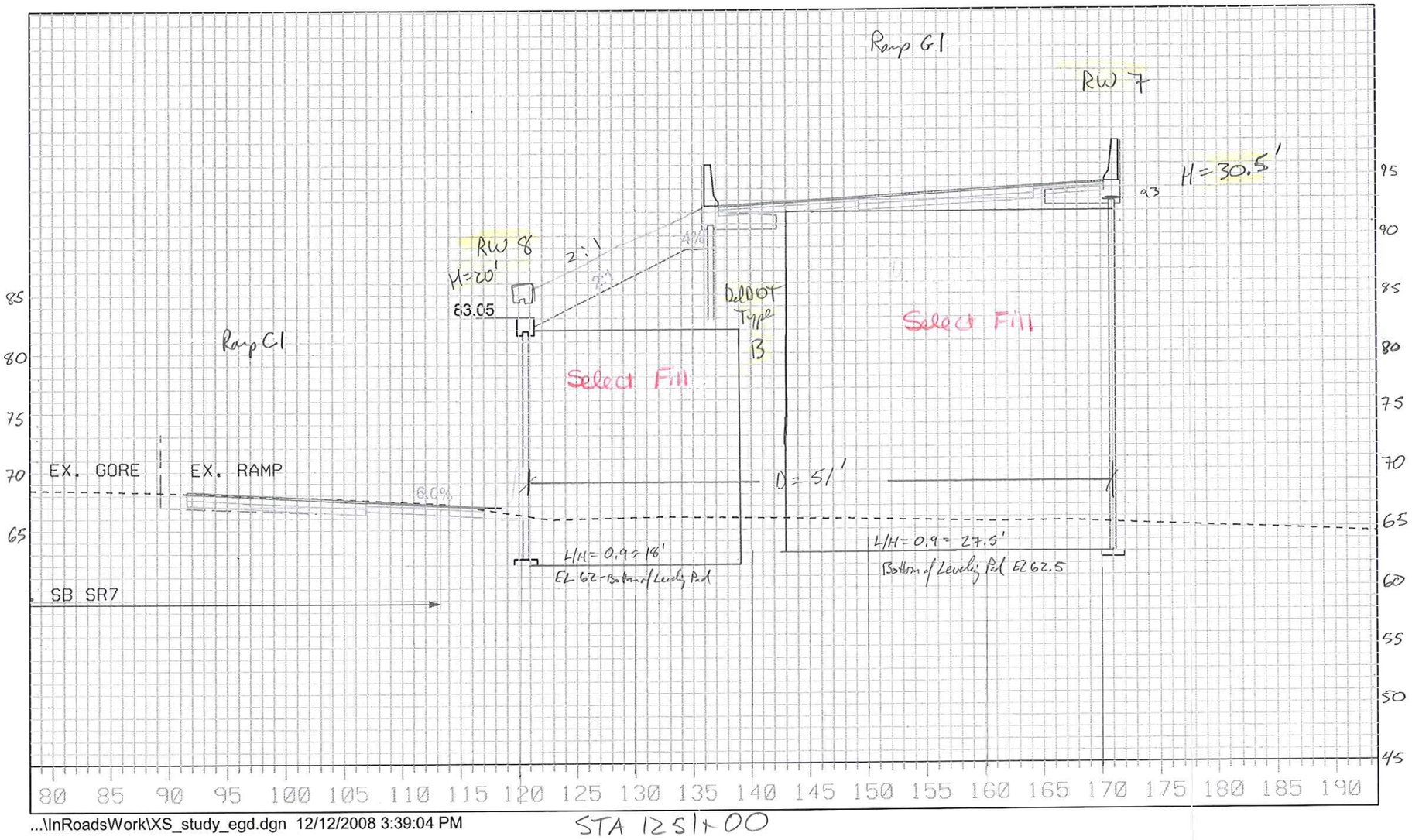
RW 7: L/H = 0.9 = 27.5' ≈ 31.5' OK
RW 8: L/H = 1.2 = 24'

Soils: Use same soils as used in individual wall analyses. → See calculation sets.

SR1/I-95 Interchange 103-059-27U 12/15/08 3

RW 7&8 Back-to-Back Wall Analysis

1-19-09
RKK-RW7&8-132



...\InRoadsWork\XS_study_egd.dgn 12/12/2008 3:39:04 PM

External Stability Analysis: Performed using MSEW 3.0 (see attached MSEW output, p. 5-20)

→ Per AASHTO LRFD, back-to-back walls must be designed per AASHTO 2002/FHWA (ASD)

Undrained: (p. 5-12)

Results: Bearing Capacity: Ultimate Bearing Capacity, q_{ULT} = 10,283 psf

Meyerhof Stress, σ_v = 3,820 psf

FS = 2.69 > 2.5 ✓OK

Sliding: OK. FS ≫ 1.5 } SEE MSEW RESULTS

Overturning: OK. FS ≫ 2.0 }

Drained: (p. 13-20)

Results: Bearing Capacity: Ultimate Bearing Capacity, q_{ULT} = 8,132 psf

Meyerhof Stress, σ_v = 3,820 psf

FS = 2.13 ✓OK - per FHWA 4.2.f, FS=2.0 may be used w/ the geotechnical analysis calculating acceptable settlement.

Sliding: OK. FS ≫ 1.5

Overturning: OK. FS ≫ 2.0

5

RKK-RW7&8-134

JMT 1-19-09

EM 1/9/09

AASHTO DESIGN METHOD
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: Ramp A STA 1251+00

Description:

Retaining Wall 7 & 8 - Ramp G1 Back to Back Wall UNDRAINED
Analysis H = 30.5 RW 7 L/H = 0.9 RW 8 L/H = 1.2

Since max reinforcement = L/2 where L = distance between RW faces.

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....NED Back to Back.BEN
Original date and time of creating this file: Fri Dec 12 07:16:19 2008

PROGRAM MODE:

ANALYSIS
of BACK to BACK WALL
using METAL STRIPS as reinforcing material.

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RKK-RW7&8-135

1-19-09

2/9/09

SOIL DATA

REINFORCED SOIL

Unit weight, γ		125.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	34.0 °

Select

RETAINED SOIL

Unit weight, γ		125.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	34.0 °

Select

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight,	$\gamma_{equiv.}$	130.0 lb/ft ^{3}
Equivalent internal angle of friction,	$\phi_{equiv.}$	0.0 °
Equivalent cohesion, c	$_{equiv.}$	2000.0 lb/ft ^{2}

Strata IIa

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 5.14 N γ= 0.00

SEISMICITY

Not Applicable

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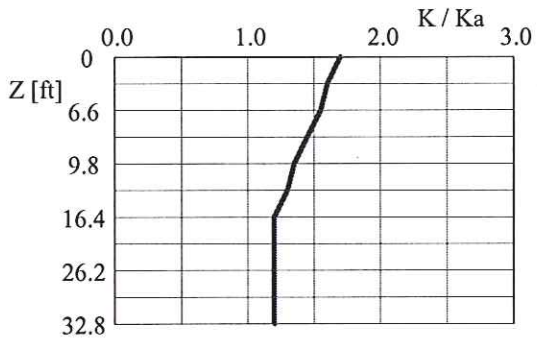
RKK-RW7&8-136
GBT 1-19-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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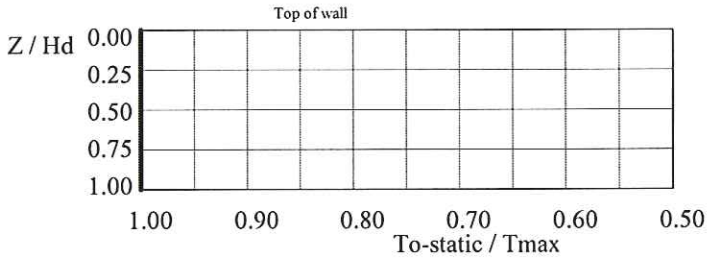
RKK-RW7&8-137

JBT 1-19-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK-RW7&8-138

INPUT DATA: Geometry and Surcharge loads (of BACK to BACK wall)

Design height, Hd 30.50 [ft] { Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 27.50 ft }

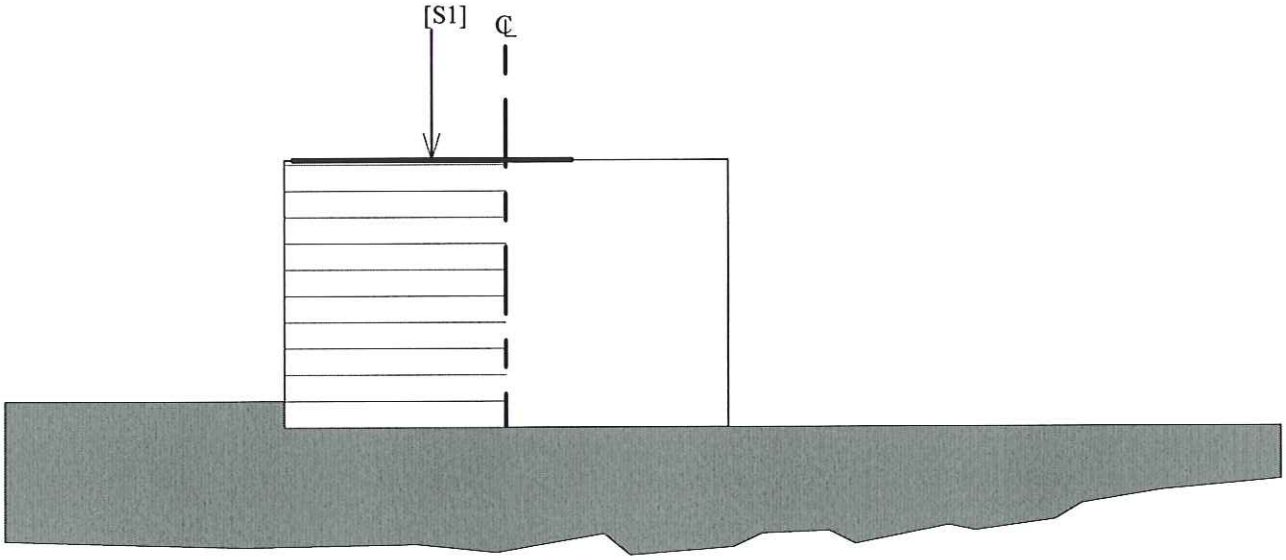
Batter, ω 0.0 [deg]
Backslope, β 0.0 [deg]
Backslope rise 0.0 [ft] Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

Distance between walls (Back to Back) = 51.0 ft, and Reinforcement length, L = 25.5 ft.

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=32.0 [ft]. Distance of center of footing from wall face, d = 17.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW7&8-139

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, Fs = 2.69, Meyerhof stress = 3820 lb/ft².

Foundation Interface: Direct sliding, Fs = 7443187.565, Eccentricity, e/L = 0.0003, Fs-overturning = 1610.57

#	METAL STRIP Elevation [ft]	Length [ft]	Type #	CONNECTION Fs-overall [pullout resistance]	Fs-overall [connection break]	Fs-overall [metal strip strength]	Metal strip strength Fs	Pullout resistance Fs	Direct sliding Fs	Eccentricity e/L	Product name
1	0.00	25.50	1	N/A	2.40	2.67	2.669	3.500	9531803.124	0.0003	---
2	3.00	25.50	1	N/A	1.30	1.44	1.443	1.586	8594248.719	0.0003	---
3	6.00	25.50	1	N/A	1.46	1.62	1.620	1.465	7656694.313	0.0003	---
4	9.00	25.50	1	N/A	1.66	1.85	1.845	1.344	6719139.907	0.0002	---
5	12.00	25.50	1	N/A	1.87	2.08	2.078	1.322	5801895.166	0.0002	---
6	15.00	25.50	1	N/A	2.11	2.35	2.348	1.419	4863602.814	0.0002	---
7	18.00	25.50	1	N/A	2.50	2.77	2.773	1.614	3922260.334	0.0002	---
8	21.00	25.50	1	N/A	3.09	3.44	3.436	1.779	2980917.854	0.0001	---
9	24.00	25.50	1	N/A	4.27	4.75	4.750	1.927	2039575.374	0.0001	---
10	27.00	25.50	1	N/A	7.58	8.42	8.420	2.073	1098232.894	0.0000	---
11	30.00	25.50	1	N/A	37.01	41.12	41.120	1.610	156890.413	0.0000	---

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RKK-RW7&8-140

1-19-09

2/9/09

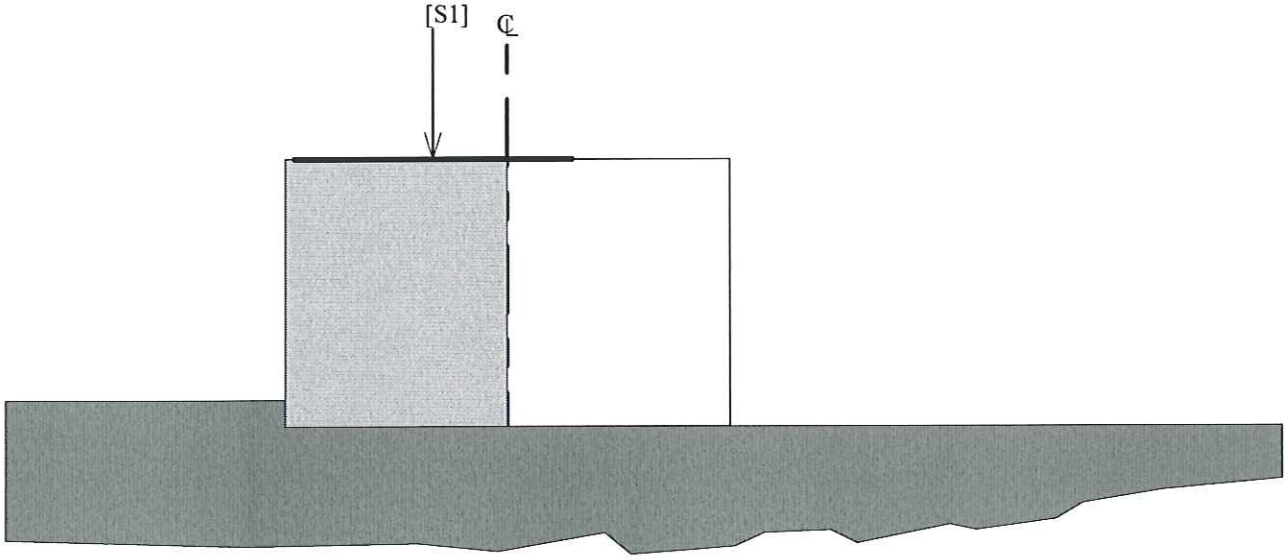
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	10283	N/A	[lb/ft ²]
Meyerhof stress, σ_V	3820.3	N/A	[lb/ft ²]
Eccentricity, e	-0.00	N/A	[ft]
Eccentricity, e/L	-0.000	N/A	
Fs calculated	2.69	N/A	
Base length	25.50	N/A	[ft]

$q_{ult} > \bar{\sigma}_V$ ∴ ok

$\frac{q_{ult}}{2.5} > \bar{\sigma}_V$

4113 psf $> \bar{\sigma}_V$ 3820 ∴ ok



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW7&8-141
1-19-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: Fs-static = 7443187.565

#	Metal strip Elevation [ft]	Metal strip Length [ft]	Fs Static	Fs Seismic	Metal strip Type #	Product name
1	0.00	25.50	9531803.124	N/A	1	---
2	3.00	25.50	8594248.719	N/A	1	---
3	6.00	25.50	7656694.313	N/A	1	---
4	9.00	25.50	6719139.907	N/A	1	---
5	12.00	25.50	5801895.166	N/A	1	---
6	15.00	25.50	4863602.814	N/A	1	---
7	18.00	25.50	3922260.334	N/A	1	---
8	21.00	25.50	2980917.854	N/A	1	---
9	24.00	25.50	2039575.374	N/A	1	---
10	27.00	25.50	1098232.894	N/A	1	---
11	30.00	25.50	156890.413	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0003; Overturning: Fs-static = 1610.57

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	25.50	0.0003	N/A	1	---
2	3.00	25.50	0.0003	N/A	1	---
3	6.00	25.50	0.0003	N/A	1	---
4	9.00	25.50	0.0002	N/A	1	---
5	12.00	25.50	0.0002	N/A	1	---
6	15.00	25.50	0.0002	N/A	1	---
7	18.00	25.50	0.0002	N/A	1	---
8	21.00	25.50	0.0001	N/A	1	---
9	24.00	25.50	0.0001	N/A	1	---
10	27.00	25.50	0.0000	N/A	1	---
11	30.00	25.50	0.0000	N/A	1	---

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RKK-RW7&8-142
1-19-09
2/9/09

AASHTO DESIGN METHOD
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: Ramp A STA 1251+00

Description:

Retaining Wall 7 & 8 - Ramp G1 Back to Back Wall DRAINED Analysis H = 30.5 L/H = 0.9 L/H = 1.2

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN..... .....NED Back to Back.BEN
Original date and time of creating this file: Fri Dec 12 07:16:19 2008

PROGRAM MODE:

ANALYSIS
of BACK to BACK WALL
using METAL STRIPS as reinforcing material.

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RKK-RW7&8-143
1-19-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select
Design value of internal angle of friction, ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select
Design value of internal angle of friction, ϕ	34.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	130.0 lb/ft ^{3}	Strata 2a
Equivalent internal angle of friction, $\phi_{equiv.}$	24.0 °	
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ^{2}	

Water table is at wall base elevation

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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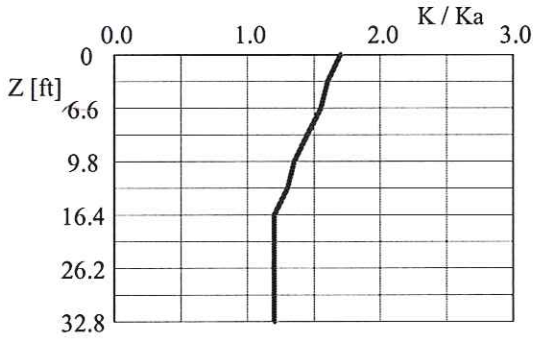
RKK-RW7&8-144
EPE 1-19-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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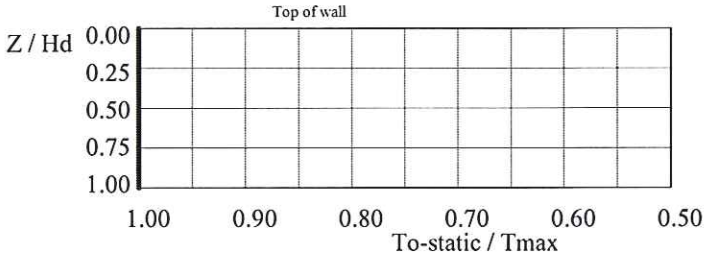
RKK-RW7&8-145 1-19-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK-RW7&8-146

JPT 1-19-09

EMC 2/9/09

INPUT DATA: Geometry and Surcharge loads (of BACK to BACK wall)

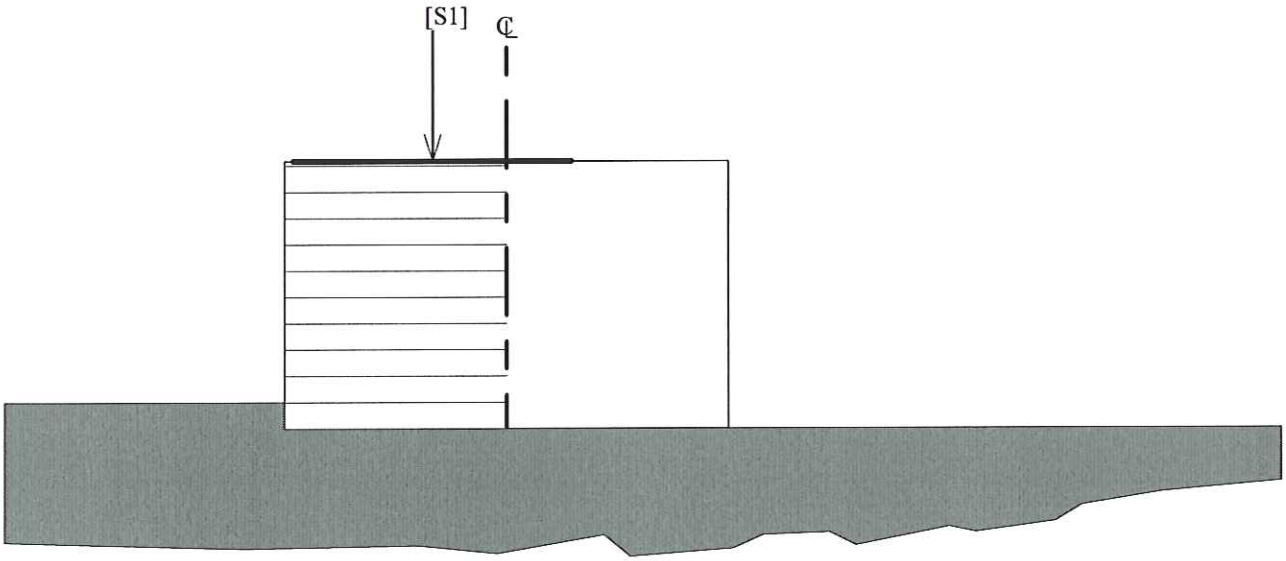
Design height, Hd	30.50	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 27.50 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

Distance between walls (Back to Back) = 51.0 ft, and Reinforcement length, L = 25.5 ft.

U N I F O R M S U R C H A R G E
Uniformly distributed dead load is 0.0 [lb/ft ²]

OTHER EXTERNAL LOAD(S)
[S1] Strip Load, Pv-d = 0.0 and Pv-l = 250.0 [lb/ft].
Footing width, b=32.0 [ft]. Distance of center of footing from wall face, d = 17.0 [ft] @ depth of 0.0 [ft] below soil surface.

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW7&8-147 JBT 1-19-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, Fs = 2.13, Meyerhof stress = 3820 lb/ft².

Foundation Interface: Direct sliding, Fs = 6317160.841, Eccentricity, e/L = 0.0003, Fs-overturning = 1610.57

METAL STRIP				CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	Fs-overall [pullout resistance]	Fs-overall [connection break]	Fs-overall [metal strip strength]	Metal strip strength Fs	Pullout resistance Fs	Direct sliding Fs	Eccentricity e/L	Product name
1	0.00	25.50	1	N/A	2.40	2.67	2.669	3.500	9531803.124	0.0003	---
2	3.00	25.50	1	N/A	1.30	1.44	1.443	1.586	8594248.719	0.0003	---
3	6.00	25.50	1	N/A	1.46	1.62	1.620	1.465	7656694.313	0.0003	---
4	9.00	25.50	1	N/A	1.66	1.85	1.845	1.344	6719139.907	0.0002	---
5	12.00	25.50	1	N/A	1.87	2.08	2.078	1.322	5801895.166	0.0002	---
6	15.00	25.50	1	N/A	2.11	2.35	2.348	1.419	4863602.814	0.0002	---
7	18.00	25.50	1	N/A	2.50	2.77	2.773	1.614	3922260.334	0.0002	---
8	21.00	25.50	1	N/A	3.09	3.44	3.436	1.779	2980917.854	0.0001	---
9	24.00	25.50	1	N/A	4.27	4.75	4.750	1.927	2039575.374	0.0001	---
10	27.00	25.50	1	N/A	7.58	8.42	8.420	2.073	1098232.894	0.0000	---
11	30.00	25.50	1	N/A	37.01	41.12	41.120	1.610	156890.413	0.0000	---

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RKK-RW7&8-148

1-19-09
EMM
2/9/09

BEARING CAPACITY for GIVEN LAYOUT

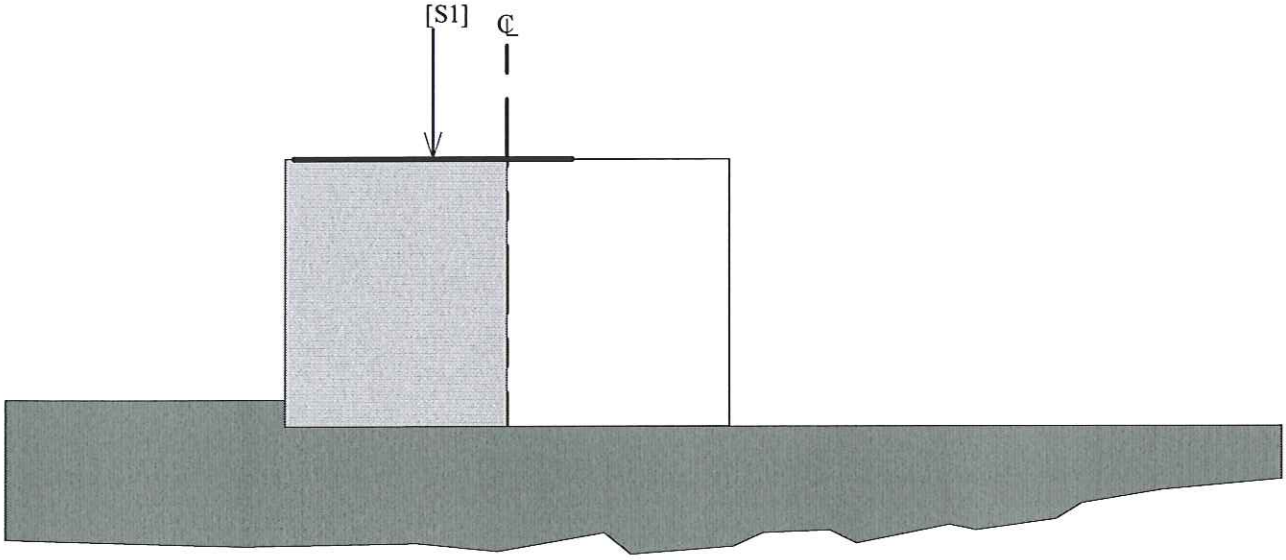
	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	8132	N/A	[lb/ft ²]
Meyerhof stress, σ_V	3820.3	N/A	[lb/ft ²]
Eccentricity, e	-0.00	N/A	[ft]
Eccentricity, e/L	-0.000	N/A	
Fs calculated	2.13	N/A	
Base length	25.50	N/A	[ft]

$q_a = \frac{q_{ult}}{2.0}$

$q_a = \frac{8132}{2} = 4066$ psf

$q_a > \sigma_V$ ∴ OK

Actual FS ≈ 2.13



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW7&8-149
JJT 1-19-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: Fs-static = 6317160.841

#	Metal strip Elevation [ft]	Metal strip Length [ft]	Fs Static	Fs Seismic	Metal strip Type #	Product name
1	0.00	25.50	9531803.124	N/A	1	---
2	3.00	25.50	8594248.719	N/A	1	---
3	6.00	25.50	7656694.313	N/A	1	---
4	9.00	25.50	6719139.907	N/A	1	---
5	12.00	25.50	5801895.166	N/A	1	---
6	15.00	25.50	4863602.814	N/A	1	---
7	18.00	25.50	3922260.334	N/A	1	---
8	21.00	25.50	2980917.854	N/A	1	---
9	24.00	25.50	2039575.374	N/A	1	---
10	27.00	25.50	1098232.894	N/A	1	---
11	30.00	25.50	156890.413	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0003; Overturning: Fs-static = 1610.57

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	25.50	0.0003	N/A	1	---
2	3.00	25.50	0.0003	N/A	1	---
3	6.00	25.50	0.0003	N/A	1	---
4	9.00	25.50	0.0002	N/A	1	---
5	12.00	25.50	0.0002	N/A	1	---
6	15.00	25.50	0.0002	N/A	1	---
7	18.00	25.50	0.0002	N/A	1	---
8	21.00	25.50	0.0001	N/A	1	---
9	24.00	25.50	0.0001	N/A	1	---
10	27.00	25.50	0.0000	N/A	1	---
11	30.00	25.50	0.0000	N/A	1	---

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Subject I-95/SR1 Interchange
Ramp G1 RW 7 & RW 8 Global Stability Analysis
Cm. No. 103-059-27U

Prepared By SAB Date 9/17/08 Checked By SJT Date 9-30-08
REV 11/25/08 SJT 1-11-09
EM 2/9/09

Global Stability Analysis: Performed using Slope/W for STA 1251+00

=> Includes RW 8. + R7

See attached cross-section, p. 2.

Soil parameters same as for external stability analysis.

LL = 250 psf for Ramp G1

* Modeled w/ fabric reinforcement even though will be metal straps *

→ Morgenstern-Price Method used for analysis.

→ For LRFD, $\phi_r = 0.65$ for slope stability with a structure.

See attached Slope/W Reports.
Packet 1: RW 7 UNDRAINED
Packet 2: RW 7 DRAINED
Packet 3: RW 8 UNDRAINED
Packet 4: RW 8 DRAINED

$\phi_r = 0.65 \rightarrow$ = FS = 1.538 required.

HISTORICALLY, FS = 1.3 to 1.5

Summary:

	RW 7	RW 8
UNDRAINED	FS = 2.51 > 1.538 ✓OK	FS = 1.55 > 1.538 ✓OK
DRAINED	FS = 1.55 > 1.538 ✓OK	FS = 1.69 > 1.538 ✓OK

* At STA 1251+00, with reinforcement length = 1.0H for both walls, the reinforcement will overlap approximately 2'. This will only occur near this station, as the distance between the wall faces increases along the walls' length. Therefore, the overlap was ignored in the external stability analysis.

* Internal stability to be verified by Contractor.

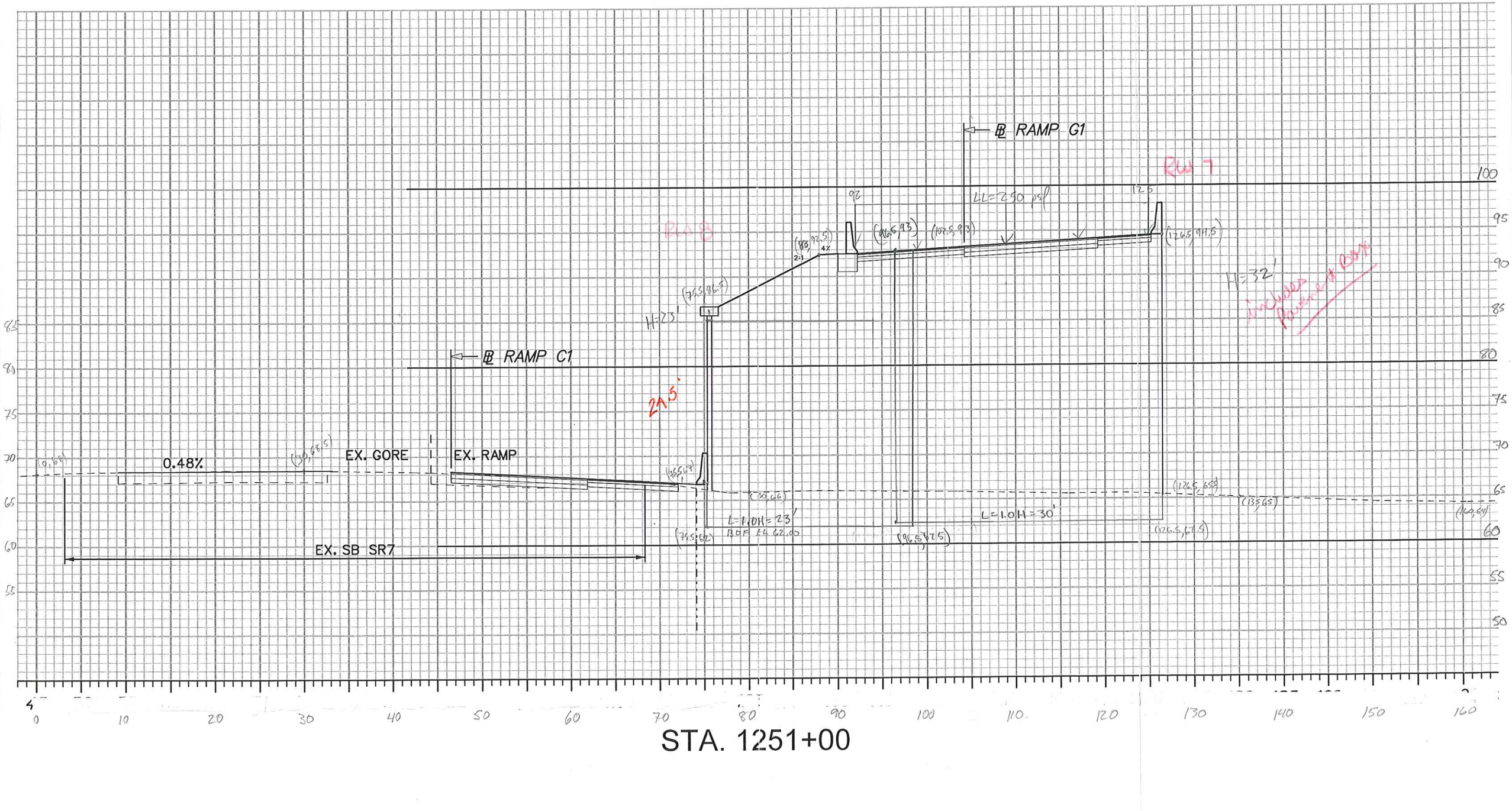
I-95/SR1 Interchange
Ramp C1 RW7&8
Global Stability

103-059-270

2

JDT 1/29

RKK-RW7&8-151



STA. 1251+00

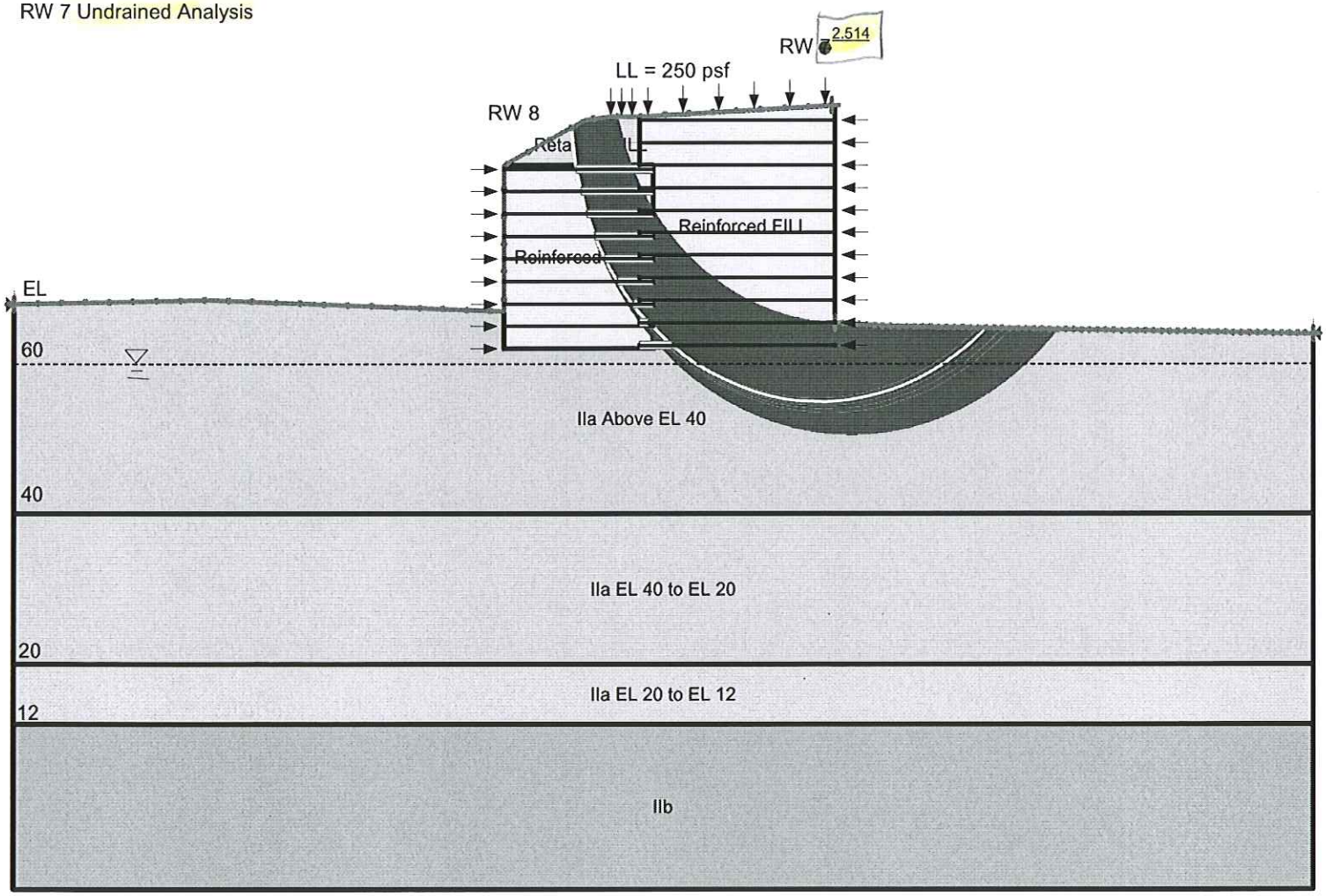
Packet 1

RKK-RW7&8-152

JJT 1-11-09

EMM 2/9/09

SR 1/I-95 Interchange 103-059-27U 11/25/08
RW 7 Undrained Analysis



SLOPE/W Analysis

Report generated using GeoStudio 2007, version 7.11. Copyright © 1991-2008 GEO-SLOPE International Ltd.

File Information

Revision Number: 59
Last Edited By: sberkheimer
Date: 11/25/2008
Time: 10:26:35 AM
File Name: Ramp G1 STA 1251+00 RW 7 UNDRAINED.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\RampG1 Retaining Wall 8\Final Design\
Last Solved Date: 11/25/2008
Last Solved Time: 10:27:20 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Description: I-95/SR 1 Interchange 103-059-27U STA 1251+00 RW 7 UNDRAINED
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- **Apply Phreatic Correction:** Yes
- Side Function
  - **Interslice force function option:** Half-Sine
- **PWP Conditions Source:** Piezometric Line
- **Use Staged Rapid Drawdown:** No

SlipSurface
- **Direction of movement:** Left to Right
- **Allow Passive Mode:** No
- **Slip Surface Option:** Entry and Exit
- **Critical slip surfaces saved:** 1
- **Optimize Critical Slip Surface Location:** No
- Tension Crack

Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 32
Ending Optimization Points: 64
Complete Passes per Insertion: 1

Materials

Reinforced FILL

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Select

Retained FILL (DelDOT Type F Borrow)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa Above EL 40

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 2000 psf
Pore Water Pressure
Piezometric Line: 1

IIa EL 40 to EL 20

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 2500 psf
Pore Water Pressure
Piezometric Line: 1

IIa EL 20 to EL 12

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 3500 psf
Pore Water Pressure
Piezometric Line: 1

IIb

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0, 68) ft
Left-Zone Right Coordinate: (125.99969, 94.474984) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (126.51, 65.499412) ft
Right-Zone Right Coordinate: (200, 64) ft
Right-Zone Increment: 60
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 68) ft
Right Coordinate: (200, 64) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	60
	200	60

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	92	93
	125	94.5

Reinforcements → [1→9 for RW 8] [10→20 for RW 7]

> Fabric used to model proposed steel straps (not an option in Slope/W)

Reinforcement 1

Type: Fabric
Outside Point: (75.5, 62) ft
Inside Point: (98.5, 62) ft
Slip Surface Intersection: (146.26, 62) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0.39724 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (75.5, 65) ft
Inside Point: (98.5, 65) ft
Slip Surface Intersection: (98.315, 65) ft
Total Length: 23 ft
Reinforcement Direction: 180 °

Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 0.073605 lbs
Resisting Force Used: 0.39724 lbs/ft
Available Bond Length: 0.18529 ft
Required Bond Length: 0.18529 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (75.5, 68) ft
Inside Point: (98.5, 68) ft
Slip Surface Intersection: (95.413, 68) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 1.2262 lbs
Resisting Force Used: 0.39724 lbs/ft
Available Bond Length: 3.0868 ft
Required Bond Length: 3.0868 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (75.5, 71) ft
Inside Point: (98.5, 71) ft
Slip Surface Intersection: (93.043, 71) ft
Total Length: 23 ft
Reinforcement Direction: 180 °

Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 2.1677 lbs
Resisting Force Used: 0.39724 lbs/ft
Available Bond Length: 5.4571 ft
Required Bond Length: 5.4571 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (75.5, 74) ft
Inside Point: (98.5, 74) ft
Slip Surface Intersection: (91.105, 74) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 2.9376 lbs
Resisting Force Used: 0.39724 lbs/ft
Available Bond Length: 7.3951 ft
Required Bond Length: 7.3951 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (75.5, 77) ft
Inside Point: (98.5, 77) ft
Slip Surface Intersection: (89.538, 77) ft
Total Length: 23 ft
Reinforcement Direction: 180 °

Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 3.56 lbs
Resisting Force Used: 0.39724 lbs/ft
Available Bond Length: 8.9618 ft
Required Bond Length: 8.9618 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (75.5, 80) ft
Inside Point: (98.5, 80) ft
Slip Surface Intersection: (88.257, 80) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 4.069 lbs
Resisting Force Used: 0.39724 lbs/ft
Available Bond Length: 10.243 ft
Required Bond Length: 10.243 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (75.5, 83) ft
Inside Point: (98.5, 83) ft
Slip Surface Intersection: (87.368, 83) ft
Total Length: 23 ft
Reinforcement Direction: 180 °

Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 4.4219 lbs
Resisting Force Used: 0.39724 lbs/ft
Available Bond Length: 11.132 ft
Required Bond Length: 11.132 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (75.5, 86) ft
Inside Point: (98.5, 86) ft
Slip Surface Intersection: (86.578, 86) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 4.7358 lbs
Resisting Force Used: 0.39724 lbs/ft
Available Bond Length: 11.922 ft
Required Bond Length: 11.922 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (126.5, 62.5) ft
Inside Point: (96.5, 62.5) ft
Slip Surface Intersection: (101.33, 62.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °

Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 ° → From AASHTO LRFD Table 3.11.5.3-1 for Steel on silty Sand (Typ.)
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 1788.9 lbs
Resisting Force Used: 370.03 lbs/ft
Available Bond Length: 4.8345 ft
Required Bond Length: 4.8345 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (126.5, 65.5) ft
Inside Point: (96.5, 65.5) ft
Slip Surface Intersection: (97.799, 65.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 444.9 lbs
Resisting Force Used: 342.44 lbs/ft
Available Bond Length: 1.2992 ft
Required Bond Length: 1.2992 ft
Governing Component: Bond

Reinforcement 12

Type: Fabric
Outside Point: (126.5, 68.5) ft
Inside Point: (96.5, 68.5) ft
Slip Surface Intersection: (94.975, 68.5) ft

Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 315.99 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 13

Type: Fabric
Outside Point: (126.5, 71.5) ft
Inside Point: (96.5, 71.5) ft
Slip Surface Intersection: (92.682, 71.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 278.26 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 14

Type: Fabric
Outside Point: (126.5, 74.5) ft

Inside Point: (96.5, 74.5) ft
Slip Surface Intersection: (90.817, 74.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 30 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0.39724 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 15

Type: Fabric
Outside Point: (126.5, 77.5) ft
Inside Point: (96.5, 77.5) ft
Slip Surface Intersection: (89.325, 77.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 180.88 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 16

Type: Fabric

Outside Point: (126.5, 80.5) ft
Inside Point: (96.5, 80.5) ft
Slip Surface Intersection: (88.043, 80.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 180.88 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 17

Type: Fabric
Outside Point: (126.5, 83.5) ft
Inside Point: (96.5, 83.5) ft
Slip Surface Intersection: (87.237, 83.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 108.97 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 18

Type: Fabric
Outside Point: (126.5, 86.5) ft
Inside Point: (96.5, 86.5) ft
Slip Surface Intersection: (86.447, 86.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 33.826 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 19

Type: Fabric
Outside Point: (126.5, 89.5) ft
Inside Point: (96.5, 89.5) ft
Slip Surface Intersection: (86.108, 89.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 33.826 lbs/ft
Available Bond Length: 0 ft

Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 20

Type: Fabric
Outside Point: (126.5, 92.5) ft
Inside Point: (96.5, 92.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Regions

	Material	Points	Area (ft²)
Region 1	IIa EL 20 to EL 12	15,16,18,17	1600
Region 2	IIa EL 40 to EL 20	13,14,16,15	4000
Region 3	IIa Above EL 40	1,2,3,4,6,22,9,10,11,12,14,13	5053.25
Region 4	Reinforced FILL	3,5,21,23,22,6,4	563.5
Region 5	Reinforced FILL	9,10,7,8,21,23,22	889.5
Region 6	IIb	17,19,20,18	4400
Region 7	Retained FILL	5,25,24,8,21	91.75

Points

	X (ft)	Y (ft)
Point 1	0	68

Point 2	30	68.5
Point 3	75.5	67
Point 4	75.5	62
Point 5	75.5	86.5
Point 6	98.5	62
Point 7	126.5	94.5
Point 8	96.5	93
Point 9	126.5	62.5
Point 10	126.5	65.5
Point 11	135	65
Point 12	200	64
Point 13	0	40
Point 14	200	40
Point 15	0	20
Point 16	200	20
Point 17	0	12
Point 18	200	12
Point 19	0	-10
Point 20	200	-10
Point 21	96.5	86.5
Point 22	98.5	62.5
Point 23	98.5	86.5
Point 24	92	93
Point 25	88	92.5

← EL 94.5 ⇒ Wall Height = Point 7 − Point 9
= 94.5 − 62.5 = 32

← EL 62.5

H = 32'

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	8945	2.514	(124.163, 93.279)	38.32	(85.8842, 91.4844)	(149.773, 64.7727)

Slices of Slip Surface: 8945

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesiv Strengt (psf)
1	8945	86.16539	88.992215	-1809.1124	115.59492	61.462908	0

2	8945	87.22327	83.550625	-1469.5537	509.48552	343.65232	0
3	8945	89	78.26	-1139.4145	1002.5457	676.22561	0
4	8945	91	74.182175	-884.96547	1396.0887	941.6737	0
5	8945	93.125	70.886265	-679.29706	1729.9023	1166.8338	0
6	8945	95.375	68.04356	-501.91793	2037.6134	1374.3876	0
7	8945	97.5	65.790235	-361.30845	2310.0484	1558.1473	0
8	8945	99.91725	63.66014	-228.39381	2669.5175	1800.6123	0
9	8945	102.29165	61.83425	-114.45838	2844.0484	0	2000
10	8945	104.20595	60.58425	-36.457481	3091.9704	0	2000
11	8945	106.26515	59.41751	36.347278	3350.576	0	2000
12	8945	108.46925	58.340015	103.58298	3623.3764	0	2000
13	8945	110.67335	57.430325	160.34586	3893.5495	0	2000
14	8945	112.87745	56.675865	207.42475	4161.6753	0	2000
15	8945	115.08155	56.067145	245.40954	4426.6101	0	2000
16	8945	117.28565	55.597075	274.74225	4686.0076	0	2000
17	8945	119.48975	55.260495	295.74698	4935.8711	0	2000
18	8945	121.69385	55.05386	308.64038	5170.4927	0	2000
19	8945	123.89795	54.975065	313.55426	5383.0324	0	2000
20	8945	125.75	54.99855	312.09181	5523.0539	0	2000
21	8945	127.5625	55.124325	304.24389	1931.4997	0	2000
22	8945	129.6875	55.37387	288.67207	1969.0759	0	2000
23	8945	131.8125	55.74529	265.49244	1972.8066	0	2000
24	8945	133.9375	56.24226	234.48378	1940.0627	0	2000
25	8945	136.02025	56.854825	196.25825	1877.4453	0	2000
26	8945	138.0608	57.584225	150.74227	1786.4939	0	2000
27	8945	140.10135	58.448365	96.820653	1661.1068	0	2000
28	8945	142.1419	59.457625	33.844075	1503.7099	0	2000
29	8945	144.2639	60.679335	-42.388808	1309.7149	0	2000
30	8945	146.46735	62.148035	-134.0387	1082.8459	0	2000
31	8945	148.6708	63.855065	-240.55691	837.7158	0	2000

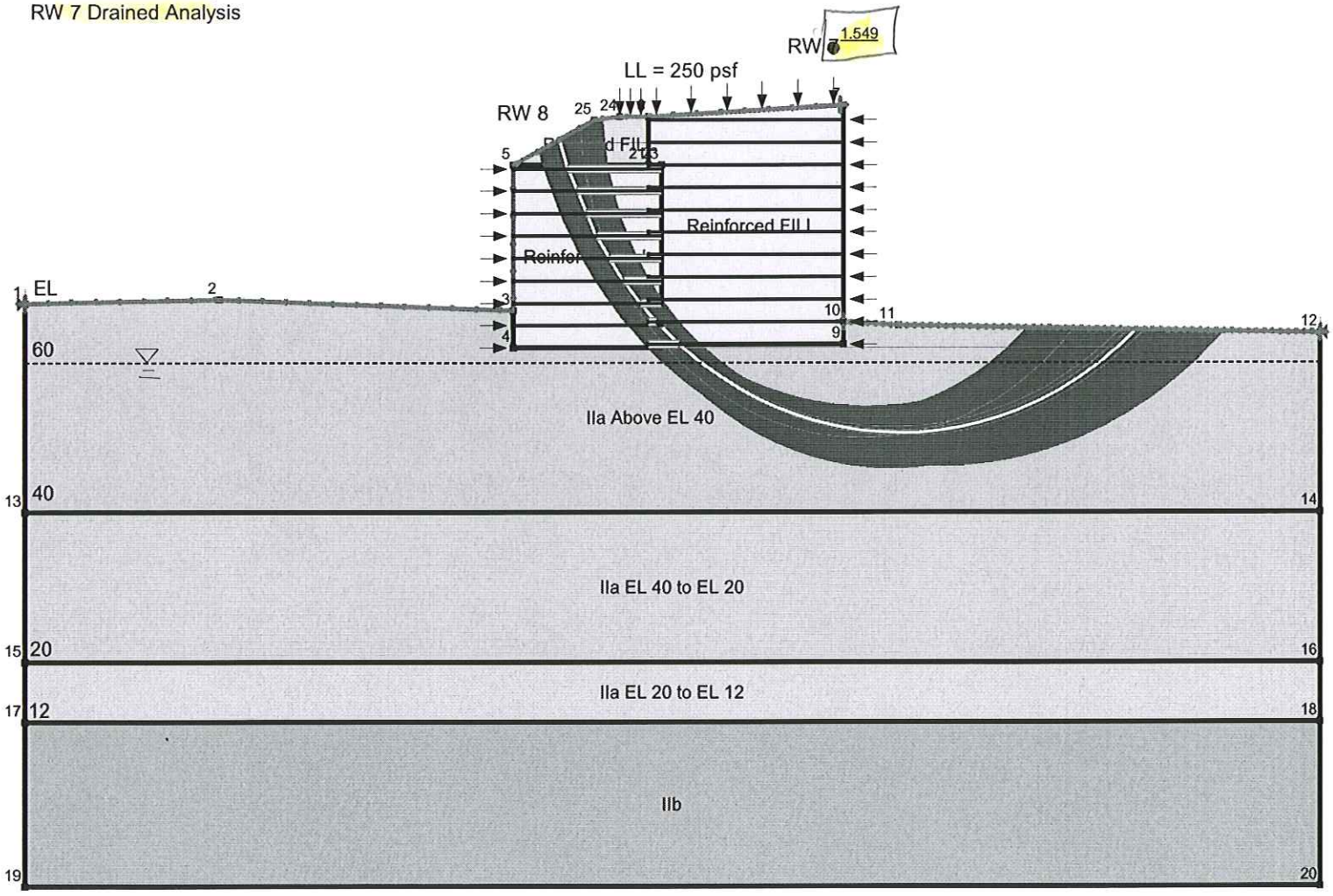
Packet 2

JST 2/9/09

RKK-RW7&8-169

EMM 2/9/09

SR 1/I-95 Interchange 103-059-27U 11/25/08
RW 7 Drained Analysis



SLOPE/W Analysis

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File Information

Revision Number: 64
Last Edited By: sberkheimer
Date: 11/25/2008
Time: 10:57:44 AM
File Name: Ramp G1 STA 1251+00 RW 7 DRAINED.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\RampG1 Retaining Wall 8\Final Design\
Last Solved Date: 11/25/2008
Last Solved Time: 10:58:18 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Description: I-95/SR 1 Interchange 103-059-27U STA 1251+00 RW 7 DRAINED
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- **Apply Phreatic Correction:** Yes
- **Side Function**
  - **Interslice force function option:** Half-Sine
- **PWP Conditions Source:** Piezometric Line
- **Use Staged Rapid Drawdown:** No

SlipSurface
- **Direction of movement:** Left to Right
- **Allow Passive Mode:** No
- **Slip Surface Option:** Entry and Exit
- **Critical slip surfaces saved:** 1
- **Optimize Critical Slip Surface Location:** No
- **Tension Crack**

Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 32
Ending Optimization Points: 64
Complete Passes per Insertion: 1

Materials

Reinforced FILL

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Select Fill

Retained FILL (DelDOT Type F Borrow)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa Above EL 40

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 24 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa EL 40 to EL 20

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf

Phi: 18 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa EL 20 to EL 12

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 18 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIb

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0, 68) ft
Left-Zone Right Coordinate: (125.99969, 94.474984) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (126.51, 65.499412) ft
Right-Zone Right Coordinate: (200, 64) ft
Right-Zone Increment: 60
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 68) ft
Right Coordinate: (200, 64) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	60
	200	60

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	92	93
	125	94.5

Reinforcements → [1→9 for RW8] [10-20 for RW7] > Fabric used to model proposed steel straps (not an option in Slope/W)

Reinforcement 1

Type: Fabric
Outside Point: (75.5, 62) ft
Inside Point: (98.5, 62) ft
Slip Surface Intersection: (168.86, 62) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 0.64591 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (75.5, 65) ft
Inside Point: (98.5, 65) ft
Slip Surface Intersection: (98.255, 65) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 0.15796 lbs
Resisting Force Used: 0.64591 lbs/ft
Available Bond Length: 0.24455 ft
Required Bond Length: 0.24455 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (75.5, 68) ft
Inside Point: (98.5, 68) ft
Slip Surface Intersection: (95.23, 68) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 2.1123 lbs

Resisting Force Used: 0.64591 lbs/ft
Available Bond Length: 3.2702 ft
Required Bond Length: 3.2702 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (75.5, 71) ft
Inside Point: (98.5, 71) ft
Slip Surface Intersection: (92.603, 71) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 3.8089 lbs
Resisting Force Used: 0.64591 lbs/ft
Available Bond Length: 5.8969 ft
Required Bond Length: 5.8969 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (75.5, 74) ft
Inside Point: (98.5, 74) ft
Slip Surface Intersection: (90.436, 74) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 5.2084 lbs

Resisting Force Used: 0.64591 lbs/ft
Available Bond Length: 8.0637 ft
Required Bond Length: 8.0637 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (75.5, 77) ft
Inside Point: (98.5, 77) ft
Slip Surface Intersection: (88.379, 77) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 6.5375 lbs
Resisting Force Used: 0.64591 lbs/ft
Available Bond Length: 10.121 ft
Required Bond Length: 10.121 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (75.5, 80) ft
Inside Point: (98.5, 80) ft
Slip Surface Intersection: (86.827, 80) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 7.5397 lbs

Resisting Force Used: 0.64591 lbs/ft
Available Bond Length: 11.673 ft
Required Bond Length: 11.673 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (75.5, 83) ft
Inside Point: (98.5, 83) ft
Slip Surface Intersection: (85.39, 83) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 8.4681 lbs
Resisting Force Used: 0.64591 lbs/ft
Available Bond Length: 13.11 ft
Required Bond Length: 13.11 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (75.5, 86) ft
Inside Point: (98.5, 86) ft
Slip Surface Intersection: (83.952, 86) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 23 lbs
Fabric Load Used: 9.3966 lbs

Resisting Force Used: 0.64591 lbs/ft
Available Bond Length: 14.548 ft
Required Bond Length: 14.548 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (126.5, 62.5) ft
Inside Point: (96.5, 62.5) ft
Slip Surface Intersection: (101.19, 62.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 ° → From AASHTO LRFD Table 3.11.5.3-1 for Steel on silty Sand (Typ.)
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 2824.4 lbs
Resisting Force Used: 602.13 lbs/ft
Available Bond Length: 4.6906 ft
Required Bond Length: 4.6906 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (126.5, 65.5) ft
Inside Point: (96.5, 65.5) ft
Slip Surface Intersection: (97.727, 65.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0

Applied Load: 12000 lbs
Fabric Load Used: 684.91 lbs
Resisting Force Used: 558.33 lbs/ft
Available Bond Length: 1.2267 ft
Required Bond Length: 1.2267 ft
Governing Component: Bond

Reinforcement 12

Type: Fabric
Outside Point: (126.5, 68.5) ft
Inside Point: (96.5, 68.5) ft
Slip Surface Intersection: (94.756, 68.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 517.76 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 13

Type: Fabric
Outside Point: (126.5, 71.5) ft
Inside Point: (96.5, 71.5) ft
Slip Surface Intersection: (92.184, 71.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs

Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 462.71 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 14

Type: Fabric
Outside Point: (126.5, 74.5) ft
Inside Point: (96.5, 74.5) ft
Slip Surface Intersection: (90.093, 74.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 30 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0.64591 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 15

Type: Fabric
Outside Point: (126.5, 77.5) ft
Inside Point: (96.5, 77.5) ft
Slip Surface Intersection: (88.036, 77.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1

Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 369.67 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 16

Type: Fabric
Outside Point: (126.5, 80.5) ft
Inside Point: (96.5, 80.5) ft
Slip Surface Intersection: (86.588, 80.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 194.14 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 17

Type: Fabric
Outside Point: (126.5, 83.5) ft
Inside Point: (96.5, 83.5) ft
Slip Surface Intersection: (85.15, 83.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1

Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 194.14 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 18

Type: Fabric
Outside Point: (126.5, 86.5) ft
Inside Point: (96.5, 86.5) ft
Slip Surface Intersection: (83.713, 86.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 41.265 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 19

Type: Fabric
Outside Point: (126.5, 89.5) ft
Inside Point: (96.5, 89.5) ft
Slip Surface Intersection: (82.705, 89.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °

Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 41.265 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 20

Type: Fabric
Outside Point: (126.5, 92.5) ft
Inside Point: (96.5, 92.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Regions

	Material	Points	Area (ft²)
Region 1	IIa EL 20 to EL 12	15,16,18,17	1600
Region 2	IIa EL 40 to EL 20	13,14,16,15	4000
Region 3	IIa Above EL 40	1,2,3,4,6,22,9,10,11,12,14,13	5053.25
Region 4	Reinforced FILL	3,5,21,23,22,6,4	563.5

Region 5	Reinforced FILL	9,10,7,8,21,23,22	889.5
Region 6	IIb	17,19,20,18	4400
Region 7	Retained FILL	5,25,24,8,21	91.75

Points

	X (ft)	Y (ft)	
Point 1	0	68	
Point 2	30	68.5	
Point 3	75.5	67	
Point 4	75.5	62	
Point 5	75.5	86.5	
Point 6	98.5	62	
Point 7	126.5	94.5	← EL 94.5
Point 8	96.5	93	
Point 9	126.5	62.5	← EL 62.5
Point 10	126.5	65.5	
Point 11	135	65	
Point 12	200	64	
Point 13	0	40	
Point 14	200	40	
Point 15	0	20	
Point 16	200	20	
Point 17	0	12	
Point 18	200	12	
Point 19	0	-10	
Point 20	200	-10	
Point 21	96.5	86.5	
Point 22	98.5	62.5	
Point 23	98.5	86.5	
Point 24	92	93	
Point 25	88	92.5	

Wall Height = Point 7 - Point 9

= 94.5 - 62.5

H = 32'

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius	Entry (ft)	Exit (ft)

				(ft)		
1	8729	1.549	(135.35, 105.741)	55.105	(82.572, 89.8946)	(171.824, 64.4335)

Slices of Slip Surface: 8729

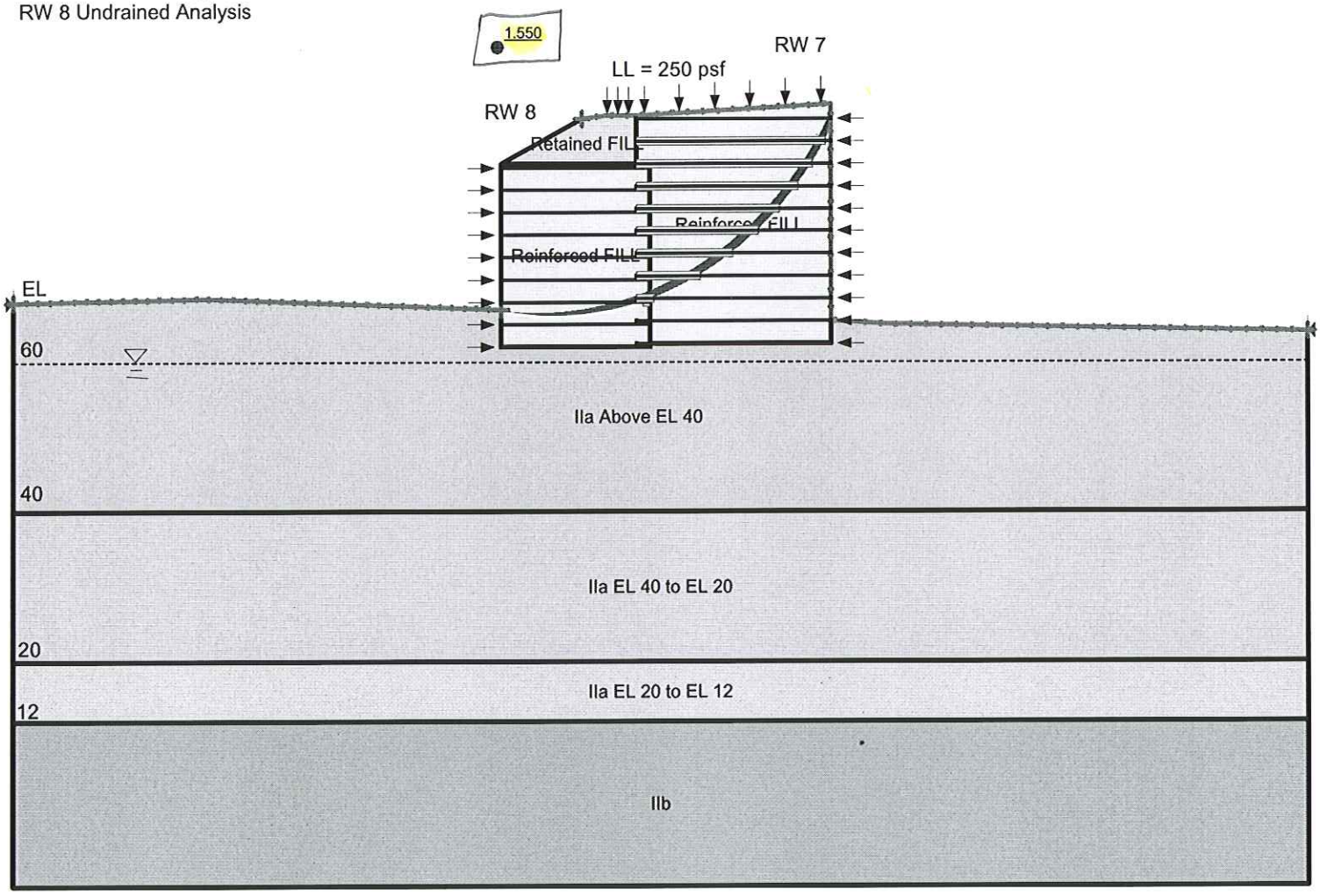
	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesi Streng (psf)
1	8729	83.142335	88.19728	-1759.5236	124.88122	66.40052	0
2	8729	85.856335	82.02604	-1374.4172	601.00641	405.38394	0
3	8729	90	74.6361	-913.29127	1299.892	876.78825	0
4	8729	93.125	70.37685	-647.52153	1729.0546	1166.262	0
5	8729	95.375	67.846795	-489.64586	2006.7408	1353.5638	0
6	8729	97.5	65.71438	-356.57794	2269.8094	1531.0058	0
7	8729	99.8453	63.634375	-226.78595	2626.8369	1771.8238	0
8	8729	102.90465	61.25	-77.998925	3022.9474	1345.9029	0
9	8729	106.0745	59.08648	57.0028	3354.3038	1468.053	0
10	8729	108.9861	57.37934	163.5301	3655.7476	1554.8354	0
11	8729	111.8977	55.90069	255.79813	3951.0854	1645.2479	0
12	8729	114.80935	54.630585	335.05951	4242.8974	1739.8815	0
13	8729	117.721	53.55373	402.24505	4532.334	1838.8341	0
14	8729	120.6326	52.65832	458.12441	4818.5474	1941.3854	0
15	8729	123.5442	51.935265	503.24133	5100.1786	2046.6883	0
16	8729	125.75	51.48314	531.45215	5293.1206	2120.0314	0
17	8729	127.91665	51.157515	551.77749	1846.0311	576.23882	0
18	8729	130.75	50.84588	571.20991	1945.6519	611.94099	0
19	8729	133.58335	50.68172	581.4538	2026.7103	643.46963	0
20	8729	136.55405	50.67025	582.17631	2097.1085	674.49127	0
21	8729	139.66215	50.826265	572.44526	2150.7673	702.71426	0
22	8729	142.77025	51.159575	551.63052	2168.9667	720.08446	0
23	8729	145.87835	51.67347	519.56566	2146.4454	724.33352	0
24	8729	148.98645	52.37319	475.908	2078.5088	713.52383	0
25	8729	152.0946	53.26619	420.19692	1961.4298	686.20109	0
26	8729	155.20275	54.36259	351.76258	1793.0858	641.71845	0
27	8729	158.31085	55.67582	269.82836	1573.0263	580.22113	0
28	8729	161.41895	57.22357	173.25002	1302.7549	502.88797	0

29	8729	164.52705	59.029295	60.571115	985.47789	411.79503	0
30	8729	167.5167	61.03292	-64.454936	622.6111	277.20432	0
31	8729	170.38795	63.24966	-202.7795	214.54885	95.523305	0

Packet 3

RKK-RW7&8-187

SR 1/I-95 Interchange 103-059-27U 11/25/08
RW 8 Undrained Analysis



SLOPE/W Analysis

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File Information

Revision Number: 74
Last Edited By: sberkheimer
Date: 11/25/2008
Time: 11:41:07 AM
File Name: Ramp G1 STA 1251+00 RW 8 UNDRAINED.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\RampG1 Retaining Wall 8\Final Design\
Last Solved Date: 11/25/2008
Last Solved Time: 11:41:21 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Description: I-95/SR 1 Interchange 103-059-27U STA 1251+00 RW 8 UNDRAINED
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- **Apply Phreatic Correction:** Yes
- **Side Function**
  - **Interslice force function option:** Half-Sine
- **PWP Conditions Source:** Piezometric Line
- **Use Staged Rapid Drawdown:** No

SlipSurface
- **Direction of movement:** Right to Left
- **Allow Passive Mode:** No
- **Slip Surface Option:** Entry and Exit
- **Critical slip surfaces saved:** 1
- **Optimize Critical Slip Surface Location:** No
- **Tension Crack**

Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 32
Ending Optimization Points: 64
Complete Passes per Insertion: 1

Materials

Reinforced FILL

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Select Fill

Retained FILL (Type F Borrow)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa Above EL 40

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 2000 psf
Pore Water Pressure
Piezometric Line: 1

IIa EL 40 to EL 20

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 2500 psf
Pore Water Pressure
Piezometric Line: 1

IIa EL 20 to EL 12

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 3500 psf
Pore Water Pressure
Piezometric Line: 1

IIb

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0, 68) ft
Left-Zone Right Coordinate: (75.4999, 67.000003) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (88, 92.5) ft
Right-Zone Right Coordinate: (200, 64) ft
Right-Zone Increment: 60
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 68) ft
Right Coordinate: (200, 64) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	60
	200	60

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	92	93
	125	94.5

Reinforcements

[1→9 for RW 8]
[10→20 for RW 7]
> Fabric used to model proposed Steel straps (not an option in Slype/W)

Reinforcement 1

Type: Fabric
Outside Point: (75.5, 62) ft
Inside Point: (98.5, 62) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
→ AASHTO T86 3.11.5.3-1 for Steel on silty SAND (typ.)
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (75.5, 65) ft
Inside Point: (98.5, 65) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft

Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (75.5, 68) ft
Inside Point: (98.5, 68) ft
Slip Surface Intersection: (97.505, 68) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 509.79 lbs
Resisting Force Used: 512.12 lbs/ft
Available Bond Length: 0.99545 ft
Required Bond Length: 0.99545 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (75.5, 71) ft
Inside Point: (98.5, 71) ft

Slip Surface Intersection: (105.3, 71) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 463.51 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (75.5, 74) ft
Inside Point: (98.5, 74) ft
Slip Surface Intersection: (110.61, 74) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 409.6 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric

Outside Point: (75.5, 77) ft
Inside Point: (98.5, 77) ft
Slip Surface Intersection: (114.74, 77) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 336.58 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (75.5, 80) ft
Inside Point: (98.5, 80) ft
Slip Surface Intersection: (118.13, 80) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 274.21 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (75.5, 83) ft
Inside Point: (98.5, 83) ft
Slip Surface Intersection: (120.96, 83) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 237.74 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (75.5, 86) ft
Inside Point: (98.5, 86) ft
Slip Surface Intersection: (123.38, 86) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 150.71 lbs/ft
Available Bond Length: 0 ft

Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (126.5, 62.5) ft
Inside Point: (96.5, 62.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 11 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (126.5, 65.5) ft
Inside Point: (96.5, 65.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 11 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 12

Type: Fabric
Outside Point: (126.5, 68.5) ft
Inside Point: (96.5, 68.5) ft
Slip Surface Intersection: (99.129, 68.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 11 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 1028.4 lbs
Resisting Force Used: 391.26 lbs/ft
Available Bond Length: 2.6285 ft
Required Bond Length: 2.6285 ft
Governing Component: Bond

Reinforcement 13

Type: Fabric
Outside Point: (126.5, 71.5) ft
Inside Point: (96.5, 71.5) ft
Slip Surface Intersection: (106.29, 71.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 11 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0

Applied Load: 14000 lbs
Fabric Load Used: 3416.1 lbs
Resisting Force Used: 348.8 lbs/ft
Available Bond Length: 9.7938 ft
Required Bond Length: 9.7938 ft
Governing Component: Bond

Reinforcement 14

Type: Fabric
Outside Point: (126.5, 74.5) ft
Inside Point: (96.5, 74.5) ft
Slip Surface Intersection: (111.36, 74.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 11 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 4490.9 lbs
Resisting Force Used: 302.2 lbs/ft
Available Bond Length: 14.861 ft
Required Bond Length: 14.861 ft
Governing Component: Bond

Reinforcement 15

Type: Fabric
Outside Point: (126.5, 77.5) ft
Inside Point: (96.5, 77.5) ft
Slip Surface Intersection: (115.34, 77.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 11 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs

Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 4944.7 lbs
Resisting Force Used: 262.41 lbs/ft
Available Bond Length: 18.844 ft
Required Bond Length: 18.844 ft
Governing Component: Bond

Reinforcement 16

Type: Fabric
Outside Point: (126.5, 80.5) ft
Inside Point: (96.5, 80.5) ft
Slip Surface Intersection: (118.62, 80.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 11 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 4729.8 lbs
Resisting Force Used: 213.78 lbs/ft
Available Bond Length: 22.125 ft
Required Bond Length: 22.125 ft
Governing Component: Bond

Reinforcement 17

Type: Fabric
Outside Point: (126.5, 83.5) ft
Inside Point: (96.5, 83.5) ft
Slip Surface Intersection: (121.4, 83.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 11 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs

Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 4615.9 lbs
Resisting Force Used: 185.35 lbs/ft
Available Bond Length: 24.904 ft
Required Bond Length: 24.904 ft
Governing Component: Bond

Reinforcement 18

Type: Fabric
Outside Point: (126.5, 86.5) ft
Inside Point: (96.5, 86.5) ft
Slip Surface Intersection: (123.73, 86.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 11 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 3199.5 lbs
Resisting Force Used: 117.5 lbs/ft
Available Bond Length: 27.231 ft
Required Bond Length: 27.231 ft
Governing Component: Bond

Reinforcement 19

Type: Fabric
Outside Point: (126.5, 89.5) ft
Inside Point: (96.5, 89.5) ft
Slip Surface Intersection: (125.74, 89.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 11 °
Interface Factor: 1

Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 2264.8 lbs
Resisting Force Used: 77.47 lbs/ft
Available Bond Length: 29.235 ft
Required Bond Length: 29.235 ft
Governing Component: Bond

Reinforcement 20

Type: Fabric
Outside Point: (126.5, 92.5) ft
Inside Point: (96.5, 92.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 11 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Regions

	Material	Points	Area (ft^2)
Region 1	IIa EL 20 to EL 12	15,16,18,17	1600
Region 2	IIa EL 40 to EL 20	13,14,16,15	4000
Region 3	IIa Above EL 40	1,2,3,4,6,22,9,10,11,12,14,13	5053.25
Region 4	Reinforced FILL	3,5,21,23,22,6,4	563.5

Region 5	Reinforced FILL	9,10,7,8,21,23,22	889.5
Region 6	IIb	17,19,20,18	4400
Region 7	Retained FILL	5,25,24,8,21	91.75

Points

	X (ft)	Y (ft)	
Point 1	0	68	
Point 2	30	68.5	
Point 3	75.5	67	
Point 4	75.5	62	← EL 62
Point 5	75.5	86.5	← EL 86.5
Point 6	98.5	62	
Point 7	126.5	94.5	
Point 8	96.5	93	
Point 9	126.5	62.5	
Point 10	126.5	65.5	
Point 11	135	65	
Point 12	200	64	
Point 13	0	40	
Point 14	200	40	
Point 15	0	20	
Point 16	200	20	
Point 17	0	12	
Point 18	200	12	
Point 19	0	-10	
Point 20	200	-10	
Point 21	96.5	86.5	
Point 22	98.5	62.5	
Point 23	98.5	86.5	
Point 24	92	93	
Point 25	88	92.5	

Wall Height = Point 5 − Point 4

= 86.5 − 62

H = 24.5'

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius	Entry (ft)	Exit (ft)

				(ft)		
1	11988	1.550	(83.701, 115.431)	49.41	(126.5, 94.5)	(73.6127, 67.0622)

Slices of Slip Surface: 11988

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	11988	74.556355	66.88446	-429.58895	339.84609	0	2000
2	11988	76.392855	66.573145	-410.16692	3015.5374	2034.0056	0
3	11988	78.17857	66.339145	-395.56411	3313.6744	2235.1016	0
4	11988	79.964285	66.17097	-385.06962	3583.448	2417.0662	0
5	11988	81.75	66.067945	-378.63947	3813.9811	2572.5628	0
6	11988	83.535715	66.02966	-376.25075	3996.0823	2695.3915	0
7	11988	85.32143	66.05597	-377.89189	4123.2457	2781.1643	0
8	11988	87.107145	66.146975	-383.57003	4192.5213	2827.8914	0
9	11988	89	66.316565	-394.15273	4151.8071	2800.4292	0
10	11988	91	66.57384	-410.20792	4000.7536	2698.5424	0
11	11988	92.75	66.862965	-428.25066	3823.9967	2579.3183	0
12	11988	94.25	67.16662	-447.19681	3642.6125	2456.9731	0
13	11988	95.75	67.51915	-469.19773	3445.1324	2323.7711	0
14	11988	97.5	67.998675	-499.1087	3287.7993	2217.6487	0
15	11988	99.38335	68.585295	-535.72435	2612.3587	1762.0582	0
16	11988	101.15	69.2145	-574.98899	2625.4724	1770.9035	0

17	11988	102.91665	69.920965	-619.07913	2371.7635	1599.7747	0
18	11988	104.68335	70.708355	-668.22552	2127.2016	1434.8156	0
19	11988	106.45	71.58104	-722.67013	1179.4953	795.57964	0
20	11988	108.21665	72.544245	-782.77531	1709.093	1152.7978	0
21	11988	109.98335	73.604235	-848.89139	1506.3605	1016.053	0
22	11988	111.75	74.7686	-921.58018	626.87395	422.83182	0
23	11988	113.51665	76.04664	-1001.3016	1196.4892	807.04218	0
24	11988	115.28335	77.44987	-1088.8583	465.95718	314.29209	0
25	11988	117.05	78.99282	-1185.1573	940.63482	634.4662	0
26	11988	118.81665	80.69422	-1291.3111	434.09931	292.80368	0
27	11988	120.58335	82.578875	-1408.9401	452.3909	305.14152	0
28	11988	122.35	84.680795	-1540.0756	616.55888	415.87422	0
29	11988	124.11665	87.048865	-1687.8374	393.87753	265.67375	0
30	11988	125.75	89.52401	-1842.2901	314.10414	211.86592	0

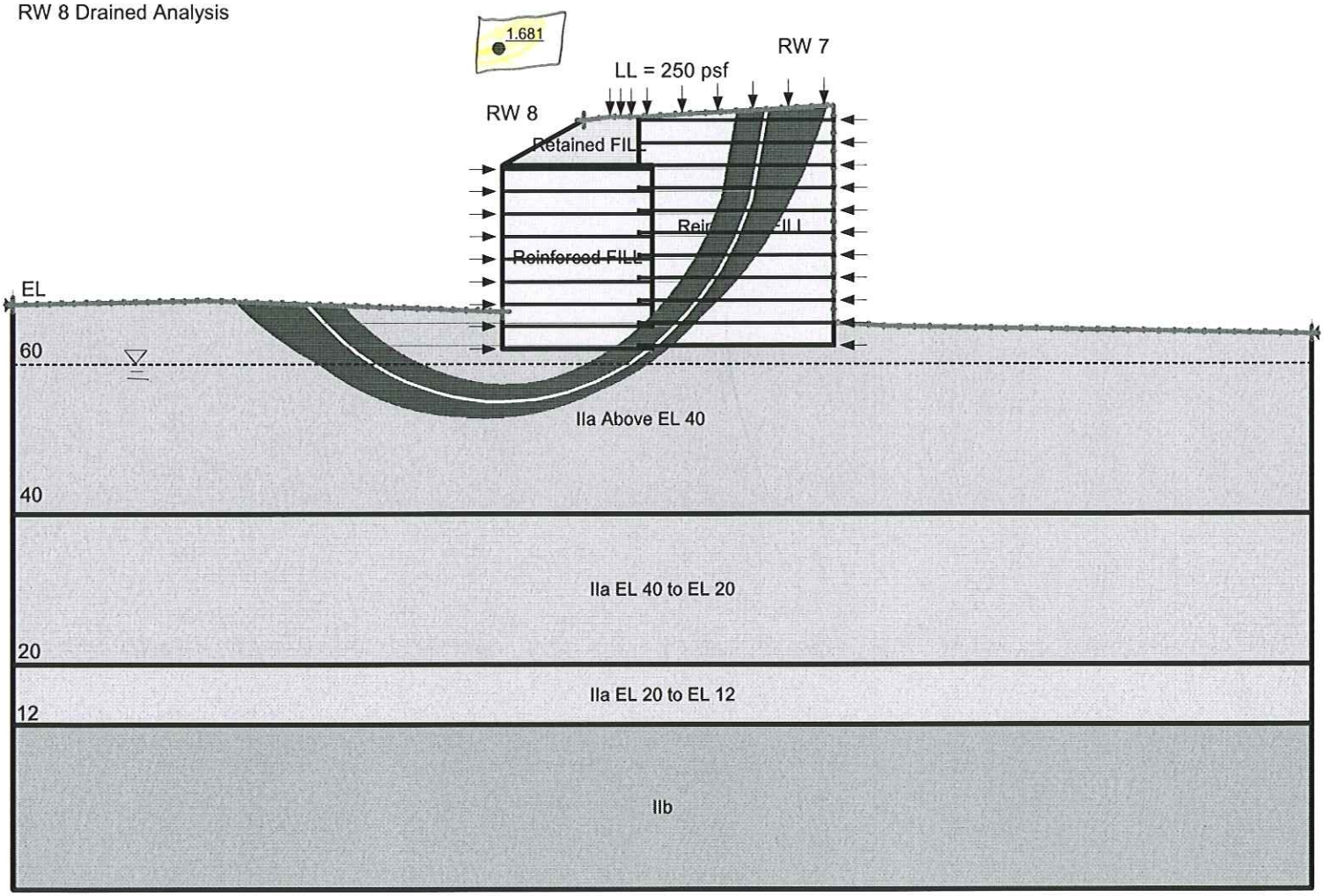
Packet 4

JJT 1-11-09

RKK-RW7&8-205

GM 2/9/09

SR 1/I-95 Interchange 103-059-27U 11/25/08
RW 8 Drained Analysis



SLOPE/W Analysis

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File Information

Revision Number: 83
Last Edited By: sberkheimer
Date: 11/25/2008
Time: 12:14:59 PM
File Name: Ramp G1 STA 1251+00 RW 8 DRAINED.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\RampG1 Retaining Wall 8\Final Design\
Last Solved Date: 11/25/2008
Last Solved Time: 12:15:10 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Description: I-95/SR 1 Interchange 103-059-27U STA 1251+00 RW 8 UNDRAINED
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- **Apply Phreatic Correction:** Yes
- **Side Function**
  - **Interslice force function option:** Half-Sine
- **PWP Conditions Source:** Piezometric Line
- **Use Staged Rapid Drawdown:** No

SlipSurface
- **Direction of movement:** Right to Left
- **Allow Passive Mode:** No
- **Slip Surface Option:** Entry and Exit
- **Critical slip surfaces saved:** 1
- **Optimize Critical Slip Surface Location:** No
- **Tension Crack**

Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 32
Ending Optimization Points: 64
Complete Passes per Insertion: 1

Materials

Reinforced FILL

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Select

Retained FILL (DelDOT Type F)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa Above EL 40

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 24 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa EL 40 to EL 20

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf

Phi: 18 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIa EL 20 to EL 12

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 18 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

IIb

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0, 68) ft
Left-Zone Right Coordinate: (75.4999, 67.000003) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (88, 92.5) ft
Right-Zone Right Coordinate: (200, 64) ft
Right-Zone Increment: 60
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 68) ft
Right Coordinate: (200, 64) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	60
	200	60

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	92	93
	125	94.5

Reinforcements

[1-9 for RW8]
[10-20 for RW7]

> Fabric used to model proposed Steel straps (not an option in Slope/W)

Reinforcement 1

Type: Fabric
Outside Point: (75.5, 62) ft
Inside Point: (98.5, 62) ft
Slip Surface Intersection: (98.182, 62) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 ° ← AASHTO LRFD Table 3.11.5.3-1 for Steel on silty SAND
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Fabric Load Used: 188.51 lbs
Resisting Force Used: 593.5 lbs/ft
Available Bond Length: 0.31762 ft
Required Bond Length: 0.31762 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (75.5, 65) ft
Inside Point: (98.5, 65) ft
Slip Surface Intersection: (102.05, 65) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 522.27 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (75.5, 68) ft
Inside Point: (98.5, 68) ft
Slip Surface Intersection: (105.15, 68) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice

Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 479.28 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (75.5, 71) ft
Inside Point: (98.5, 71) ft
Slip Surface Intersection: (107.68, 71) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 427.45 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (75.5, 74) ft
Inside Point: (98.5, 74) ft
Slip Surface Intersection: (109.76, 74) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1

Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 363.11 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (75.5, 77) ft
Inside Point: (98.5, 77) ft
Slip Surface Intersection: (111.52, 77) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 277.63 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (75.5, 80) ft
Inside Point: (98.5, 80) ft
Slip Surface Intersection: (112.88, 80) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1

Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 277.63 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (75.5, 83) ft
Inside Point: (98.5, 83) ft
Slip Surface Intersection: (113.94, 83) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 116.17 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (75.5, 86) ft
Inside Point: (98.5, 86) ft
Slip Surface Intersection: (114.55, 86) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °

Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 116.17 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (126.5, 62.5) ft
Inside Point: (96.5, 62.5) ft
Slip Surface Intersection: (51.65, 62.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (126.5, 65.5) ft
Inside Point: (96.5, 65.5) ft
Slip Surface Intersection: (47.848, 65.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 12

Type: Fabric
Outside Point: (126.5, 68.5) ft
Inside Point: (96.5, 68.5) ft
Slip Surface Intersection: (105.62, 68.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 9.1186 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 13

Type: Fabric
Outside Point: (126.5, 71.5) ft
Inside Point: (96.5, 71.5) ft
Slip Surface Intersection: (108.07, 71.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °

Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 11.571 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 14

Type: Fabric
Outside Point: (126.5, 74.5) ft
Inside Point: (96.5, 74.5) ft
Slip Surface Intersection: (110.07, 74.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 13.573 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 15

Type: Fabric
Outside Point: (126.5, 77.5) ft
Inside Point: (96.5, 77.5) ft
Slip Surface Intersection: (111.74, 77.5) ft

Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 15.244 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 16

Type: Fabric
Outside Point: (126.5, 80.5) ft
Inside Point: (96.5, 80.5) ft
Slip Surface Intersection: (113.1, 80.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 16.602 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 17

Type: Fabric
Outside Point: (126.5, 83.5) ft

Inside Point: (96.5, 83.5) ft
Slip Surface Intersection: (114.04, 83.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 17.539 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 18

Type: Fabric
Outside Point: (126.5, 86.5) ft
Inside Point: (96.5, 86.5) ft
Slip Surface Intersection: (114.65, 86.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 18.147 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 19

Type: Fabric
Outside Point: (126.5, 89.5) ft
Inside Point: (96.5, 89.5) ft
Slip Surface Intersection: (115.25, 89.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 18.754 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 20

Type: Fabric
Outside Point: (126.5, 92.5) ft
Inside Point: (96.5, 92.5) ft
Slip Surface Intersection: (115.86, 92.5) ft
Total Length: 30 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 14000 lbs
Fabric Safety Factor: 1
Fabric Load: 14000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 14000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 19.362 ft

Required Bond Length: -1 ft
Governing Component: Bond

Regions

	Material	Points	Area (ft²)
Region 1	IIa EL 20 to EL 12	15,16,18,17	1600
Region 2	IIa EL 40 to EL 20	13,14,16,15	4000
Region 3	IIa Above EL 40	1,2,3,4,6,22,9,10,11,12,14,13	5053.25
Region 4	Reinforced FILL	3,5,21,23,22,6,4	563.5
Region 5	Reinforced FILL	9,10,7,8,21,23,22	889.5
Region 6	IIb	17,19,20,18	4400
Region 7	Retained FILL	5,25,24,8,21	91.75

Points

	X (ft)	Y (ft)	
Point 1	0	68	
Point 2	30	68.5	
Point 3	75.5	67	
Point 4	75.5	62	← EL 62
Point 5	75.5	86.5	← EL 86.5
Point 6	98.5	62	
Point 7	126.5	94.5	
Point 8	96.5	93	
Point 9	126.5	62.5	
Point 10	126.5	65.5	
Point 11	135	65	
Point 12	200	64	
Point 13	0	40	
Point 14	200	40	
Point 15	0	20	
Point 16	200	20	
Point 17	0	12	
Point 18	200	12	
Point 19	0	-10	
Point 20	200	-10	

Wall Height = Point 5 - Point 4
= 86.5 - 62
H = 24.5'

Point 21	96.5	86.5
Point 22	98.5	62.5
Point 23	98.5	86.5
Point 24	92	93
Point 25	88	92.5

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	7385	1.681	(75.252, 95.937)	40.958	(116.162, 93.9831)	(45.3048, 67.9955)

Slices of Slip Surface: 7385

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	7385	46.592035	66.732225	-420.09224	229.46357	102.16376	0
2	7385	49.16652	64.40414	-274.81944	662.27465	294.86367	0
3	7385	51.741005	62.435905	-151.99949	1041.9979	463.92734	0
4	7385	54.315495	60.766265	-47.815478	1365.6082	608.00793	0
5	7385	56.84632	59.373995	39.062584	1615.511	701.88004	0
6	7385	59.333475	58.223105	110.87832	1794.619	749.64963	0
7	7385	61.82063	57.266305	170.58377	1918.5689	778.25311	0
8	7385	64.30779	56.489385	219.0619	1988.8055	787.94063	0
9	7385	66.79495	55.88183	256.97241	2009.0992	780.0971	0
10	7385	69.282105	55.435985	284.79396	1984.9421	756.95472	0
11	7385	71.76926	55.146525	302.85574	1922.919	721.29863	0
12	7385	74.25642	55.010125	311.36789	1829.8617	676.07698	0
13	7385	76.75	55.02567	310.39991	4388.6578	1815.7574	0
14	7385	79.25	55.194125	299.88734	4323.6293	1791.4853	0
15	7385	81.75	55.51777	279.69208	4230.4706	1758.9999	0
16	7385	84.25	56.00039	249.57505	4116.4002	1721.6215	0
17	7385	86.75	56.647875	209.17391	3988.305	1682.5776	0
18	7385	89	57.370195	164.09965	3823.9839	1629.4855	0
19	7385	91	58.14338	115.85403	3629.9114	1564.5591	0
20	7385	93.450185	59.28004	44.927082	3384.6633	1486.9464	0

21	7385	95.700185	60.461025	-28.767662	3161.3827	1407.5383	0
22	7385	97.34119	61.461025	-91.166836	2991.1991	1331.7677	0
23	7385	98.34119	62.108395	-131.5629	2737.9791	1846.7902	0
24	7385	98.702755	62.358395	-147.16351	2829.8887	1259.9476	0
25	7385	100.13816	63.4441	-214.91266	2533.8871	1709.1285	0
26	7385	102.60345	65.49576	-342.94149	2254.9776	1521.0016	0
27	7385	105.06875	67.91494	-493.87963	1967.8794	1327.3514	0
28	7385	107.534	70.81026	-674.55924	1661.9196	1120.9789	0
29	7385	109.99925	74.38097	-897.36229	1319.5926	890.07643	0
30	7385	112.46455	79.090945	-1191.2801	905.98114	611.092	0
31	7385	114.92985	87.89852	-1740.84	248.66266	167.72508	0

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RKK-RW7&8-223

Subject I-95/SR 1 Interchange
RW 7 & RW 8 Settlement Analysis

Page 1 of

Cm. No. 103-059-27U

Prepared By SAB Date 9/19/08 REV 1/7/09

Checked By LBT Date 9.30-08
GW 1-19-09

Objective: To estimate the settlement anticipated to occur as a result of the construction of MSE walls RW 7 & RW 8. @ Max wall height

RW 7 = Length 925 ft

RW 8 = 435 ft

see page 5 for layout

Distance 7 from edge of max height

Wall Details: See page 4-8 for cross-section. Say length of wall section to be analyzed, L = 100'

Avg. width = 56' RW 7 L/H = 0.9 → 1.1, RW 8 L/H = 1.2
↳ use 29', ↳ use 27'

* RW 7 & 8 from Ring A STA 1251+00 to 1252+00 chosen for analysis due to soils. Borings and DMTs indicate the soils in this area of the walls are most susceptible to settlements. The walls are also the tallest here, generating the largest loads on the soil.

STA 1251+00 → 1252+00: 100' back-to-back walls. → From MSEW, σ_v = 3,820 psf
(calculated using service loads, p. 1/a)

=> To estimate differential settlement, model STA 1252+00 to 1253+00 as an embankment:

=> Average Height = 23' Average width = 58'

→ So use a 100' long, 56' wide footing with σ_v = 23'(130 pcf) = 2,990 psf

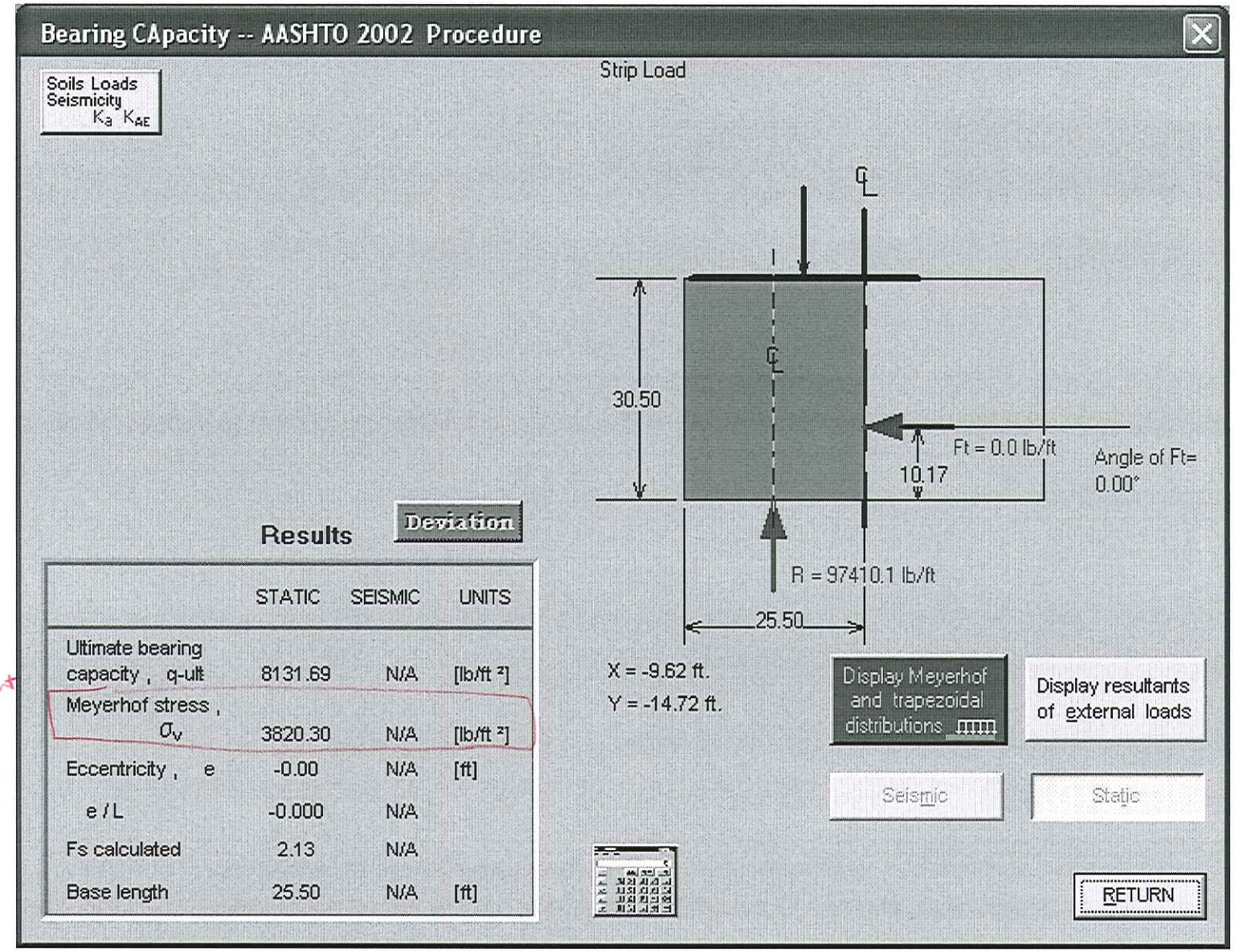
=> RW 7 & 8 meet S-5 Abutment B of Ring G1 @ STA 1251+00.

From URS: Abutment B Bearing Stress = 5,280 psf & B = 27'

* See URS calculations for Abutment settlement

SR 1/I-95 Interchange 103-059-27U
RW 7 and 8 Meyerhof Stress calculated with Service loads

1/7/09



For Settlement only

Service Loads

RKK-RW7&8-2209

EPT
SMC
2/9/09

1a

Soils: See fence diagram, p. 3.

-Assume ROF EL = EL 62 -Water Table @ EL 60

Stratum	EL	γ_t (pcf)	μ	E (ksf)(1)	C(3)	C_r(3)	e_o(3)	C_v (ft²/day)	OCR(3)	P_c (psf)(2)	P_o @ (2) (psf)
IIa	62-50	130	0.4	818	0.015	0.015	0.487	—	3.5	7,800	936
IIa	50-40	130	0.4	545	0.015	0.015	0.487	—	3.5	7,800	1,612
IIb	40-30	130	0.3	1,364	—	—	—	—	—	—	2,288
IIa	30-17	130	0.4	818	0.015	0.015	0.661	—	1.0	7,800	3,167
IIb	17-"42	130	0.3	1,364	—	—	—	—	—	—	—

IGNORE; use general site E-values.

*1: Based on M-value (constrained modulus) from nearby DMT testing (IDMT-06, 07) using the equation:

$E = \frac{\mu(1+\mu)(1-2\mu)}{(1-\mu)}$ (See page 3) & Consolidation Test data from IBR-4 & IBR-5

*E values also based on correlations w/ different plots for Ramp A, B, C+ GI embankment.

*2: P_c estimated based on graph of K_o values ~ 60' FILL x 130 pcf = 7,800 psf See Sheet 3a

P_o: IIa EL 62-50: 2'(130) + 10'(130-62.4) = 936 psf
IIb EL 40-30: 1,612 + 10'(67.6 pcf) = 2,288 psf
IIa EL 30-17: 2,288 + 13'(67.6 pcf) = 3,167 psf
IIa EL 50-40: 936 + 10'(67.6) = 1,612 psf

→ $P_c - P_o$ = 6,864 psf
= 5,512 psf
= 4,633 psf
= 6,188 psf
> Used in Foss a Sheet 13

*3: Consolidation parameters based on tube tests for project:

Boring	Stratum	GS EL	Sample Depth (ft)	Sample EL	eo	Cc	Cr	Cv Max	Cv Min
IBR-04	2a	65	18	47.0	0.487	0.05	0.01	0.15	0
IBR-05	2a	66	31.5	34.5	0.661	0.15	0.02	1	
Averages:					0.5740	0.10	0.02	0.58	

→ Use C_r = 10% C_c with $C_r \geq 0.015$ → 10% C_c = 0.01 → So use $C_r = 0.015$

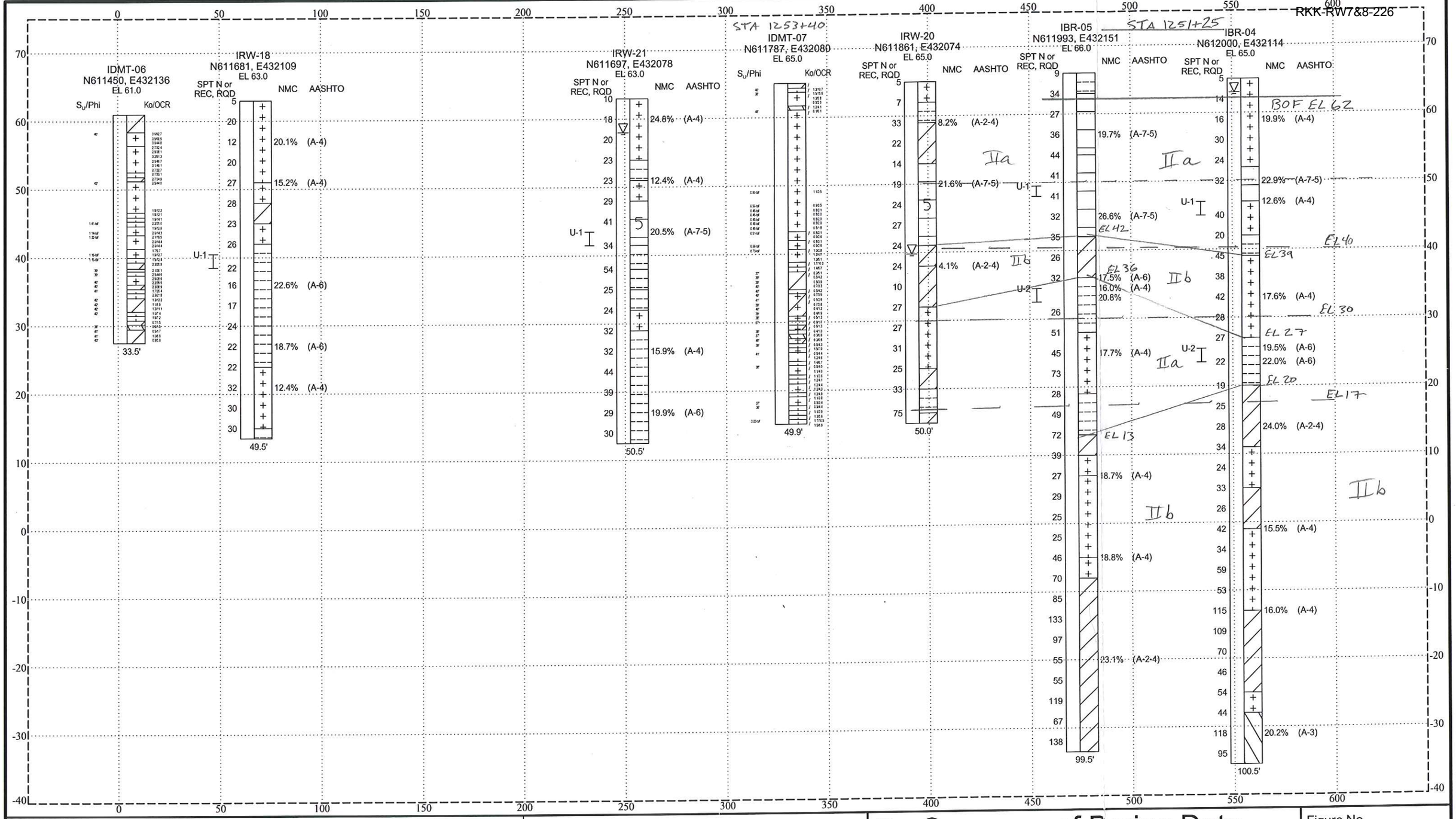
Use $C_c = C_r$ since $\Delta\sigma < P_c$.

SR1/I-95 Interchange 103-059-27U
RW 7 & 8 Settlement

3

JJT 1-19-09

RKK-RW7&8-226



AASHTO SOIL KEY

A	A-1-a	A-2-5	A-5	A-8	
B	A-1-b	A-2-6	A-6	Asphalt	
	A-3	A-2-7	A-7-5	FILL	
	A-2-4	A-4	A-7-6	Decomposed Rock	

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data
Retaining Wall 7 and 8 (for Settlement)

Figure No. A-4x

Drawn: SAB | Approved: EMK | Date: 1/8/09 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 1/8/09

I-95/SR1 Interchange
103-059-270
RW 7 & 8 Settlement

3a

RKK-RW7&8-227

JST 9-30-08
JST 1-19-09
EMM 2/9/09

= ~60'

So $P_c \approx 60'$ FILL

= 60' (125 pcf)
= 7500-psf

FROM LABS TESTING & STRESS HISTORY P_c = 7800-psf
or 60'(130 pcf) = 7800 psf

* extended trend line to find how much Fill Pc was equal to.

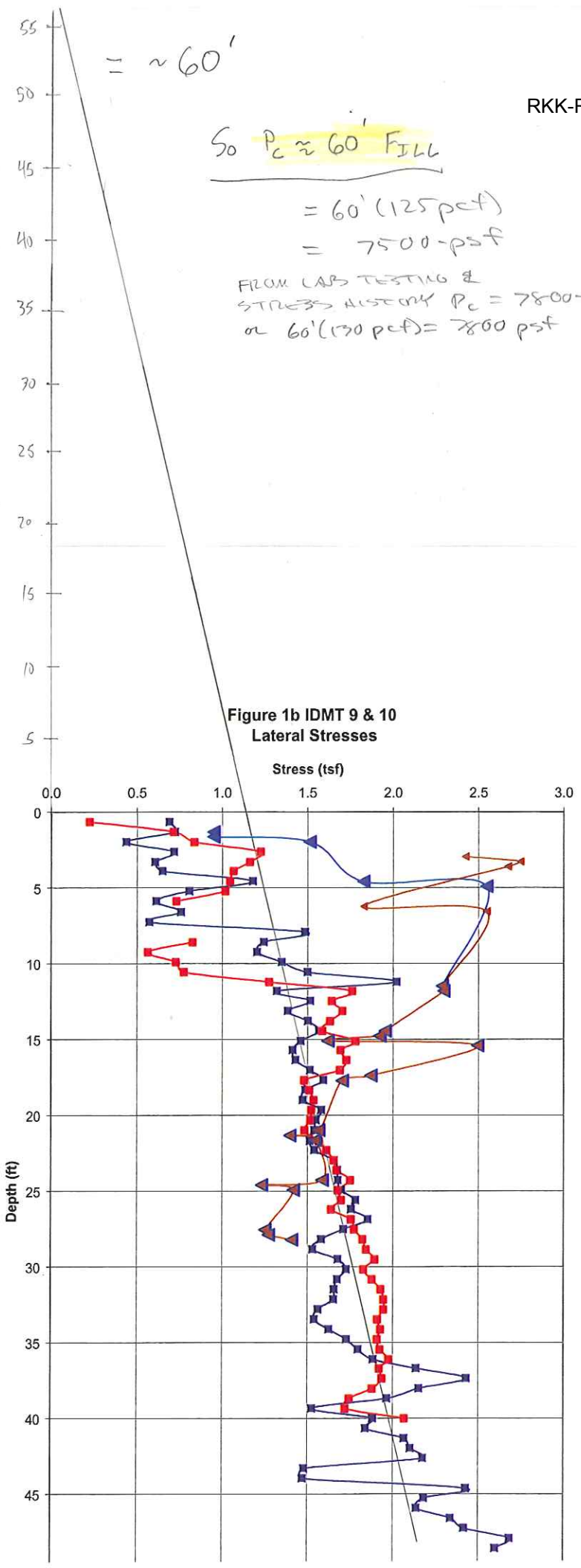
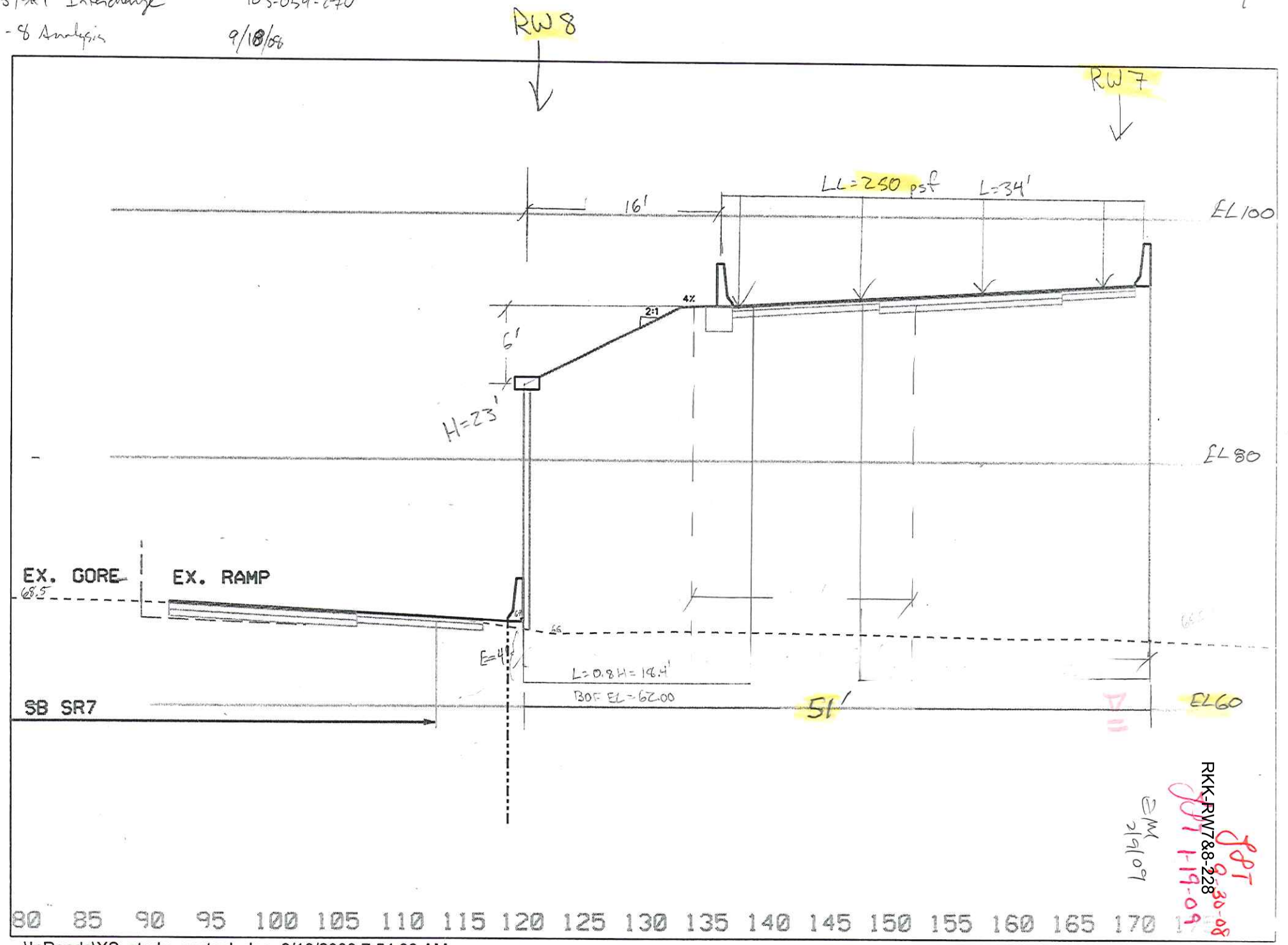


Figure 1b IDMT 9 & 10
Lateral Stresses

I-95/SR1 Interchange 103-059-270

RW-8 Analysis 9/18/08



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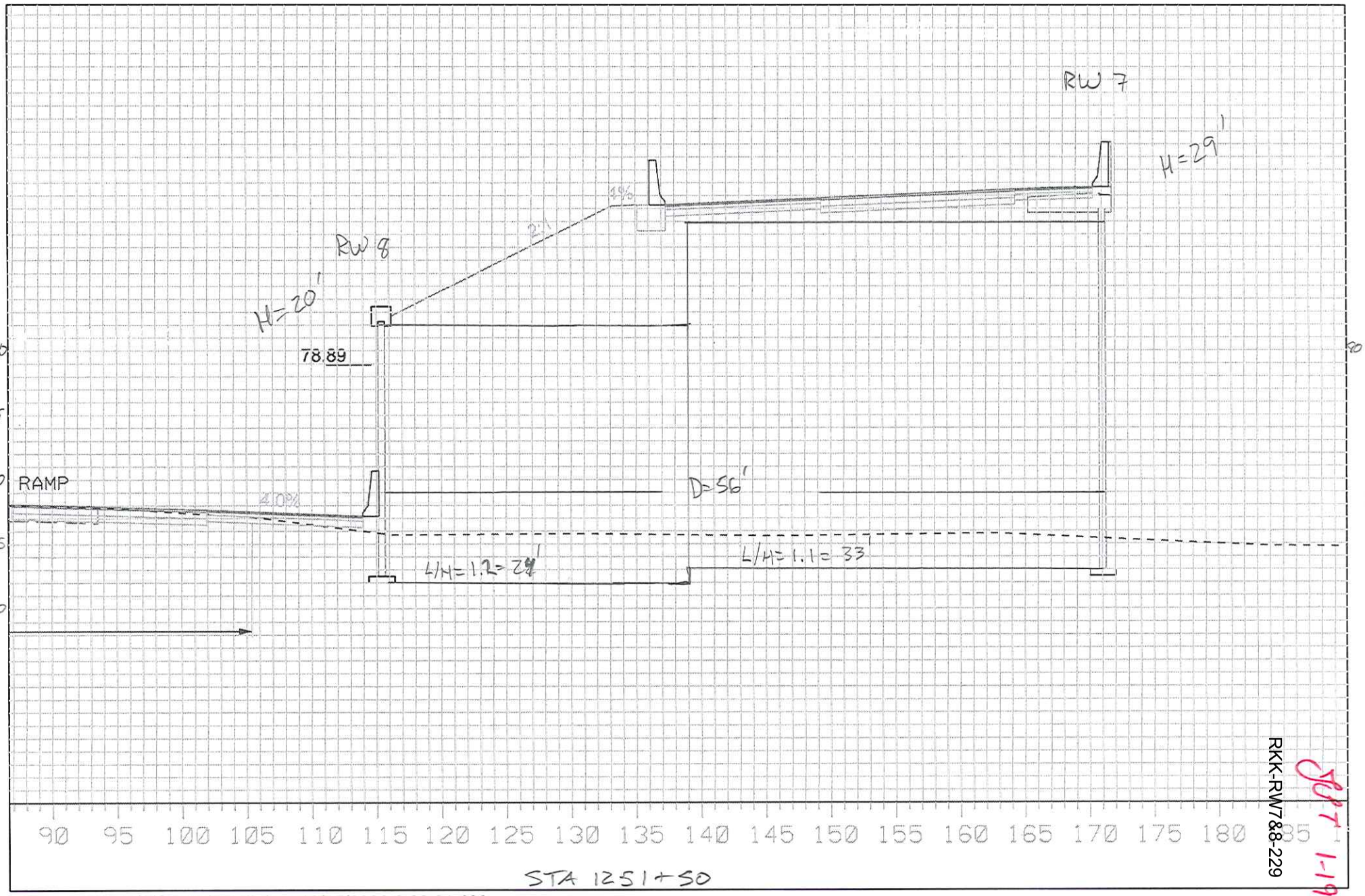
RKK-RW7&8-228

JDT 9-30-08
JDT 1-19-09

SR1/I-95 Interchange 12/15/08
103-059-270
RW 7 & 8



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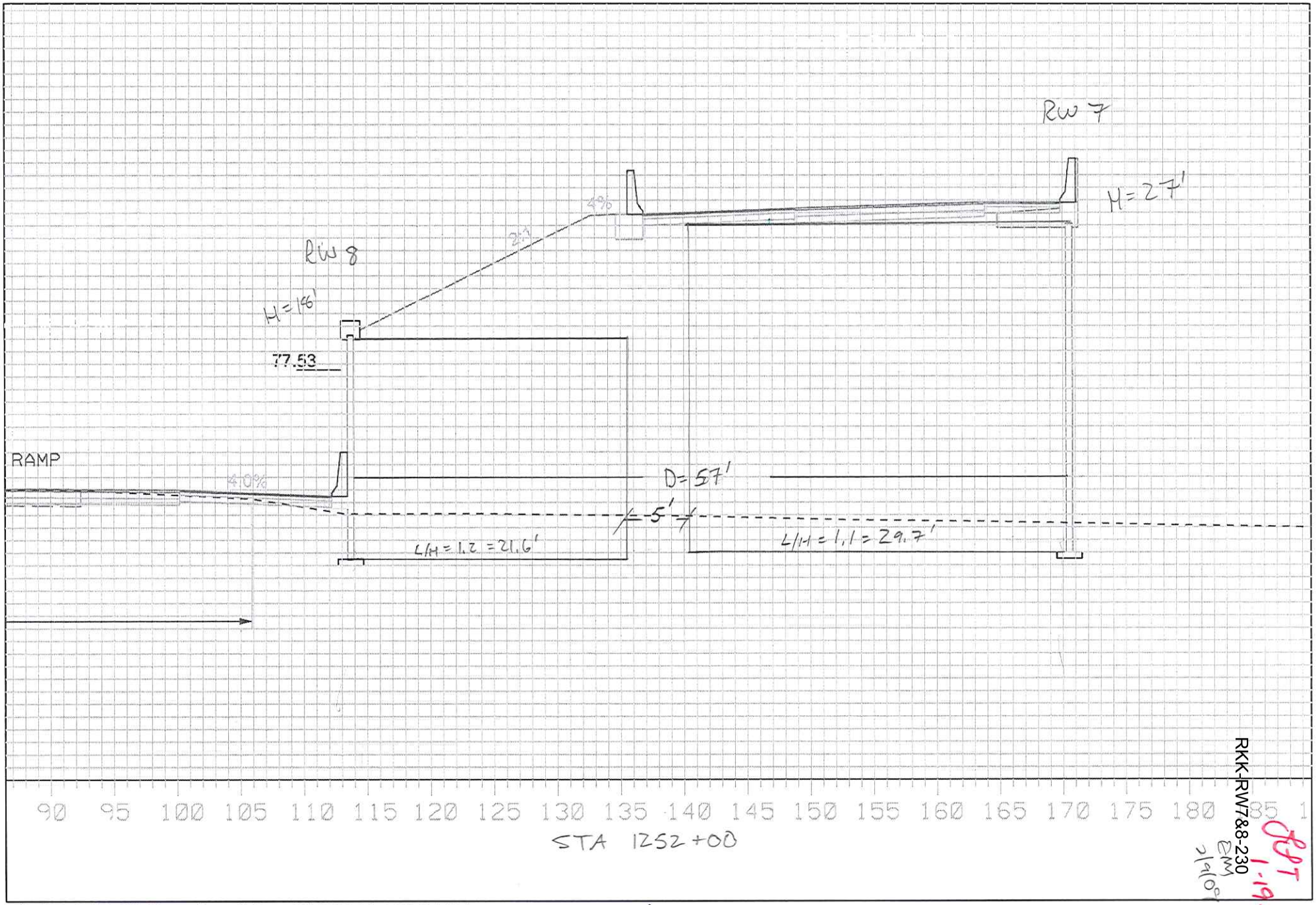
RKK-RW7&8-229

SCT 1-19-09

SR1 / I-95 Interchange 103-059-270 12/15/08
RW 7 & 8



RKK-RW7&8-230
EMW
1/9/09

RPT 1-19-09

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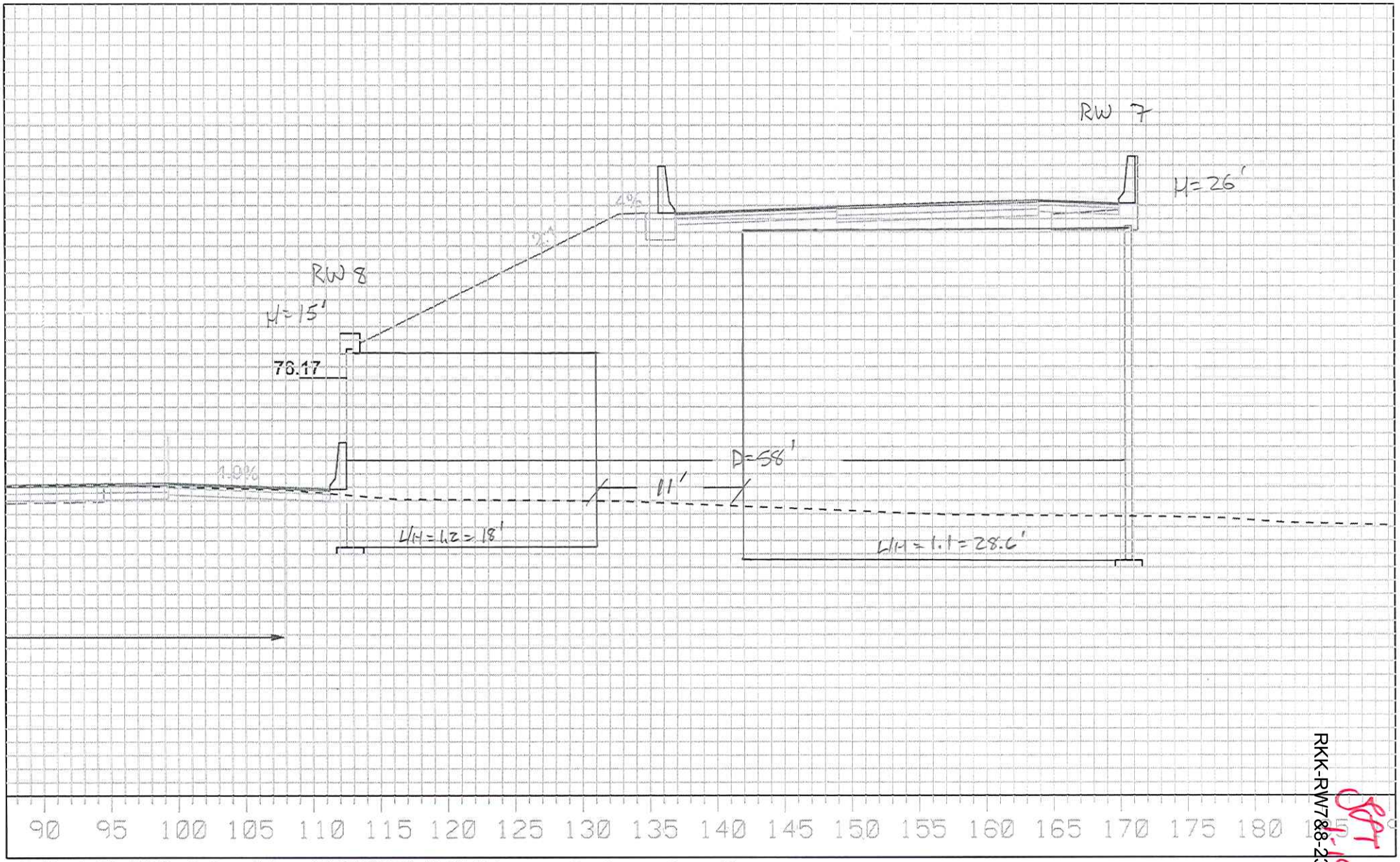
SR1/I-95 Interchange 103-059-270 12/15/08

RW 7 & 8



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STA 1252+50

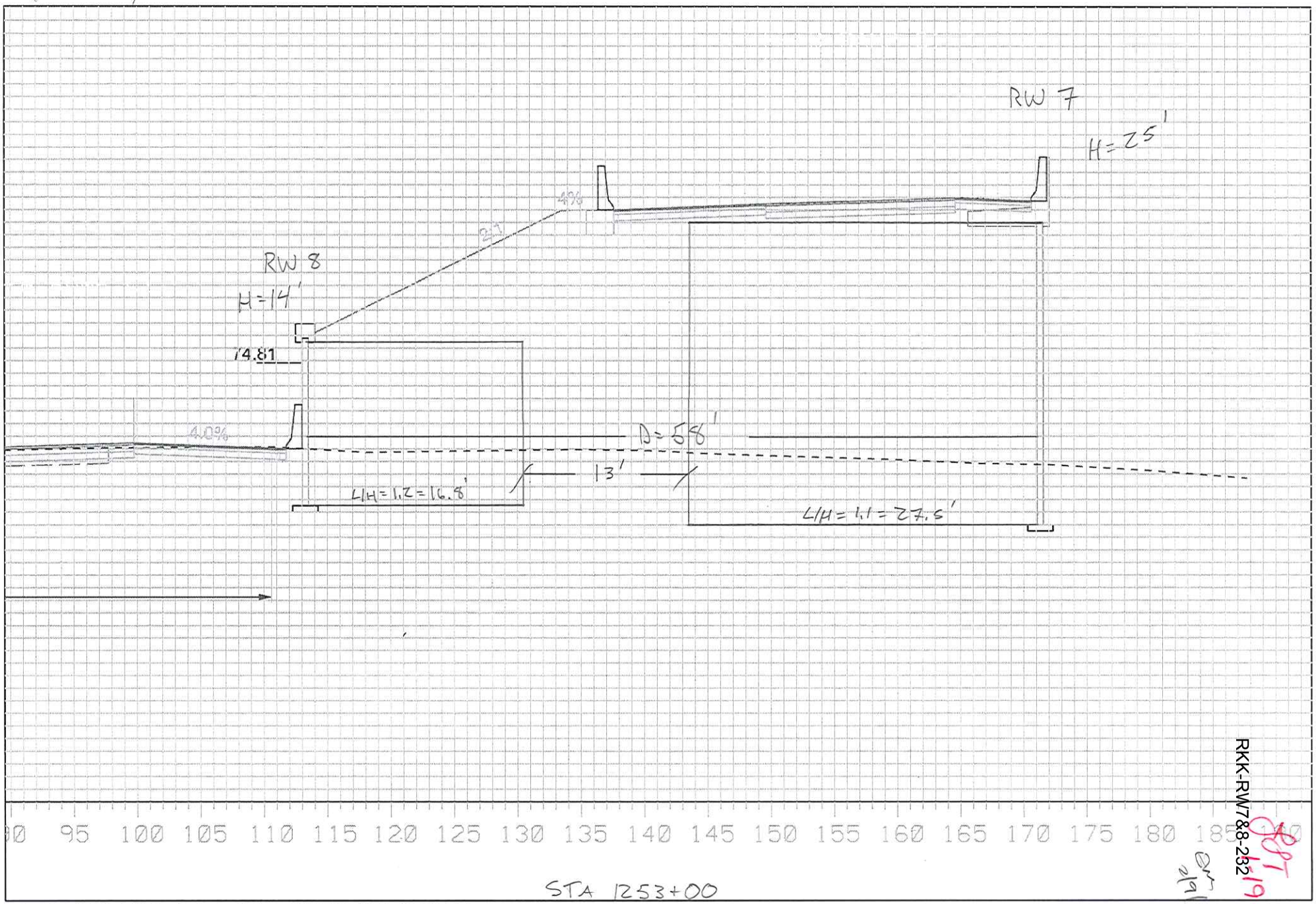
RKK-RW7&8-231

12-19-08

EMS 2/9/09

7

SR1 / I-95 Interchange 103-059-270 12/15/08
RW 7 & 8 Analysis



RKK-RW7&8-232

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2/19/09

Analysis: Performed using FoSSA. (See attached FoSSA output.) Sheet 6 → 21

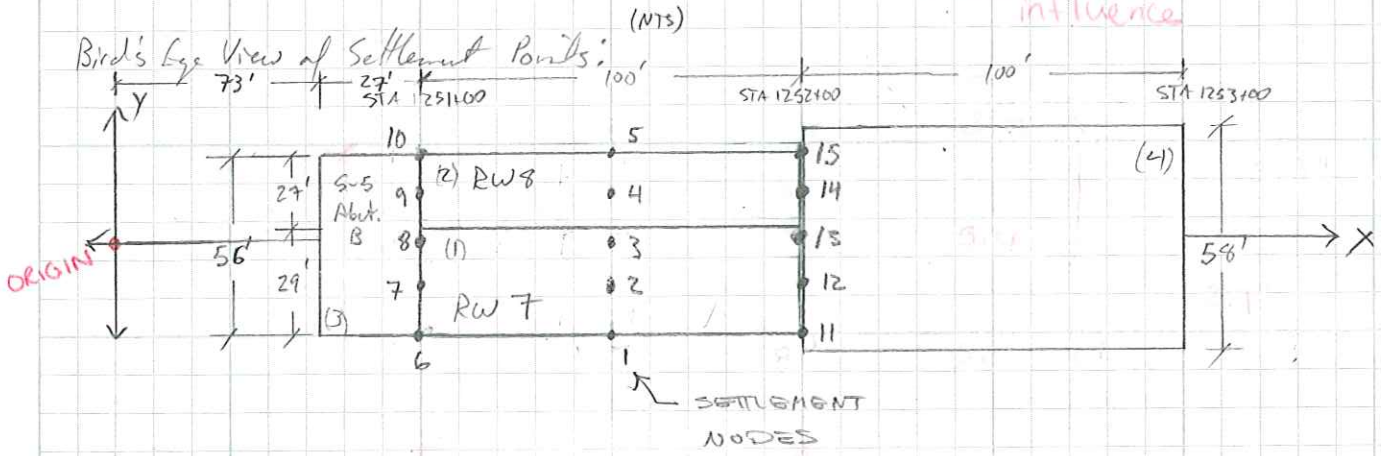
→ Calculate Elastic settlement to a depth of 4B below BOF EL.

⇒ Full "footing" width for both walls ⇒ B = 51' (see page 4)

⇒ 4B = 204'

BOF EL = 62 → 62 − 204 = EL −142 ← Bottom of Settlement influence

Bird's Eye View of Settlement Points: (NTS)



SUMMARY: (See page 22)

(immediate)

Maximum Elastic Settlement = 0.19' = 2.3" @ Pt 3

Maximum Consolidation Settlement = 0.23' = 2.8" @ Pt 8

} Maximum total settlement = 0.4' = 4.8"

→ Based on our interpretation of the settlement plate data, it is anticipated that the consolidation settlement will occur within less than a month of construction completion.

→ See page 22 for differential settlements

AASHTO Tolerance = 1/100 See page 22 for Summary

∴ OK

10

RKK-RW7&8-234

JBT 1-19-09

EML 2/9/09

SR 1/I-95 Interchange

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PROJECT IDENTIFICATION

Title:	SR 1/I-95 Interchange
Project Number:	103-059-27U -
Client:	DelDOT
Designer:	SAB
Station Number:	Ramp G1 STA 1251+00 RW 7/8

Description:
RW 7 and RW 8

Company's information:

Name:	RK&K Engineers, LLP
Street:	81 Mosher Street Baltimore, MD 21217
Telephone #:	410-728-2900
Fax #:	410-728-0282
E-Mail:	

Original file path and name: M:\project ..... ing Wall 8\Final Design\RW7 and RW8 Settlement.2ST
Original date and time of creating this file: Thu Jan 08 11:49:11 2009

GEOMETRY: Analysis of a Multiple Footings

RKK-RW7&8-235 JLT 1-19-09

INPUT DATA – FOUNDATION LAYERS – 5 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	130.00	0.40	IIa EL 62 to 50
2	130.00	0.40	IIa EL 50 to 40
3	130.00	0.30	IIb EL 40 to 30
4	130.00	0.40	IIa EL 30 to 17
5	130.00	0.30	IIb

INPUT DATA – MULTIPLE FOOTINGS – 4 footings

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	0.00	360.00
2	300.00	360.00

Actual EL = Z - 300

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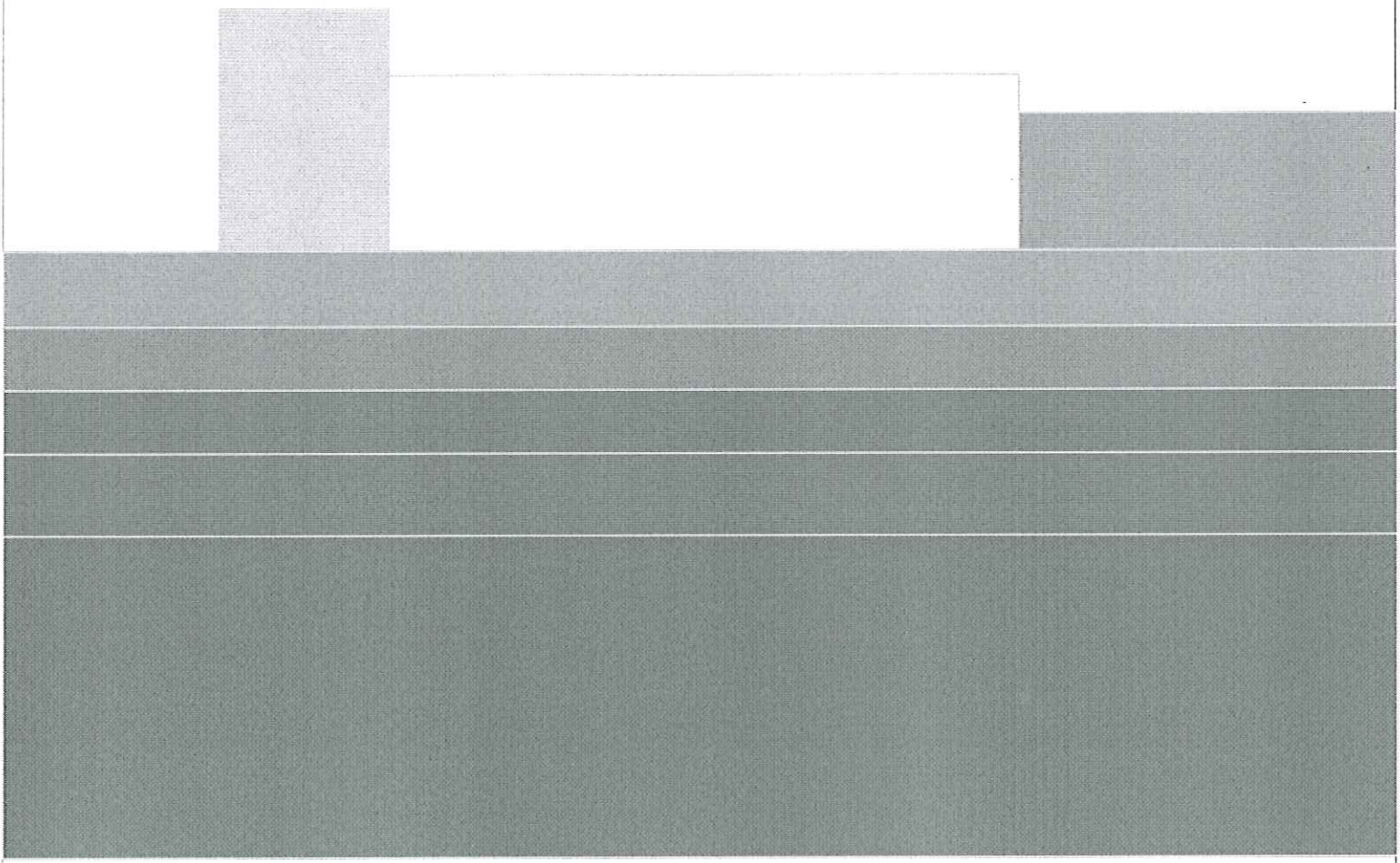
RKK-RW7&8-236 1-19-09

DRAWING OF SPECIFIED GEOMETRY



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JPT 1-19-09

RKK-RW7&8-237

INPUT DATA FOR CONSOLIDATION -- $\alpha = 1/6$

Layer # Undergoing Consolidation [Yes/No]		$(\sigma'_\rho - \sigma'_o)$ given at layer's boundaries in [lb/ft²] at Top	Bottom	Cc	Cr	e0	Cv [ft ²/day]	Drains at :
1	Yes	7800.0	6864.0	0.01	0.01	0.49	0.5800	Top
2	Yes	6864.0	6188.0	0.01	0.01	0.49	0.5800	Bottom
3	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	Yes	5512.0	4633.0	0.01	0.01	0.66	0.5800	Top & Bot.
5	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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JOT 1-19-09
RKK-RW7&8-238

TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	362.00	IIa EL 62 to 50
	2	100.00	362.00	
	3	150.00	362.00	
	4	200.00	362.00	
	5	300.00	362.00	
2	1	0.00	350.00	IIa EL 50 to 40
	2	100.00	350.00	
	3	150.00	350.00	
	4	200.00	350.00	
	5	300.00	350.00	
3	1	0.00	340.00	IIb EL 40 to 30
	2	100.00	340.00	
	3	150.00	340.00	
	4	200.00	340.00	
	5	300.00	340.00	
4	1	0.00	330.00	IIa EL 30 to 17
	2	100.00	330.00	
	3	150.00	330.00	
	4	200.00	330.00	
	5	300.00	330.00	
5	1	0.00	317.00	IIb
	2	100.00	317.00	
	3	150.00	317.00	
	4	200.00	317.00	
	5	300.00	317.00	

Actual EL = Z - 350

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RKK-RW7&8-239 JJT 1-19-09

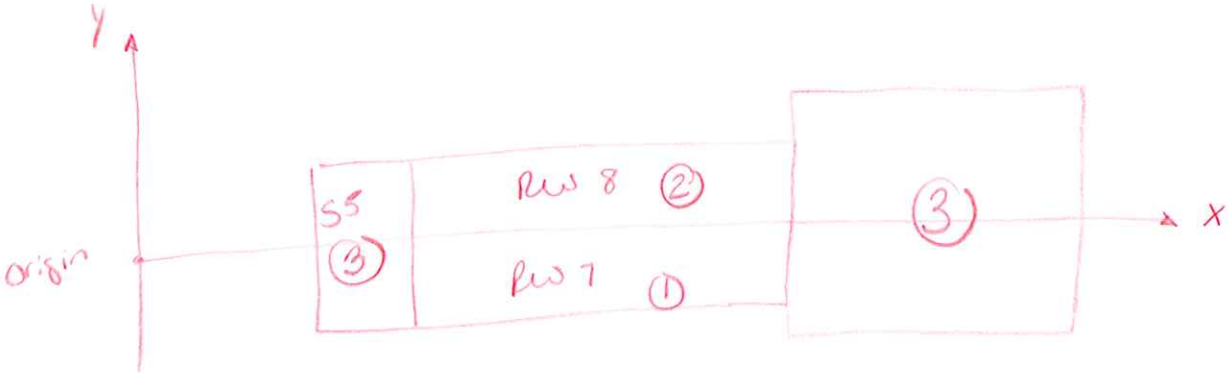
TABULATED GEOMETRY: INPUT OF MULTIPLE FOOTINGS – 4 footings

Footing #	L (in X direction) [ft]	B (in Y direction) [ft]	X of center [ft]	Y of center [ft]	q [ft]l [lb/ft²]
1	100.00	29.00	150.00	-13.50	3820.00
2	100.00	27.00	150.00	14.50	3820.00
3	27.00	56.00	86.50	0.00	5280.00
4	100.00	58.00	250.00	0.00	2990.00

RW 7
RW 8
S-S Abut B
STA 1252 to 1253

* For plan view see sheet 9

Footing Locations



* NTS

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	150.00	-28.00	1	818000	0.4000	0.0102	362.00	361.80	0.20
			2	545000	0.4000	0.0177			= 0.1565'
			3	1364000	0.3000	0.0102			= 1.9"
			4	818000	0.4000	0.0196			
			5	1364000	0.3000	0.1463			
2	150.00	-14.00	1	818000	0.4000	0.0249	362.00	361.73	0.27
			2	545000	0.4000	0.0392			= 0.1797'
			3	1364000	0.3000	0.0175			= 2.2"
			4	818000	0.4000	0.0305			
			5	1364000	0.3000	0.1622			
3	150.00	0.00	1	818000	0.4000	0.0238	362.00	361.71	0.29
			2	545000	0.4000	0.0417			= 0.1879'
			3	1364000	0.3000	0.0197			= 2.3"
			4	818000	0.4000	0.0346			
			5	1364000	0.3000	0.1682			
4	150.00	14.00	1	818000	0.4000	0.0249	362.00	361.73	0.27
			2	545000	0.4000	0.0392			= 0.1797'
			3	1364000	0.3000	0.0175			= 2.2"
			4	818000	0.4000	0.0305			
			5	1364000	0.3000	0.1622			
5	150.00	28.00	1	818000	0.4000	0.0105	362.00	361.80	0.20
			2	545000	0.4000	0.0177			= 0.1565'
			3	1364000	0.3000	0.0102			= 1.9"
			4	818000	0.4000	0.0196			
			5	1364000	0.3000	0.1463			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

actual EL = Z - 360

ignore elastic settlement in Strata IIa

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RKK-RW7&8-241

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
6	100.00	-28.00	1	818000	0.4000	0.0143	362.00	361.80	0.20
			2	545000	0.4000	0.0244			= 0.1416'
			3	1364000	0.3000	0.0121			= 1.7"
			4	818000	0.4000	0.0218			
			5	1364000	0.3000	0.1295			
7	100.00	-14.00	1	818000	0.4000	0.0328	362.00	361.72	0.28
			2	545000	0.4000	0.0510			= 0.1651'
			3	1364000	0.3000	0.0207			= 2.0"
			4	818000	0.4000	0.0340			
			5	1364000	0.3000	0.1444			
8	100.00	0.00	1	818000	0.4000	0.0317	362.00	361.70	0.30
			2	545000	0.4000	0.0541			= 0.1732'
			3	1364000	0.3000	0.0232			= 2.1"
			4	818000	0.4000	0.0384			
			5	1364000	0.3000	0.1500			
9	100.00	14.00	1	818000	0.4000	0.0328	362.00	361.72	0.28
			2	545000	0.4000	0.0510			= 0.1651'
			3	1364000	0.3000	0.0207			= 2.0"
			4	818000	0.4000	0.0340			
			5	1364000	0.3000	0.1444			
10	100.00	28.00	1	818000	0.4000	0.0146	362.00	361.80	0.20
			2	545000	0.4000	0.0244			= 0.1416'
			3	1364000	0.3000	0.0121			= 1.7"
			4	818000	0.4000	0.0218			
			5	1364000	0.3000	0.1295			

act EL = Z - 300

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

ignore elastic settlement in strata Ia

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RKK-RW7&8-242

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	200.00	-28.00	1	818000	0.4000	~~0.0121~~	362.00	~~361.80~~	~~0.20~~
			2	545000	0.4000	~~0.0170~~			= 0.1503'
			3	1364000	0.3000	0.0095			= 1.8"
			4	818000	0.4000	~~0.0178~~			
			5	1364000	0.3000	0.1408			
2	200.00	-14.00	1	818000	0.4000	~~0.0229~~	362.00	~~361.74~~	~~0.26~~
			2	545000	0.4000	~~0.0359~~			= 0.1716'
			3	1364000	0.3000	0.0160			= 2.1"
			4	818000	0.4000	~~0.0277~~			
			5	1364000	0.3000	0.1556			
3	200.00	0.00	1	818000	0.4000	~~0.0220~~	362.00	~~361.73~~	~~0.27~~
			2	545000	0.4000	~~0.0379~~			= 0.179'
			3	1364000	0.3000	0.0179			= 2.1"
			4	818000	0.4000	~~0.0313~~			
			5	1364000	0.3000	0.1611			
4	200.00	14.00	1	818000	0.4000	~~0.0229~~	362.00	~~361.74~~	~~0.26~~
			2	545000	0.4000	~~0.0359~~			= 0.1716'
			3	1364000	0.3000	0.0160			= 2.1"
			4	818000	0.4000	~~0.0277~~			
			5	1364000	0.3000	0.1556			
5	200.00	28.00	1	818000	0.4000	~~0.0123~~	362.00	~~361.80~~	~~0.20~~
			2	545000	0.4000	~~0.0170~~			= 0.1503'
			3	1364000	0.3000	0.0095			= 1.8"
			4	818000	0.4000	~~0.0178~~			
			5	1364000	0.3000	0.1408			

actual EL = Z - 300

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

ignore elastic settlement in Strata IIa

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	150.00	-28.00	362.00	0.15	361.85
2	150.00	-14.00	362.00	0.21	361.79
3	150.00	0.00	362.00	0.21	361.79
4	150.00	14.00	362.00	0.21	361.79
5	150.00	28.00	362.00	0.15	361.85

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

Actual EL = Z - 300

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
6	100.00	-28.00	362.00	0.17	361.83
7	100.00	-14.00	362.00	0.22	361.78
8	100.00	0.00	362.00	0.23	361.77
9	100.00	14.00	362.00	0.22	361.78
10	100.00	28.00	362.00	0.17	361.83

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

Actual EL = Z - 300

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RKK-RW7&8-245

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	200.00	-28.00	362.00	0.15	361.85
2	200.00	-14.00	362.00	0.20	361.80
3	200.00	0.00	362.00	0.20	361.80
4	200.00	14.00	362.00	0.20	361.80
5	200.00	28.00	362.00	0.15	361.85

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

actual EL = Z - 300

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SR 1/I-95 Interchange 103-059-27U 1/19/2009
Retaining Wall 7 8 Settlement Results

	Settlement (ft)		
Point	Elastic	Consolidation	Total
1	0.16	0.15	0.31
2	0.18	0.21	0.39
3	0.19	0.21	0.40
4	0.18	0.21	0.39
5	0.16	0.15	0.31
6	0.14	0.17	0.31
7	0.17	0.22	0.39
8	0.17	0.23	0.40
9	0.17	0.22	0.39
10	0.14	0.17	0.31
11	0.15	0.15	0.30
12	0.17	0.20	0.37
13	0.18	0.20	0.38
14	0.17	0.20	0.37
15	0.15	0.15	0.30

	Settlement (in)		
Point	Elastic	Consolidation	Total
1	1.9	1.8	3.7
2	2.2	2.5	4.7
3	2.3	2.5	4.8
4	2.2	2.5	4.7
5	1.9	1.8	3.7
6	1.7	2.0	3.7
7	2.0	2.6	4.6
8	2.1	2.8	4.8
9	2.0	2.6	4.6
10	1.7	2.0	3.7
11	1.8	1.8	3.6
12	2.1	2.4	4.5
13	2.1	2.4	4.5
14	2.1	2.4	4.5
15	1.8	1.8	3.6

Max 4.8"
Min 3.6"

	RW 7 & 8 Differential Settlement							
	Front RW 7		Front RW 8		Between Walls		Front to Front	
	6 to 1	1 to 11	10 to 5	5 to 15	8 to 3	3 to 13	1 to 3	3 to 5
Inches	0.06	0.07	0.06	0.07	0.06	0.23	1.10	1.10
Ratio	1/9804	1/8065	1/9804	1/8065	0/1	2/5291	1/309	1/249

NO A-SETTLEMENT

All differential settlmenets are within the AASHTO allowable tolerance of 1/100.

* Plan view of point locations
see pg 9.

RKK-RW7&8-246

CALCULATION CHECKLIST

Project: **SR 1/I-95 Interchange** Comm. No.: **103-059-27U**

Title of Calculation Set: **Retaining Wall 9 Analysis**

Project Manager: **EMK/JLT**

Calculations Prepared By: **SAB**

Calculation Checked By:

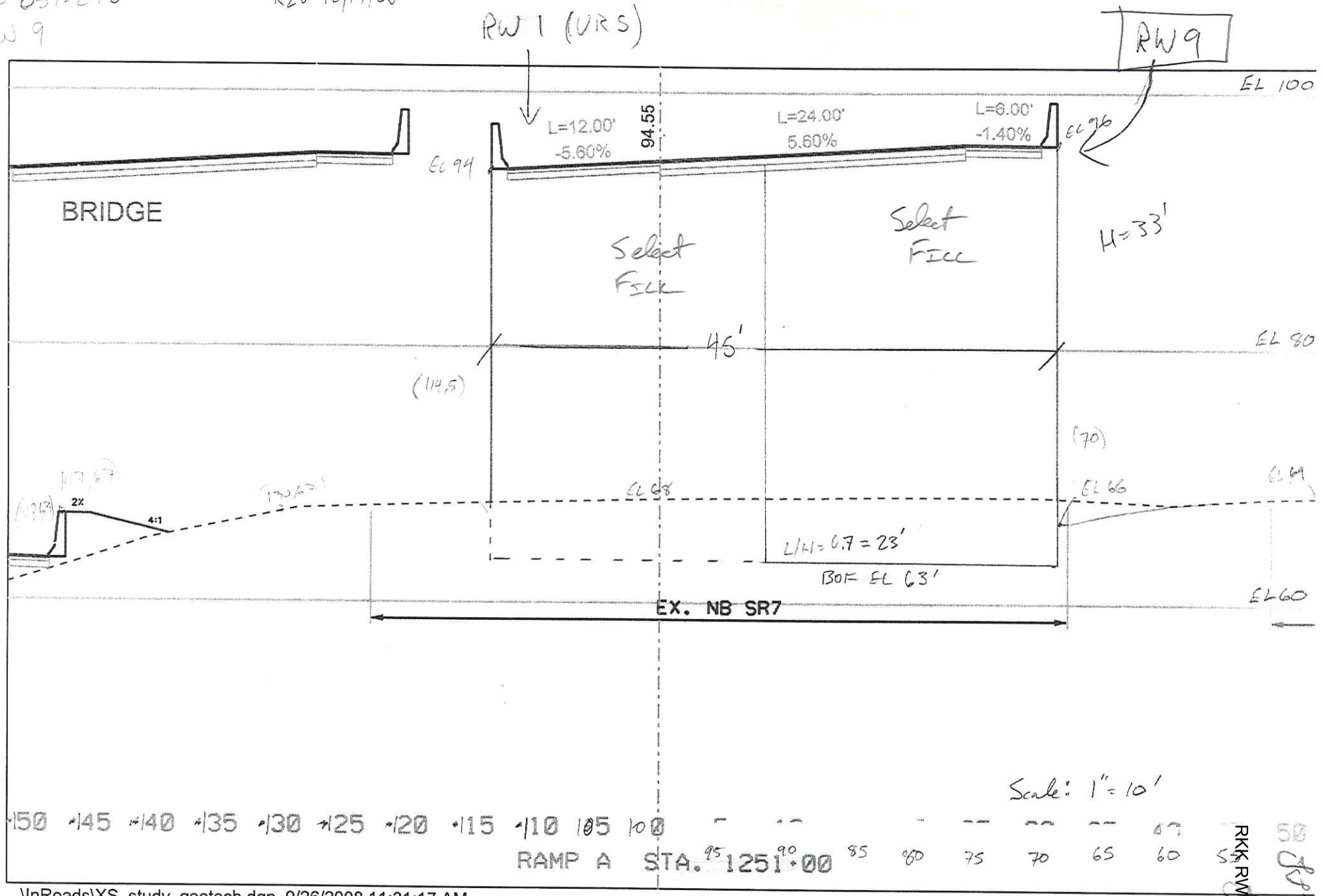
Computer Programs / Files: **MSEW 3.0, Slope/w, FoSSA**

Initial	Date	
		Subsurface Characterization approved by Project Manager
SAB	1/15/09	Calculations are neat, legible and understandable.
SAB	1/15/09	Table of Contents is provided.
SAB	1/15/09	Heading on each page filled out
SAB	1/15/09	The first page contains purpose of the calculation.
SAB	1/15/09	Symbols are defined.
SAB	1/15/09	References for data, methods, formulas and computer program names and version numbers are given.
SAB	1/15/09	Assumptions are listed and those that need to be verified later are Flagged.
SAB	1/15/09	Headings on front sheet of each set of computer input and output.
SAB	1/15/09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JLT	1-18-09	All calculations checked and each calculation sheet initialed by checker.
EMK	1/22/09	Calculation set reviewed by Project Manager.
		Has this calculation been superseded? Reference new calculation, if applicable.

This sheet is to be prepared by the originator of the calculation and attached to the front of the calculation set.

103-0059-270
RW 9

REV 12/17/08



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PROPOSED CONSTRUCTION (for RW9 back-to-back w/ RW1)

START WALL to STA 1252+14
(STA 1250+92)

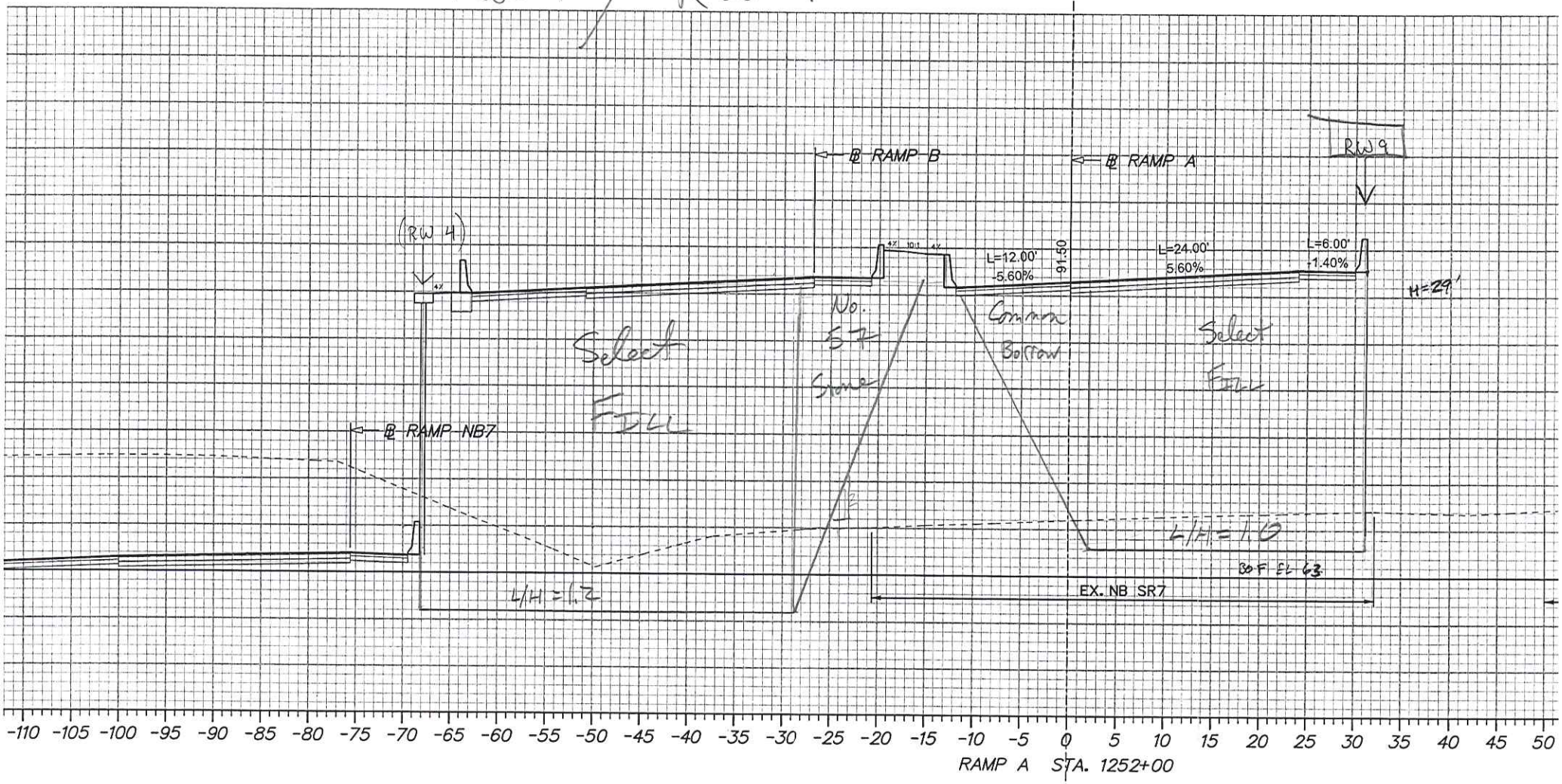
RKK RW9-2
1-2-09

9-30-08

SR1/I-95 Interchange 105-057-474 12/17/08 3

RW 9 SBT 1-2-09

RW4 / RW 9



PROPOSED CONSTRUCTION (with no back-to-back condition)

STA 1252+14 to End Wall

RKK RW9-3

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject I-95/SR 1 Interchange
Ramp A Retaining Wall 9 Stability Analysis
Page 1 of 50
Cm. No. 103-059-27V
Prepared By SAB Date 9/23/06 Checked By [illegible] Date 9-30-08
RGV 12/17/08 [illegible] 1-2-09
EMC 1/29/09

Objective: To evaluate the external and global stability of Ramp A Retaining Wall 9. This wall is proposed to be a mechanically stabilized earth (MSE) wall.

References: 1) AASHTO LRFD Bridge Design Specifications, 4th ed.
2) FHWA Publication No. FHWA-NHI-00-043 "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines."

Summary:

Ramp A STA 1251+00 - Back-to-back w/ RW1 (start wall - STA 1250+92 to STA 1252+14)
L/H = 0.7 assumed (reinforcement for walls meet @ back of reinforced zone).

UNDRAINED ANALYSIS
Foundation Soil
γ = ~~120~~ 92 pcf φ = 0° S_u = 2,500 psf
Bearing Capacity: q_{ult} = 12,850 psf
σ_v = 4,375 psf
FS = 2.94
Sliding: FS ≥ 1.5 OK
Overturning: FS ≥ 2.0 OK
Select in Reinf zone
Select in wedge
γ WAS ADJUSTED IN MSEW TO ACCOUNT FOR GROUNDWATER

DRAINED ANALYSIS
Foundation Soil
γ = ~~120~~ 92 pcf φ' = 24° c' = 0 psf
Bearing Capacity: q_{ult} = 9,772 psf ← GOVERNS
σ_v = 4,375 psf
FS = 2.23
Sliding: FS ≥ 1.5 OK
Overturning: FS ≥ 2.0 OK

Ramp A STA 1252+00 - No back-to-back influence. (STA 1252+14 to end wall)
* L/H = 1.0 required for bearing capacity *

UNDRAINED ANALYSIS
Foundation Soil
γ = 85 pcf φ = 0° S_u = 2,500 psf
Bearing Capacity: q_R = 8,355 psf
σ_v = 6,326 psf
Sliding Resistance: CDR = 2.07
Overturning Resistance: CDR = 4.32

DRAINED ANALYSIS
Foundation Soil
γ = 85 pcf φ' = 24° c' = 0 psf
Bearing Capacity: q_R = 6,374 psf ← GOVERNS
σ_v = 6,326 psf
Select in reinf. zone
common Borrow in wedge
Sliding Resistance: CDR = 1.37
Overturning Resistance: CDR = 4.32

I-95/SR1 Interchange 103-059-270 9/24/08
RW 9 REV 12/17/08

JJT 9-30-08 JJT 1-2-09 2

RKK RW9-5

Wall Details:

TABLE X.X Dimensions of Retaining Wall 9				
RAMP A STA	Design Wall Height (ft)	Bottom of Leveling Pad EL.	Top of Wall EL.	Front Slope/ Slope Height (ft)
1251+00	32.8	63.0	95.8	Horizontal
1251+50	31.3	63.0	94.3	Horizontal
1252+00	~~30.8~~ 29	~~62.0~~ 63.0	93 92.8	Horizontal
1252+50	29.1	62.0	91.1	Horizontal
1253+00	28.4	61.0	89.4	Horizontal
1253+50	26.7	61.0	87.7	Horizontal
1254+00	25.8	60.0	85.8	Horizontal
1254+50	24.9	59.0	83.9	Horizontal
1255+00	23.0	59.0	82.0	Horizontal
1255+50	22.0	58.0	80.0	Horizontal
1256+00	20.0	58.0	78.0	Horizontal
1256+50	19.0	57.0	76.0	Horizontal
1257+00	17.0	57.0	74.0	Horizontal
1257+50	16.0	56.0	72.0	Horizontal
1258+00	14.0	56.0	70.0	Horizontal
1258+50	13.0	55.0	68.0	Horizontal
1259+00	12.0	54.0	66.0	Horizontal
1259+50	10.0	54.0	64.0	Horizontal
1260+00	8.5	53.5	62.0	Horizontal

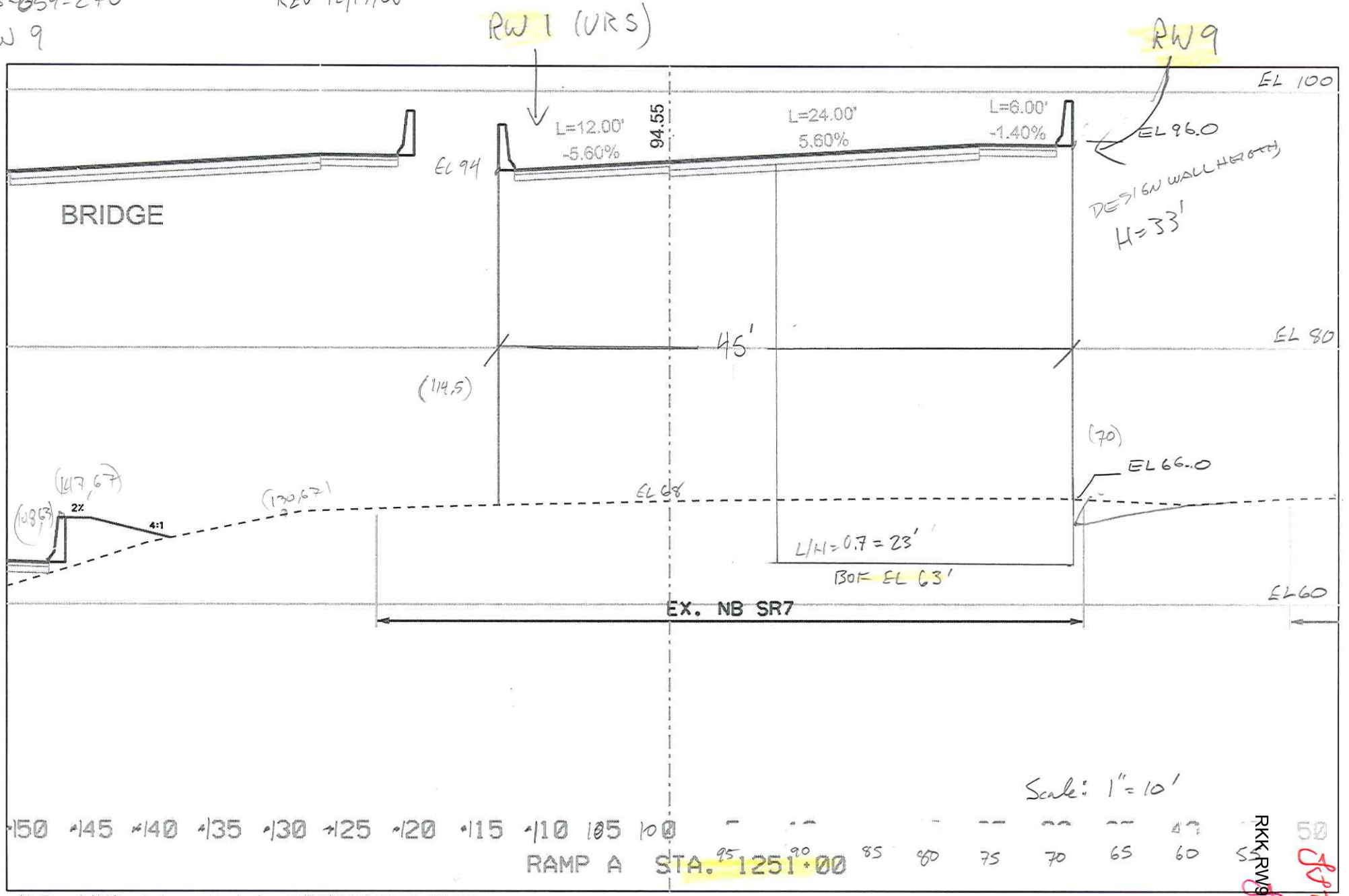
1 ⇒ 2 ⇒

Ramp A STA 1251+00 chosen for analysis 1: Tallest wall section (see cross-section, p. 3)
→ RW 9 is back-to-back with RW 1 at this station.
→ BOF EL = EL 63.0
→ Embedment Depth, E = 3'
→ Traffic LL = 250psf

Ramp A STA 1252+00 chosen for Analysis 2: Tallest wall section without influence of back-to-back walls, (see cross-section, p. 3a)
→ BOF EL = EL 63.0 / TOP OF LEVELING PAD = EL 64
→ Embedment Depth, E = 3'
→ Traffic LL = 250psf

I-95/SR1 Interchange
103-059-270
RW 9

9/26/08
REV 12/17/08



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RKK RW9-6

JPT 9-30-08
JPT 1-2-09
BM 1/20/09

3

SR1/I-95 Interchange

RW 9

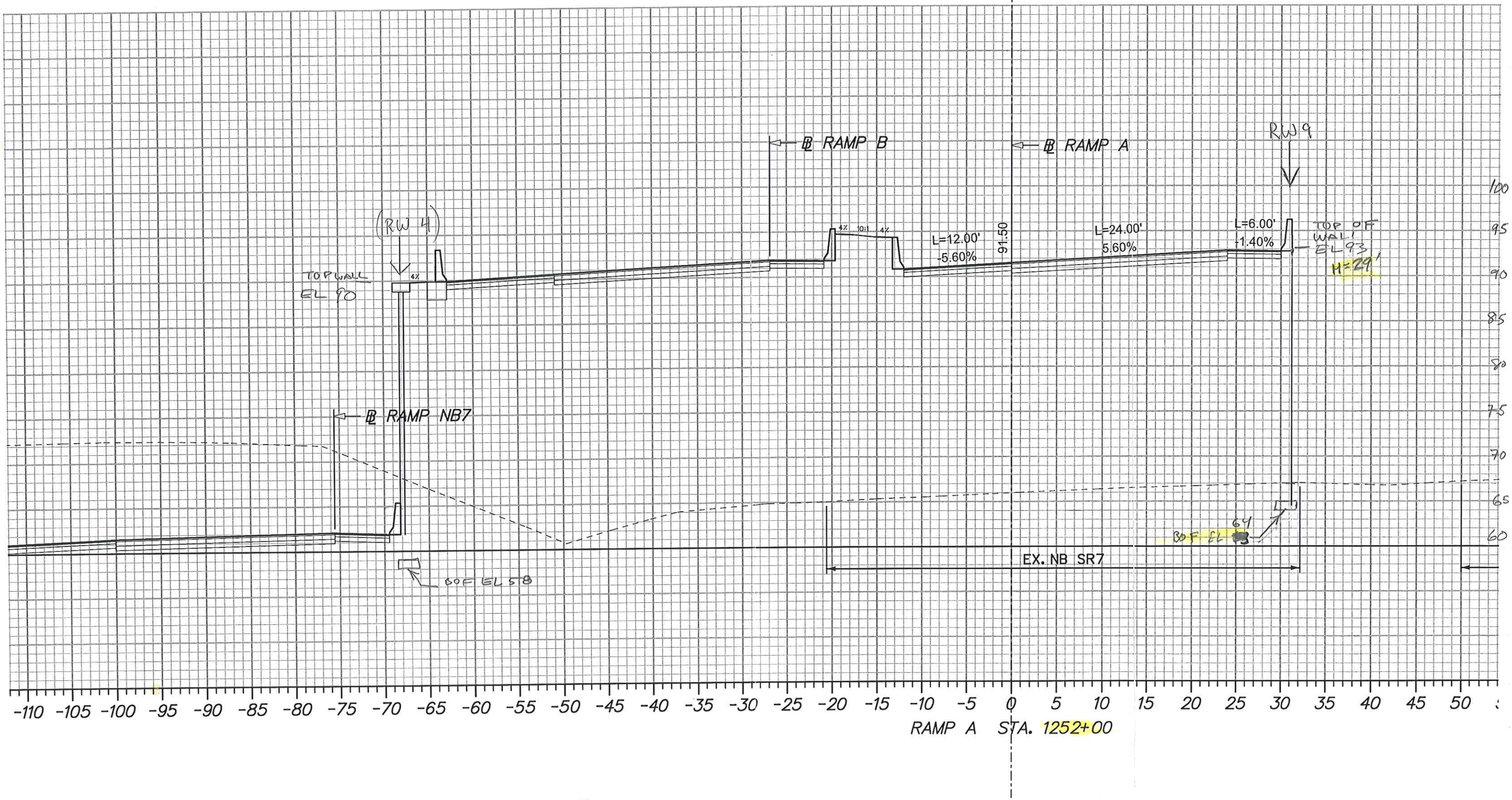
103-059-270

12/17/08

3a

GBT 1-2-09

RKK RW9-7 EMC 1/29/09



RUMMEL, KLEPPER & KAHL, LLP
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Subject I-95/SR1 Interchange — RW 9 Analysis
Page 4 of
Cm. No. 103-059-270
Prepared By SAB Date 9/26/08 Checked By SBT Date 9-30-08
SBT 1-2-09
EMK 1/20/09

Soils: (see attached fence diagram, p. 5)

Soil	γ (pcf)	ϕ (deg)	c' (psf)	S_u (psf)	EL (ft.)
STA 1251+00					
Reinforced Soil (Select)	125	34°	0	–	
Retained Soil (Select)	125	34	0	–	
Foundation Soil (IIa)	~~130~~ 92	24°	0	2,500 (1)	63 - 20
Water	62.4				54
STA 1252+00					
Reinforced Soil (Select)	125	34	0	–	
Retained Soil (Common Borrow)	130	28	0	–	
Foundation Soil	~~130~~ 85	24	0	2,500 (1)	62 - 20
Water	62.4				54 ≈ 9' ↓ BOF

*(1) S_u from DMT Probe IDMT-16 → minimum value used.

⇒ Since groundwater is not at the BOF EL, but is within a footing width (B) below the BOF EL, calculate an average unit weight for the foundation soil:

Ref: Das, Principles of Geotechnical Engineering, 2002. (see p. 4a) p. 517

→ Case III: $\gamma_{av} = \frac{1}{B}\left[\gamma D + \gamma'(B-D)\right]$ where: γ_{av} = γ for bearing capacity calculation
B = footing width
D = Depth below BOF to groundwater
γ' = Effective unit weight of soil ($\gamma - \gamma_w$)

STA 1251+00: $\gamma_{av} = \frac{1}{23'}\left[130(9') + (130-62.4)(23'-9')\right] = 92.0$ pcf

STA 1252+00: $\gamma_{av} = \frac{1}{B}\left[130(8') + (130-62.4)(B-8')\right] = \frac{1}{B}\left(1040 + 67.6B - 540.8\right) = \frac{1}{B}\left(67.6B + 499.2\right)$

$\gamma_{av} = \frac{499.2}{B} + 67.6$

For $L = 1.0B \Rightarrow \gamma_{av} = \frac{499.2}{29'} + 67.6 = 85$ pcf

4a

RKK RW9-9

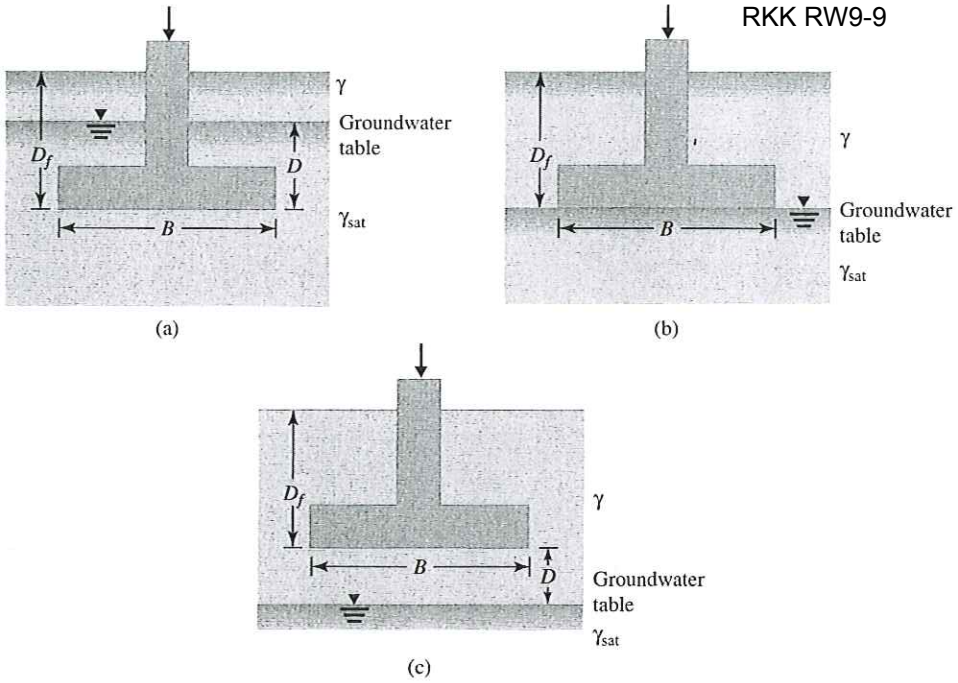

Figure 15.8 Effect of the location of groundwater table on the bearing capacity of shallow foundations: (a) Case I; (b) Case II; (c) Case III

where $\gamma' = \gamma_{sat} - \gamma_w$ = effective unit weight of soil. Also, the unit weight of soil, γ, that appears in the third term of the bearing capacity equations should be replaced by γ'.

- *Case II (Figure 15.8b):* If the groundwater table coincides with the bottom of the foundation, the magnitude of q is equal to γD_f. However, the unit weight, γ, in the third term of the bearing capacity equations should be replaced by γ'.
- *Case III (Figure 15.8c):* When the groundwater table is at a depth D below the bottom of the foundation, $q = \gamma D_f$. The magnitude of γ in the third term of the bearing capacity equations should be replaced by γ_{av}

$$\gamma_{av} = \frac{1}{B}[\gamma D + \gamma'(B - D)] \quad (\text{for } D \leq B) \tag{15.31}$$

$$\gamma_{av} = \gamma \quad (\text{for } D > B) \tag{15.32}$$

sections we as-
than the width,
footing, some
o (15.13), Eqs.
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ance D above
erm of the

(15.30)

15.5 Factor of Safety

Generally, a factor of safety, F_s, of about 3 or more is applied to the ultimate soil-bearing capacity to arrive at the value of the allowable bearing capacity. An F_s of 3

SR1/I-95 Interchange
RW9

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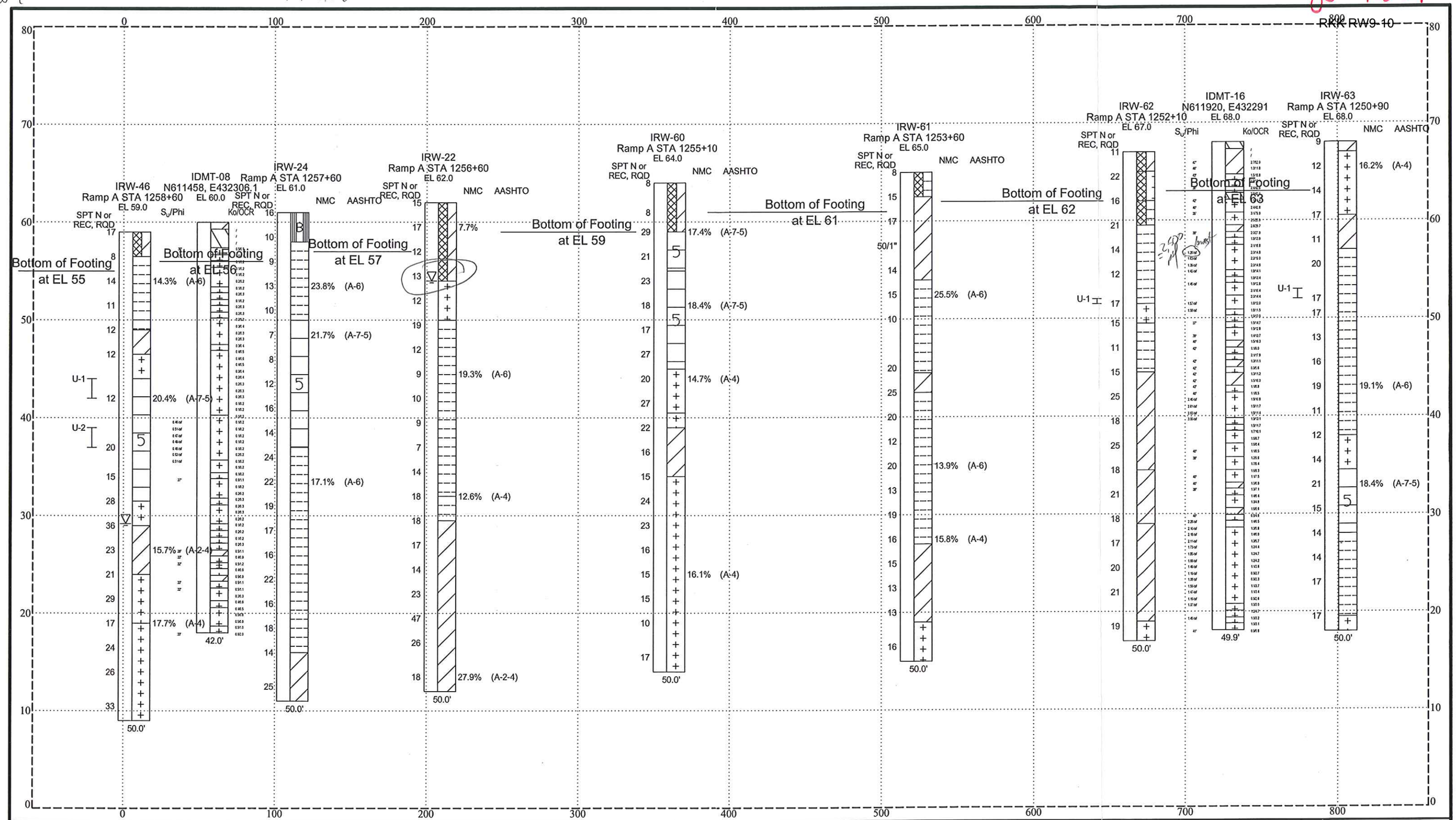
12/17/08

JDT 1-2-09

RKK RW9-10



AASHTO SOIL KEY

A	A-1-a	5	A-2-5		A-5		A-8
B	A-1-b		A-2-6		A-6		Asphalt
	A-3	7	A-2-7	5	A-7-5		FILL
	A-2-4	+ + +	A-4		A-7-6		Decomposed Rock

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data
Retaining Wall 9

Figure No. A-4g

Drawn: TAS | Approved: EMK | Date: 9/24/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 9/24/08

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject SR 1/I-95 Interchange — RW 9 External Stability Analysis | Page 6 of ____ | Cm. No. 103-059-270
Prepared By SAB Date 12/17/08 Checked By JGT Date 1-2-09
EMK 1/20/09

External Stability Analysis: Performed using MSEW 3.0

STA 1251+00

For back-to-back walls, per FHWA (Ref. 2), p. 178 Eqn. 5.5, reduce active thrust if:

$D < H_1 \tan(45 - \phi/2)$ where: D = Distance between walls; H_1 = Wall Height; ϕ = Retained Soil Friction Angle (= 34° for Select Fill)

$D < 33' \tan(45 - 34/2) = 17.5'$

↳ So RW 9 & RW 1 are back-to-back with active thrust reduced for D < 17.5'

⇒ In MSEW, maximum reinforcement length = distance between wall faces/2

→ So, $L = 45'/2 = 22.5' = 0.7H$

→ Per AASHTO LRFD, back-to-back walls must be designed per AASHTO 2002/FHWA (ASD)

Drained: (see p. 7-14)

Results: Bearing Capacity: Ultimate Bearing Capacity, $q_{ult} = 9,772$ psf ← Governing Case

Megerhof Stress, $\sigma_v = 4,375$ psf ⇒ FS = 2.23 > 2.0 ✓ OK

(per FHWA 4.2f, FS = 2.0 may be used w/ geotechnical analysis calculating acceptable settlement)

Sliding: OK FS ≫ 1.50

Overturning: OK FS ≫ 2.0

Undrained: (see p. 15-22)

Results: Bearing Capacity: Ultimate Bearing Capacity, $q_{ult} = 12,853$ psf

Megerhof Stress, $\sigma_v = 4,375$ psf ⇒ FS = 2.94 > 2.50 ✓ OK

Sliding: OK FS ≫ 1.50

Overturning: OK FS ≫ 2.0

FOR FS = 2, S_u CAN BE AS LOW AS 1700-psf

* Check Global Stability
* Check Settlement

7

RKK RW9-12

JST 1-2-09
EMK 1/20/09

AASHTO DESIGN METHOD
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1251+00

Description:

Retaining Wall 9 DRAINED Analysis H = 33' L/H = 0.7 (Back to Back w/ RW 1)

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....A 1251+00 L=pt7H.BEN
Original date and time of creating this file: Mon Oct 20 15:37:52 2008

PROGRAM MODE:

ANALYSIS
of BACK to BACK WALL
using METAL STRIPS as reinforcing material.

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License number MSEW-301874

RKK RW9-13
1-2-09
1/20/09

SOIL DATA

REINFORCED SOIL

Unit weight,	γ	125.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	34.0 °

Select

RETAINED SOIL

Unit weight,	γ	125.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	34.0 °

Select

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight,	$\gamma_{equiv.}$	92.0 lb/ft ^{3}
Equivalent internal angle of friction,	$\phi_{equiv.}$	24.0 °
Equivalent cohesion,	$c_{equiv.}$	0.0 lb/ft ^{2}

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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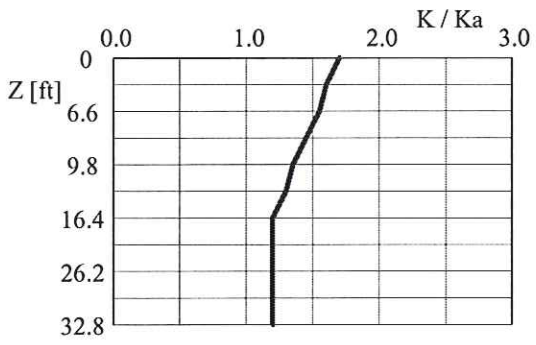
RKK RW9-14
1-2-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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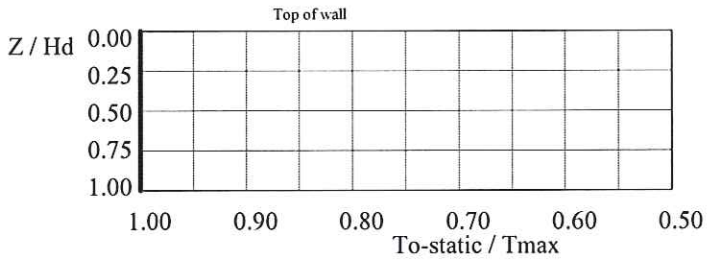
RKK RW9-15

JBM 1-2-09

INPUT DATA: Facia and Connection (Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK RW9-16
1-2-09
EMK
1/20/09

INPUT DATA: Geometry and Surcharge loads (of BACK to BACK wall)

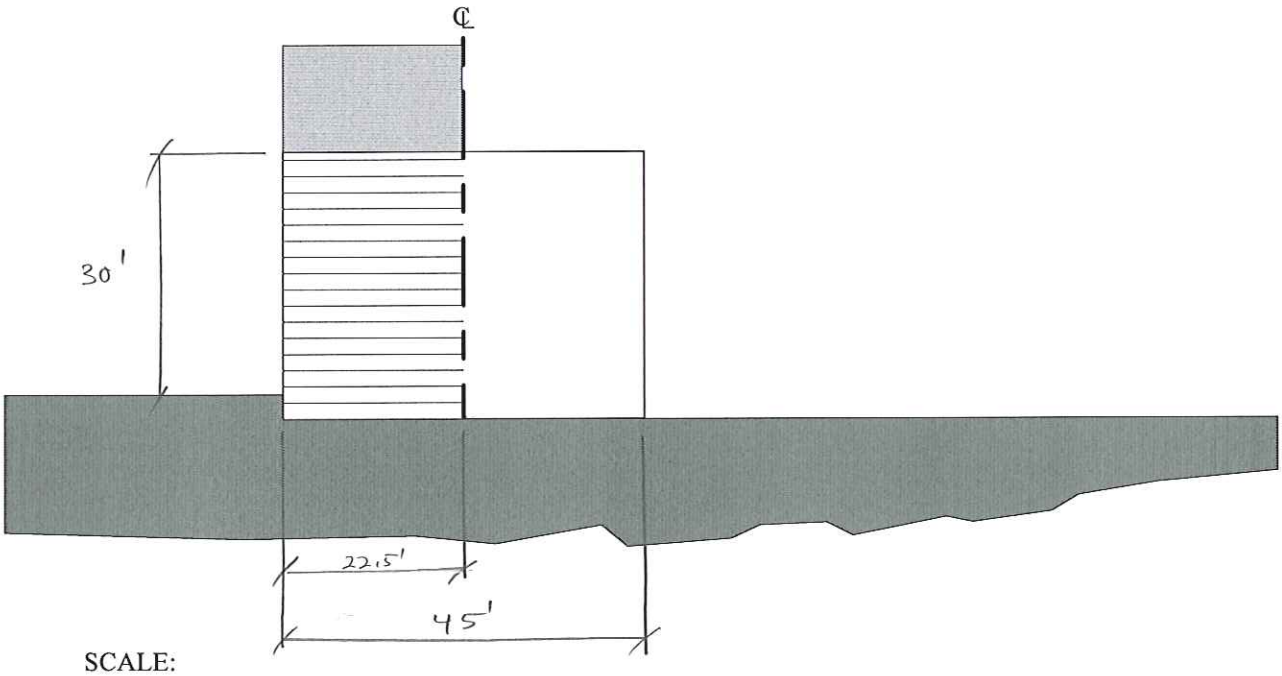
Design height, Hd 33.00 [ft] { Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 30.00 ft }

Batter, ω 0.0 [deg]
Backslope, β 0.0 [deg]
Backslope rise 0.0 [ft] Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

Distance between walls (Back to Back) = 45.0 ft, and Reinforcement length, L = 22.5 ft.

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 5 10 15 20 25 30 [ft]

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RKK RW9-17 JPT 1-2-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, Fs = 2.23, Meyerhof stress = 4375 lb/ft².

Foundation Interface: Direct sliding, Fs = 6030847.862, Eccentricity, e/L = 0.0000, Fs-overturning = 55413427.06

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	Fs-overall [pullout resistance]	Fs-overall [connection break]	Fs-overall [metal strip strength]	Metal strip strength Fs	Pullout resistance Fs	Direct sliding Fs	Eccentricity e/L	Product name
1	0.00	22.50	1	N/A	3.11	3.46	3.457	4.327	9099792.761	0.0000	---
2	2.00	22.50	1	N/A	1.63	1.81	1.807	2.012	8548290.170	0.0000	---
3	4.00	22.50	1	N/A	1.73	1.92	1.924	1.891	7996787.578	0.0000	---
4	6.00	22.50	1	N/A	1.85	2.06	2.056	1.769	7445284.986	0.0000	---
5	8.00	22.50	1	N/A	1.99	2.21	2.209	1.648	6893782.395	0.0000	---
6	10.00	22.50	1	N/A	2.15	2.39	2.385	1.527	6342279.803	0.0000	---
7	12.00	22.50	1	N/A	2.33	2.59	2.593	1.404	5790777.212	0.0000	---
8	14.00	22.50	1	N/A	2.50	2.78	2.783	1.340	5249825.291	0.0000	---
9	16.00	22.50	1	N/A	2.65	2.95	2.949	1.370	4706712.401	0.0000	---
10	18.00	22.50	1	N/A	2.87	3.19	3.188	1.472	4152981.530	0.0000	---
11	20.00	22.50	1	N/A	3.16	3.51	3.511	1.591	3599250.659	0.0000	---
12	22.00	22.50	1	N/A	3.51	3.90	3.898	1.669	3045519.789	0.0000	---
13	24.00	22.50	1	N/A	3.98	4.42	4.417	1.709	2491788.918	0.0000	---
14	26.00	22.50	1	N/A	4.68	5.20	5.199	1.713	1938058.047	0.0000	---
15	28.00	22.50	1	N/A	5.85	6.50	6.505	1.663	1384327.177	0.0000	---
16	30.00	22.50	1	N/A	8.01	8.90	8.895	1.473	830596.306	0.0000	---
17	32.00	22.50	1	N/A	12.94	14.38	14.376	0.852	276865.435	0.0000	---

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RKK RW9-18

JGT 1-2-09

BEARING CAPACITY for GIVEN LAYOUT

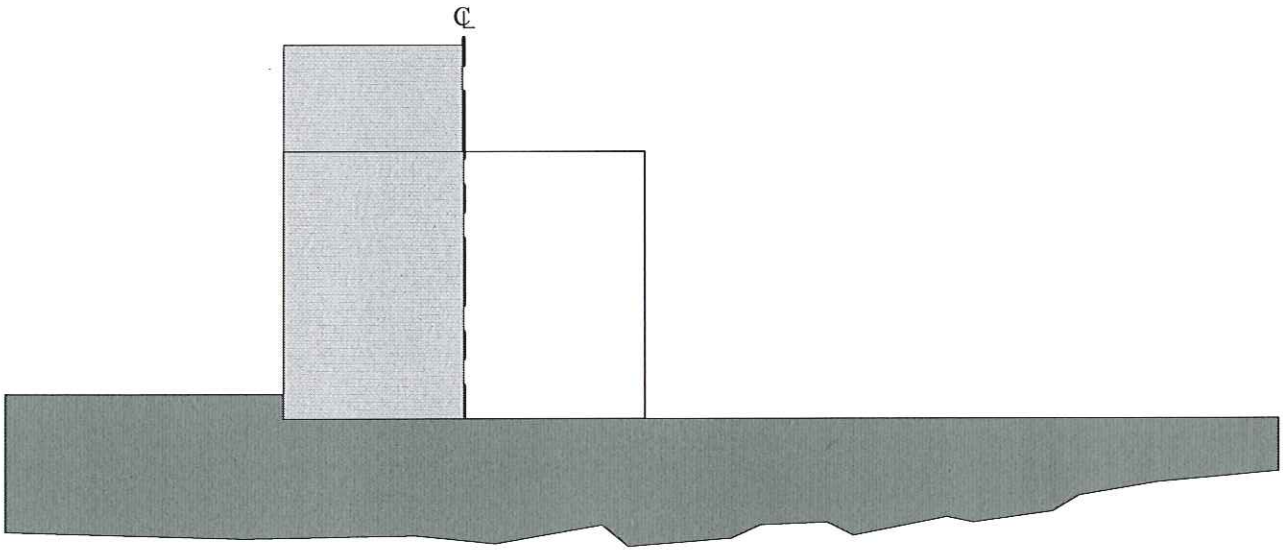
γ_w ADJUSTED FOR GWL

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Ultimate bearing capacity, q-ult	9772	N/A	[lb/ft ²]
Meyerhof stress, σ_V	4375.0	N/A	[lb/ft ²]
Eccentricity, e	0.00	N/A	[ft]
Eccentricity, e/L	0.000	N/A	
Fs calculated	2.23	N/A	
Base length	22.50	N/A	[ft]

$q_{ult} > \bar{\sigma}_V$ ∴ OK

$CDR = \frac{q_{ult}}{\bar{\sigma}_V} = 2.23$

∴ OK



SCALE:

0 5 10 15 20 25 30 [ft]

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RKK RW9-19
1-2-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: Fs-static = 6030847.862

#	Metal strip Elevation [ft]	Metal strip Length [ft]	Fs Static	Fs Seismic	Metal strip Type #	Product name
1	0.00	22.50	9099792.761	N/A	1	---
2	2.00	22.50	8548290.170	N/A	1	---
3	4.00	22.50	7996787.578	N/A	1	---
4	6.00	22.50	7445284.986	N/A	1	---
5	8.00	22.50	6893782.395	N/A	1	---
6	10.00	22.50	6342279.803	N/A	1	---
7	12.00	22.50	5790777.212	N/A	1	---
8	14.00	22.50	5249825.291	N/A	1	---
9	16.00	22.50	4706712.401	N/A	1	---
10	18.00	22.50	4152981.530	N/A	1	---
11	20.00	22.50	3599250.659	N/A	1	---
12	22.00	22.50	3045519.789	N/A	1	---
13	24.00	22.50	2491788.918	N/A	1	---
14	26.00	22.50	1938058.047	N/A	1	---
15	28.00	22.50	1384327.177	N/A	1	---
16	30.00	22.50	830596.306	N/A	1	---
17	32.00	22.50	276865.435	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0000; Overturning: Fs-static = 55413427.06

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	22.50	0.0000	N/A	1	---
2	2.00	22.50	0.0000	N/A	1	---
3	4.00	22.50	0.0000	N/A	1	---
4	6.00	22.50	0.0000	N/A	1	---
5	8.00	22.50	0.0000	N/A	1	---
6	10.00	22.50	0.0000	N/A	1	---
7	12.00	22.50	0.0000	N/A	1	---
8	14.00	22.50	0.0000	N/A	1	---
9	16.00	22.50	0.0000	N/A	1	---
10	18.00	22.50	0.0000	N/A	1	---
11	20.00	22.50	0.0000	N/A	1	---
12	22.00	22.50	0.0000	N/A	1	---
13	24.00	22.50	0.0000	N/A	1	---
14	26.00	22.50	0.0000	N/A	1	---
15	28.00	22.50	0.0000	N/A	1	---
16	30.00	22.50	0.0000	N/A	1	---
17	32.00	22.50	0.0000	N/A	1	---

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RKK RW9-20

1-2-09

1/20/09

AASHTO DESIGN METHOD
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1251+00

Description:

Retaining Wall 9 UNDRAINED Analysis H = 33' L/H = 0.7 (Back to Back w/ RW 1)

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....A 1251+00 L=pt7H.BEN
Original date and time of creating this file: Mon Oct 20 15:37:52 2008

PROGRAM MODE:

ANALYSIS
of BACK to BACK WALL
using METAL STRIPS as reinforcing material.

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RKK RW9-21

JRT 1-2-09

EMK 1/20/09

SOIL DATA

REINFORCED SOIL

Unit weight,	γ	125.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	34.0 °

Select Soil

RETAINED SOIL

Unit weight,	γ	125.0 lb/ft ^{3}
Design value of internal angle of friction,	ϕ	34.0 °

Select Soil

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight,	$\gamma_{equiv.}$	92.0 lb/ft ^{3} ← ADJUSTED FOR GWL
Equivalent internal angle of friction,	$\phi_{equiv.}$	0.0 °
Equivalent cohesion,	$c_{equiv.}$	2500.0 lb/ft ^{2}

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 5.14 N γ= 0.00

SEISMICITY

Not Applicable

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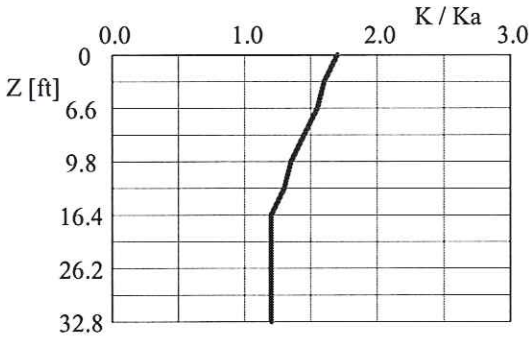
RKK RW9-22
JPT 1-2-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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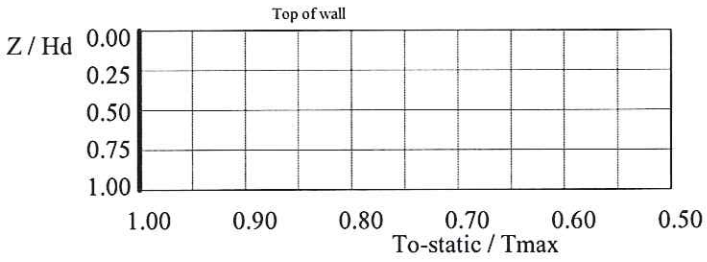
RKK RW9-23
JDS 1-2-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK-RW9-24

JAT 1-2-09

SMC 1/20/09

INPUT DATA: Geometry and Surcharge loads (of BACK to BACK wall)

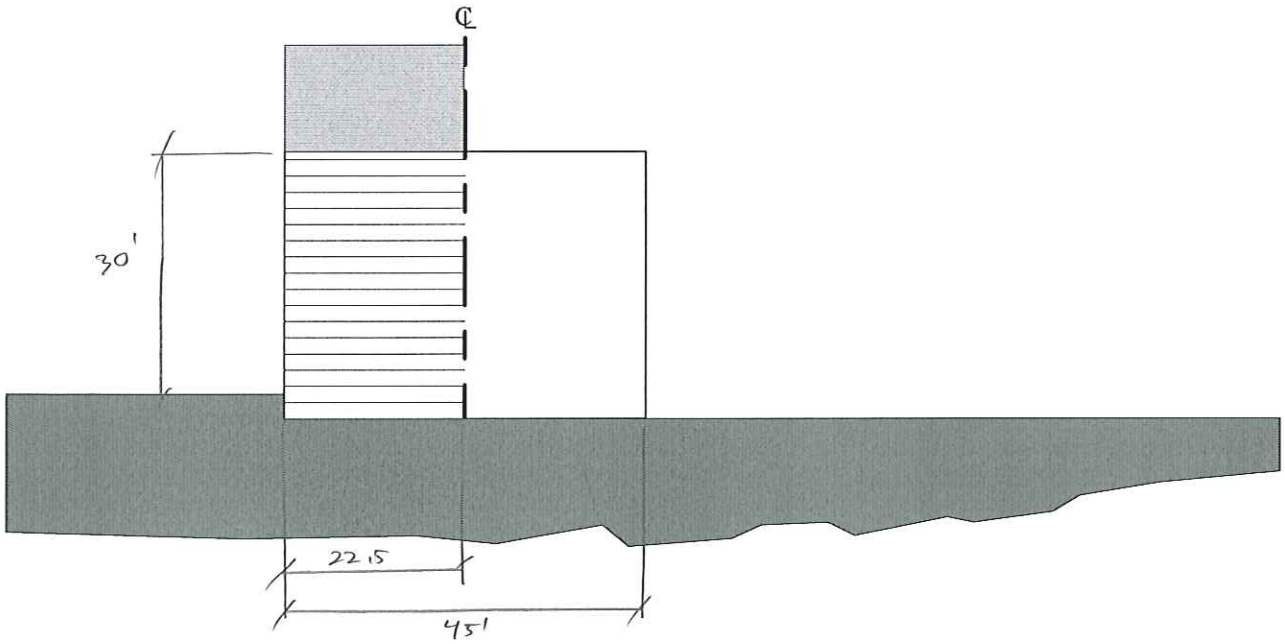
Design height, Hd	33.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 30.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

Distance between walls (Back to Back) = 45.0 ft, and Reinforcement length, L = 22.5 ft.

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 5 10 15 20 25 30 [ft]

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RKK RW9-25 JPT 1-2-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, Fs = 2.94, Meyerhof stress = 4375 lb/ft².

Foundation Interface: Direct sliding, Fs = 8209398.050, Eccentricity, e/L = 0.0000, Fs-overturning = 55413427.06

	METAL STRIP			CONNECTION						
#	Elevation [ft]	Length [ft]	Type #	Fs-overall [pullout resistance]	Fs-overall [connection break]	Fs-overall [metal strip strength]	Metal strip strength Fs	Pullout resistance Fs	Direct sliding Fs	Eccentricity e/L	Product name
1	0.00	22.50	1	N/A	3.11	3.46	3.457	4.327	9099792.761	0.0000	---
2	2.00	22.50	1	N/A	1.63	1.81	1.807	2.012	8548290.170	0.0000	---
3	4.00	22.50	1	N/A	1.73	1.92	1.924	1.891	7996787.578	0.0000	---
4	6.00	22.50	1	N/A	1.85	2.06	2.056	1.769	7445284.986	0.0000	---
5	8.00	22.50	1	N/A	1.99	2.21	2.209	1.648	6893782.395	0.0000	---
6	10.00	22.50	1	N/A	2.15	2.39	2.385	1.527	6342279.803	0.0000	---
7	12.00	22.50	1	N/A	2.33	2.59	2.593	1.404	5790777.212	0.0000	---
8	14.00	22.50	1	N/A	2.50	2.78	2.783	1.340	5249825.291	0.0000	---
9	16.00	22.50	1	N/A	2.65	2.95	2.949	1.370	4706712.401	0.0000	---
10	18.00	22.50	1	N/A	2.87	3.19	3.188	1.472	4152981.530	0.0000	---
11	20.00	22.50	1	N/A	3.16	3.51	3.511	1.591	3599250.659	0.0000	---
12	22.00	22.50	1	N/A	3.51	3.90	3.898	1.669	3045519.789	0.0000	---
13	24.00	22.50	1	N/A	3.98	4.42	4.417	1.709	2491788.918	0.0000	---
14	26.00	22.50	1	N/A	4.68	5.20	5.199	1.713	1938058.047	0.0000	---
15	28.00	22.50	1	N/A	5.85	6.50	6.505	1.663	1384327.177	0.0000	---
16	30.00	22.50	1	N/A	8.01	8.90	8.895	1.473	830596.306	0.0000	---
17	32.00	22.50	1	N/A	12.94	14.38	14.376	0.852	276865.435	0.0000	---

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RKK RW9-26

JBP 1-2-09

CMM 1/20/09

BEARING CAPACITY for GIVEN LAYOUT

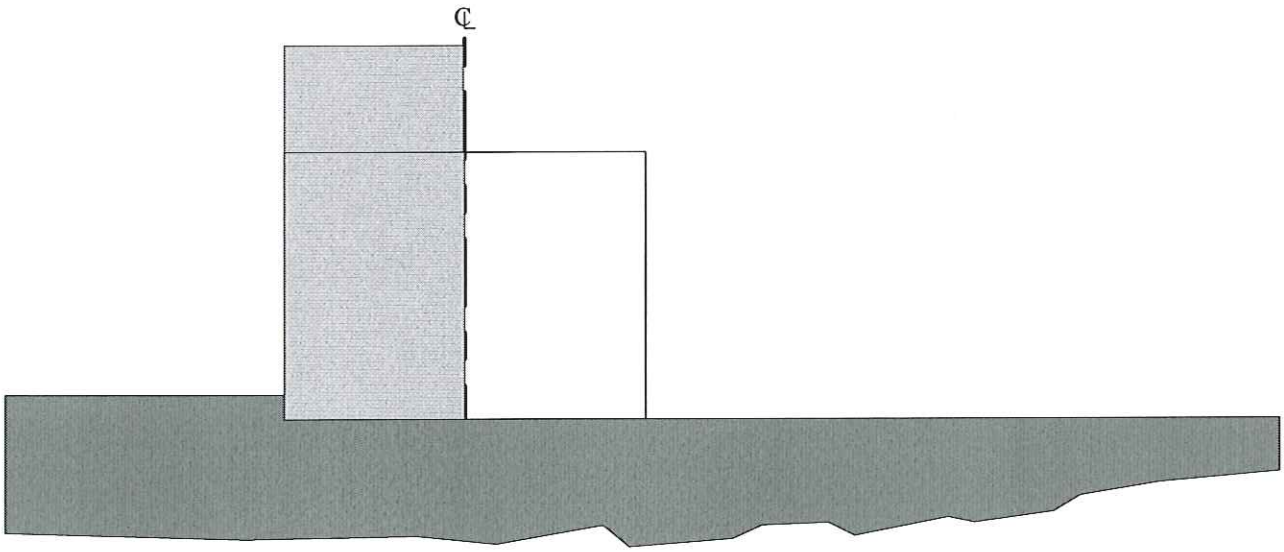
	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Ultimate bearing capacity, q-ult	12854	N/A	[lb/ft ²]
Meyerhof stress, σ_V	4375.0	N/A	[lb/ft ²]
Eccentricity, e	0.00	N/A	[ft]
Eccentricity, e/L	0.000	N/A	
Fs calculated	2.94	N/A	
Base length	22.50	N/A	[ft]

$q_{ult} > \bar{\sigma}_V$ ∴ ok

$CDR = \frac{q_{ult}}{\bar{\sigma}_V} = 2.94$

∴ ok

* Drained Analysis Governs *



SCALE:

0 5 10 15 20 25 30 [ft]

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RKK RW9-27
1-2-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: Fs-static = 8209398.050

#	Metal strip Elevation [ft]	Metal strip Length [ft]	Fs Static	Fs Seismic	Metal strip Type #	Product name
1	0.00	22.50	9099792.761	N/A	1	---
2	2.00	22.50	8548290.170	N/A	1	---
3	4.00	22.50	7996787.578	N/A	1	---
4	6.00	22.50	7445284.986	N/A	1	---
5	8.00	22.50	6893782.395	N/A	1	---
6	10.00	22.50	6342279.803	N/A	1	---
7	12.00	22.50	5790777.212	N/A	1	---
8	14.00	22.50	5249825.291	N/A	1	---
9	16.00	22.50	4706712.401	N/A	1	---
10	18.00	22.50	4152981.530	N/A	1	---
11	20.00	22.50	3599250.659	N/A	1	---
12	22.00	22.50	3045519.789	N/A	1	---
13	24.00	22.50	2491788.918	N/A	1	---
14	26.00	22.50	1938058.047	N/A	1	---
15	28.00	22.50	1384327.177	N/A	1	---
16	30.00	22.50	830596.306	N/A	1	---
17	32.00	22.50	276865.435	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.0000; Overturning: Fs-static = 55413427.06

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	22.50	0.0000	N/A	1	---
2	2.00	22.50	0.0000	N/A	1	---
3	4.00	22.50	0.0000	N/A	1	---
4	6.00	22.50	0.0000	N/A	1	---
5	8.00	22.50	0.0000	N/A	1	---
6	10.00	22.50	0.0000	N/A	1	---
7	12.00	22.50	0.0000	N/A	1	---
8	14.00	22.50	0.0000	N/A	1	---
9	16.00	22.50	0.0000	N/A	1	---
10	18.00	22.50	0.0000	N/A	1	---
11	20.00	22.50	0.0000	N/A	1	---
12	22.00	22.50	0.0000	N/A	1	---
13	24.00	22.50	0.0000	N/A	1	---
14	26.00	22.50	0.0000	N/A	1	---
15	28.00	22.50	0.0000	N/A	1	---
16	30.00	22.50	0.0000	N/A	1	---
17	32.00	22.50	0.0000	N/A	1	---

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RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject SR1/I-95 Interchange
RW9 External Stability Analysis
Page 23 of
Cm. No. 63-059-270
Prepared By SAB Date Checked By JST Date 1-2-09
EMK 1/20/09

STA 1252+00

Drained: * L/H = 1.0 must be used to satisfy bearing capacity. * (see p. 42-50 for L/H=0.8 case - No Good)

Results: Bearing Capacity: Factored Bearing Resistance, q_R = 6,374 psf ← GOVERNS
(see p. 24-32)
Mayerhof Stress, σ_v = 6,326 psf
$q_R > \sigma_v$ ∴ OK
CDR = 1.01 > 1.0 ✓OK FOR L/H, CDR = 0.65 SEE PAGE 42

Sliding Resistance: CDR = 1.37 > 1.0 ✓OK

Overturning Resistance: CDR = 4.32 > 1.0 ✓OK

(*) Select Borrow in reinforced zone
Common Borrow in wedge.

Undrained: → Check with L/H = 1.0 (needed for Drained case) (see p. 33-41)

Results: Bearing Capacity: Factored Bearing Resistance, q_R = 8,355 psf
Mayerhof Stress, σ_v = 6,326 psf
CDR = 1.32 > 1.0 ✓OK

Sliding Resistance: CDR = 2.07 > 1.0 ✓OK

Overturning Resistance: CDR = 4.32 > 1.0 ✓OK

* Drained analysis Governs
* Check Global stability
* Check Settlement

24

RKK RW9-29

1-2-09

EM 1/20/09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1252+00

Description:

Retaining Wall 9 DRAINED Analysis H = 29' L/H = 1.0

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....2+00 DRAINED L=H.BEN
Original date and time of creating this file: Mon Oct 20 13:34:41 2008

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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RKK RW9-30
JDP 1-2-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select
Design value of internal angle of friction, ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ	130.0 lb/ft ^{3}	Common Borrow Type F
Design value of internal angle of friction, ϕ	28.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	85.0 lb/ft ^{3}
Equivalent internal angle of friction, $\phi_{equiv.}$	24.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ^{2}

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3610 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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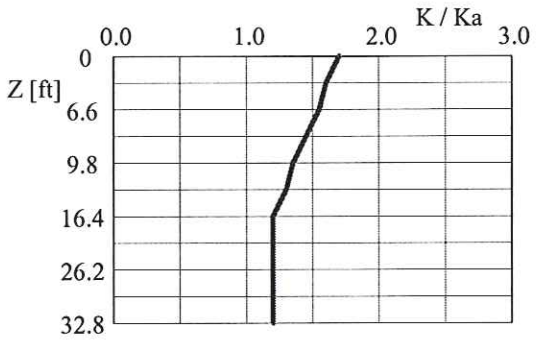
RKK RW9-31
JLT 1-2-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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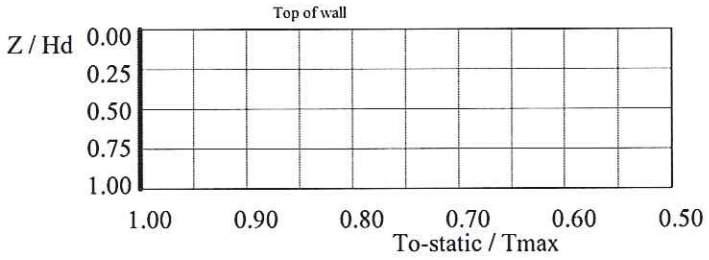
RKK RW9-32
JBT 1-2-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK RW9-33 BOT 1-2-09

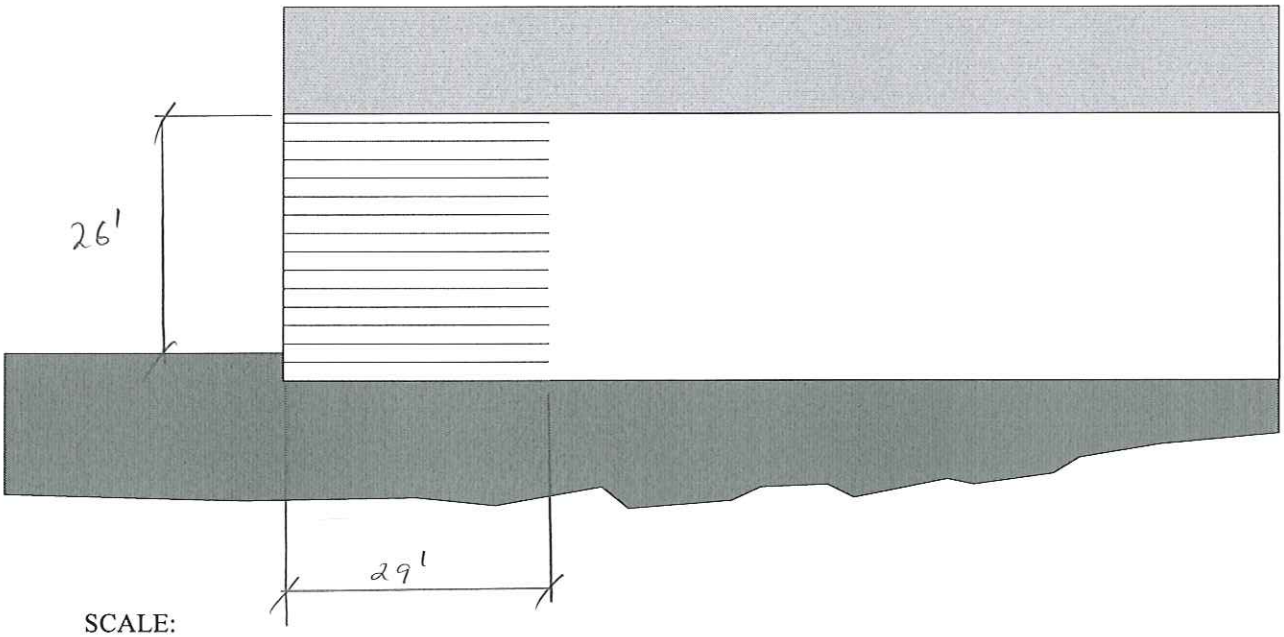
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	29.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 26.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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RKK RW9-34
JBP 1-2-09

AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00

Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90		1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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RKK RW9-35 JCT 1-2-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.01, Meyerhof stress = 6326 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.369, Eccentricity, e/L = 0.1157, CDR-overturning = 4.32

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	29.00	1	N/A	1.92	2.13	2.131	3.626	2.066	0.1157	---
2	2.00	29.00	1	N/A	1.01	1.12	1.120	1.700	2.197	0.1017	---
3	4.00	29.00	1	N/A	1.08	1.20	1.201	1.616	2.346	0.0885	---
4	6.00	29.00	1	N/A	1.17	1.29	1.295	1.530	2.517	0.0763	---
5	8.00	29.00	1	N/A	1.26	1.40	1.404	1.444	2.714	0.0650	---
6	10.00	29.00	1	N/A	1.35	1.50	1.504	1.417	2.951	0.0546	---
7	12.00	29.00	1	N/A	1.43	1.59	1.589	1.498	3.233	0.0450	---
8	14.00	29.00	1	N/A	1.54	1.71	1.711	1.551	3.564	0.0364	---
9	16.00	29.00	1	N/A	1.69	1.88	1.876	1.644	3.972	0.0286	---
10	18.00	29.00	1	N/A	1.86	2.07	2.071	1.714	4.485	0.0218	---
11	20.00	29.00	1	N/A	2.10	2.33	2.328	1.742	5.150	0.0158	---
12	22.00	29.00	1	N/A	2.44	2.71	2.710	1.726	6.047	0.0107	---
13	24.00	29.00	1	N/A	3.00	3.33	3.331	1.647	7.322	0.0065	---
14	26.00	29.00	1	N/A	3.97	4.42	4.417	1.415	9.277	0.0033	---
15	28.00	29.00	1	N/A	6.00	6.66	6.662	0.764	12.659	0.0009	---

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RKK RW9-36

1-2-09

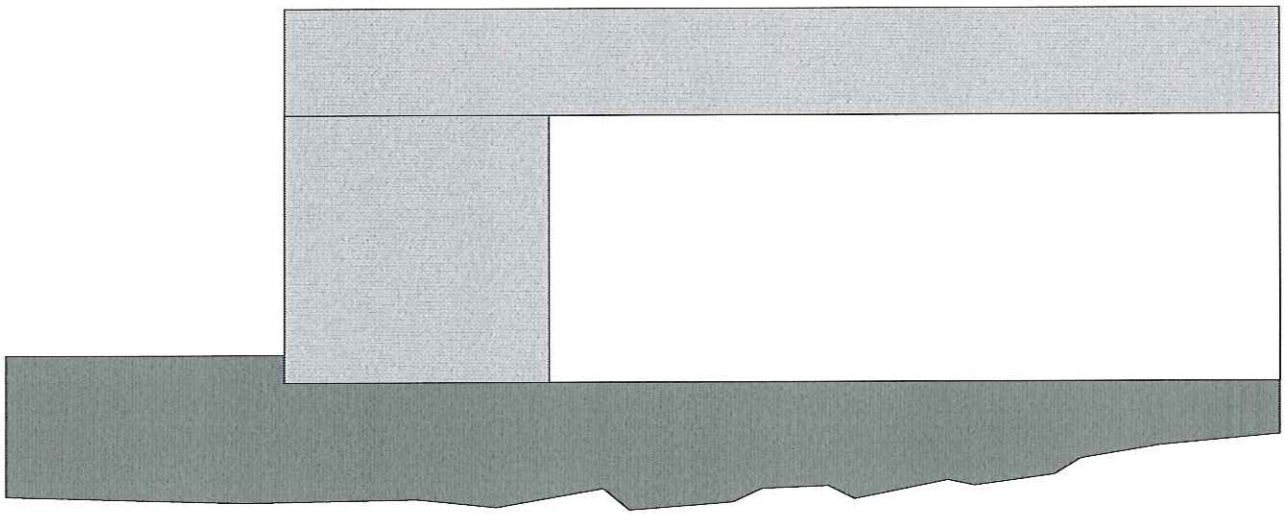
EMJ 1/2/09

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Ultimate bearing capacity, q-ult	6374	N/A	[lb/ft ²]
Meyerhof stress, σ_V	6326.2	N/A	[lb/ft ²]
Eccentricity, e	2.28	N/A	[ft]
Eccentricity, e/L	0.079	N/A	
CDR calculated	1.01	N/A	
Base length	29.00	N/A	[ft]

$q_{ult} > \bar{\sigma_V}$ 1.0k

$CDR = \frac{q_{ult}}{\bar{\sigma_V}}$



SCALE:

0 2 4 6 8 10[ft]

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RKK RW9-37
BBT 1-2-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.369

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	29.00	2.066	N/A	1	---
2	2.00	29.00	2.197	N/A	1	---
3	4.00	29.00	2.346	N/A	1	---
4	6.00	29.00	2.517	N/A	1	---
5	8.00	29.00	2.714	N/A	1	---
6	10.00	29.00	2.951	N/A	1	---
7	12.00	29.00	3.233	N/A	1	---
8	14.00	29.00	3.564	N/A	1	---
9	16.00	29.00	3.972	N/A	1	---
10	18.00	29.00	4.485	N/A	1	---
11	20.00	29.00	5.150	N/A	1	---
12	22.00	29.00	6.047	N/A	1	---
13	24.00	29.00	7.322	N/A	1	---
14	26.00	29.00	9.277	N/A	1	---
15	28.00	29.00	12.659	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1157; Overturning: CDR-static = 4.32

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	29.00	0.1157	N/A	1	---
2	2.00	29.00	0.1017	N/A	1	---
3	4.00	29.00	0.0885	N/A	1	---
4	6.00	29.00	0.0763	N/A	1	---
5	8.00	29.00	0.0650	N/A	1	---
6	10.00	29.00	0.0546	N/A	1	---
7	12.00	29.00	0.0450	N/A	1	---
8	14.00	29.00	0.0364	N/A	1	---
9	16.00	29.00	0.0286	N/A	1	---
10	18.00	29.00	0.0218	N/A	1	---
11	20.00	29.00	0.0158	N/A	1	---
12	22.00	29.00	0.0107	N/A	1	---
13	24.00	29.00	0.0065	N/A	1	---
14	26.00	29.00	0.0033	N/A	1	---
15	28.00	29.00	0.0009	N/A	1	---

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RKK RW9-38

SBT 1-2-09

EMC 1/20/09

AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1252+00

Description:

Retaining Wall 9 UNDRAINED Analysis H = 29' L/H = 1.0

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....00 UNDRAINED L=H.BEN
Original date and time of creating this file: Mon Oct 20 13:34:41 2008

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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RKK RW9-39
1-8-09

SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}	Select
Design value of internal angle of friction, ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ	130.0 lb/ft ^{3}	Common Borrow Type F
Design value of internal angle of friction, ϕ	28.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	85.0 lb/ft ^{3}	← ADJUSTED FOR GWL
Equivalent internal angle of friction, $\phi_{equiv.}$	0.0 °	
Equivalent cohesion, $c_{equiv.}$	2500.0 lb/ft ^{2}	

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3610 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 5.14 N γ= 0.00

SEISMICITY

Not Applicable

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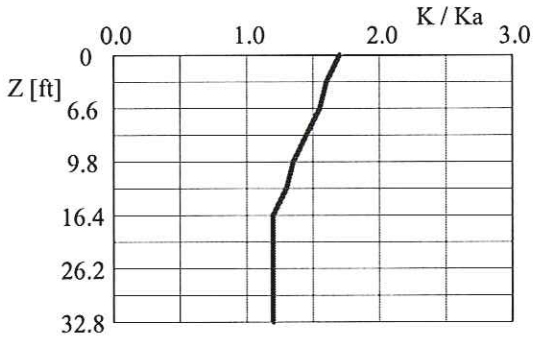
RKK RW9-40
JBT 1-2-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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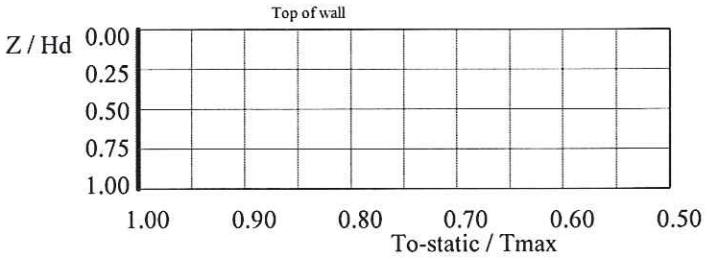
RKK RW9-41
8891
1-2-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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RKK RW9-42
JHT 1-2-09

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

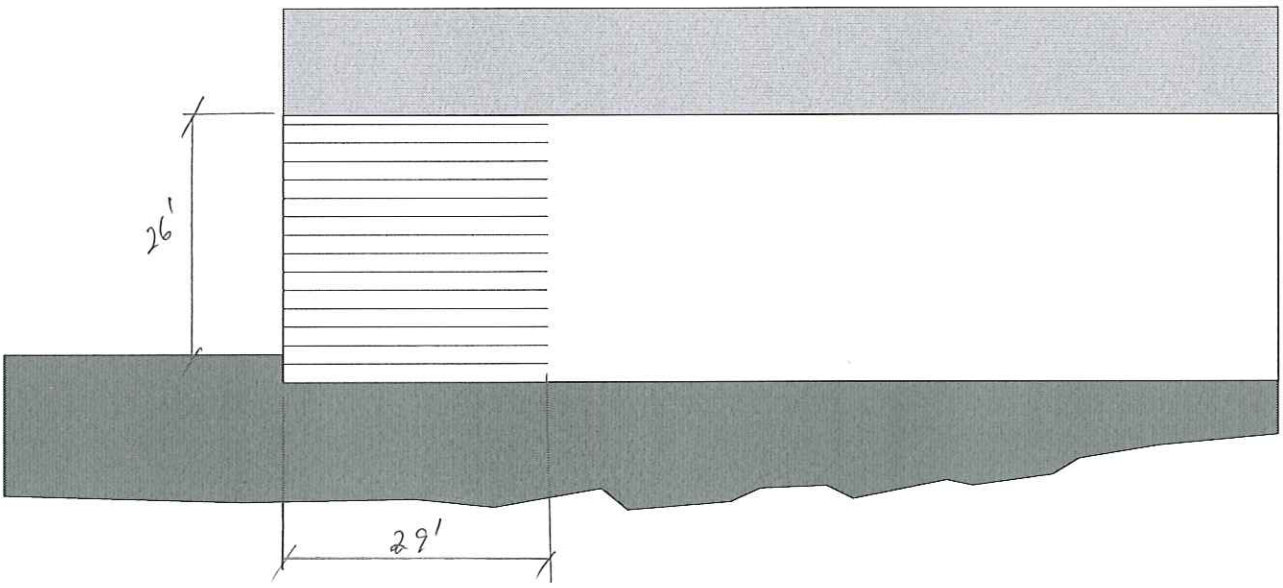
EM 1/20/09

Design height, Hd	29.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 26.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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RKK-RW9-43 JBT 1-2-09

AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00	
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00	

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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RKK RW9-44 12-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 1.32, Meyerhof stress = 6326 lb/ft².

Foundation Interface: Direct sliding, CDR = 2.074, Eccentricity, e/L = 0.1157, CDR-overturning = 4.32

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	29.00	1	N/A	1.92	2.13	2.131	3.626	2.066	0.1157	---
2	2.00	29.00	1	N/A	1.01	1.12	1.120	1.700	2.197	0.1017	---
3	4.00	29.00	1	N/A	1.08	1.20	1.201	1.616	2.346	0.0885	---
4	6.00	29.00	1	N/A	1.17	1.29	1.295	1.530	2.517	0.0763	---
5	8.00	29.00	1	N/A	1.26	1.40	1.404	1.444	2.714	0.0650	---
6	10.00	29.00	1	N/A	1.35	1.50	1.504	1.417	2.951	0.0546	---
7	12.00	29.00	1	N/A	1.43	1.59	1.589	1.498	3.233	0.0450	---
8	14.00	29.00	1	N/A	1.54	1.71	1.711	1.551	3.564	0.0364	---
9	16.00	29.00	1	N/A	1.69	1.88	1.876	1.644	3.972	0.0286	---
10	18.00	29.00	1	N/A	1.86	2.07	2.071	1.714	4.485	0.0218	---
11	20.00	29.00	1	N/A	2.10	2.33	2.328	1.742	5.150	0.0158	---
12	22.00	29.00	1	N/A	2.44	2.71	2.710	1.726	6.047	0.0107	---
13	24.00	29.00	1	N/A	3.00	3.33	3.331	1.647	7.322	0.0065	---
14	26.00	29.00	1	N/A	3.97	4.42	4.417	1.415	9.277	0.0033	---
15	28.00	29.00	1	N/A	6.00	6.66	6.662	0.764	12.659	0.0009	---

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RKK RW9-45

JLT 1-2-09

EMT 1/26/09

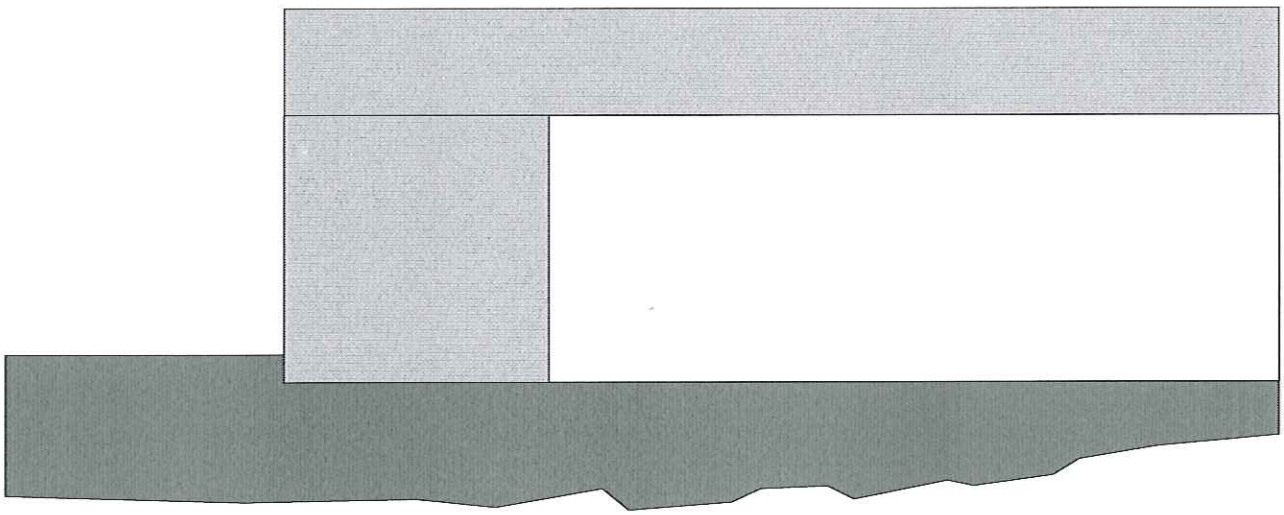
BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Ultimate bearing capacity, q-ult	8355	N/A	[lb/ft ²]
Meyerhof stress, σ_V	6326.2	N/A	[lb/ft ²]
Eccentricity, e	2.28	N/A	[ft]
Eccentricity, e/L	0.079	N/A	
CDR calculated	1.32	N/A	
Base length	29.00	N/A	[ft]

$q_{ult} > \sigma_V$ ∴ ok

$CDR = \frac{q_{ult}}{\sigma_V}$ ∴ ok

* Drained Analysis Governs *



SCALE:

0 2 4 6 8 10[ft]

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DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 2.074

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	29.00	2.066	N/A	1	---
2	2.00	29.00	2.197	N/A	1	---
3	4.00	29.00	2.346	N/A	1	---
4	6.00	29.00	2.517	N/A	1	---
5	8.00	29.00	2.714	N/A	1	---
6	10.00	29.00	2.951	N/A	1	---
7	12.00	29.00	3.233	N/A	1	---
8	14.00	29.00	3.564	N/A	1	---
9	16.00	29.00	3.972	N/A	1	---
10	18.00	29.00	4.485	N/A	1	---
11	20.00	29.00	5.150	N/A	1	---
12	22.00	29.00	6.047	N/A	1	---
13	24.00	29.00	7.322	N/A	1	---
14	26.00	29.00	9.277	N/A	1	---
15	28.00	29.00	12.659	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1157; Overturning: CDR-static = 4.32

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	29.00	0.1157	N/A	1	---
2	2.00	29.00	0.1017	N/A	1	---
3	4.00	29.00	0.0885	N/A	1	---
4	6.00	29.00	0.0763	N/A	1	---
5	8.00	29.00	0.0650	N/A	1	---
6	10.00	29.00	0.0546	N/A	1	---
7	12.00	29.00	0.0450	N/A	1	---
8	14.00	29.00	0.0364	N/A	1	---
9	16.00	29.00	0.0286	N/A	1	---
10	18.00	29.00	0.0218	N/A	1	---
11	20.00	29.00	0.0158	N/A	1	---
12	22.00	29.00	0.0107	N/A	1	---
13	24.00	29.00	0.0065	N/A	1	---
14	26.00	29.00	0.0033	N/A	1	---
15	28.00	29.00	0.0009	N/A	1	---

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AASHTO 2007 (LRFD)
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: 1252+00

RKK EMK 11/22/09

Description:

Retaining Wall 9 DRAINED Analysis H = 29' L/H = 0.8

No Good!!
γ_R = 4,564 psf
σ_v = 7,068 psf
CDR = 0.65 X

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St
Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN.....
.....0 DRAINED L=pt8H.BEN
Original date and time of creating this file: Mon Oct 20 13:34:41 2008

PROGRAM MODE:

ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

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SOIL DATA

REINFORCED SOIL

Unit weight, γ	125.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	130.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ	28.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	85.0 lb/ft ^{3}
Equivalent internal angle of friction, $\phi_{equiv.}$	24.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ^{2}

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3610 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 19.32 N γ= 9.44

SEISMICITY

Not Applicable

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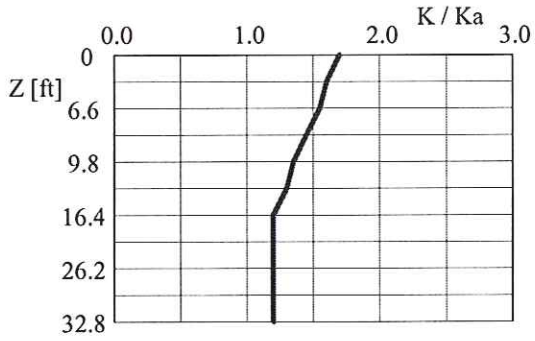
INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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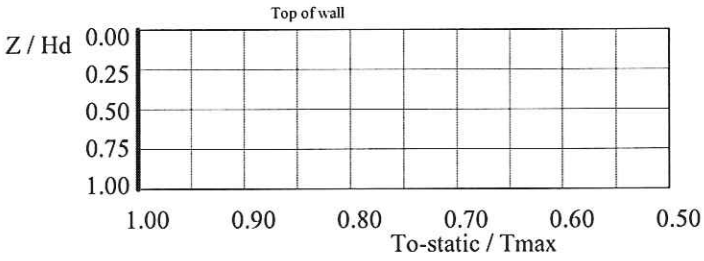
INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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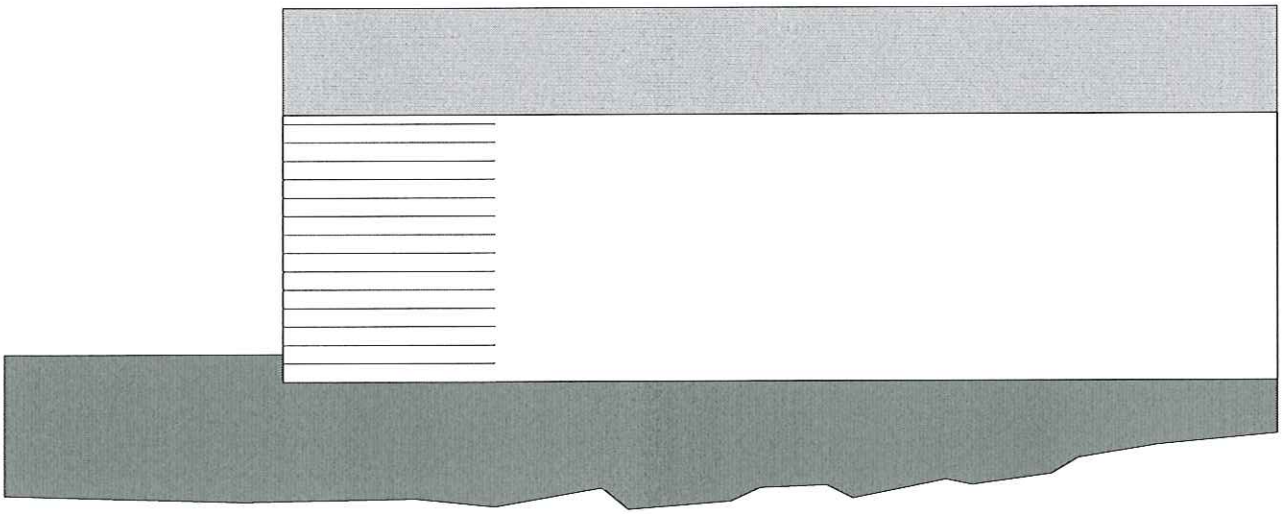
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	29.00	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 26.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

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AASHTO 2007 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75		1.00
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic	
Metal Strips:		0.75	1.00	
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20	

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic	
Reinforced Soil and Foundation	ϕ_τ	1.00		1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00		1.00

Resistance factor for bearing capacity of shallow foundation from Table 10.5.5.2.2-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

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RKK RW9-53

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 0.65, Meyerhof stress = 7068 lb/ft².

Foundation Interface: Direct sliding, CDR = 1.095, Eccentricity, e/L = 0.1807, CDR-overturning = 2.77

	METAL STRIP			CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	CDR [pullout resistance]	CDR [connection break]	CDR [metal strip strength]	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.00	23.20	1	N/A	1.92	2.13	2.131	2.902	1.653	0.1807	---
2	2.00	23.20	1	N/A	1.01	1.12	1.120	1.346	1.758	0.1588	---
3	4.00	23.20	1	N/A	1.08	1.20	1.201	1.264	1.877	0.1383	---
4	6.00	23.20	1	N/A	1.17	1.29	1.295	1.181	2.014	0.1193	---
5	8.00	23.20	1	N/A	1.26	1.40	1.404	1.098	2.172	0.1016	---
6	10.00	23.20	1	N/A	1.35	1.50	1.504	1.059	2.361	0.0853	---
7	12.00	23.20	1	N/A	1.43	1.59	1.589	1.099	2.586	0.0704	---
8	14.00	23.20	1	N/A	1.54	1.71	1.711	1.114	2.852	0.0568	---
9	16.00	23.20	1	N/A	1.69	1.88	1.876	1.175	3.178	0.0447	---
10	18.00	23.20	1	N/A	1.86	2.07	2.071	1.225	3.588	0.0340	---
11	20.00	23.20	1	N/A	2.10	2.33	2.328	1.245	4.120	0.0247	---
12	22.00	23.20	1	N/A	2.44	2.71	2.710	1.234	4.837	0.0168	---
13	24.00	23.20	1	N/A	3.00	3.33	3.331	1.177	5.857	0.0102	---
14	26.00	23.20	1	N/A	3.97	4.42	4.417	1.011	7.422	0.0051	---
15	28.00	23.20	1	N/A	6.00	6.66	6.662	0.546	10.127	0.0013	---

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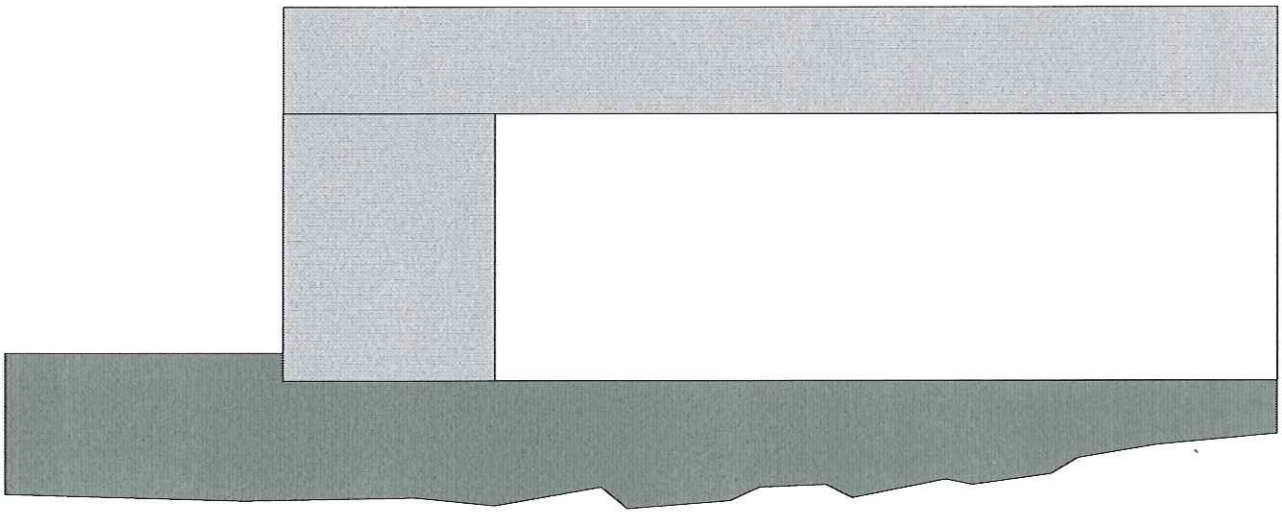
RKK RW9-54

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Ultimate bearing capacity, q-ult	4564	N/A	[lb/ft ²]
Meyerhof stress, σ_V	7068.3	N/A	[lb/ft ²]
Eccentricity, e	2.85	N/A	[ft]
Eccentricity, e/L	0.123	N/A	
CDR calculated	0.65	N/A	
Base length	23.20	N/A	[ft]



SCALE:

0 2 4 6 8 10[ft]

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RKK RW9-55

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.095

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	0.00	23.20	1.653	N/A	1	---
2	2.00	23.20	1.758	N/A	1	---
3	4.00	23.20	1.877	N/A	1	---
4	6.00	23.20	2.014	N/A	1	---
5	8.00	23.20	2.172	N/A	1	---
6	10.00	23.20	2.361	N/A	1	---
7	12.00	23.20	2.586	N/A	1	---
8	14.00	23.20	2.852	N/A	1	---
9	16.00	23.20	3.178	N/A	1	---
10	18.00	23.20	3.588	N/A	1	---
11	20.00	23.20	4.120	N/A	1	---
12	22.00	23.20	4.837	N/A	1	---
13	24.00	23.20	5.857	N/A	1	---
14	26.00	23.20	7.422	N/A	1	---
15	28.00	23.20	10.127	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1807; Overturning: CDR-static = 2.77

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	23.20	0.1807	N/A	1	---
2	2.00	23.20	0.1588	N/A	1	---
3	4.00	23.20	0.1383	N/A	1	---
4	6.00	23.20	0.1193	N/A	1	---
5	8.00	23.20	0.1016	N/A	1	---
6	10.00	23.20	0.0853	N/A	1	---
7	12.00	23.20	0.0704	N/A	1	---
8	14.00	23.20	0.0568	N/A	1	---
9	16.00	23.20	0.0447	N/A	1	---
10	18.00	23.20	0.0340	N/A	1	---
11	20.00	23.20	0.0247	N/A	1	---
12	22.00	23.20	0.0168	N/A	1	---
13	24.00	23.20	0.0102	N/A	1	---
14	26.00	23.20	0.0051	N/A	1	---
15	28.00	23.20	0.0013	N/A	1	---

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RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject SR1/I-95 Interchange — RW9 Global Stability Analysis
Page 1 of 56
Cm. No. 103-059-270
Prepared By SAB Date 12/17/08 Checked By JDT Date 1-2-09
EMK 1/20/09

Global Stability Analysis: Performed using Slope/W & GSTABL7 w/ STEDwin

⇒ STA 1251+00 chosen for global stability analysis – Tallest wall section & least distance between back-to-back wall faces (results in narrowest footprint/footing for wall/embankment). STA 1252+00 need not be evaluated since the wall height is shorter & the reinforcement straps are longer. Thus, global stability will be adequate if STA 1251+00 is stable.
→ See cross-sections, p. 2.

Soils: → See Fence Diagram, p. 3

Soil	γ_t (pcf)	DRAINED ϕ' (deg)	DRAINED c' (psf)	UNDRAINED S_u (psf)	EL (ft)
Reinforced Soil (Select Fill)	125	34	0	–	
Common Borrow	130	28	0	–	
Stratum IIa	130	24	0	2,500 (1)	63-45
Stratum IIb	130	34	0	–	45-30
Stratum IIa	130	24	0	2,500	30...
Water	62.4				54

⇒ (1) Undrained shear strength from 1DMT-16 - minimum value used.

⇒ Check using Drained & Undrained Soil Parameters.

→ Morgenstern-Price Method used for analysis, → Per AASHTO LRFD 11.6.2.3, $\phi = 0.65$

See attached: Slope/W reports: RW9 DRAINED Analysis – p. 4–29
UNDRAINED Analysis – p. 30–54
GSTABL7 : RW9 DRAINED Analysis – p. 55
UNDRAINED Analysis – p. 56

SUMMARY:	DRAINED FS	UNDRAINED FS	$FS = \frac{1.0}{\phi}$, $\phi = 0.65$ – Required	
Slope/W	6.64	16.96	1.538	✓ OK for both cases
GSTABL	2.30	3.61	1.538	✓ OK for both cases

*Wall manufacturer to check internal stability.

SR1/I-95 Interchange 103-059-27U 12/17/08

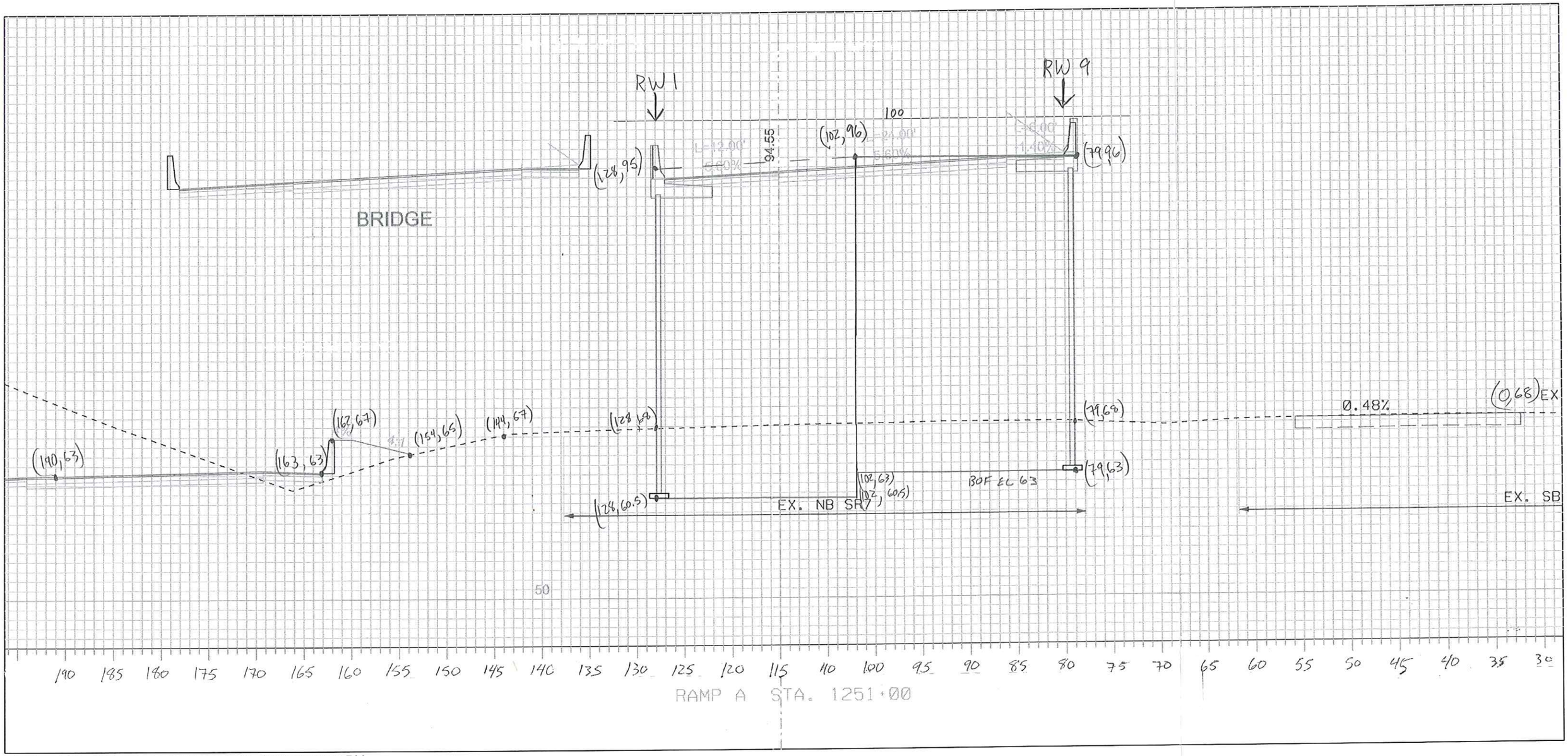
RW 9 Analysis

2

SJT 1-2-09

RKK RW9-57

EMC 1/21/09



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SR1/I-95 Interchange
RW9

103-059-27U
12/17/08

3

SDT 1-2-09

RKK RW9-58

IRW-46
Ramp A STA 1258+60
EL 59.0

IDMT-08 ~~N611458, E432306.1~~
STA 1256+55
EL 60.0

IRW-24
Ramp A STA 1257+60
EL 61.0

IRW-22
Ramp A STA 1256+60
EL 62.0

IRW-60
Ramp A STA 1255+10
EL 64.0

IRW-61
Ramp A STA 1253+60
EL 65.0

IRW-62
Ramp A STA 1252+10
EL 67.0

IDMT-16 ~~N611920, E432294~~
STA 1251+85
EL 68.0

IRW-63
Ramp A STA 1250+90
EL 68.0

SPT N or REC, RQD | S_u/Phi | Ko/OCR | NMC | AASHTO

Bottom of Footing at EL 55

Bottom of Footing at EL 56

Bottom of Footing at EL 57

Bottom of Footing at EL 59

Bottom of Footing at EL 61

Bottom of Footing at EL 62

Bottom of Footing at EL 63

U-1

U-2

IIa

IIb

~EL45

EL30

IIa

14.3% (A-6)
20.4% (A-7-5)
15.7% (A-2-4)
17.7% (A-4)
50.0'
42.0'

23.8% (A-6)
21.7% (A-7-5)
17.1% (A-6)
50.0'

7.7%
19.3% (A-6)
12.6% (A-4)
27.9% (A-2-4)
50.0'

17.4% (A-7-5)
18.4% (A-7-5)
14.7% (A-4)
16.1% (A-4)
50.0'

25.5% (A-6)
13.9% (A-6)
15.8% (A-4)
50.0'

50.0'

49.9'

16.2% (A-4)
19.1% (A-6)
18.4% (A-7-5)
50.0'

AASHTO SOIL KEY

A	A-1-a	A-2-5	A-5	A-8	
B	A-1-b	A-2-6	A-6	Asphalt	
	A-3	A-2-7	A-7-5	FILL	
	A-2-4	A-4	A-7-6	Decomposed Rock	

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

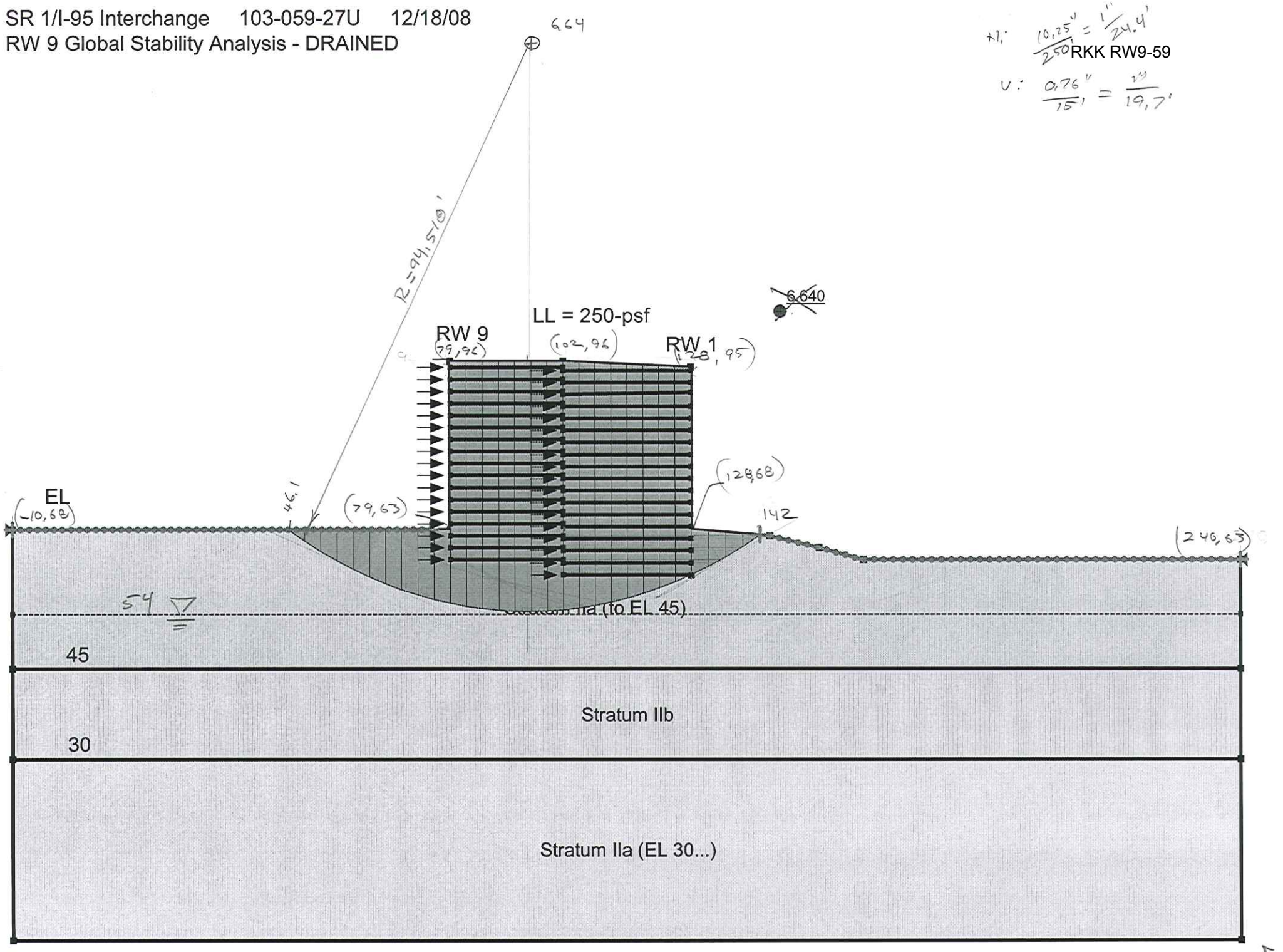
Title: Summary of Boring Data
Retaining Wall 9

Figure No. A-4g

Drawn: TAS | Approved: EMK | Date: 9/24/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 9/24/08

SR 1/I-95 Interchange 103-059-27U 12/18/08
RW 9 Global Stability Analysis - DRAINED



+1: 10,25" / 250' = 1" / 24.4'

RKK RW9-59

V: 0,76" / 15' = 1" / 19,7'

SR 1/I-95 Interchange 103-059-27U Retaining Wall 9

Report generated using GeoStudio 2007, version 7.11. Copyright © 1991-2008 GEO-SLOPE International Ltd.

File Information

Created By: sberkheimer
Revision Number: 40
Last Edited By: sberkheimer
EWL 1/22/09
Date: 1/21/2009
Time: 9:12:15 AM
File Name: STA 1251+00 DRAINED.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 9\Final Design\STA 1251+00\
Last Solved Date: 1/21/2009
Last Solved Time: 9:12:56 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SR 1/I-95 Interchange 103-059-27U Retaining Wall 9

Description: STA 1251+00 DRAINED Analysis
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- **Apply Phreatic Correction:** Yes
- **Side Function**
  - **Interslice force function option:** Half-Sine
- **PWP Conditions Source:** Piezometric Line
- **Use Staged Rapid Drawdown:** No

SlipSurface
- **Direction of movement:** Left to Right
- **Allow Passive Mode:** No

Slip Surface Option: Entry and Exit
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 32
Ending Optimization Points: 64
Complete Passes per Insertion: 1

Materials

Select FILL

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Stratum IIa (to EL 45)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 24 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Stratum IIb

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Stratum IIa (EL 30...)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 24 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (-10, 68) ft
Left-Zone Right Coordinate: (75, 68) ft
Left-Zone Increment: 50
Right Projection: Range
Right-Zone Left Coordinate: (142, 67.125) ft
Right-Zone Right Coordinate: (240, 63) ft
Right-Zone Increment: 50
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (-10, 68) ft
Right Coordinate: (240, 63) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-10	54
	240	54

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	79	96
	102	96
	128	95

Reinforcements ⇒ Fabric used to model steel strips (not an option in Slope/w)

Reinforcement 1 ⇒ 1-17 = RW9, 18-35 = RW1

Type: Fabric
Outside Point: (79, 63) ft
Inside Point: (102, 63) ft
Slip Surface Intersection: (133.94, 63) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 ° ← AASHTO LRFD Table 3.11.5.3-1 for Steel on Silty SAND (typ.)
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 24.317 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (79, 65) ft
Inside Point: (102, 65) ft
Slip Surface Intersection: (138.09, 65) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °

Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 15.21 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (79, 67) ft
Inside Point: (102, 67) ft
Slip Surface Intersection: (141.77, 67) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 5.2214 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (79, 69) ft
Inside Point: (102, 69) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (79, 71) ft
Inside Point: (102, 71) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (79, 73) ft
Inside Point: (102, 73) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °

Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (79, 75) ft
Inside Point: (102, 75) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (79, 77) ft
Inside Point: (102, 77) ft
Slip Surface Intersection: (0, 0) ft

Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (79, 79) ft
Inside Point: (102, 79) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (79, 81) ft

Inside Point: (102, 81) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (79, 83) ft
Inside Point: (102, 83) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 12

Type: Fabric
Outside Point: (79, 85) ft
Inside Point: (102, 85) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 13

Type: Fabric
Outside Point: (79, 87) ft
Inside Point: (102, 87) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft

Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 14

Type: Fabric
Outside Point: (79, 89) ft
Inside Point: (102, 89) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 15

Type: Fabric
Outside Point: (79, 91) ft
Inside Point: (102, 91) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 16

Type: Fabric
Outside Point: (79, 93) ft
Inside Point: (102, 93) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 17

Type: Fabric
Outside Point: (79, 95) ft
Inside Point: (102, 95) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0

Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 18

Type: Fabric
Outside Point: (102, 60.5) ft
Inside Point: (128, 60.5) ft
Slip Surface Intersection: (127.95, 60.5) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0.13753 lbs
Resisting Force Used: 2.8034 lbs/ft
Available Bond Length: 0.049059 ft
Required Bond Length: 0.049059 ft
Governing Component: Bond

Reinforcement 19

Type: Fabric
Outside Point: (102, 62.5) ft
Inside Point: (128, 62.5) ft
Slip Surface Intersection: (132.82, 62.5) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs

Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 24.317 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 20

Type: Fabric
Outside Point: (102, 64.5) ft
Inside Point: (128, 64.5) ft
Slip Surface Intersection: (137.08, 64.5) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 15.21 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 21

Type: Fabric
Outside Point: (102, 66.5) ft
Inside Point: (128, 66.5) ft
Slip Surface Intersection: (140.86, 66.5) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs

Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 5.2214 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 22

Type: Fabric
Outside Point: (102, 68.5) ft
Inside Point: (128, 68.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 23

Type: Fabric
Outside Point: (102, 70.5) ft
Inside Point: (128, 70.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1

Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 24

Type: Fabric
Outside Point: (102, 72.5) ft
Inside Point: (128, 72.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 25

Type: Fabric
Outside Point: (102, 74.5) ft
Inside Point: (128, 74.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf

Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 26

Type: Fabric
Outside Point: (102, 76.5) ft
Inside Point: (128, 76.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 27

Type: Fabric
Outside Point: (102, 78.5) ft
Inside Point: (128, 78.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable

F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 28

Type: Fabric
Outside Point: (102, 80.5) ft
Inside Point: (128, 80.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 29

Type: Fabric
Outside Point: (102, 82.5) ft
Inside Point: (128, 82.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft

Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 30

Type: Fabric
Outside Point: (102, 84.5) ft
Inside Point: (128, 84.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 31

Type: Fabric
Outside Point: (102, 86.5) ft
Inside Point: (128, 86.5) ft

Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 32

Type: Fabric
Outside Point: (102, 88.5) ft
Inside Point: (128, 88.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 33

Type: Fabric

Outside Point: (102, 90.5) ft
Inside Point: (128, 90.8) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26.001731 ft
Reinforcement Direction: 180.66 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 34

Type: Fabric
Outside Point: (102, 92.5) ft
Inside Point: (128, 92.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 35

Type: Fabric
Outside Point: (102, 94.5) ft
Inside Point: (128, 94.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Regions

	Material	Points	Area (ft²)
Region 1	Stratum IIa (EL 30...)	19,17,18,20	7500
Region 2	Stratum IIb	17,15,16,18	3750
Region 3	Stratum IIa (to EL 45)	15,1,3,2,9,10,8,7,11,12,13,14,16	4991
Region 4	Select FILL	3,4,5,9,2	759
Region 5	Select FILL	5,6,7,8,10,9	910

Points

	X (ft)	Y (ft)
Point 1	-10	68
Point 2	79	63
Point 3	79	68
Point 4	79	96
Point 5	102	96

← Toe of Wall RW9

← Top of RW9

Wall Height = Point 4 - Point 2
= 96 - 63
H = 33'

Point 6	128	95
Point 7	128	68
Point 8	128	60.5
Point 9	102	63
Point 10	102	60.5
Point 11	144	67
Point 12	154	65
Point 13	163	63
Point 14	240	63
Point 15	-10	45
Point 16	240	45
Point 17	-10	30
Point 18	240	30
Point 19	-10	0
Point 20	240	0

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	8417	6.640	(94.793, 149.01)	94.518	(46.1, 68)	(142, 67.125)

Slices of Slip Surface: 8417

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	8417	47.745	67.055645	-814.66368	118.14139	52.599936	0
2	8417	51.035	65.251885	-702.11529	344.69976	153.47022	0
3	8417	54.325	63.612945	-599.85486	551.6775	245.62265	0
4	8417	57.615	62.12948	-507.26938	740.09968	329.51361	0
5	8417	60.905	60.79363	-423.93019	910.82144	405.52383	0
6	8417	64.195	59.59876	-349.3497	1064.6136	473.99651	0

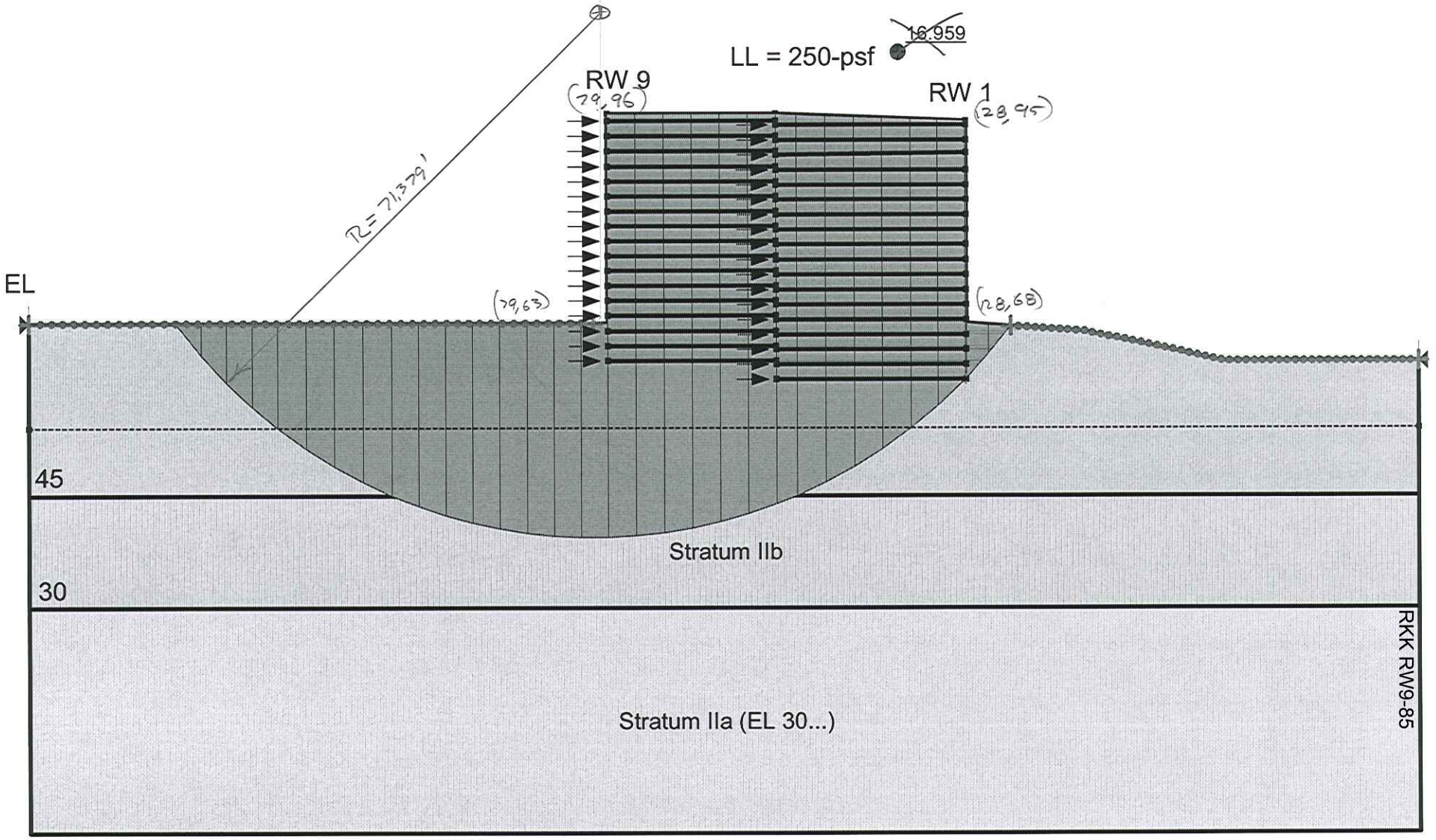
RKK RW9-83

7	8417	67.485	58.539275	-283.25015	1202.0279	535.17731	0
8	8417	70.775	57.610465	-225.29337	1323.6037	589.30633	0
9	8417	74.065	56.808375	-175.24313	1429.7555	636.56817	0
10	8417	77.355	56.129715	-132.89388	1520.7247	677.07025	0
11	8417	80.642855	55.572075	-98.095859	953.84599	424.67959	0
12	8417	83.92857	55.13315	-70.708918	1013.3191	451.15875	0
13	8417	87.214285	54.81084	-50.595647	1058.0552	471.0765	0
14	8417	90.5	54.60395	-37.688007	1088.1059	484.45596	0
15	8417	93.785715	54.51173	-31.933403	1103.3808	491.25677	0
16	8417	97.07143	54.533835	-33.310311	1103.8528	491.46695	0
17	8417	100.35715	54.670345	-41.829919	1089.3157	484.99462	0
18	8417	103.6221	54.91945	-57.373799	732.18727	325.99078	0
19	8417	106.8663	55.2806	-79.908089	686.88306	305.82004	0
20	8417	110.1105	55.755975	-109.57281	626.21723	278.80988	0
21	8417	113.3547	56.34734	-146.47355	549.83117	244.80061	0
22	8417	116.5989	57.056935	-190.75172	457.32425	203.61388	0
23	8417	119.8431	57.88752	-242.58157	348.24772	155.04987	0
24	8417	123.0873	58.84245	-302.16047	222.00001	98.840773	0
25	8417	126.3547	59.93442	-370.32199	77.994486	34.725383	0

RKK RW9-84

26	8417	129.75	61.21416	-450.17173	894.84871	398.41231	0
27	8417	133.25	62.690595	-542.30071	669.3482	298.01302	0
28	8417	136.75	64.33741	-645.06318	419.7506	186.88501	0
29	8417	140.25	66.164785	-759.07051	144.4824	64.327708	0

SR 1/I-95 Interchange 103-059-27U 12/18/08
RW 9 Global Stability Analysis - UNDRAINED



SR 1/I-95 Interchange 103-059-27U Retaining Wall 9

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File Information

Created By: sberkheimer
Revision Number: 20
Last Edited By: sberkheimer SMW 1/22/09
Date: 1/21/2009
Time: 9:26:49 AM
File Name: STA 1251+00 UNDRAINED rev.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 9\Final Design\STA 1251+00\
Last Solved Date: 1/21/2009
Last Solved Time: 9:27:44 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SR 1/I-95 Interchange 103-059-27U Retaining Wall 9

Description: STA 1251+00 UNDRAINED Analysis
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- **Apply Phreatic Correction:** Yes
- **Side Function**
  - **Interslice force function option:** Half-Sine
- **PWP Conditions Source:** Piezometric Line
- **Use Staged Rapid Drawdown:** No

SlipSurface
- **Direction of movement:** Left to Right
- **Allow Passive Mode:** No

Slip Surface Option: Entry and Exit
Critical slip surfaces saved: 1
Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 32
Ending Optimization Points: 64
Complete Passes per Insertion: 1

Materials

Special FILL (Select Fill)

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Stratum IIa (to EL 45)

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 2500 psf
Pore Water Pressure
Piezometric Line: 1

Stratum IIb

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Stratum IIa (EL 30...)

Model: Undrained (Phi=0)

Unit Weight: 130 pcf
Cohesion: 2500 psf
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0, 68) ft
Left-Zone Right Coordinate: (77, 68) ft
Left-Zone Increment: 50
Right Projection: Range
Right-Zone Left Coordinate: (134, 67.625) ft
Right-Zone Right Coordinate: (190, 63) ft
Right-Zone Increment: 50
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 68) ft
Right Coordinate: (190, 63) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	54
	190	54

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	79	96
	102	96

	128	95

Reinforcements → Fabric used to model steel straps (not an option in Slope/w)

Reinforcement 1 1-17 for RW9, 18-35 for RW1

Type: Fabric
Outside Point: (79, 63) ft
Inside Point: (102, 63) ft
Slip Surface Intersection: (130.13, 63) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 ° ← AASHTO LRFD Table 3.11.5.3-1 for Steel (strips) on Silty SAND (typ.)
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 10.685 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (79, 65) ft
Inside Point: (102, 65) ft
Slip Surface Intersection: (131.87, 65) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice

Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 3.7047 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (79, 67) ft
Inside Point: (102, 67) ft
Slip Surface Intersection: (133.49, 67) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 3.7047 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (79, 69) ft
Inside Point: (102, 69) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1

Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (79, 71) ft
Inside Point: (102, 71) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (79, 73) ft
Inside Point: (102, 73) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1

Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (79, 75) ft
Inside Point: (102, 75) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (79, 77) ft
Inside Point: (102, 77) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °

Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (79, 79) ft
Inside Point: (102, 79) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (79, 81) ft
Inside Point: (102, 81) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (79, 83) ft
Inside Point: (102, 83) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 12

Type: Fabric
Outside Point: (79, 85) ft
Inside Point: (102, 85) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °

Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 13

Type: Fabric
Outside Point: (79, 87) ft
Inside Point: (102, 87) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 14

Type: Fabric
Outside Point: (79, 89) ft
Inside Point: (102, 89) ft
Slip Surface Intersection: (0, 0) ft

Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 15

Type: Fabric
Outside Point: (79, 91) ft
Inside Point: (102, 91) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 16

Type: Fabric
Outside Point: (79, 93) ft

Inside Point: (102, 93) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 17

Type: Fabric
Outside Point: (79, 95) ft
Inside Point: (102, 95) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 23 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 18

Type: Fabric
Outside Point: (102, 60.5) ft
Inside Point: (128, 60.5) ft
Slip Surface Intersection: (127.81, 60.5) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0.64407 lbs
Resisting Force Used: 3.3222 lbs/ft
Available Bond Length: 0.19387 ft
Required Bond Length: 0.19387 ft
Governing Component: Bond

Reinforcement 19

Type: Fabric
Outside Point: (102, 62.5) ft
Inside Point: (128, 62.5) ft
Slip Surface Intersection: (129.67, 62.5) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 10.685 lbs/ft
Available Bond Length: 0 ft

Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 20

Type: Fabric
Outside Point: (102, 64.5) ft
Inside Point: (128, 64.5) ft
Slip Surface Intersection: (131.46, 64.5) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 3.7047 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 21

Type: Fabric
Outside Point: (102, 66.5) ft
Inside Point: (128, 66.5) ft
Slip Surface Intersection: (133.09, 66.5) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 3.7047 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 22

Type: Fabric
Outside Point: (102, 68.5) ft
Inside Point: (128, 68.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 23

Type: Fabric
Outside Point: (102, 70.5) ft
Inside Point: (128, 70.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0

Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 24

Type: Fabric
Outside Point: (102, 72.5) ft
Inside Point: (128, 72.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 25

Type: Fabric
Outside Point: (102, 74.5) ft
Inside Point: (128, 74.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs

Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 26

Type: Fabric
Outside Point: (102, 76.5) ft
Inside Point: (128, 76.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 27

Type: Fabric
Outside Point: (102, 78.5) ft
Inside Point: (128, 78.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs

Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 28

Type: Fabric
Outside Point: (102, 80.5) ft
Inside Point: (128, 80.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 29

Type: Fabric
Outside Point: (102, 82.5) ft
Inside Point: (128, 82.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1

Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 30

Type: Fabric
Outside Point: (102, 84.5) ft
Inside Point: (128, 84.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 31

Type: Fabric
Outside Point: (102, 86.5) ft
Inside Point: (128, 86.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf

Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 32

Type: Fabric
Outside Point: (102, 88.5) ft
Inside Point: (128, 88.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 33

Type: Fabric
Outside Point: (102, 90.5) ft
Inside Point: (128, 90.8) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26.001731 ft
Reinforcement Direction: 180.66 °
Applied Load Option: Variable

F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 34

Type: Fabric
Outside Point: (102, 92.5) ft
Inside Point: (128, 92.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 35

Type: Fabric
Outside Point: (102, 94.5) ft
Inside Point: (128, 94.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 26 ft

Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 6000 lbs
Fabric Safety Factor: 1
Fabric Load: 6000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 6000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Regions

	Material	Points	Area (ft²)
Region 1	Stratum IIa (EL 30...)	19,17,18,20	5700
Region 2	Stratum IIb	17,15,16,18	2850
Region 3	Stratum IIa (to EL 45)	15,1,3,2,9,10,8,7,11,12,13,14,16	3861
Region 4	Special FILL	3,4,5,9,2	759
Region 5	Special FILL	5,6,7,8,10,9	910

Points

	X (ft)	Y (ft)	
Point 1	0	68	
Point 2	79	EL 63	← Toe of RW 9
Point 3	79	68	
Point 4	79	EL 96	← Top of RW 9
Point 5	102	96	
Point 6	128	95	
Point 7	128	68	
Point 8	128	60.5	
Point 9	102	63	
Point 10	102	60.5	

Wall Height = Point 4 - Point 2
= EL 96 - EL 63
H = 33'

Point 11	144	67
Point 12	154	65
Point 13	163	63
Point 14	190	63
Point 15	0	45
Point 16	190	45
Point 17	0	30
Point 18	190	30
Point 19	0	0
Point 20	190	0

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	3318	16.959	(77.151, 110.79)	71.379	(20.02, 68)	(134, 67.625)

Slices of Slip Surface: 3318

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesiv Strengt (psf)
1	3318	21.75615	65.859465	-740.03053	96.498588	0	2500
2	3318	25.22845	61.87597	-491.4607	640.5755	0	2500
3	3318	28.70075	58.42658	-276.2181	1110.9603	0	2500
4	3318	32.17305	55.410075	-87.989441	1521.9983	0	2500
5	3318	35.853365	52.61973	86.127787	1902.1887	0	2500
6	3318	39.74169	50.0422	246.97306	2253.3718	0	2500
7	3318	43.630015	47.81014	386.23721	2557.4339	0	2500
8	3318	47.518345	45.88767	506.21729	2819.5447	0	2500
9	3318	51.3086	44.28266	606.36722	3058.2175	1653.7939	0
10	3318	55.000785	42.96243	688.73329	3234.2221	1716.9539	0
11	3318	58.692975	41.865145	757.21484	3380.6897	1769.5561	0
12	3318	62.38516	40.98026	812.42647	3499.5813	1812.5088	0
13	3318	66.077345	40.299745	854.88266	3591.1975	1845.6676	0
14	3318	69.769535	39.81771	884.96982	3656.9557	1869.7281	0
15	3318	73.46172	39.53011	902.91585	3697.1891	1884.7611	0

16	3318	77.153905	39.434585	908.89221	3712.4339	1891.0127	0
17	3318	80.916665	39.535935	902.54936	3051.3077	1449.3558	0
18	3318	84.75	39.8425	883.41711	3013.5475	1436.7911	0
19	3318	88.583335	40.35888	851.21625	2948.6273	1414.7216	0
20	3318	92.416665	41.08976	805.59218	2856.1279	1383.1038	0
21	3318	96.25	42.042005	746.18444	2735.1969	1341.6058	0
22	3318	100.08334	43.225	672.36282	2584.6617	1289.8619	0
23	3318	103.42015	44.437765	596.67203	2100.7425	1014.5084	0
24	3318	106.78445	45.88767	506.21729	1955.6439	0	2500
25	3318	110.67275	47.81014	386.23721	1717.9871	0	2500
26	3318	114.5611	50.0422	246.97306	1441.7638	0	2500
27	3318	118.44945	52.61973	86.127787	1122.5698	0	2500
28	3318	122.24675	55.511775	-94.335737	764.26958	0	2500
29	3318	125.953	58.761775	-297.13392	361.64184	0	2500
30	3318	127.90305	60.598015	-411.71324	-1.3746384	-0.92720529	0
31	3318	129.5	62.31594	-518.92504	883.68769	0	2500
32	3318	132.5	65.780425	-735.10268	432.72509	0	2500

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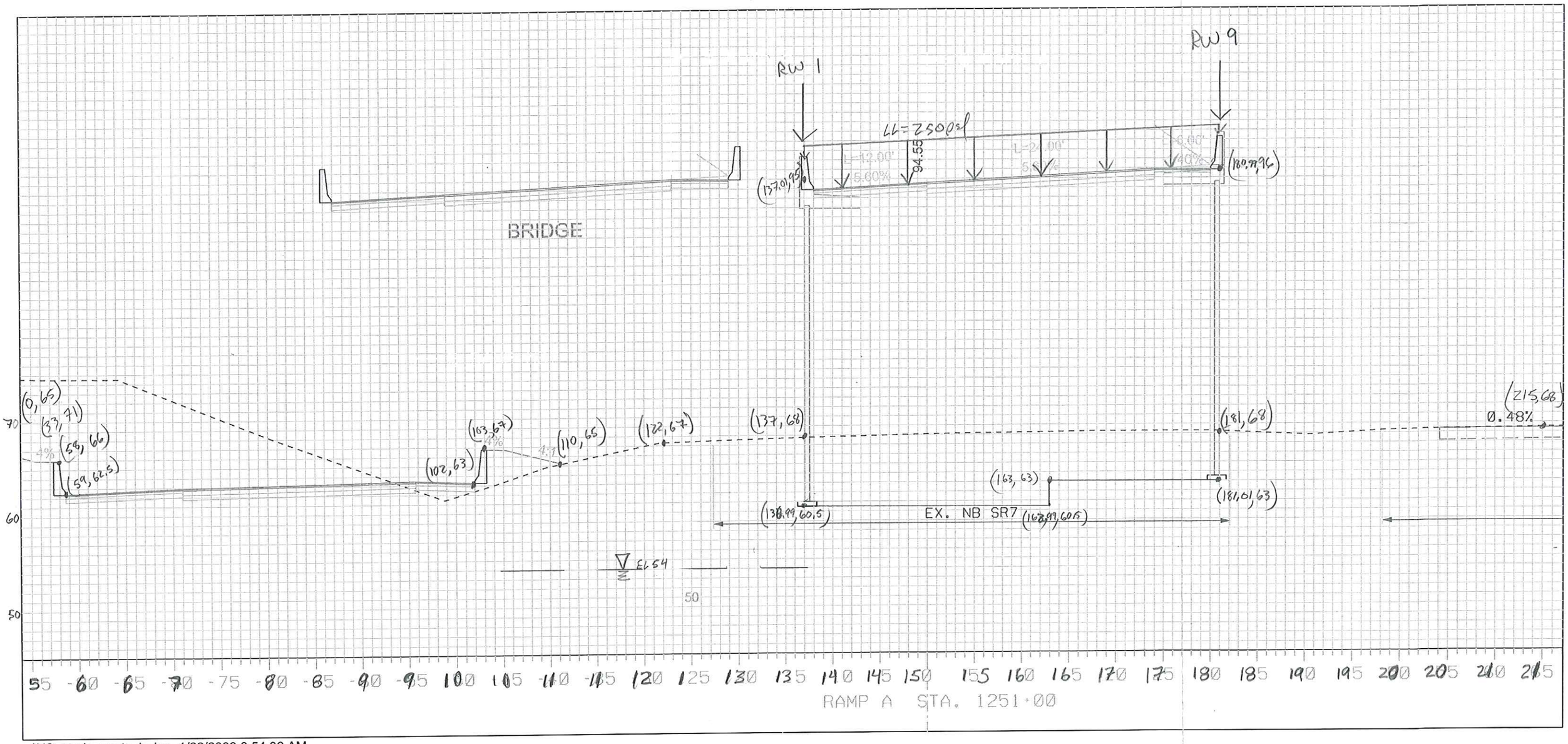
RW 9

RKK RW9-110



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SR1/I-95 Interchange 103-059-27U RW 9 STA 1251+00 DRAINED

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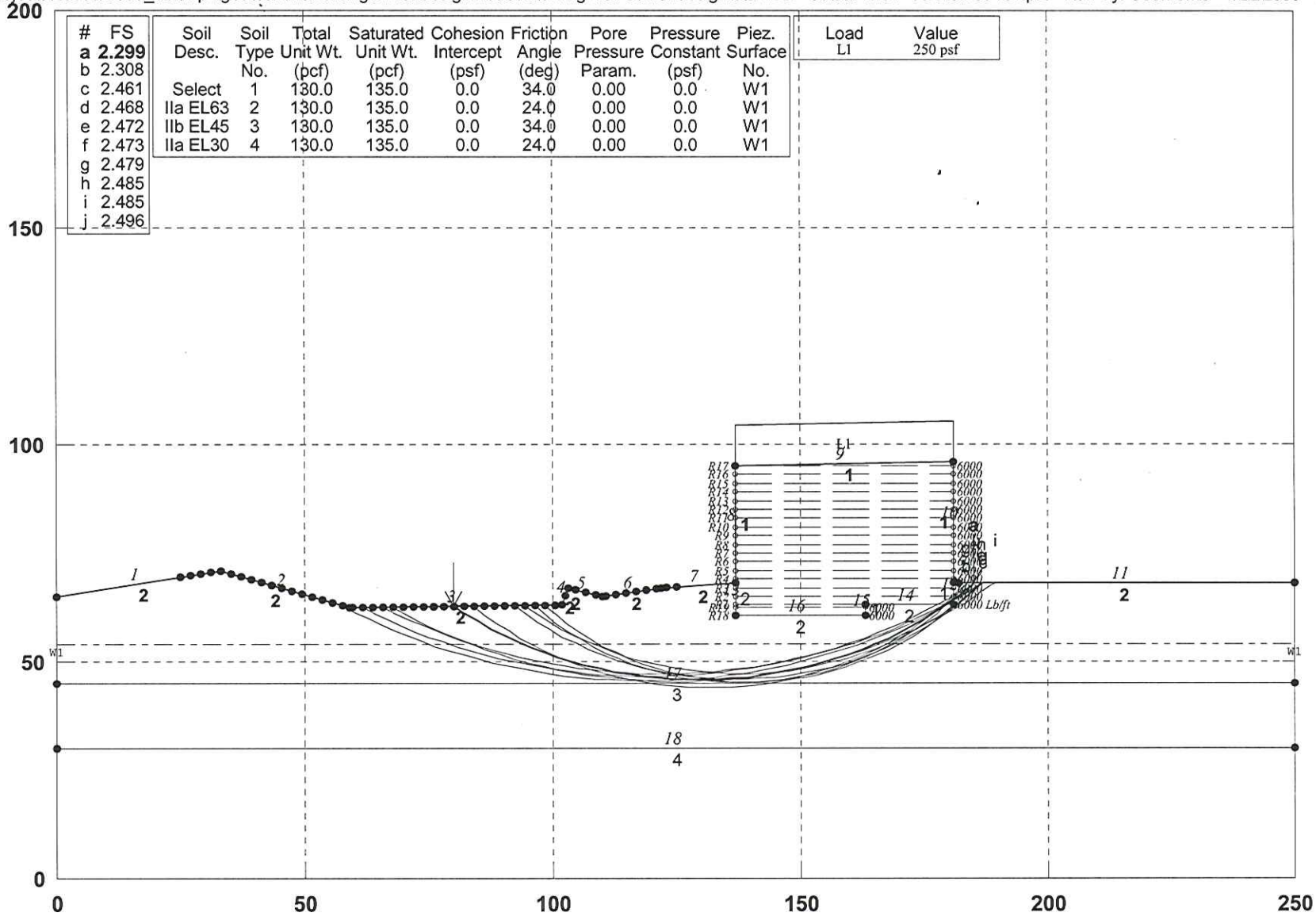

#	FS
a	2.299
b	2.308
c	2.461
d	2.468
e	2.472
f	2.473
g	2.479
h	2.485
i	2.485
j	2.496

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
Select	1	130.0	135.0	0.0	34.0	0.00	0.0	W1
IIa EL63	2	130.0	135.0	0.0	24.0	0.00	0.0	W1
IIb EL45	3	130.0	135.0	0.0	34.0	0.00	0.0	W1
IIa EL30	4	130.0	135.0	0.0	24.0	0.00	0.0	W1

Load	Value
L1	250 psf

GSTABL7 v.2 FSmin=2.299

Safety Factors Are Calculated By The Modified Bishop Method

GSTABL7

RKK RW9-111

11/24/09

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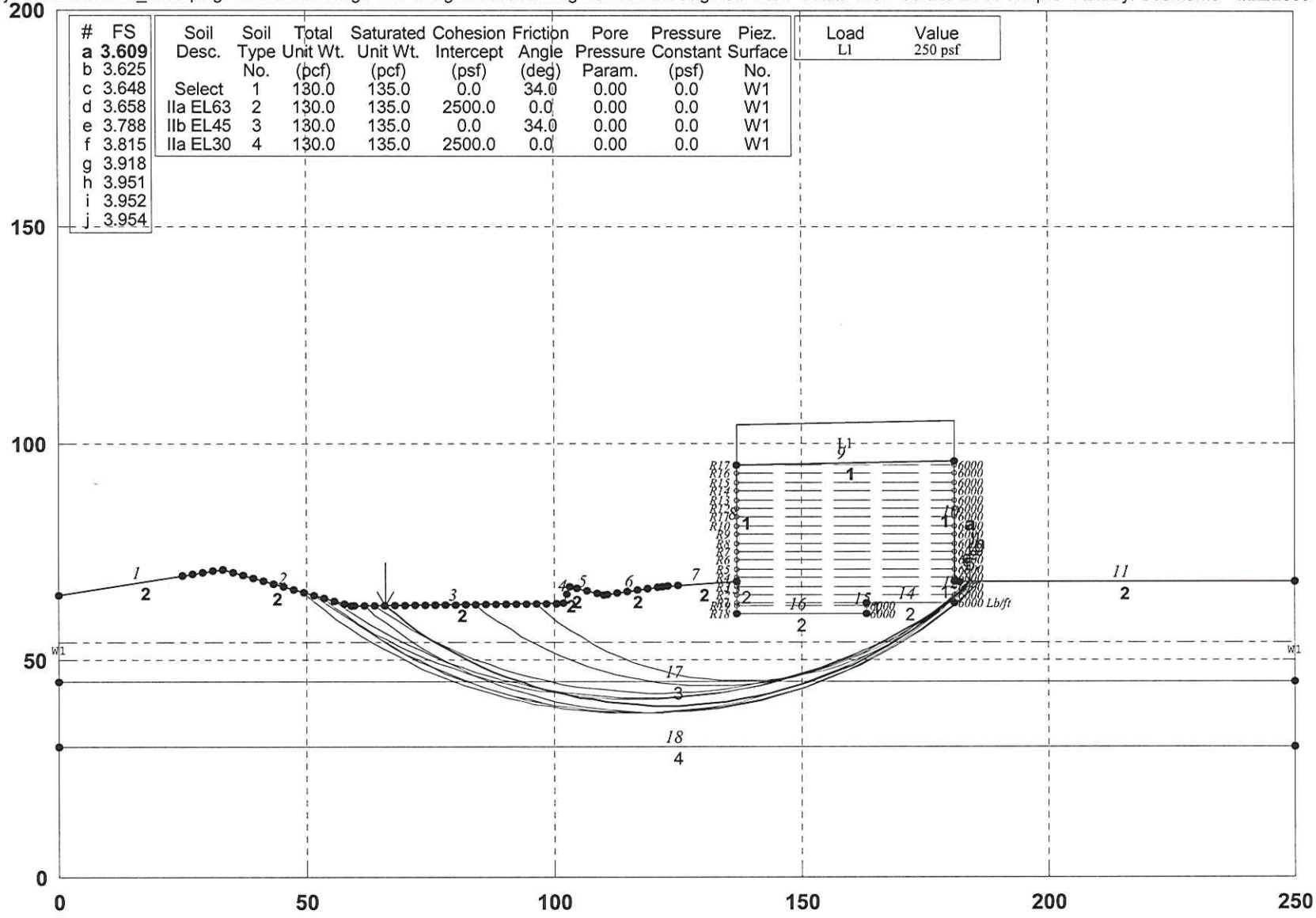
a	3.609
b	3.625
c	3.648
d	3.658
e	3.788
f	3.815
g	3.918
h	3.951
i	3.952
j	3.954

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
Select	1	130.0	135.0	0.0	34.0	0.00	0.0	W1
IIa EL63	2	130.0	135.0	2500.0	0.0	0.00	0.0	W1
IIb EL45	3	130.0	135.0	0.0	34.0	0.00	0.0	W1
IIa EL30	4	130.0	135.0	2500.0	0.0	0.00	0.0	W1

Load	Value
L1	250 psf



GSTABL7 v.2 FSmin=3.609

Safety Factors Are Calculated By The Modified Bishop Method

GSTABL7

RKK RW9-112

1/22/09

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Subject I-95/SR 1 Interchange — RW 9 Settlement Calculations
Page 1 of 19
Cm. No. 103059-27U
Prepared By SAB Date 9/26/08 REV 1/7/09 Checked By SMK Date 9-30-08 1-18-09 1/22/09

Objective: To estimate the settlement anticipated to occur during and following the construction of Retaining Wall 9.

Wall Details:

Retaining Wall 9 = 872'

Starts @ Ramp A STA 1250+92 and is back-to-back with Retaining Wall 4 to STA 1252+14.
→ This length = 122'
At ~ STA 1252+14 RW 4 terminates and the embankment widens. At this point, Retaining Wall 1 starts, and supports the far side of the embankment. Here, RW 9 is back-to-back with RW 1. [RW 1 is to be designed by URS]

⇒ From STA 1250+92 to 1252+14, the approximate distance b/t wall faces is 45'

→ From MSEW Analysis, using Service loads (see p. 26) Meyerhof Stress = 4,375 psf & B' = 22.5' (e=0') for RW 9

RW 1: (From URS) Meyerhof Stress = 4,710 psf → use B' = 22.5'

Abutment B of Ramp A Bridge S-2 adjoins RW 9 @ STA 1250+92. From URS, Bearing Stress = 5,140 psf, B = 26'

→ To estimate differential settlement model next 100' of wall (STA 1252+14 to ~1253+14). (RW 1 terminates & there is no back-to-back wall in ↑)

→ From MSEW, using Service Loads, Meyerhof Stress = 4,508 psf for RW 9

B = 29', e = 2.04 → B' = B - 2e = 24.9'

Total width = 107' → Embankment width = 107' - 24.9' = 82.1'

Avg. Embankment Height = 29' ⇒ σ_v = 130 pcf (29') = 3,770 psf

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Subject I-95/SR1 Interchange
RW9 Settlement

Page 2 of 23
Cm. No. 103-059-27U

Prepared By SAB Date 9/26/08 Checked By [illegible] Date 9-30-08
REV 1/7/09 [illegible] 1-28-09
[illegible] 1/22/09

Soils: (see attached fence diagram, p. 3)

→ Assume BOF EL = EL 63 → Water table @ ~ EL 54

Stratum	EL	γ_T (pcf)	Avg. N-value	μ	E (ksf)(3)*	C_c (1)	C_r (1)	c_v (1)	c_v (ft^2/day) (1)	OCR (1)	P_o (psf) (1)	P_o @ Bottom (ksf) (2)	S_u (ksf)
1. IIa	63-45	130	15	0.35	545	0.016	0.016	0.633	—	3.7	~8,000	1,778	2.5
2. IIb	45-30	130	17	0.3	1,364	—	—	—	—	2.7	~9,500	2,792	—
3. IIa	30-27	130	~20	0.4	1,364	0.016	0.016	0.654	—	~2	~9,500	6,646	2.5

*Assume no consolidation occurs at depths > 2B = 90' = EL -27

*(1) $C_c = C_r$ since $\Delta\sigma < P_o$. Use $C_r = 10\% C_c$.
Consolidation parameters from general site laboratory testing, see p. 4.

*(2): P_o: 1. 9'(130 pcf) + 9'(67.6 pcf) = 1,778 psf
2. 1,778 + 15'(67.6 pcf) = 2,792 psf
3. 2,792 + 57'(67.6 pcf) = 6,646 psf

$P_c - P_o$: 8,000 - 1,778 = 6,222
9,500 - 2,792 = 6,708
9,500 - 6,646 = 2,854

*(3): Young's Modulus, E: (Calculated using Table 5-5 & Table 2-7, attached, p. 5) → * IGNORE - use general site parameters. *

1. Table 5-5: Clay (I_p < 30) E_s = 500 to 1500 S_u = 500 to 1500 (1.5 ksf) = 750 to 2250 ksf
Table 2-7: Clay (medium) E_s = 300 to 1,000 ksf
→ So use E = 400 ksf

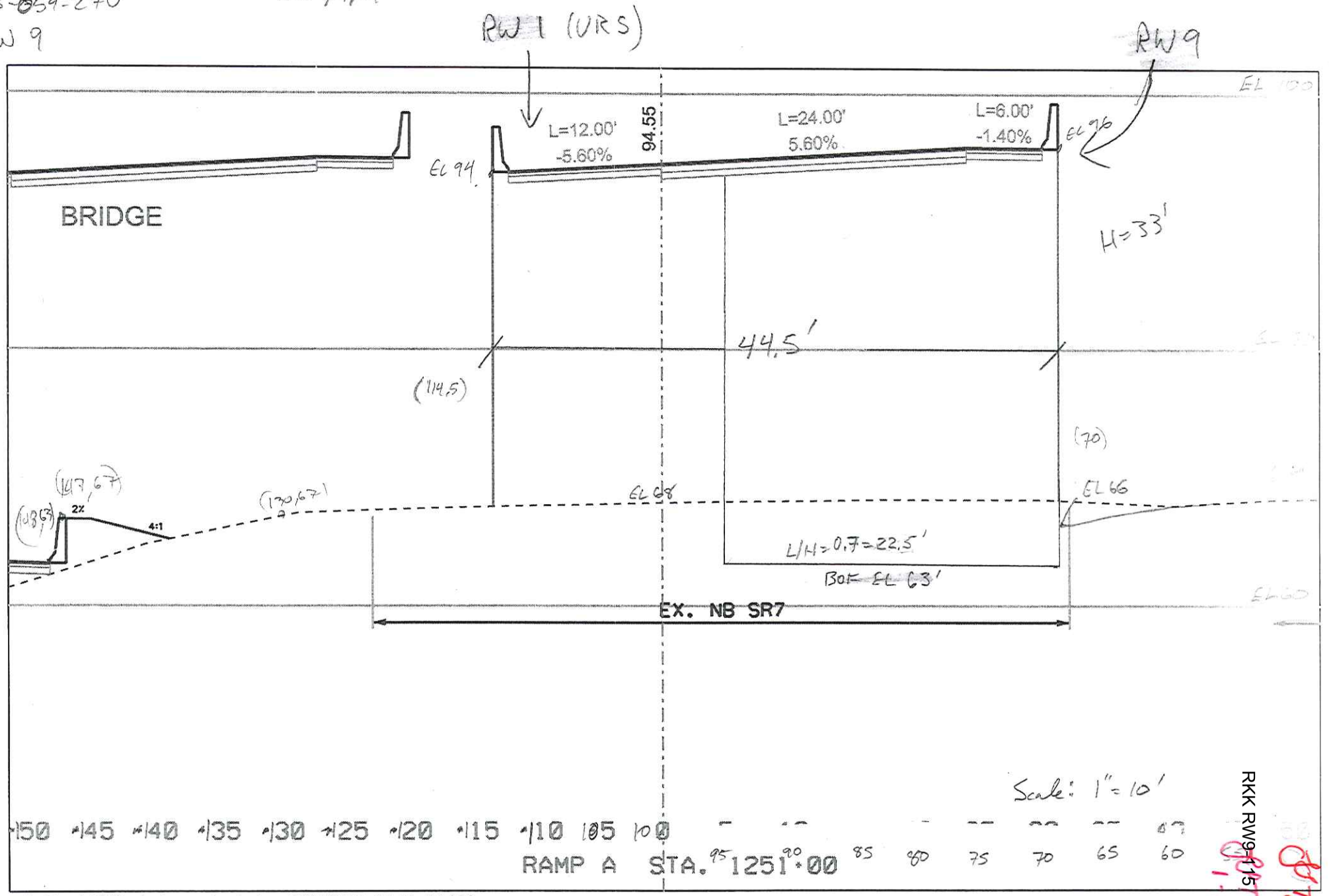
2. Table 5-5: Clay (I_p < 30) E_s = 500 to 1500 S_u = 500 to 1500 (2.5 ksf) = 1250 - 3750 ksf
Table 2-7: Clay (medium) E_s = 300 - 1000 ksf
→ So use E = 450 ksf

3. Table 5-5: Clay (I_p < 30) E_s = 500 to 1500 S_u = 500 to 1500 (3.5 ksf) = 1750 - 3250 ksf
Table 2-7: Clay (medium) E_s = 300 - 1000 ksf
→ So use E = 1,000 ksf

* E Values Checked w/ Ramp A, B, C, + G-1 embankment Settlement Plates.

I-95/SR1 Interchange
103-059-270
RW 9

9/26/08
REV 1/7/09



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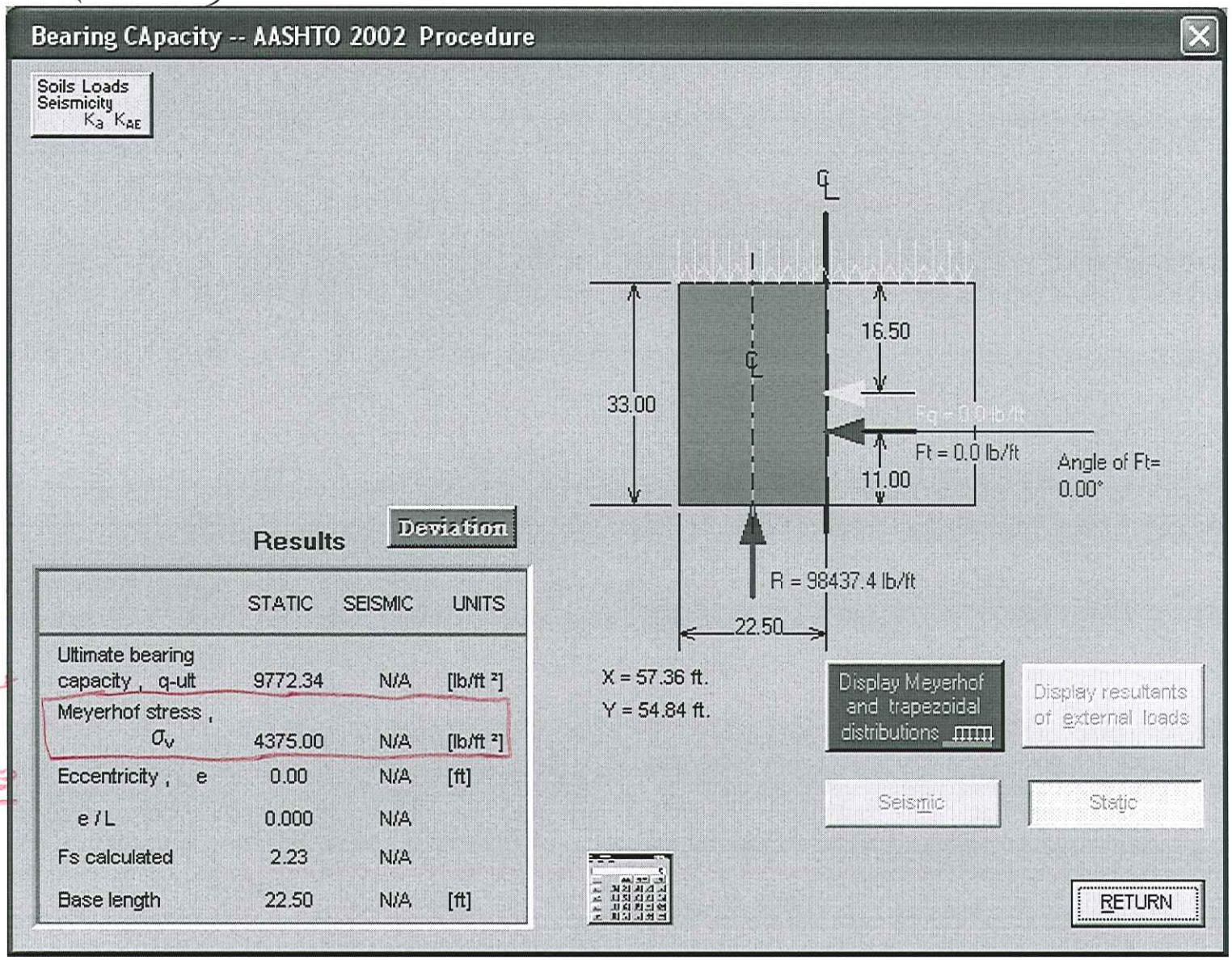
RKK RW9-115

9-30-08
1-18-09

29

SR 1/I-95 Interchange 103-059-27U
RW 9 - Meyerhof Stress calculated using Service loads
(MSEW 3.0)

1/7/09



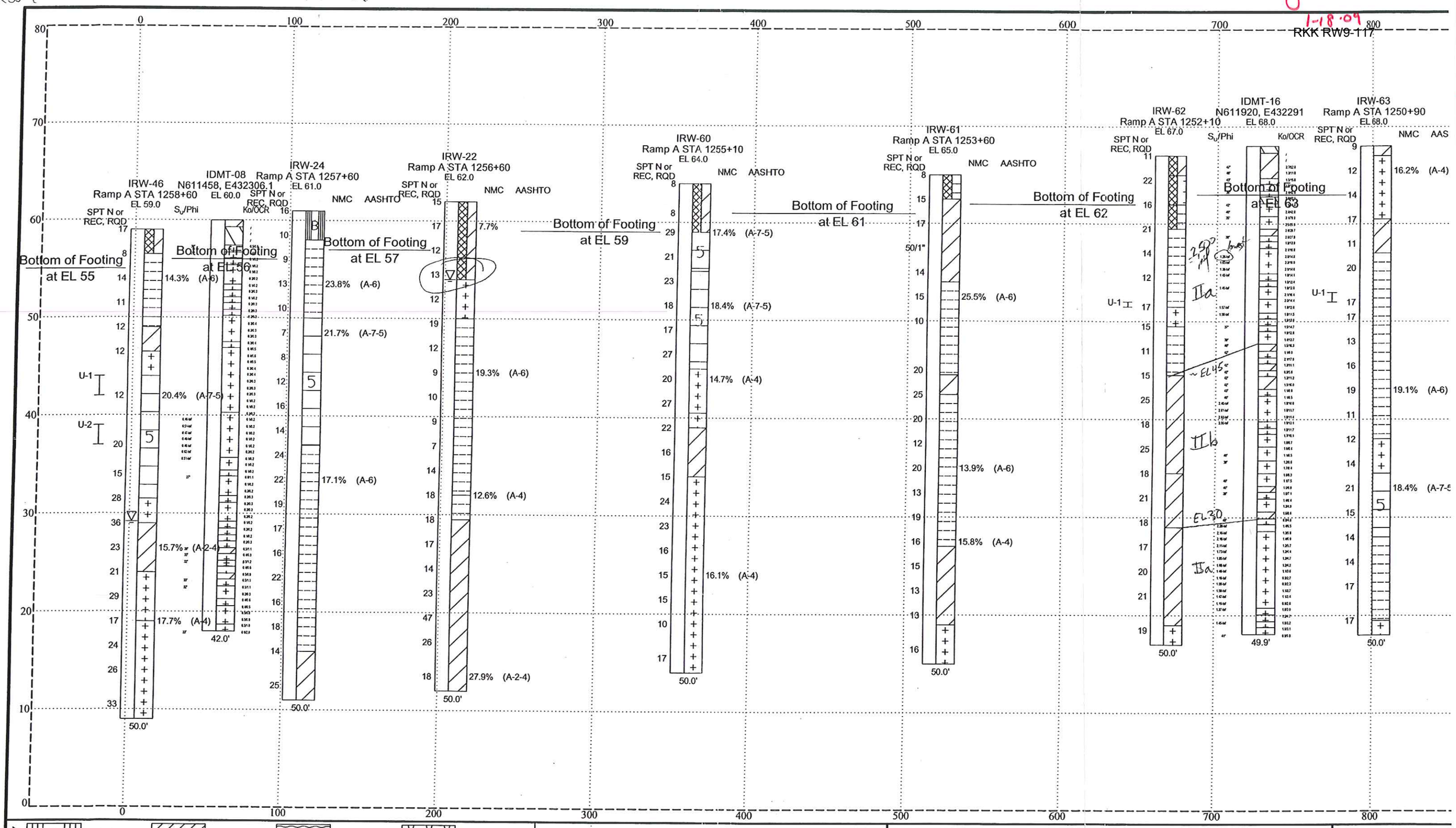
For Settlement only
Service Loads

RKK RW9-118

Sept 18-09

SR1/I-95 Interchange
RW9
103-059-240
12/19/08

SPT
1-18-09
RKK RW9-117



AASHTO SOIL KEY

A	A-1-a	A-2-5	A-5	A-8	
B	A-1-b	A-2-6	A-6	Asphalt	
	A-3	A-2-7	A-7-5	FILL	
	A-2-4	A-4	A-7-6	Decomposed Rock	

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Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data
Retaining Wall 9

Figure No. A-4g

Drawn: TAS | Approved: EMK | Date: 9/24/08 | Comm. No. 103-059-2

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 9/24/08

SR 1/I-95 Interchange - Consolidation Soil Parameters - Stratum 2a

PointID	Sample	GS EL	GWL (ft)	Depth (ft)	Sample EL	γ_T (pcf)	NMC (%)	LL	PL	PI	LI	P_0 (tsf)	$Pc_{Casagrande}$ (tsf)	$Pc_{Work\ Energy}$ (tsf)	OCR_C	$OCR_{W.E.}$	FINAL P_c (tsf)	FINAL OCR	e_0	c_c	c_r	$C_{v(Max)}$ (ft²/d)	$C_{v(Min)}$ (ft²/d)	cr/cc	CC	CR
IEB-15	U-1	83	52.0	12	71	129.5	26.7	49	26	23	0.03	0.78	3.53	6.00	4.5	7.7	3.53	4.5	0.669	0.19	0.05	3.17	0.02	26	11.384	0.030
IBR-61	U-1	84	24.0	14	70	123.6	30.7	34	21	13	0.75	0.87	2.91	1.85	3.4	2.1	2.91	3.4	0.748	0.24	0.05	2.64	0.03	21	13.730	0.029
IEB-13A	T-1	84	9.6	15	69	77.8	18.7	33	19	14	-0.02	0.82	2.95	3.30	3.6	4.0	3.13	3.8	0.554	0.12	0.02	0.23		17	7.722	0.013
IBR-60	U-1	86	11.4	18	68	133.3	20.5	30	19	11	0.14	0.94	1.97	1.83	2.1	2.0	1.97	2.1	0.521	0.13	0.03	2.10	0.01	23	8.547	0.020
ICPT-15A	T-1	80.19	3.0	19	61.19	101.5	24.4	49	23	26	0.05	0.69	2.30	3.10	3.3	4.5	2.7	3.9	0.666	0.12	0.03	0.19	0.09	25	7.203	0.018
IRW-33A	T-1	80	15.0	24	56	107.8	23.3	42	21	21	0.11	1.10	1.25	0.90	1.1	0.8	1.08	1.0	0.685	0.19	0.07	0.41	0.01	37	11.276	0.042
IRW-44	T-1	81	10.0	25	56	103.6	20.1	40	19	21	0.05	1.11	2.91	3.93	2.6	3.5	3.42	3.1	0.657	0.17	0.05	0.11	0	29	10.260	0.030
URS-4	U-1	77	14.0	22	55	123.9	34.7	53	28	25	0.27	1.12	1.78	3.10	1.6	2.8	3.1	2.8	0.851	0.25	0.09	2.50	0.01	36	13.506	0.049
IRW-51	T-1	80	10.7	25	55	105.8	21.6	38	19	19	0.14	1.17	1.94	2.75	1.7	2.4	2.35	2.0	0.64	0.23	0.09	0.2	0.03	39	14.024	0.055
IRW-32	T-1	79	13.4	25	54	114.2	19.5	39	19	20	0.03	1.24	6.50	4.60	5.3	3.7	NV	NV	0.545	0.14	0.04	0.24	0.05	29	9.061	0.026
ICPT-16A	T-1	84.87	14.4	31	53.87	134.1	16.4	34	19	15	-0.17	1.90	3.90	5.00	2.1	2.6	4.45	2.3	0.474	0.07	0.01	2.27	0.29	14	4.749	0.007
IRW-52	T-2	88	15.2	35	53	108.3	22.3	44	19	25	0.13	1.63	2.56	2.60	1.6	1.6	2.58	1.6	0.628	0.16	0.05	0.47	0.24	31	9.828	0.031
IRW-50	T-1	77.69	5.2	25	52.69	111.2	19.9	NP	NP	NP		1.02	8.28	5.25	8.1	5.2	NV	NV	0.563	0.19	0.03	1.0	0	16	12.156	0.019
IEB-15	U-2	83	52.0	31	52	132.8	22.6	36	20	16	0.16	2.02	5.29	1.91	2.6	0.9	5.29	2.6	0.527	0.17	0.05	1.10	0.01	29	11.133	0.033
IRW-33	T-1	79	DRY	27	52	100.5	26.1	47	22	25	0.16	1.30	1.12	1.40	0.9	1.1	1.26	1.0	0.801	0.20	0.07	0.16	0.02	35	11.105	0.039
ICPT-15A	T-2	80.19	3.0	29	51.19	72.3	36.7	50	24	26	0.49	1.00	11.00	12.00	11.0	12.0	11.5	11.5	1.333	0.15	0.02	6.74	2.36	13	6.429	0.009
IBR-15	T-1	70	2.0	19.5	50.5	96.9	24.6	42	20	22	0.21	0.72	1.63	2.30	2.3	3.2	1.97	2.7	0.772	0.22	0.06	0.15	0.03	27	12.415	0.034
URS-1	U-1	73	6.0	24	49	126.0	33.5	48	24	24	0.40	0.95	0.67	0.70	0.7	0.7	NV	NV	0.792	0.23	0.07	0.17	0.03	30	12.835	0.039
IEB-13B	T-2	81.64	7.0	33	48.64	115.9	16.1	28	17	11	-0.08	1.40	5.70	7.25	4.1	5.2	6.48	4.6	0.454	0.04	0.01	6.87	2.47	25	2.751	0.007
IRW-53	T-1	63.39	18.5	15	48.39	107.6	19.9	39	17	22	0.13	0.96	1.96	4.00	2.0	4.2	NV	NV	0.539	0.15	0.04	0.32	0.04	27	9.747	0.026
URS-3	U-1	82	6.0	35	47	132.3	26.1	40	22	18	0.23	1.33	2.59	2.40	1.9	1.8	2.59	1.9	0.614	0.20	0.07	1.92	0.02	35	12.392	0.043
IBR-04	T-1	65	2.0	18	47	115.5	12.6	22	17	5	-0.88	0.67	3.00	2.75	4.5	4.1	2.88	4.3	0.487	0.05	0.01	1.5	0	20	3.362	0.007
IRW-49	T-2	77	2.6	30	47	113.4	20.7	60	19	41	0.04	1.12	5.11	4.00	4.5	3.6	4.56	4.1	0.475	0.09	0.03	0.3	0.08	33	6.102	0.020
IRW-42	T-2	75	1.0	30	45	114.7	26.1	44	22	22	0.19	1.18	3.96	4.38	3.4	3.7	4.17	3.5	0.541	0.18	0.04	0.22	0.01	22	11.681	0.026
IEB-13B	T-3	81.64	7.0	39	42.64	116.9	15.5	27	14	13	0.12	1.63	10.00	7.25	6.1	4.5	8.63	5.3	0.447	0.05	0.03	4.99	1.59		3.455	0.021
IBR-52	U-1	57	11.5	16	41	126.9	29.8	43	23	20	0.34	0.88	1.10	3.75	1.3	4.3	3.75	4.3	0.678	0.18	0.07	0.22	0.02	39	10.727	0.042
IBR-60	U-2	86	11.4	46	40	132.3	24.2	36	21	15	0.21	1.90	1.23	2.00	0.6	1.1	2.00	1.1	0.602	0.16	0.04	1.11	0.01	25	9.988	0.025
URS-4	U-2	77	14.0	37	40	131.2	26.9	42	22	20	0.25	1.64	1.01	1.12	0.6	0.7	NV	NV	0.458	0.20	0.06	2.35	0.01	30	13.717	0.041
														Above EL 40 Averages:			3.75	3.37	0.633	0.16	0.05	1.56	0.28	27	9.689	0.028
ICPT-16A	T-2	84.87	14.4	45	39.87	134.1	16.7	41	18	23	-0.06	2.45	4.20	3.90	1.7	1.6	4.05	1.7	0.304	0.07	0.01	0.99	0.23	14	5.368	0.008
IBR-32	T-3	89		50	39	132.7	16.7	31	18	13	-0.10	2.11	3.00	3.38	1.4	1.6	3.19	1.5	0.519	0.16	0.05	0.02		31	10.533	0.033
IRW-23	T-2	60	36.7	24.5	35.5	108.7	18.4	36	21	15	-0.17	0.81	4.96	3.63	6.1	4.5	4.29	5.3	0.522	0.13	0.03	0.38	0.06	23	8.541	0.020
ICPT-15A	T-3	80.19	3.0	45	35.19	97.3	22.3	53	22	31	0.01	1.47	3.50	2.20	2.4	1.5	2.85	1.9	0.739	0.12	0.04	0.09	0.05	33	6.901	0.023
IBR-05	T-2	66	38.0	31.5	34.5	119.0	16.0	21	18	3	-0.67	1.17	4.75	2.70	4.1	2.3	NV	NV	0.661	0.15	0.02	1.0		13	9.031	0.012
URS-3	U-2	82	6.0	50	32	117.0	42.8	51	24	27	0.70	1.74	0.84	1.20	0.5	0.7	NV	NV	0.987	0.27	0.08	0.33	0.01	30	13.588	0.040
ICPT-16A	T-3	84.87	14.4	55	29.87	134.1	13.2	64	26	38	-0.34	3.39	5.00	5.40	1.5	1.6	5.20	1.5	0.872	0.19	0.04	1.08	0.08	21	10.150	0.021
URS-5	U-1	63	4.0	35.5	27.5	121.5	34.5	55	29	26	0.21	1.24	2.01	1.60	1.6	1.3	2.01	1.6	0.786	0.23	0.09	1.61	0.01	39	12.878	0.050
IEB-15	U-3	83	52.0	56	27	132.8	25.5	47	25	22	0.02	3.56	2.40	4.05	0.7	1.1	4.05	1.1	0.582	0.20	0.06	1.70	0.01	30	12.642	0.038
IBR-61	U-2	84	24.0	59	25	123.3	33.3	46	24	22	0.42	2.55	0.69	2.50	0.3	1.0	2.50	1.0	0.839	0.22	0.06	0.56	0.01	27	11.963	0.033
IRW-09	T-2	59	DRY	35	24	110.9	17.5	23	18	5	-0.10	1.39	3.92	2.30	2.8	1.7	NV	NV	0.536	0.11	0.03	2.8	0.2	27	7.161	0.020
IEB-13B	T-4	81.64	7.0	59	22.64	104.1	22.1	NP	NP	NP		2.13	8.00	9.60	3.8	4.5	8.8	4.1	0.505	0.04	0.01	1.76	0.34	25	2.658	0.007
														EL 40 to 20 Averages:			4.10	2.2	0.654	0.16	0.04	1.03	0.10	26	9.285	0.025
														Total Average:			3.85	3.0	0.639	0.16	0.05	1.40	0.23	27	9.567	0.027

NV: Consolidation Test Not Valid

RKK RW9-118

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I-95/SR1 Interchange 103-059-270 9/26/08
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BOWLES, 4th Ed

TABLE 5-5 Equations for stress-strain modulus E_s by several test methods

E_s in kPa for SPT and units of q_c for CPT; divide kPa by 50 to obtain ksf. The N values should be estimated as N_{55} and not N_{70}

Soil	SPT	CPT
Sand (normally consolidated)	$E_s = 500(N + 15)$ $E_s = (15\,000 \text{ to } 22\,000) \ln N$ E_s§ $= (35\,000 \text{ to } 50\,000) \log N$	$E_s = 2 \text{ to } 4q_c$ E_s† $= (1 + D_r^2)q_c$
Sand (saturated)	$E_s = 250(N + 15)$	
Sand (overconsolidated)	E_s‡ $= 18\,000 + 750N$ $E_{s(OCR)} = E_{s(nc)}(OCR)^{1/2}$	$E_s = 6 \text{ to } 30q_c$
Gravelly sand and gravel	$E_s = 1200(N + 6)$ $E_s = 600(N + 6) \quad N \leq 15$ $E_s = 600(N + 6) + 2000 \quad N > 15$	
Clayey sand	$E_s = 320(N + 15)$	$E_s = 3 \text{ to } 6q_c$
Silty sand	$E_s = 300(N + 6)$	$E_s = 1 \text{ to } 2q_c$
Soft clay	—	$E_s = 3 \text{ to } 8q_c$
Clay	Using the undrained shear strength s_u in units of s_u $I_P > 30$ or organic $I_P < 30$ or stiff $E_{s(OCR)} = E_{s(nc)}(OCR)^{1/2}$	$E_s = 100 \text{ to } 500s_u$ $E_s = 500 \text{ to } 1500s_u$

† Vesić (1970.
‡ Author's equation from plot of D'Appolonia et al. (1970).
§ USSR (and may not be standard blow count N).
General sources: European Conference on Standard Penetration Testing (1974), vol. 2.1, pp. 150–151; CGJ, November 1983, pp. 726–737; Use of In Situ Tests in Geotechnical Engineering, ASCE (1986), p. 1173; Mitchel and Gardner (1975).

CLAYS

	S_u (ksf)
HARD	>4
VERY STIFF	2–4
STIFF	1–2
MEDIUM	0.5–1
SOFT	0.25–0.5
VERY SOFT	0–0.25

TRIAXIAL $E = 2.5q_c$
PLANE-STRAIN $E = 3.5q_c$

TABLE 2-7 Typical range of values for the static stress-strain modulus E_s for selected soils

Field values depend on stress history, water content, density, etc.

Soil	E_s ksf	E_s Mpa
Clay		
Very soft	50–250	2–15
Soft	100–500	5–25
Medium	300–1000	15–50
Hard	1000–2000	50–100
Sandy	500–5000	25–250
Glacial till		
Loose	200–3200	10–150
Dense	3000–15 000	150–720
Very dense	10 000–30 000	500–1440
Loess	300–1200	15–60
Sand		
Silty	150–450	5–20
Loose	200–500	10–25
Dense	1000–1700	50–81
Sand and gravel		
Loose	1000–3000	50–150
Dense	2000–4000	100–200
Shale	3000–300 000	150–5000
Silt	40–400	2–20

pg 99 Bowles

TABLE 2-8 Values or value ranges for Poisson's ratio μ

Type of soil	μ
Clay, saturated	0.4–0.5
Clay, unsaturated	0.1–0.3
Sandy clay	0.2–0.3
Silt	0.3–0.35
Sand, gravelly sand	−0.1–1.00
commonly used	0.3–0.4
Rock	0.1–0.4 (depends somewhat on type of rock)
Loess	0.1–0.3
Ice	0.36
Concrete	0.15

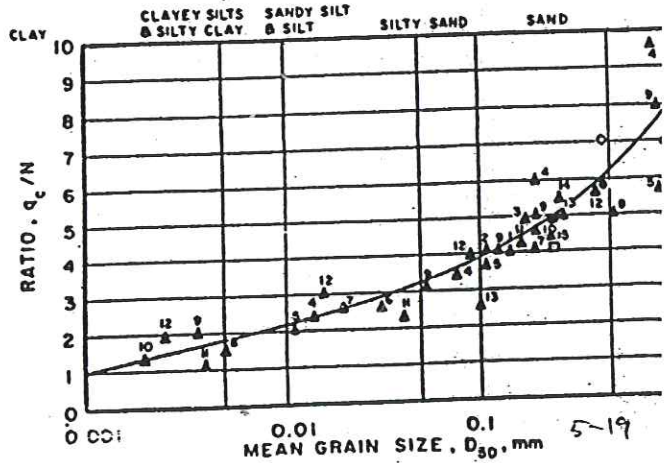
μ FOR SAND $= \frac{1 - \sin\phi}{2 - \sin\phi}$

$\mu = 0.1 + 0.3\phi_r$

$\phi_r = \frac{\phi - 25°}{45° - 25°}$

FAIR $\mu = 0.40$

q_c, bars ; N, blows/foot (1 bar = 100 kPa)



5-19

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Subject I-95/SR 1 Interchange
RW-9 Settlement

Page 6 of 19
Cm. No. 103-059-294

Prepared By SAB Date 9/29/08 Checked By JST Date 9-30-08
REV 1/7/09 JST 1-18-09
RLM 1/28/09

Analysis: Performed using FOSSA (See attached output, p. 7 ~ 18)

* Use C_c : C_r since $\Delta\sigma < P_c$.

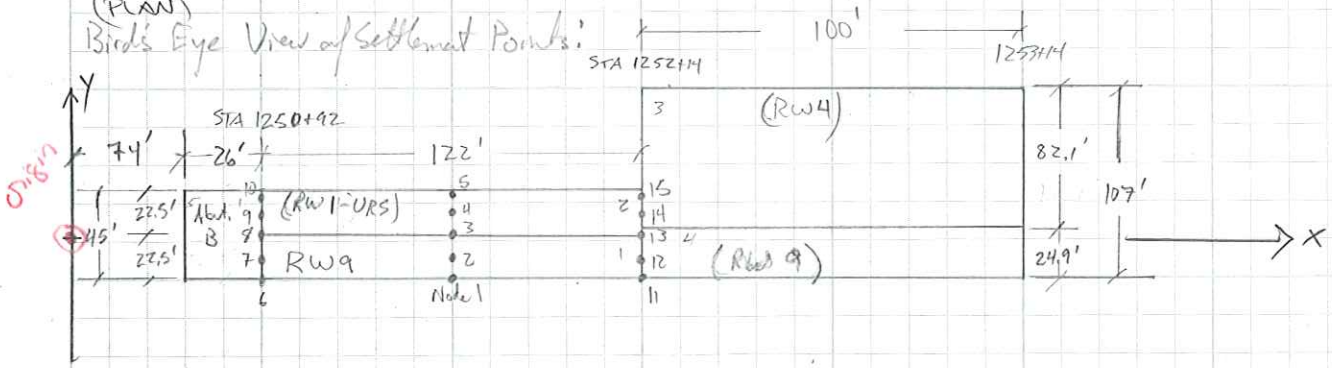
→ Calculate elastic settlement to a depth of 4B below the BOF EL.

⇒ Full "footing" width for RW9 & returned soil = 45', 4B = 180'

BOF EL = EL 63 → 63 - 180 = EL -117 ← Bottom EL for Settlement analysis

* Assume no elastic settlement from CLAY (IIa) - only consolidation.

(PLAN)
Bird's Eye View of Settlement Points:



Summary:

Maximum Elastic Settlement = 0.03' = 0.4" @ Nodes 3, 4, 8, 9, 13, & 14.
⇒ Maximum Total Settlement = 0.27' = 3.3" (@ Nodes 3, 13, & 14)

Maximum Consolidation Settlement = 0.24' = 2.9" @ Nodes 3, 13, & 14

↳ Time-rate Settlement: Based on our interpretation of the settlement plate data, it is anticipated that the consolidation settlement will occur primarily within less than a month of construction completion.

⇒ See p. 19 for differential settlement. (AASHTO Tolerance = 1/100)

7

RKK RW9-121
1-18-09

SR 1/I-95 Interchange

Report created by FoSSA(2.0): Copyright (c) 2003-2006, ADAMA Engineering, Inc.

PROJECT IDENTIFICATION

SW 1/22/09

Title:	SR 1/I-95 Interchange
Project Number:	103-059-27U -
Client:	DelDOT
Designer:	SAB
Station Number:	1251+00 RW 9

Description:
Retaining Wall 9

Company's information:

Name:	RK&K Engineers, LLP
Street:	81 Mosher Street Baltimore, MD 21217
Telephone #:	410-728-2900
Fax #:	410-728-0282
E-Mail:	

Original file path and name: M:\project ..... aining Wall 9\Final Design\For Settlement\RW 9.2ST
Original date and time of creating this file: Thu Jan 08 09:21:45 2009

GEOMETRY: Analysis of a Multiple Footings

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8

RKK RW9-122

JDT 1-18-09

INPUT DATA – FOUNDATION LAYERS – 4 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	130.00	0.35	IIa EL 63-45
2	130.00	0.30	IIb EL 45-30
3	130.00	0.40	IIa Below EL 30
4	130.00	0.40	Bottom Consol. Layer

1/2 Layer Saturated ∴ reduced μ from 0.4 to 0.35.

INPUT DATA – MULTIPLE FOOTINGS – 5 footings

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	0.00	354.00
2	100.00	354.00
3	150.00	354.00
4	200.00	354.00
5	300.00	354.00

Actual GW EL = Z - 300

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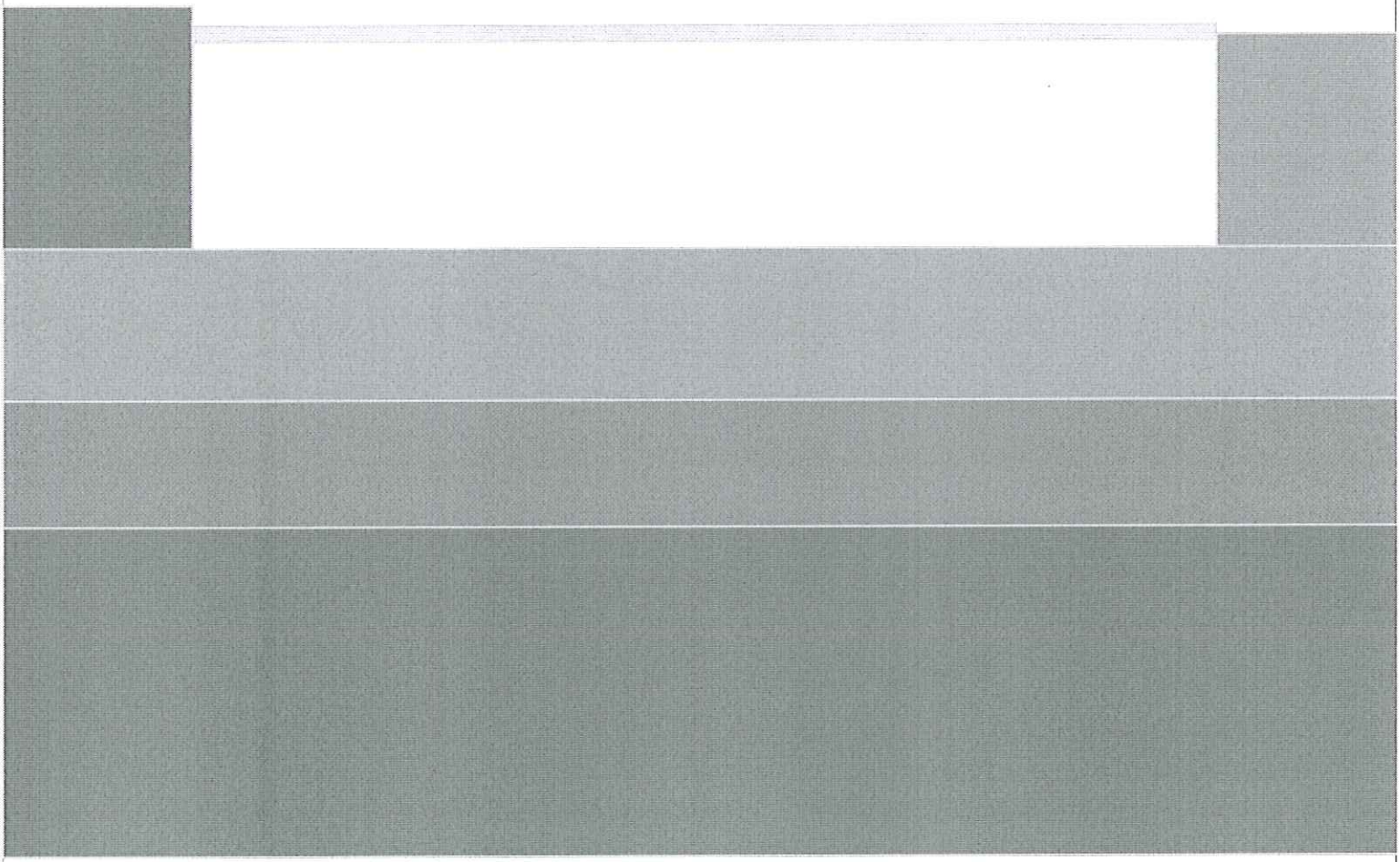
RKK RW9-123
JBT
1-18-09

DRAWING OF SPECIFIED GEOMETRY



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1-18-09

INPUT DATA FOR CONSOLIDATION -- $\alpha = 1/6$

Layer # Undergoing Consolidation [Yes/No]		$(\sigma'_p - \sigma'_o)$ given at layer's boundaries in [lb/ft²] at Top	Bottom	Cc	Cr	e0	Cv [ft ²/day]	Drains at :
1	Yes	8000.0	6222.0	0.02	0.02	0.63	0.0973	Top & Bot.
2	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	Yes	6708.0	2854.0	0.02	0.02	0.65	0.5900	Top
4	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Rounded from 0.016

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RKK RW9-125
1-18-09

TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	363.00	IIa EL 63-45
	2	89.00	363.00	
	3	150.00	363.00	
	4	200.00	363.00	
	5	300.00	363.00	
2	1	0.00	345.00	IIb EL 45-30
	2	100.00	345.00	
	3	150.00	345.00	
	4	200.00	345.00	
	5	300.00	345.00	
3	1	0.00	330.00	IIa Below EL 30
	2	100.00	330.00	
	3	150.00	330.00	
	4	200.00	330.00	
	5	300.00	330.00	
4	1	0.00	273.00	Bottom Consol. Layer
	2	100.00	273.00	
	3	150.00	273.00	
	4	200.00	273.00	
	5	300.00	273.00	

Actual EL = Z - 300

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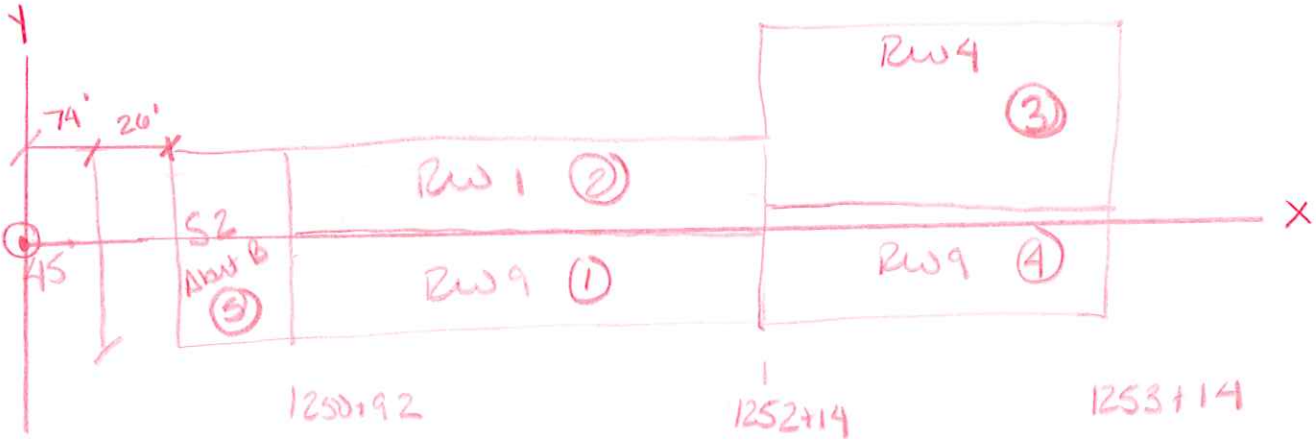
RKK RW9-126
1-18-09

TABULATED GEOMETRY: INPUT OF MULTIPLE FOOTINGS – 5 footings

Footing #	L (in X direction) [ft]	B (in Y direction) [ft]	X of center [ft]	Y of center [ft]	q [ft]l [lb/ft²]	
1	122.00	22.50	89.00	-11.25	4375.00	RW1
2	122.00	22.50	89.00	11.25	4710.00	RW1
3	100.00	82.10	200.00	43.45	3770.00	RW4 + emb
4	100.00	24.90	200.00	-10.05	4508.00	
5	26.00	45.00	15.00	0.00	5140.00	S2 Abut 6

See Pg 6 for Plan View

* Footing Locations



* NTS

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RKK RW9-127
JEL 1-18-09

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	89.00	-22.50	1	545000	0.3500	~~0.0369~~	363.00	~~362.77~~	~~0.23~~
			2	1364000	0.3000	0.0172			
			3	1364000	0.4000	~~0.0524~~			
			4	1364000	0.4000	~~0.1232~~			
2	89.00	-11.25	1	545000	0.3500	~~0.0813~~	363.00	~~362.70~~	~~0.30~~
			2	1364000	0.3000	0.0284			
			3	1364000	0.4000	~~0.0662~~			
			4	1364000	0.4000	~~0.1287~~			
3	89.00	0.00	1	545000	0.3500	~~0.0864~~	363.00	~~362.68~~	~~0.32~~
			2	1364000	0.3000	0.0327			
			3	1364000	0.4000	~~0.0721~~			
			4	1364000	0.4000	~~0.1317~~			
4	89.00	11.25	1	545000	0.3500	~~0.0879~~	363.00	~~362.68~~	~~0.32~~
			2	1364000	0.3000	0.0295			
			3	1364000	0.4000	~~0.0678~~			
			4	1364000	0.4000	~~0.1319~~			
5	89.00	22.50	1	545000	0.3500	~~0.0401~~	363.00	~~362.76~~	~~0.24~~
			2	1364000	0.3000	0.0182			
			3	1364000	0.4000	~~0.0548~~			
			4	1364000	0.4000	~~0.1293~~			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

A

Ignse elastic Settlement of Strata IIa

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RKK RW9-128 1-18-09

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
6	28.00	-22.50	1	545000	0.3500	0.0448	363.00	362.80	0.20
			2	1364000	0.3000	0.0188			
			3	1364000	0.4000	0.0463			
			4	1364000	0.4000	0.0938			
7	28.00	-11.25	1	545000	0.3500	0.0950	363.00	362.72	0.28
			2	1364000	0.3000	0.0307			
			3	1364000	0.4000	0.0590			
			4	1364000	0.4000	0.0974			
8	28.00	0.00	1	545000	0.3500	0.0988	363.00	362.70	0.30
			2	1364000	0.3000	0.0349			
			3	1364000	0.4000	0.0641			
			4	1364000	0.4000	0.0990			
9	28.00	11.25	1	545000	0.3500	0.0983	363.00	362.71	0.29
			2	1364000	0.3000	0.0313			
			3	1364000	0.4000	0.0595			
			4	1364000	0.4000	0.0985			
10	28.00	22.50	1	545000	0.3500	0.0466	363.00	362.79	0.21
			2	1364000	0.3000	0.0193			
			3	1364000	0.4000	0.0470			
			4	1364000	0.4000	0.0959			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

Ignore elastic settlement of strata Ia

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	150.00	-22.50	1	545000	0.3500	0.0380	363.00	362.75	0.25
			2	1364000	0.3000	0.0174			
			3	1364000	0.4000	0.0556			
			4	1364000	0.4000	0.1370			
2	150.00	-11.25	1	545000	0.3500	0.0834	363.00	362.67	0.33
			2	1364000	0.3000	0.0287			
			3	1364000	0.4000	0.0716			
			4	1364000	0.4000	0.1448			
3	150.00	0.00	1	545000	0.3500	0.0844	363.00	362.65	0.35
			2	1364000	0.3000	0.0327			
			3	1364000	0.4000	0.0809			
			4	1364000	0.4000	0.1502			
4	150.00	11.25	1	545000	0.3500	0.0787	363.00	362.66	0.34
			2	1364000	0.3000	0.0309			
			3	1364000	0.4000	0.0819			
			4	1364000	0.4000	0.1528			
5	150.00	22.50	1	545000	0.3500	0.0530	363.00	362.69	0.31
			2	1364000	0.3000	0.0246			
			3	1364000	0.4000	0.0764			
			4	1364000	0.4000	0.1525			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

Ignore elastic Settlement of Strata IIa

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RKK RW9-130
JMT 1-18-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	89.00	-22.50	363.00	0.18	362.82
2	89.00	-11.25	363.00	0.23	362.77
3	89.00	0.00	363.00	0.24	362.76
4	89.00	11.25	363.00	0.23	362.77
5	89.00	22.50	363.00	0.18	362.82

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
6	28.00	-22.50	363.00	0.17	362.83
7	28.00	-11.25	363.00	0.22	362.78
8	28.00	0.00	363.00	0.23	362.77
9	28.00	11.25	363.00	0.22	362.78
10	28.00	22.50	363.00	0.17	362.83

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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RKK RW9-132
SPT 1-18-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	150.00	-22.50	363.00	0.18	362.82
2	150.00	-11.25	363.00	0.23	362.77
3	150.00	0.00	363.00	0.24	362.76
4	150.00	11.25	363.00	0.24	362.76
5	150.00	22.50	363.00	0.22	362.78

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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SR 1/I-95 Interchange 103-059-27U 1/15/2009
Retaining Wall 9 Settlement Results

	Settlement (ft)		
Point	Elastic	Consolidation	Total
1	0.02	0.18	0.20
2	0.03	0.23	0.26
3	0.03	0.24	0.27
4	0.03	0.23	0.26
5	0.02	0.18	0.20
6	0.02	0.17	0.19
7	0.03	0.22	0.25
8	0.03	0.23	0.26
9	0.03	0.22	0.25
10	0.02	0.17	0.19
11	0.02	0.18	0.20
12	0.03	0.23	0.26
13	0.03	0.24	0.27
14	0.03	0.24	0.27
15	0.02	0.22	0.24

	Settlement (in)		
Point	Elastic	Consolidation	Total
1	0.2	2.2	2.4
2	0.3	2.8	3.1
3	0.4	2.9	3.3
4	0.4	2.8	3.1
5	0.2	2.2	2.4
6	0.2	2.0	2.3
7	0.4	2.6	3.0
8	0.4	2.8	3.2
9	0.4	2.6	3.0
10	0.2	2.0	2.3
11	0.2	2.2	2.4
12	0.3	2.8	3.1
13	0.4	2.9	3.3
14	0.4	2.9	3.3
15	0.3	2.6	2.9

	RW 9 Differential Settlement							
	Front RW 9		Front RW 4		Back of RW 9		Front to Front	
	6 to 1	1 to 11	10 to 5	5 to 15	8 to 3	3 to 13	1 to 3	3 to 5
Inches	0.1	0.0	0.1	0.6	0.1	0.0	0.9	0.9
Ratio	1/5952	0	1/5618	5/5388	1/6410	0	1/662	1/671

All within AASHTO tolerance of 1/100.

* For Point Locations see P8 ⑨

Max 3.3"
Min 2.3"

RKK RW9-133

1-18-09

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 9\Final Design\RW 9 Settlement Results Final.xls

19

CALCULATION CHECKLIST

Project: SR-1/I-95 INTERCHANGE Comm. No.: 103-059

Title of Calculation Set: RETAINING WALL 10

Project Manager: EMK

Calculations Prepared By: BBS

Calculation Checked By:

Computer Programs / Files: ~~AL~~ SLOPE W & FOSSA

Initial	Date	
BBS	1-20-09	Subsurface Characterization approved by Project Manager
BBS	1-20-09	Calculations are neat, legible and understandable.
BBS	1-20-09	Table of Contents is provided.
BBS	1-20-09	Heading on each page filled out
BBS	1-20-09	The first page contains purpose of the calculation.
BBS	1-20-09	Symbols are defined.
BBS	1-20-09	References for data, methods, formulas and computer program names and version numbers are given.
BBS	1-20-09	Assumptions are listed and those that need to be verified later are Flagged.
BBS	1-20-09	Headings on front sheet of each set of computer input and output.
BBS	1-20-09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JJT	1-20-09	All calculations checked and each calculation sheet initialed by checker.
EMK	2/8/09	Calculation set reviewed by Project Manager.
		Has this calculation been superseded? Reference new calculation, if applicable.

This sheet is to be prepared by the originator of the calculation and attached to the front of the calculation set.

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Subject SR-1/I-95 INTERCHANGE
RETAINING WALL 10
Page _____ of _____
Cm. No. 103-059
Prepared By BBS Date 1-20-09 Checked By JT Date 1-20-09

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Subject SR-1 INTERCHANGE
RETAINING WALL 10
Page 1 of 82
Cm. No. 103-059
Prepared By BBS Date 9-30-08 Checked By [illegible] Date 1-20-09

PURPOSE: DESIGN OF RETAINING WALL 10:

(ABUTMENT & WINGWALL (30-ft) DESIGN, RESPONSIBILITY OF URS)

REFERENCE: AASHTO LRFD BRIDGE DESIGN SPECIFICATION
CUSTOMARY US UNITS 14th EDITION 2007

SOFTWARE: MSEW 2.0
FOSSA 2.0

SYMBOLS:

UNIT WEIGHT → γ
FRICTION ANGLE → ϕ
UNDRAINED SHEAR STRENGTH → S_u
MODULUS OF ELASTICITY → E_s
POISSON'S RATIO → μ

COMPRESSION INDEX → C_c
RECOMPRESSION INDEX (SWELL) → C_R ; C_s
COEFFICIENT OF CONSOLIDATION → C_v
SETTLEMENT PARAMETERS BASED ON LAB TESTING & SP DATA

WALL:

LENGTH OF WALL = 361-ft
MAX HEIGHT OF WALL = 32
MAX EXPOSED WALL HEIGHT = 29
DEPTH OF EMBEDMENT = 3.0-ft

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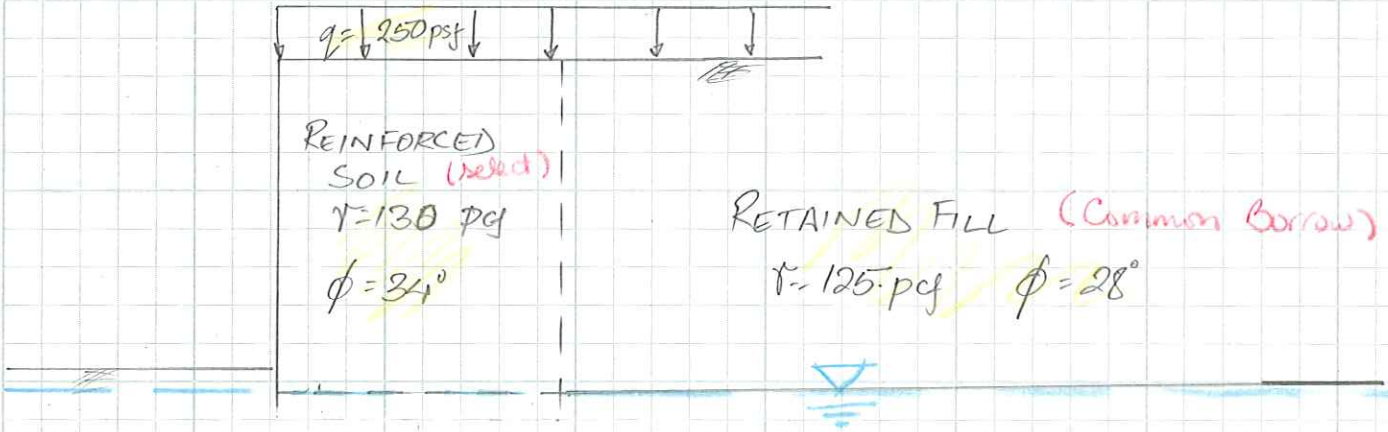
Subject SR-1 INTERCHANGE Page 2 of 82
RETAINING WALL - 10 Cm. No. 103-059
Prepared By BBS Date 9-30-08 Checked By JJT Date 1-20-09
EM 1/22/09

SOIL PARAMETERS RW-10

FOUNDATION LEVEL @ EL 69.0



Strata 2a (i)

γ = 130 pcf
C = 2000 psf
μ = 0.4
E_s = 818 ksf
C_c = 0.175
C_R = 0.015
C_V = 0.15 ft²/day
OCR = 8.3
P_c = 9 ksf

STRATA 2a (ii)

γ = 130 pcf
C = 3000 psf
μ = 0.4
E_s = 818 ksf
C_c = 0.154
C_R = 0.015
C_V = 0.15 ft²/day
OCR = 2.1

STRATA 2a (iii)

γ = 130 pcf C = 4000 psf μ = 0.4 E_s = 1364 ksf C_c = 0.077 C_R = 0.015 C_V = 0.15 ft²/day OCR = 2.1

STRATA 2b Coarse Grained

γ = 125 pcf
φ = 34°
μ = 0.3
E_s = 1364 ksf

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Subject SR-1 INTERCHANGE RETAINING WALL - 10 Page 3 of 82
Cm. No. 103-059
Prepared By BBS Date 9-30-08 Checked By JJT Date 1-20-09
EM 1/22/09

SOIL PARAMETERS.

UNDRAINED SHEAR STRENGTH OF SOIL ESTIMATED FROM URS CHART FOR UU & CU TEST RESULTS. SEE CHART

THE S_u VALUES WERE COMPARED WITH ICPT-4 RESULTS. ICPT-11

THE DRAINED PARAMETERS ESTIMATED USING CU RESULTS & CHARTS

YOUNG'S MODULUS ESTIMATED FROM BACK CALCULATED E_s VALUES FROM SETTLEMENT PLATE RESULTS.

SEE ATTACHED E_s CALCULATION.

CONSOLIDATION PARAMETERS ESTIMATED FROM LIMITED TEST RESULTS. & ATTERBERG LIMITS.

FOR STRATA 2a (ii)

Avg LL = 32
PL = 21
PI = 13

$C_c = 0.009(LL-10) = 0.20$
$C_R = \frac{1}{5} C_c = 0.04$
$C_V = 0.45\ ft^2/day$ DM 7.1-144 Figure 4

FOR STRATA 2a (iii)

Avg LL = 21
PL = 14
PI = 7

$C_c = 0.009(LL-10) = 0.10$
$C_R = \frac{1}{5} C_c = 0.02$
$C_V = 0.6\ ft^2/day$ DM 7.1-144 Figure 4

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Subject SR-1 INTERCHANGE
RETAINING WALL 10
Page 4 of 82
Cm. No. 103-059
Prepared By BBS Date 10-9-08 Checked By JST Date 1-20-09
JM 1/22/09

SOIL PARAMETERS

UNDRAINED SOIL PARAMETER

PARAMETER BASED ON CPT DATA & LAB RESULTS

UNDRAINED SHEAR STRENGTH

EL 40 - 69 → S_u = 2000 psf

EL 20 - 40 → S_u = 3000 psf

EL 20 & BELOW → S_u = 4000 psf

DRAINED SOIL PARAMETER FOR FOUNDATION SOIL

SEE CU RESULTS PAGE> 11-13

EL 40 - 69

ATTERBERG LIMITS.

	AVG	MIN	MAX
LL	35	21	47
PL	22	17	26
PI	14	3	23

SEE PI Vs ϕ CHARTS

TAKE INTO CONSIDERATION BOTH PEAK & RESIDUAL ϕ

ϕ_{res} = 19° PI Vs ϕ_{res}

ϕ_{res} = 20° LL Vs ϕ_{res}

ϕ_{res} = 24° PI Vs DRAINED ANGLE OF SHEARING RESISTANCE

ϕ_{peak} = 33° PI Vs Sin ϕ' Peak

Avg Residual ϕ_{res} = 21°

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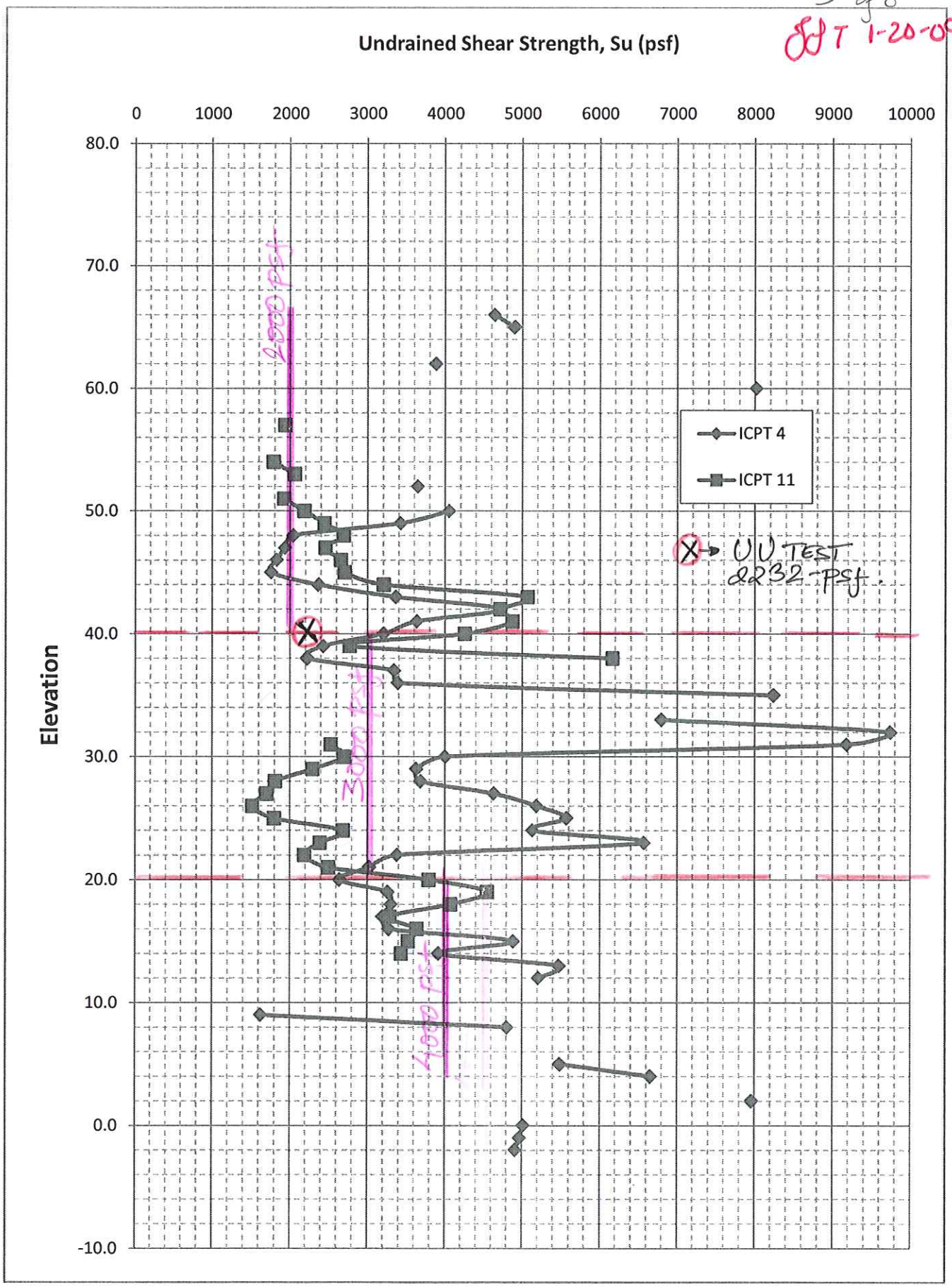

Retaining Wall 10 (Atterberg Limits)

PointID	Depth	Elevation	PL	LL	PI	Passing 200	USCS	NMC	Strata	UW	TSC	TSP	UDS	IVR	Pc	Cc	Cr	Cv Max	Cv Min
URS-1	0	73	20	22	3	56.4	ML	12.1	2a										
URS-1	2	71	22	25	3	75	ML	20.2	2a										
URS-1	4	69	19	21	3	47.1	SM	14.1	2a										
URS-1	6	67	17	30	13	44.2	SC	14.7	2a										
URS-1	8	65	19	23	4	49.7	SC-SM	16.4	2a										
URS-1	10	63	25	47	22	96.6	CL	25	2a										
URS-1	12	61	26	44	18	99.1	CL	24.9	2a										
URS-1	14	59	23	39	16	99.5	CL	22.7	2a										
URS-1	16	57	23	40	17	99.2	CL	21.4	2a										
URS-1	18	55	22	34	12	98.1	CL	24	2a										
IBR-15	19.5	50.5	20	42	22	95	CL	24.6	2a		910	1.5							
IBR-15	19.51	50.49							2a	96.9				0.772	1.63	0.22	0.06	0.015	0.003
URS-1	20	53	23	40	17	87.5	CL	27.2	2a										
URS-1	22	51	22	37	15	93.9	CL	28.6	2a										
IBR-15	25	48	22	42	20	97	CL	19.3	2a		Average LL		35		Min LL	21		Max LL	47
URS-1	26	47	21	44	23	84.1	CL	24	2a		Average PL		22		Min PL	17		Max PL	26
URS-1	28	45	20	35	15	88.6	CL	18.3	2a		Average PI		14		Min PI	3		Max PI	23
IBR-15	29.5	40.5	25	46	21	99	CL	24	2a										
IBR-15	29.51	40.49							2a				2232						
URS-1	34	39	19	28	10	84.1	CL	22.2	2a		Average LL		32						
URS-1	39	34	19	29	10	93	CL	21.1	2a		Average PL		21						
URS-1	44	29	20	32	12	98.4	CL	22	2a		Average PI		13						
URS-1	49	24	NP	23	NP	59	ML	24.9	2a								Average LL		33
URS-1	54	19	NP	NV	NP	76.5	ML	23.2	2a		Average LL		21				Average PL		21
IBR-15	59	11	14	21	7	60	CL-ML	16.5	2a		Average PL		14				Average PI		13
URS-1	59	14	NP	20	NP	66.8	ML	16.5	2a		Average PI		7				Average NMC		21

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Retaining Wall 10 (Atterberg Limits)

PointID	Depth	Elevation	PL	LL	PI	Passing 200	USCS	NMC	Strata	UW	TSC	TSP	UDS	IVR	Pc	Cc	Cr	Cv Max	Cv Min
IBR-15	6	64	20	39	19	38	SC	14.7	2b										
IBR-15	35	35	14	23	9	67	CL	16.3	2b										
IBR-15	47	26	17	22	5	45	SC-SM	20.9	2b										
URS-1	64	9	NP	18	NP	46.7	SM	19.7	2b										
URS-1	69	4	17	19	2	62	ML	20.3	2b										
URS-1	74	-1	NP	17	NP	45	SM	19.5	2b										
URS-1	79	-6	NP	16	NP	35.5	SM	20.2	2b										
IBR-15	80	-10	NP	NP	NP	28	SM	18.2	2b										
URS-1	84	-11	NP	18	NP	53.3	ML	19.8	2b										
URS-1	89	-16	NP	NV	NP	20.7	SM	16.4	2b										
IBR-15	92	-22	14	20	6	21	SC-SM	19.9	2b										
URS-1	94	-21	NP	NV	NP	20.5	SM	10.6	2b										
URS-1	99	-26	NP	NV	NP	14.8	SM	16.6	2b										
URS-1	104	-31	NP	NV	NP	16.6	SM	16.4	2b										
URS-1	109	-36	NP	NV	NP	20.3	SM	15.2	2b	Average LL			19						
URS-1	114	-41	14	18	4	40.3	SC-SM	13.2	2b	Average PL			15						
URS-1	119	-46	21	40	19	77.9	CL	26.1	2b	Average PI			5						
URS-1	124	-51	17	36	19	33.7	SC	15.5	2b	Average NMC			18						

RKK RW10-907

RKK RW10-10

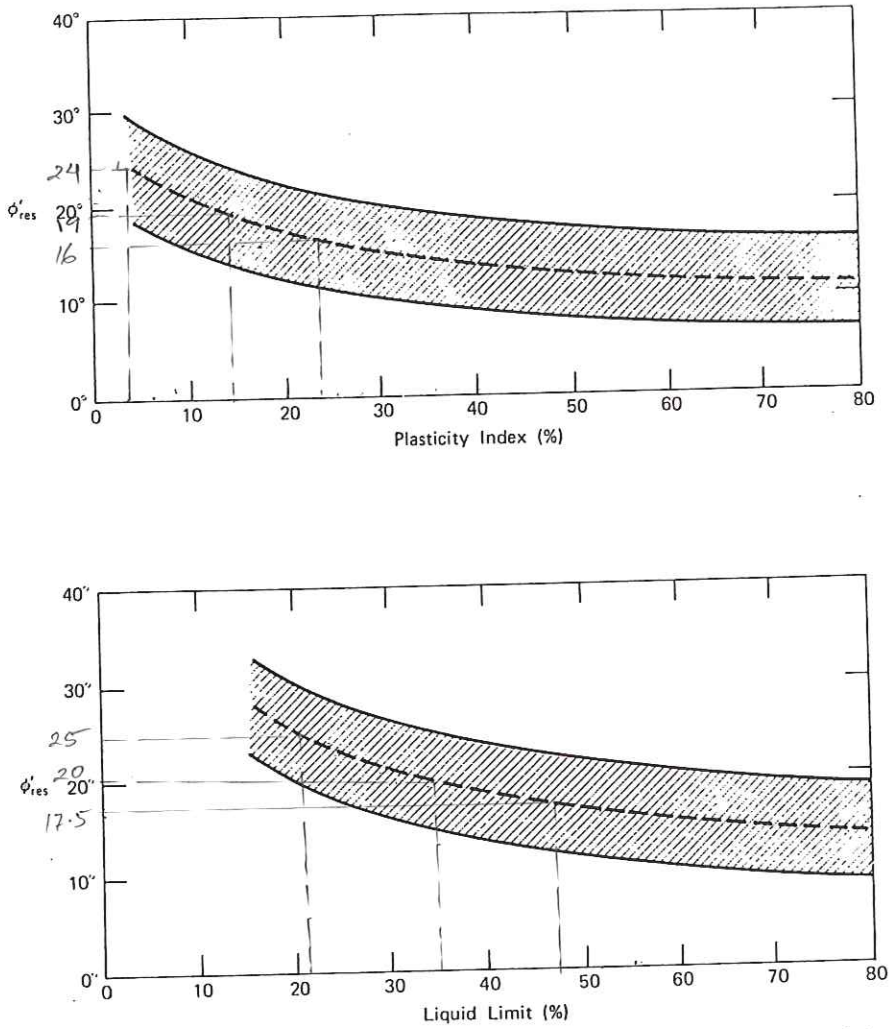

Fig. 14.2 Relationship between residual friction angle and plasticity (Compiled by Deere, 1974).

mally consolidated clays, as shown in Fig. 14.6. The difference between the two strength envelopes at any value of effective stress depends on type of clay, drainage conditions during shear, and amount of overconsolidation.

8. The envelope for overconsolidated clay shown in Fig. 14.6 reflects the influences of both stress history and differences in water content. For comparisons at the same water content but different effective stress, as for points A and A' in Fig. 14.6 the Hvorslev strength parameters c_e and ϕ_e are obtained (Hvorslev, 1937, 1960). The parameter ϕ_e has been assumed to be independent of water content and effective normal stress; whereas, c_e depends only on water content. The Hvorslev parameters have been termed "true friction angle" and "true cohesion," and considered by some to reflect the mechanism of shear strength in terms of interparticle forces (c_e) and friction (ϕ_e). Such an interpretation is controversial, however, because as shown in Chapter 12, two samples at the same water content but different effective stresses must have different structures. This will manifest itself by differences in volume change in the case of drained tests, and by differences in pore pressures in undrained tests. In addition, the procedures for evaluation of c_e and ϕ_e fail to take the curvature of the failure envelope into account. Present evidence is that a true cohesion

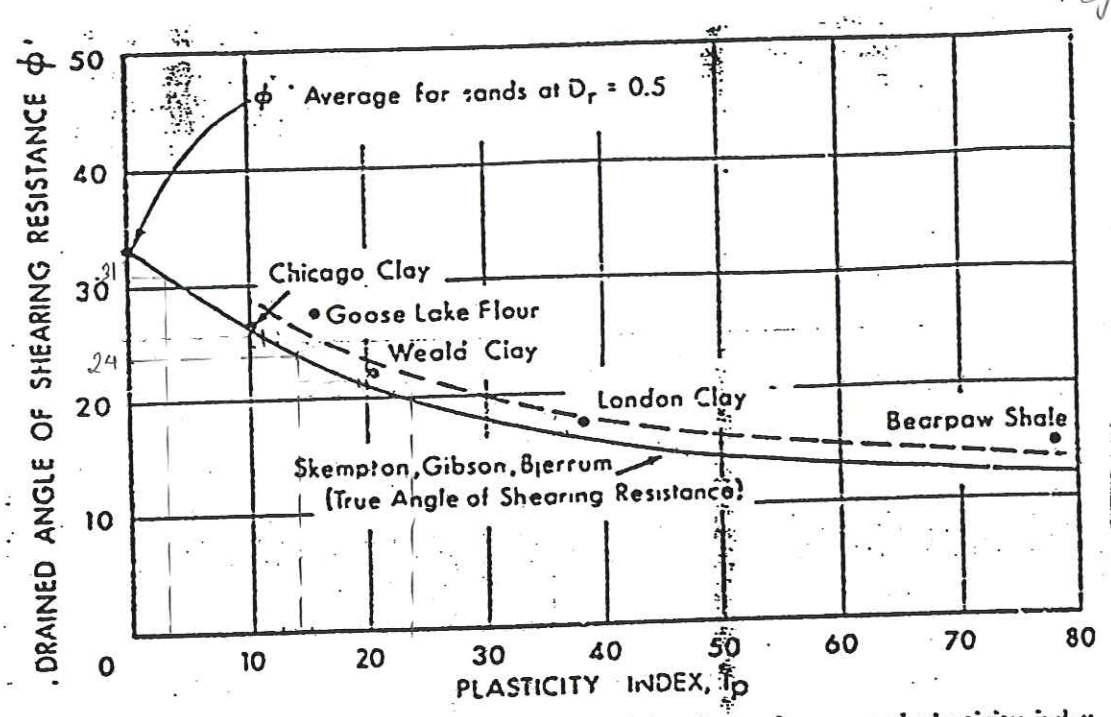

FIGURE 10. Relationship between drained angle of shearing resistance and plasticity index

James K. Mitchell
Fundamentals of Soil Behavior
1976 - University of Calif, Berkeley
John Wiley & Sons, Inc

Pg 284

BROOKER & IRELAND (1965)
CGJ 2/65

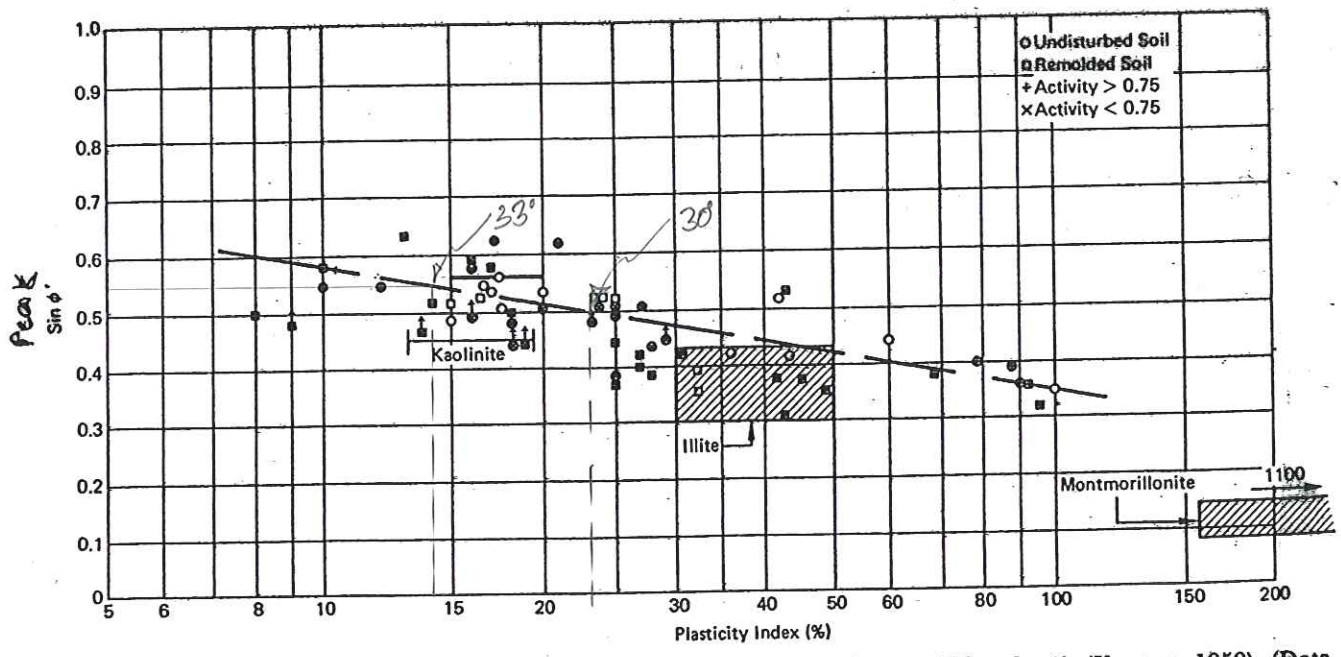

Fig. 14.1 Relationship between sin ϕ and plasticity index for normally consolidated soils (Kenney, 1959). (Data for pure clays from Olson, 1974.)

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CU TEST RESULTS (GLOBAL) SEE CHART

TOTAL STRESS $\phi = 23$ $C = 0$?

EFFECTIVE STRESS $\phi = 24°$ $C = 0 \sim 380$ psf

DRAINED CONDITION USE (LONG TERM ANALYSIS)

$\phi = 24$ FOR FOUNDATION SOIL

$C = 0 \sim 380$ PSF DONOT USE C FOR LONG TERM

DRAINED CONDITION FOR GLOBAL STABILITY

USE SPLINE FUNCTION (POWER)

SHEAR STRESS $= 0.7753\,(\text{NORMAL STRESS})^{0.6701}$

SEE CHART

Figure C-3a
Summary of CU with Pore Pressure for External Stability Analysis
Effective Stress - Stratum IIa
EL 40 & Above

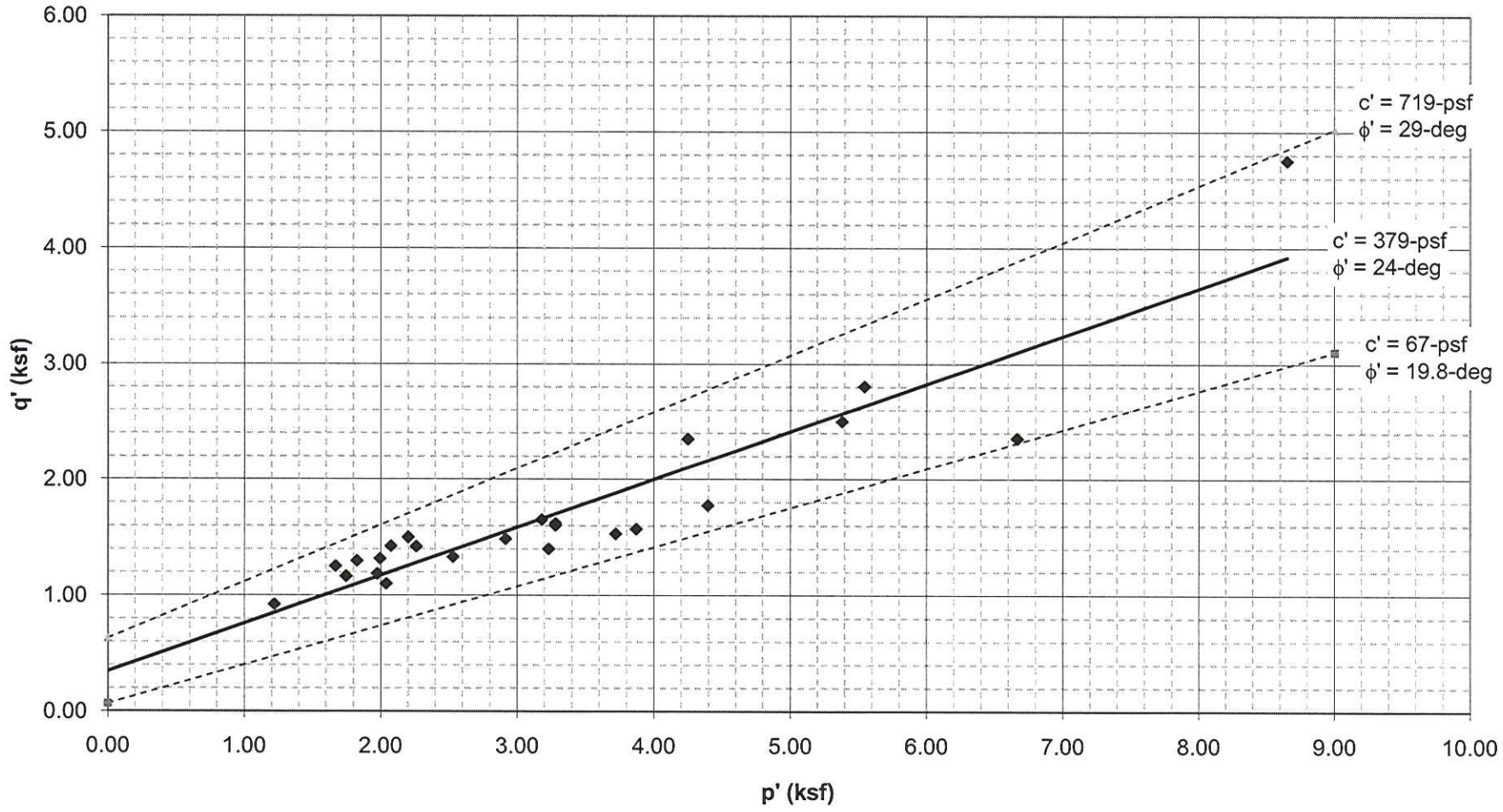

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Figure C-2a
Summary of CU with Pore Pressure
Effective Stress - Strata IIa
EL 40 & Above (SPLINE FUNCTION)

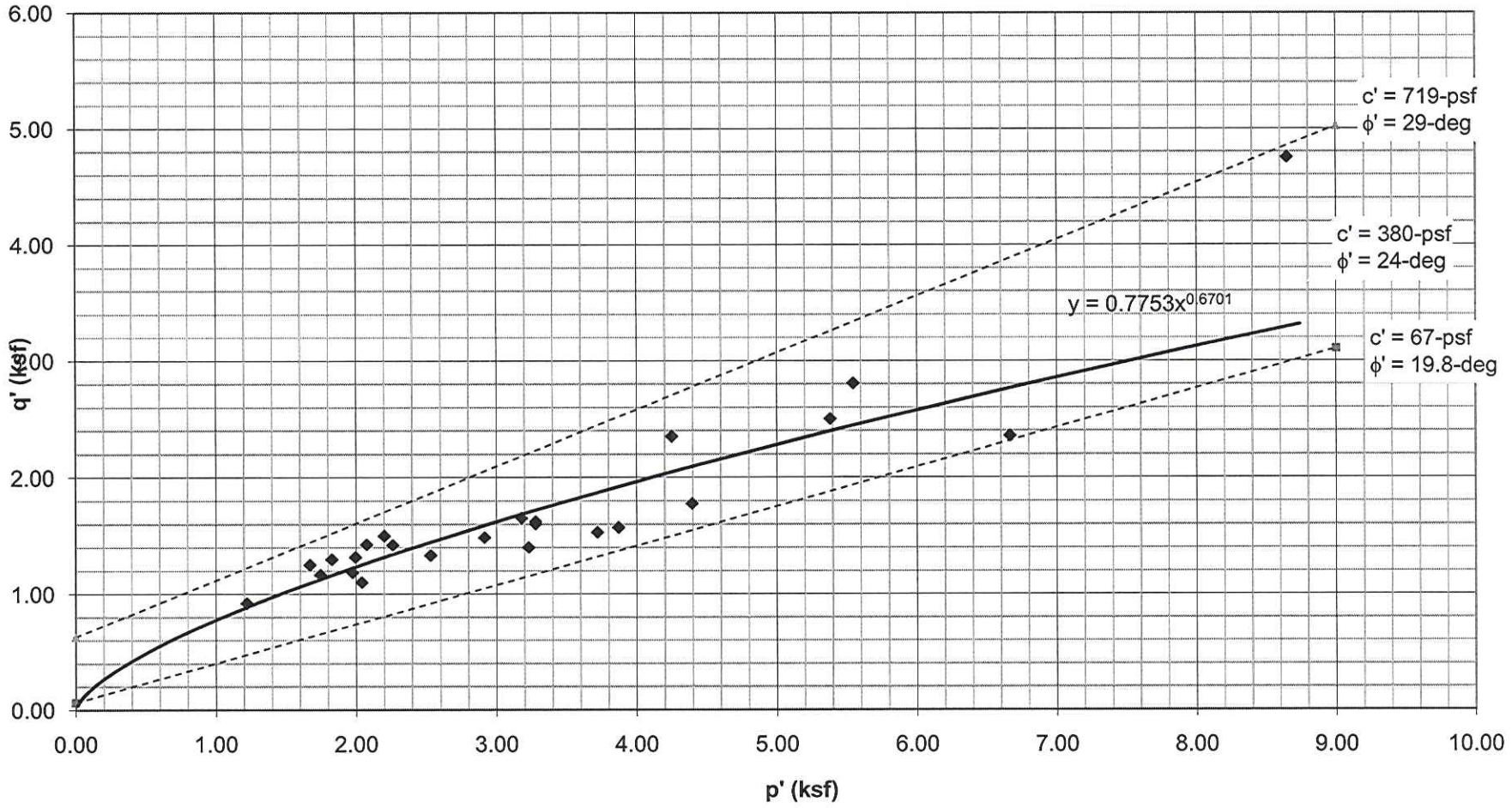

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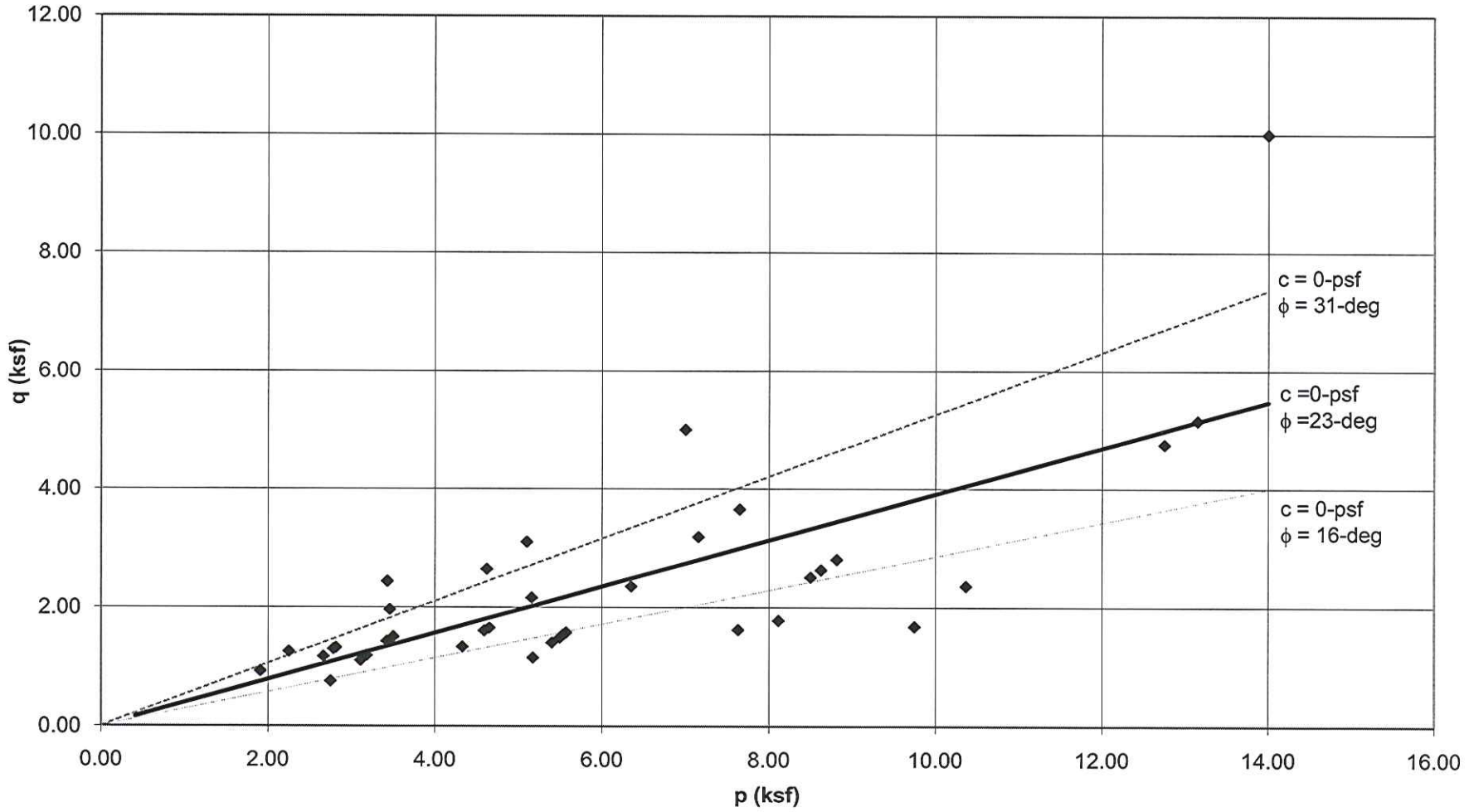
Figure C-2b
Summary of CU with Pore Pressure
Total Stress - Strata IIa



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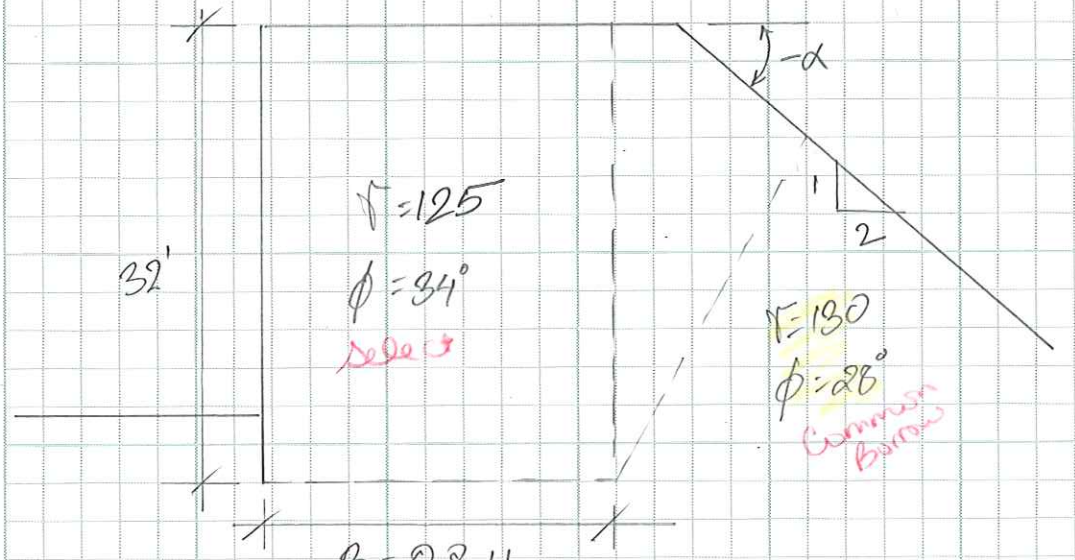
TYPICAL CROSS SECTION OF WALL



THE DOWNWARD SLOPE IN THE ACTIVE PRESSURE ZONE REDUCES THE HORIZONTAL THRUST ON THE WALL

SOIL PARAMETERS

REINFORCED SOIL

$\gamma = 125$ pcf $\phi = 34°$ Select Borrow

RETAINED SOIL

$\gamma = 130$ pcf $\phi = 28°$ Common Borrow

FOUNDATION SOIL

$\gamma = 130$ pcf DRAINED $\phi = 24°$ $C = 0$

UNDRAINED $\phi = 0$ $C = 2000$ psf

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ACTIVE EARTH PRESSURE COEFFICIENT WITH DOWNWARD SLOPE

COULUMB'S METHOD

$$K_a = \frac{\sin^2(\phi+\theta)}{\sin^2\theta \sin(\theta-\delta)\left[1+\sqrt{\frac{\sin(\delta+\phi)\sin(\phi-\alpha)}{\sin(\theta-\delta)\sin(\theta+\alpha)}}\right]^2}$$

WHERE

$\theta = 90$ SLOPE OF WALL

$\alpha = -26°$

$\delta = 28°$ FRICTION ANGLE BETWEEN SOIL & WALL

$\delta = \phi$

$\phi = 28°$ FRICTION ANGLE OF RETAINED SOIL

$$K_a = \frac{\sin^2 118}{\sin^2 90 \sin 62\left[1+\sqrt{\frac{\sin 56 \sin 54}{\sin 62 \sin 64}}\right]^2}$$

$= 0.24$ FOR COMMON BORROW

FOR

$\phi = 38°$ #57 STONE $\delta = 38°$

$$k_a = \frac{\sin^2 128}{\sin^2 90 \sin 52\left[1+\sqrt{\frac{\sin 76 \sin 64}{\sin 52 \sin 64}}\right]^2}$$

$K_a = 0.18$ FOR #57

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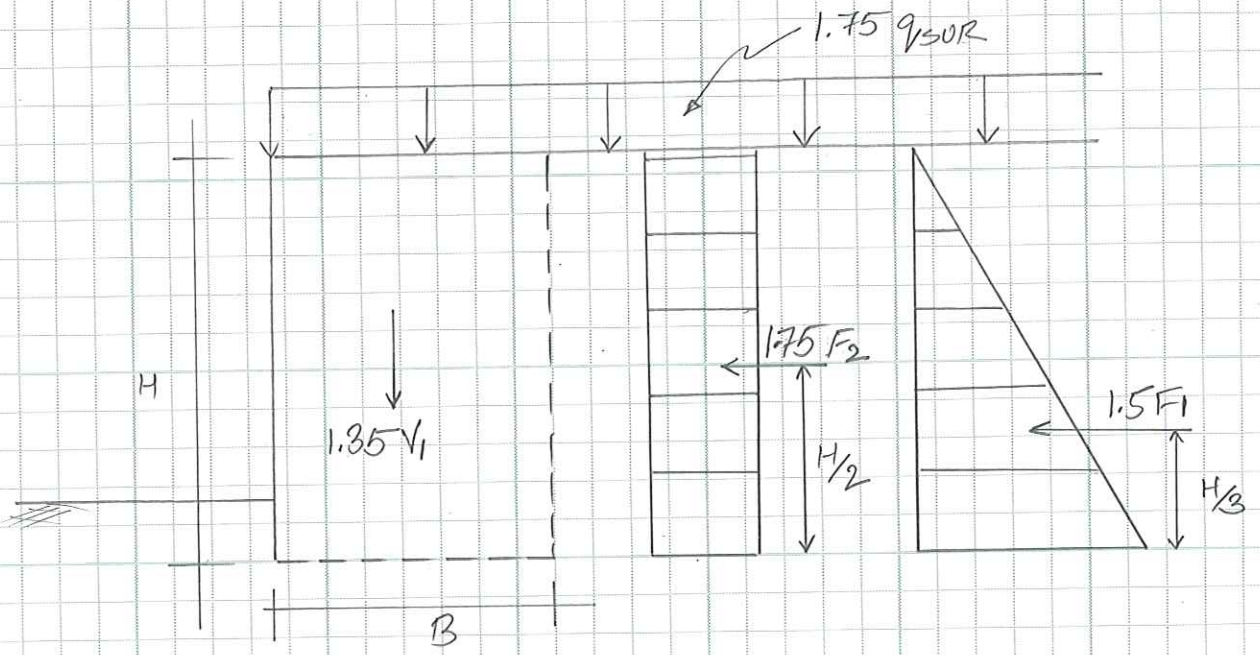
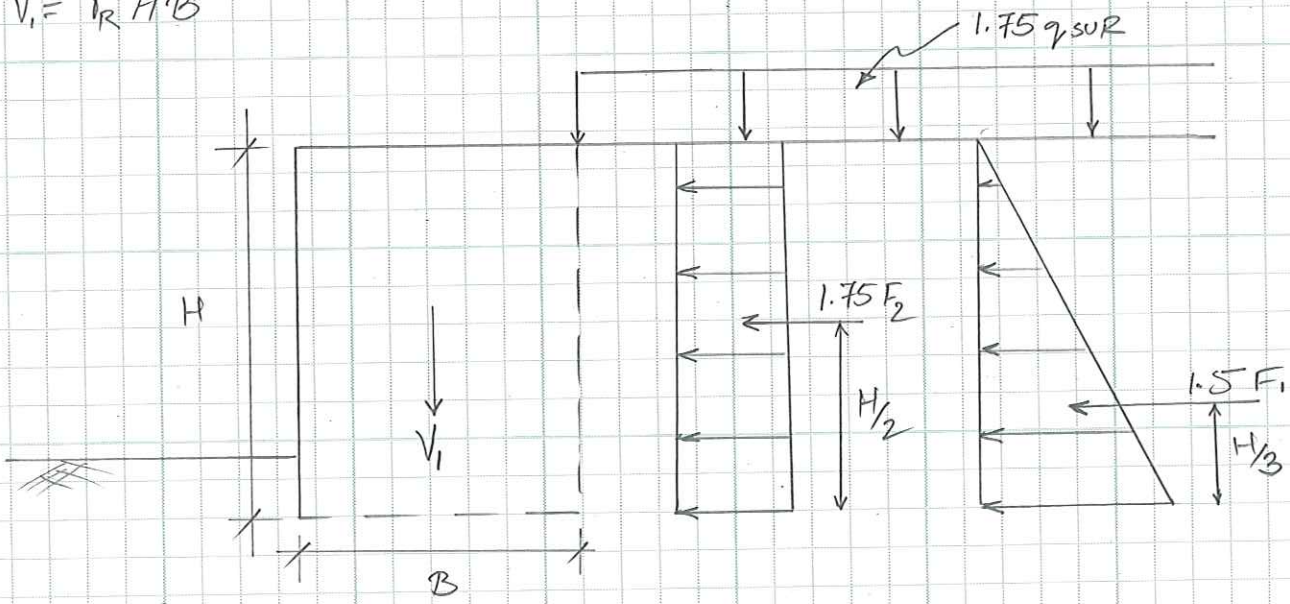


FOR BEARING PRESSURE CALCULATION

$F_1 = \frac{1}{2} K_a \gamma H^2$

$F_2 = K_a q_{SUR} H$

$V_1 = \gamma_R H B$



FOR ECCENTRICITY & SLIDING CALCULATION

STRENGTH LIMIT STATE

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STRENGTH LIMIT STATE

$H = 32\text{-ft}$

$B = 26\text{-ft} = 0.8H$ $\quad K_a = 0.24$

$q_{SUR} = 250\ psf$ $\quad \gamma = 130\ pcf$ $\quad \gamma_R = 125\ pcf$

$F_1 = \frac{1}{2} K_a \gamma H^2 = 15974.4\ lb/ft$

$F_2 = K_a q_{SUR} H = 1920\ lb/ft$

$V_1 = \gamma_R H B = 104000\ lb/ft$

ECCENTRICITY

$$e = \frac{1.5 F_1 \cos\alpha\ ^{H}/_{3} + 1.75 F_2 \cos\alpha\ ^{H}/_{2}}{V_1}$$

$$= \frac{1.5 \times 15974.4\ \cos -26\ ^{32}/_{3} + 1.75 \times 1920 \times \cos(-26)\ ^{32}/_{2}}{104000}$$

$= 2.67$

OVERTURNING STABILITY

RESULTANT OF REACTION FORCES SHALL BE WITHIN $\frac{1}{2}$ OF THE CENTER BASE WIDTH

ECCENTRICITY $< \frac{26}{4}$

$2.67 < 6.5$ OK

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SLIDING STABILITY

FACTORED RESISTANCE AGAINST SLIDING

$R_R = \phi R_n$

$\phi = 1.0$ Table 11.5.6-1

$R_n = V \tan \delta + CB$

δ = SMALLER OF ϕ_f & ϕ_R

ϕ_f = FOUNDATION SOIL

ϕ_R = REINFORCED SOIL

$\delta = 0$ UNDRAINED CONDITION

$C = 2000$ PSF

$R_n = 0 + 2000 \times 26 = 52000$ lb/ft

HORIZONTAL DRIVING FORCES

$R_{DR} = 1.5 F_1 + 1.75 F_2$

$= 1.5 \times 15974.4 + 1.75 \times 1920$

$= 27321.6$ lb/ft

$R_R = \phi R_n$

$= 52000$ lb/ft $> R_{DR}$ OK

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BEARING CAPACITY CHECK

STRENGTH LIMIT STATE

ECCENTRICITY

$$e = \frac{1.5 F_1 \cos\alpha \, 4/3 + 1.75 F_2 \cos\alpha \, 1/2}{1.35 V_1 + 1.75 q_{SUR} B}$$

$$= \frac{1.5 \times 15974.4 \cos(-26) \times 32/3 + 1.75 \times 1920 \times \cos(-26) \, 32/2}{1.35 \times 104000 + 1.75 \times 250 \times 26}$$

$$= \frac{278042.3}{151775}$$

$$= 1.83 \text{ ft}$$

EFFECTIVE FOOTING WIDTH

$$B' = B - 2e$$

$$= 26 - 2 \times 1.83$$

$$= 22.34 \text{ ft} \quad , B = 26' \quad L/H = 0.8$$

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EQUIVALENT UNIFORM VERTICAL STRESS ON THE BASE (MYERHOF)

$$\sigma_v = \frac{\Sigma V}{B-2e}$$

$$= \frac{1.35V_1 + 1.75qB}{B-2e}$$

$$= \frac{1.35\times 104000 + 1.75\times 250\times 26}{26-2\times 1.83}$$

$$= 6793.9 \text{ psf}.$$

EQUIVALENT FOOTING $B' = 26-2\times 1.83$

$= 22.34$ ft, $B=26'$, $t/H = 0.8$

BEARING CAPACITY CALCULATION

$$q_n = cN_c s_c i_t + \gamma D_f N_q s_q d_q i_q C_{wq} + 0.5\gamma B N_\gamma s_\gamma i_\gamma C_{w\gamma}$$

$c = 2000$ psf $\quad \phi = 0$ (UNDRAINED CONDITION)

$N_c = 5.14$ $\quad N_q = 0$ $\quad N_\gamma = 0$ $\quad$ 10.6.3.1.2a-1

$C_{wq} = 1$ $\quad C_{w\gamma} = 0.5$ $\quad$ 10.6.3.1.2a-2

$d_q = 1$ $\quad$ OUT OF RANGE $\quad$ 10.6.3.1.2a-4

$$S_c = 1 + \frac{B}{5L} = 1 + \frac{20.86}{5\times 361} = 1.01$$ $\quad$ 10.6.3.1.2a-3

$S_\gamma = 1$ $\quad S_q = 1$

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$q_n = 2000 \times (5.14) \times 1.01$

$= 10,382.8$ psf

$= 10,382.8 - p$ psf

FACTORED BEARING RESISTANCE

$q_R = \phi_b \, q_n$

$\phi_b = 0.65$ Table 11.5.6-1

$q_R = 10382.8 \times (0.65)$

$= 6748.8 < \sigma_v = 6793.9$ ← APPLIED BRG STRESS SEE PAGE 20 of 82

CDR = 0.99
FOR e/H = 0.8

REVISE DESIGN

1) INCREASE STRAP LENGTH (B = 1.0H)
2) USE #57 STONE IN REINFORCED ZONE

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STRENGTH LIMIT STATE (REDESIGN) W/ No. 57 Stone

H/N=1

$H = 32$ ft $K_a = 0.24$

$B = 32$ ft $\gamma = 130$ pcf $\gamma_R = 105$ pcf

$F_1 = \frac{1}{2} K_a \gamma H^2 = 15974.4$ lb/ft

$F_2 = K_a q_{surc} H = 1920$ lb/ft

$V_1 = \gamma_R H B = 107520$ lb/ft

ECCENTRICITY

$$e = \frac{1.5 F_1 \cos\alpha \frac{H}{3} + 1.75 F_2 \cos\alpha \frac{H}{2}}{V_1}$$

$$= \frac{1.5 \times 15974.4 \times \cos(-26) \times \frac{32}{3} + 1.75 \times 1920 \times \cos(-26) \frac{32}{2}}{107520}$$

$= 2.57$

OVERTURNING STABILITY

RESULTANT OF REACTION FORCES SHALL BE WITH IN ½ OF THE CENTER BASE WIDTH

$$\text{ECCENTRICITY} < \frac{32}{4}$$

$2.59 < 8$ OK

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BEARING CAPACITY CHECK

STRENGTH LIMIT STATE

ECCENTRICITY

$$e = \frac{1.5 F_1 \cos\alpha \, H/3 + 1.75 F_2 \cos\alpha \, H/2}{1.35 V_1 + 1.75 q_{SUR} B}$$

$$= \frac{1.5 \times 15974.4 \cos(-26) \times 32/3 + 1.75 \times 1920 \times \cos(-26) \, 32/2}{1.35 \times 107520 + 1.75 \times 250 \times 32}$$

$$= \frac{278042.3}{159152}$$

$$= 1.75$$

EFFECTIVE FOOTING WIDTH

$$B' = B - 2e$$

$$= 32 - 2 \times 1.75$$

$$= 28.5 \text{ ft}$$

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EQUIVALENT UNIFORM VERTICAL STRESS ON THE BASE (MYERHOF)

$$\sigma_v = \frac{\Sigma V}{B-2e}$$

$$= \frac{1.35\,V_1 + 1.75\,q_{SUR}\,B}{B-2e}$$

$$= \frac{1.35 \times 107520 + 1.75 \times 250 \times 32}{32 - 2\times 1.75}$$

$$= 5584 \text{ psf.}$$

EFFECTIVE FOOTING WIDTH

$$B' = B - 2e = 32 - 2\times 2.59 = 26.82 \text{ FT}$$

BEARING CAPACITY

$$q_n = cN_c S_c i_q + \gamma D_f N_q S_q d_q i_q C_{wq} + 0.5\gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$$

$C = 2000$ psf $\phi = 0$ UNDRAINED CONDITION

$N_c = 5.14$	$N_q = 1$	$N_\gamma = 0$	10.6.3.1.2a-1
$C_{wq} = 1$	$C_{w\gamma} = 0.5$		10.6.3.1.2a-2
$d_q = 1$	OUT OF RANGE		10.6.3.1.2a-4

$$S_c = 1 + \frac{B}{5L} = 1 + \frac{26.82}{5\times 361} = 1.01$$ 10.6.3.1.2a-3

$S_\gamma = 1$ $S_q = 1$

NO INCLINATION EFFECTS OF OVERBURDEN NEGLECTED PER AASHTO

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$q_n = 2000 \times 5.14 \times 1.01$

$= 10382.8$ psf

FACTORED BEARING RESISTANCE

$q_R = \phi_b q_n$

$\phi_b = 0.65$ 11.5.6-1

$q_R = 0.65 \times 10382.8$

$= 6748.8 > \sigma_v = 5584$ psf

BRG STRESS SEE PAGE 24 of 82

CDR = 1.21

FOR L = 1.0H
B = 32.0

OK

CHECK FOR BEARING CAPACITY (LONG TERM DRAINED) (CONT'D)

$\phi = 24$ $c = 0$ psf (COHESION = 0 FOR LONG TERM ANALYSIS)

$q_n = c N_c s_c i_q + \gamma D_f N_q s_q d_q i_q C_{wq} + 0.5 \gamma B N_\gamma s_\gamma i_\gamma C_{w\gamma}$

$N_c = 19.3$ $N_\gamma = 9.4$ $N_q = 9.6$ 10.6.3.1.2a-1

$C_{wq} = 1$ $C_{w\gamma} = 0.5$ 10.6.3.1.2a-2

$d_q = 1$ OUT OF RANGE 10.6.3.1.2a-4

$s_c = 1 + \frac{B}{L}\left(\frac{N_q}{N_c}\right) = 1 + \frac{28.5}{361} \times \frac{9.6}{9.4} = 1.08$

$s_\gamma = 1 - 0.4\frac{B}{L} = 1 - 0.4\frac{28.5}{361} = 0.97$

$s_q = 1 + \frac{B}{L}\tan\phi_f = 1 + \frac{28.5}{361}\tan 24° = 1.03$

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NO INCLINATION

$q_n = 0 \times 19.3 \times 1.08 + 0 + 0.5 \times 130 \times 28.5 \times 9.4 \times 0.97 \times 0.5$

$= 0 + 8445$

$q_n = \underline{8445 \text{ psf}}$

FACTORED BEARING RESISTANCE

$q_R = \phi_b q_n$

$\phi_b = 0.65$ 11.5.6.1

$q_R = 0.65 \times 8445$

$= \underline{5489} < q_v = 5584$ psf NOT O.K

CDR = 0.98 $L/H = 1.0$ FOR DRAINED

MSE WALL DIMENSION

MAX WALL HEIGHT = 32-ft.

STRAP LENGTH = 32-ft

REINFORCED ZONE → #57 STONE $\gamma = 105$ pcf $\phi = 38°$

RETAINED SOIL → COMMON BORROW $\gamma = 125$ pcf $\phi = 28°$

FOUNDATION SOIL → FINE GRAINED

* REDESIGN WITH #57 REINFORCED ZONE
SELECT BACKFILL RETAINED

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STRENGTH LIMIT STATE (REDESIGN) No ST in reinforcent Zone select in retained

4/N=1

H = 32-ft REINFORCED SOIL γ_R = 105pcf ϕ = 38° (#57)

B = 32-ft RETAINED SOIL γ = 125pcf ϕ = 34°

ACTIVE EARTH PRESSURE COEFFICIENT

COULUMBS METHOD

$$K_a = \frac{\sin^2(\phi+\theta)}{\sin^2\theta \sin(\theta-\delta)\left[1+\sqrt{\frac{\sin(\delta+\phi)\sin(\phi-\alpha)}{\sin(\theta-\delta)\sin(\theta+\alpha)}}\right]^2}$$

WHERE,

θ = 90 SLOPE OF WALL

α = -26 BACK SLOPE

$\delta = \phi$ = 34° FRICTION ANGLE BETWEEN SOIL & WALL

ϕ = 34° FRICTION OF RETAINED SOIL

$$K_a = \frac{\sin^2 124}{\sin^2 90 \sin 56\left[1+\sqrt{\frac{\sin 68 \sin 60}{\sin 56 \sin 64}}\right]^2}$$

$$= \frac{0.6873}{3.4436}$$

$$= 0.20$$

0.621

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$F_1 = \frac{1}{2} K_a \gamma H^2 = \frac{1}{2} \times 0.2 \times 125 \times 32^2 = 12800$ Lb/ft

$F_2 = K_a q_{sur} H = 0.20 \times 250 \times 32 = 1600$ Lb/ft.

$V_1 = \gamma_R H B = 105 \times 32 \times 32 = 107520$ Lb/ft

ECCENTRICITY:

$$e = \frac{1.5 F_1 \cos\alpha \frac{H}{3} + 1.75 F_2 \cos\alpha \frac{H}{2}}{V_1}$$

$$= \frac{1.5 \times 12800 \times \cos(-26) \frac{32}{3} + 1.75 \times 1600 \times \cos(-26) \times \frac{32}{2}}{107520}$$

$$= \frac{224339}{107520}$$

$$= 2.086$$

OVERTURNING STABILITY

RESULTANT OF REACTION FORCES SHALL BE WITHIN ½ OF THE CENTER BASE WIDTH

$$\text{ECCENTRICITY} < \frac{32}{4}$$

$$2.086 < 8$$

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SLIDING STABILITY

FACTORED RESISTANCE AGAINST SLIDING

$R_R = \phi R_n$

$\phi = 1.0$ Table 11.5.6-1

$R_n = V \tan\delta + cB$

δ = Smaller of ϕ_f & ϕ_R

ϕ_f = FOUNDATION SOIL = 24° (DRAINED CONDITION)

ϕ_R = REINFORCED SOIL = 38°

C=0 (DRAINED CONDITION

$R_n = V \tan\delta$

$= (105 \times 32 \times 32) \tan 24$

$= 47870$ lb/ft

HORIZONTAL DRIVING FORCES

$R_{DR} = 1.5F_1 + 1.75F_2$

$= 1.5 \times 12800 + 1.75 \times 1600$

$= 22000$ lb/ft

$R_R = \phi R_n$

$= 1 \times 47870 = 47870$ lb/ft $> R_{DR}$ OK

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BEARING CAPACITY CHECK

STRENGTH LIMIT STATE

ECCENTRICITY

$$e = \frac{1.5 F_1 \cos\alpha\, H/3 + 1.75 F_2 \cos\alpha\, H/2}{1.35 V_1 + 1.75 q_{SUR} B}$$

$$= \frac{1.5 \times 12800 \times \cos -26 \times 32/3 + 1.75 \times 1600 \times \cos(-26)\, 32/2}{1.35 \times 107520 + 1.75 \times 250 \times 32}$$

$$= \frac{224339}{159152}$$

$$= 1.41$$

EFFECTIVE FOOTING WIDTH

$$B' = B - 2e$$

$$= 32 - 2 \times 1.41$$

$$= 29.18$$

FOR B=32', L/H=1

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EQUIVALENT UNIFORM VERTICAL STRESS ON THE BASE (MYERHOF)

$$\sigma_V = \frac{\Sigma V}{B-2e}$$

$$= \frac{1.35 V_1 + 1.75 q_{SUR} B}{B-2e}$$

$$= \frac{1.35 \times 107520 + 1.75 \times 250 \times 32}{32 - 2 \times 1.41}$$

$$= \frac{159152}{29.18}$$

$$\sigma_V = 5454 \text{ psf}$$

CHECK FOR BEARING CAPACITY (LONG TERM DRAINED CONDITION)

$\phi = 24^\circ$ $c = 0$ psf. $B' = B - 2e = 29.18$ ft.

$$q_n = cN_c^0 S_c + \gamma D_f N_q S_q^0 d_q C_{wq} + 0.5 \gamma B N_\gamma S_\gamma C_{w\gamma}$$

$N_\gamma = 9.4$ 10.6.3.1.2a-1

$C_{w\gamma} = 0.5$ 10.6.3.1.2a-2

$$S_\gamma = 1 - 0.4 \frac{B}{L} = 1 - 0.4 \frac{29.18}{361} = 0.967$$

$$q_n = 0.5 \times 130 \times 29.18 \times 9.4 \times 0.967 \times 0.5$$

$$= 8620.3 \text{ psf}$$

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FACTORED BEARING RESISTANCE

$q_R = \phi_b q_n$

$\phi_b = 0.65$ 11.5.6.1

$q_R = 0.65 \times 8620.3$

$= 5603$ psf $> G_v = 5454$ psf OK

UNDRAINED CONDITION

$\phi = 0$ $C = 2000$psf

$q_n = CN_c S_c + \gamma D_f N_q \cancel{S_q}^{0} d_q C_{wq} + 0.5 \gamma B \cancel{N_\gamma}^{0} S_\gamma C_{w\gamma}$

$N_c = 5.14$ for $\phi = 0$ 10.6.3.1.2a-1

$S_c = 1 + \frac{B}{5L} = 1 + \frac{29.18}{5 \times 361} = 1.016$ 10.6.3.1.2a-3

$q_n = 2000 \times 5.14 \times 1.016$

$= 10444$ psf

FACTORED BEARING RESISTANCE

$q_R = \phi q_n$

$= 0.65 \times 10444$ psf

$= 6788$ psf $> G_v = 5454$ psf OK

* For plane $q_R = 5600$ psf L/N = 1
No 57 in reinforced zone
select at wedge.

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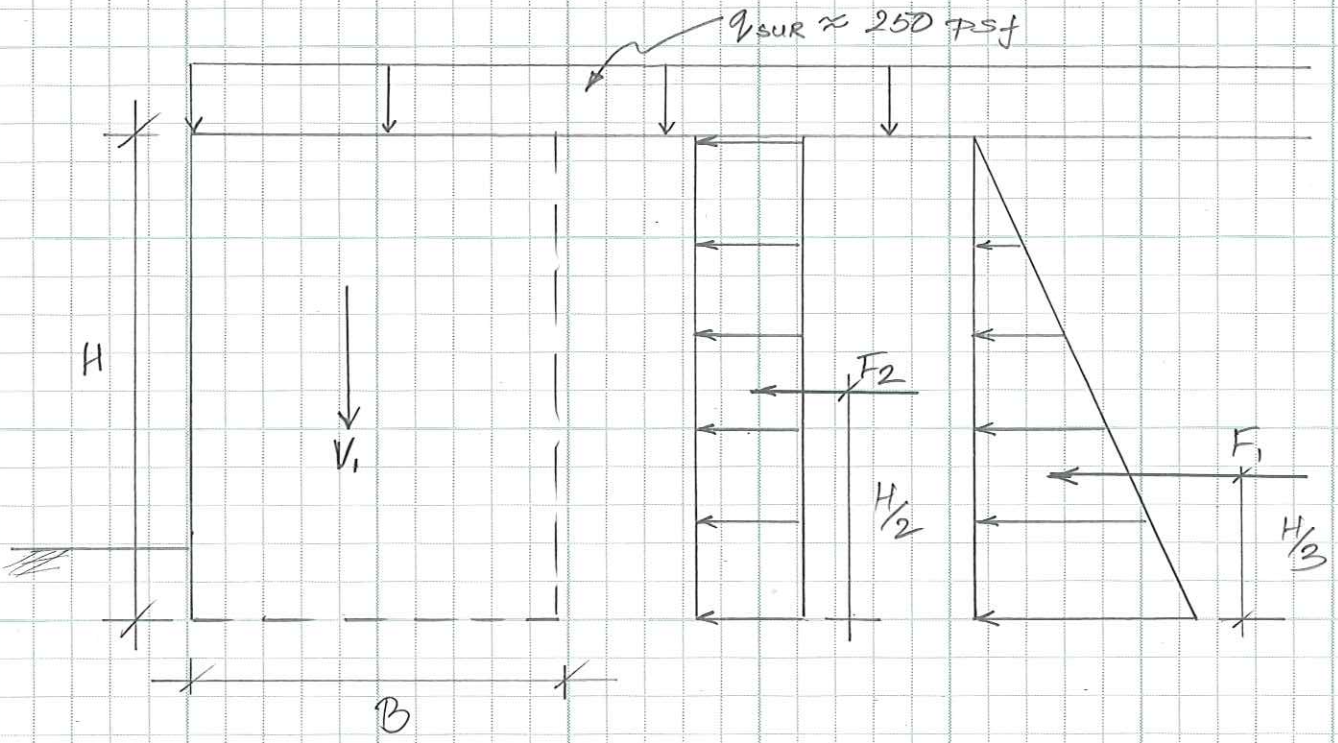

$F_1 = \frac{1}{2} K_a \gamma H^2$ $\quad \gamma$ = RETAINED SOIL

$F_2 = K_a H q_{SUR}$

$V_1 = \gamma_R H B$ $\quad \gamma_R$ = REINFORCED SOIL

SERVICE LIMIT STATE

FOR SETTLEMENT ANALYSIS

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SERVICE LIMIT STATE

BEARING PRESSURE FOR SETTLEMENT CALCULATION

$H = 32\text{-ft}$ $K_a = 0.20$ $q_{SUR} = 250\text{ psf}$

$B = 32\text{ ft}$

$\gamma_R = 105\text{ pcf}$

$F_1 = \frac{1}{2} K_a \gamma H^2 = 12800\text{ lb/ft}$

$F_2 = K_a q_{SUR} H = 1600\text{ lb/ft}$

$V_1 = 105 \times 32 \times 32 = 107520\text{ lb/ft}$

ECCENTRICITY

$$e = \frac{F_1 \cos\alpha \, H/3 + F_2 \cos\alpha \, H/2}{V_1 + q_{SUR} B}$$

$$= \frac{12800 \times \cos(-26) \times 32/3 + 1600 \times \cos(-26) \times 32/2}{107520 + 250 \times 32}$$

$$= \frac{145724.5}{115520}$$

$$= 1.26$$

$$B' = B - 2e = 32 - 2 \times 1.26 = 29.48\text{-ft}$$

EQUIVALENT UNIFORM VERTICAL STRESS ON THE BASE

$$\sigma_V = \frac{\Sigma V}{B - 2e} = \frac{V_1 + q_{SUR} B}{B - 2e} = \frac{107520 + 250 \times 32}{29.48}$$

$$\boxed{\sigma_V = 3918.6\text{ psf}}$$

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GLOBAL STABILITY.

CHECK FOR GLOBAL STABILITY FOR HIGHEST PORTION OF WALL

SEE CROSS SECTION @ RAMP C STA 1114+00

SOIL PARAMETERS

UNDRAINED

EL 40 & ABOVE	$\gamma = 130$ pcf	$c = 2000$ psf	STRATUM IIa
EL 20 TO 40	$\gamma = 130$ pcf	$c = 3000$ psf	
EL 11 TO 20	$\gamma = 130$ pcf	$c = 4000$ psf	
EL 11 & BELOW	$\gamma = 125$ pcf	$\phi = 34°$	STRATUM IIb

WATER TABLE @ FOOTING LEVEL EL 69

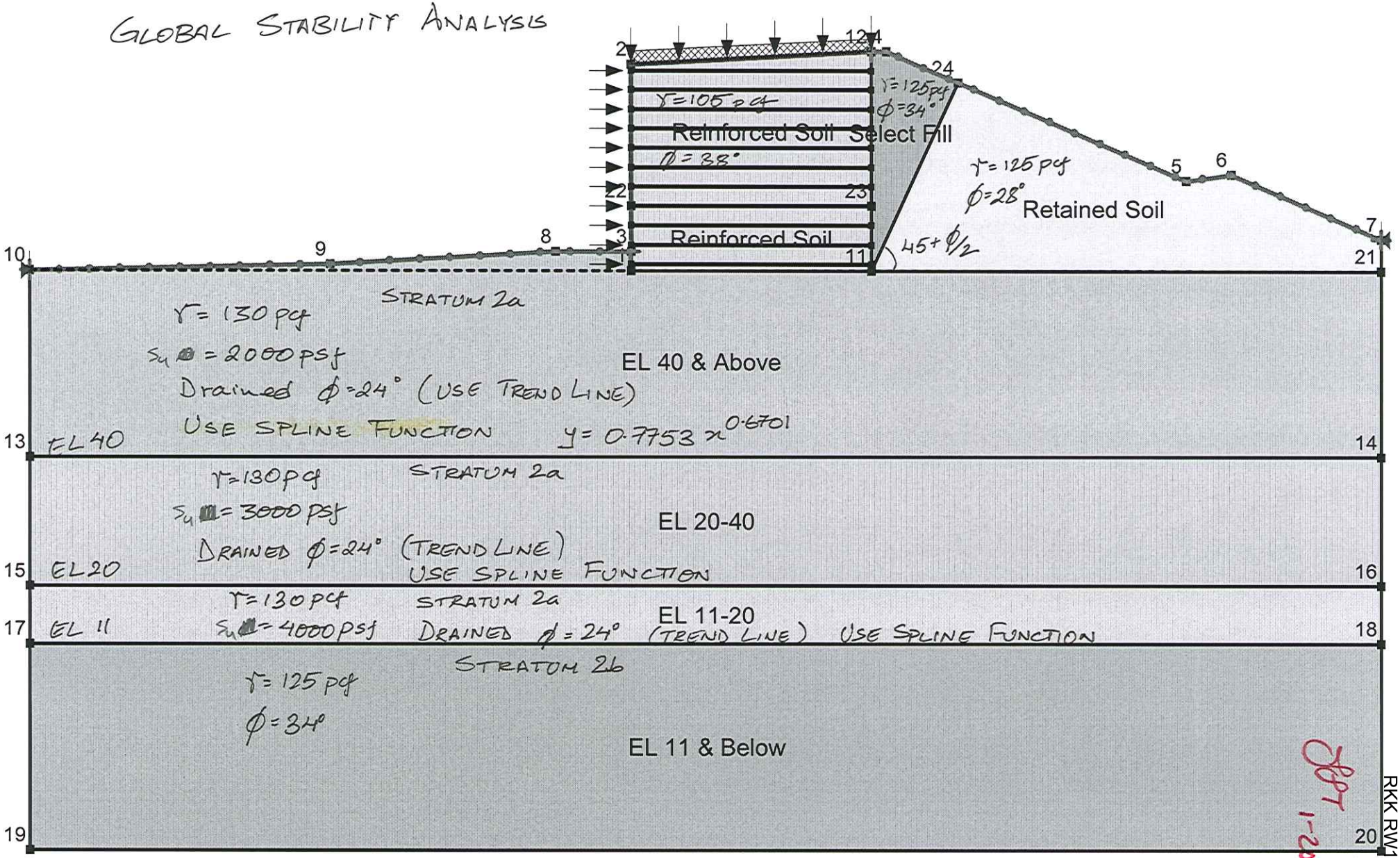
DRAINED

EL 11 & ABOVE (STRATUM IIa)	$\gamma = 130$ pcf	SHEAR STRENGTH FUNCTION SPLINE	$y = 0.7753\,x^{0.6701}$
EL 11 & BELOW	$\gamma = 125$ pcf	$\phi = 34°$, $c = 0$	STRATUM 2b

SUMMARY OF RESULTS

CONDITION	FACTOR OF SAFETY	FACTORED RESISTANCE
UNDRAINED	2.475	$0.40 < 0.65$ ok
DRAINED	1.745	$0.57 < 0.65$ ok

GLOBAL STABILITY ANALYSIS



RETAINING WALL 10

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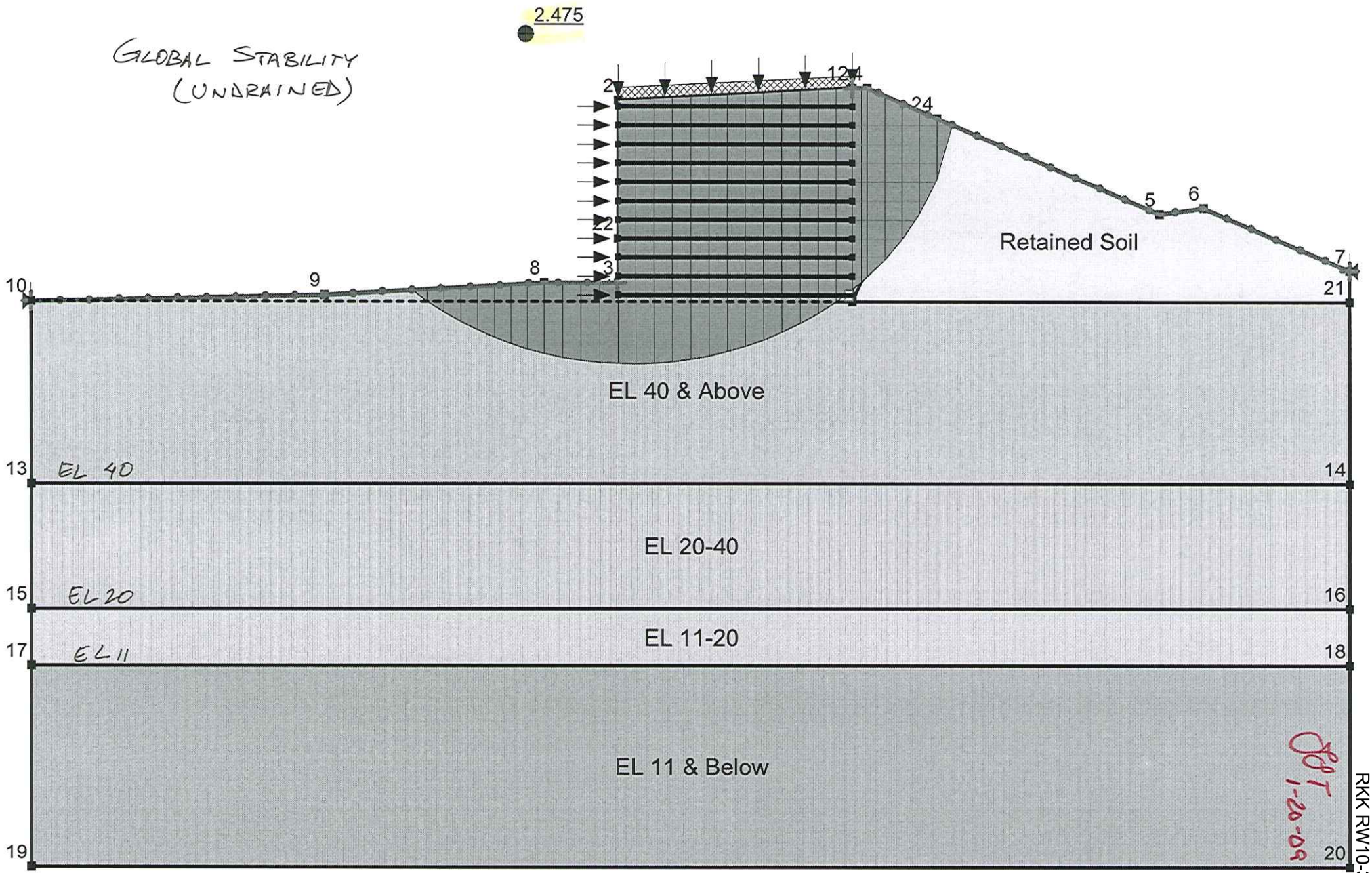
RKK RW10-38


GLOBAL STABILITY
(UNDRAINED)
2.475
2
12
24
5
6
7
10
9
8
3
22
21
Retained Soil
EL 40 & Above
13
EL 40
14
EL 20-40
15
EL 20
16
EL 11-20
17
EL 11
18
EL 11 & Below
19
20
RETAINING WALL 10
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RKK RW10-39

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Slope Stability

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File Information

Revision Number: 52
Date: 1/20/2009
Time: 8:39:15 AM
File Name: RW-10 wo CLSM (undrained).gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Retaining Wall 10\Global Stability\
Last Solved Date: 1/20/2009
Last Solved Time: 8:39:30 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Slope Stability

Description: Retaining Wall 10
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Apply Phreatic Correction: No
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

SlipSurface
- Direction of movement: Right to Left
- Allow Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: No
- Tension Crack
  - Tension Crack Option: (none)

SPT 1-20-09

FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1

Materials

Retained Soil

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

select

Reinforced Soil

Model: Mohr-Coulomb
Unit Weight: 105 pcf
Cohesion: 0 psf
Phi: 38 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

No ST stone

EL 40 & Above

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 2000 psf
Pore Water Pressure
Piezometric Line: 1

EL 20-40

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 3000 psf
Pore Water Pressure
Piezometric Line: 1

JJT 1-20-09

EL 11-20

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 4000 psf
Pore Water Pressure
Piezometric Line: 1

EL 11 & Below

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 32 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Select Fill

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (20, 100) ft
Left-Zone Right Coordinate: (99.9, 103) ft
Left-Zone Increment: 20
Right Projection: Range
Right-Zone Left Coordinate: (132, 134) ft
Right-Zone Right Coordinate: (200, 105) ft
Right-Zone Increment: 20
Radius Increments: 20

Slip Surface Limits

Left Coordinate: (20, 100) ft
Right Coordinate: (200, 105) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	20	100
	200	100

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	100	134
	132	136

for 2' = 250 psf

Reinforcements

Reinforcement 1

Type: Fabric
Outside Point: (100, 101) ft
Inside Point: (132, 101) ft
Slip Surface Intersection: (130.95, 101) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Fabric Load Used: 393.06 lbs
Resisting Force Used: 373.63 lbs/ft
Available Bond Length: 1.052 ft
Required Bond Length: 1.052 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (100, 104) ft
Inside Point: (132, 104) ft
Slip Surface Intersection: (134.09, 104) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 353.91 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (100, 107) ft
Inside Point: (132, 107) ft
Slip Surface Intersection: (136.65, 107) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice

Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 300.96 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (100, 110) ft
Inside Point: (132, 110) ft
Slip Surface Intersection: (138.82, 110) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 239.6 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (100, 113) ft
Inside Point: (132, 113) ft
Slip Surface Intersection: (140.58, 113) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1

Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 239.6 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (100, 116) ft
Inside Point: (132, 116) ft
Slip Surface Intersection: (142.03, 116) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 164.09 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (100, 119) ft
Inside Point: (132, 119) ft
Slip Surface Intersection: (143.32, 119) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1

Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 164.09 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (100, 122) ft
Inside Point: (132, 122) ft
Slip Surface Intersection: (144.16, 122) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 60.888 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (100, 125) ft
Inside Point: (132, 125) ft
Slip Surface Intersection: (144.89, 125) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °

Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 60.888 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (100, 128) ft
Inside Point: (132, 128) ft
Slip Surface Intersection: (145.62, 128) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 60.888 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (100, 131) ft
Inside Point: (132, 131) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Regions

	Material	Points	Area (ft^2)
Region 1	Reinforced Soil	2,12,23,22	736
Region 2	EL 40 & Above	3,8,9,10,13,14,21,11,1	5330
Region 3	Retained Soil	24,5,6,7,21,11	1113.7513
Region 4	EL 20-40	13,15,16,14	3600
Region 5	EL 11-20	15,17,18,16	1620
Region 6	EL 11 & Below	17,18,20,19	5760
Region 7	Reinforced Soil	22,23,11,1,3	320
Region 8	Select Fill	12,4,24,11,23	201.24874

Points

	X (ft)	Y (ft)
Point 1	100	100
Point 2	100	132
Point 3	100	103
Point 4	134	134
Point 5	174	114
Point 6	180	115
Point 7	200	105
Point 8	90	103
Point 9	60	101

Point 10	20	100
Point 11	132	100
Point 12	132	134
Point 13	20	71
Point 14	200	71
Point 15	20	51
Point 16	200	51
Point 17	20	42
Point 18	200	42
Point 19	20	10
Point 20	200	10
Point 21	200	100
Point 22	100	110
Point 23	132	110
Point 24	143.55707	129.22146

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	5836	2.475	(101.909, 134.248)	44.168	(145.657, 128.172)	(71.9474, 101.796)

Slices of Slip Surface: 5836

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	5836	72.983	100.89825	-56.051322	868.74442	0	2000
2	5836	75.160135	99.130495	54.255641	1125.1138	0	2000
3	5836	77.44319	97.500965	155.9397	1379.5072	0	2000
4	5836	79.72625	96.07753	244.76246	1612.0951	0	2000
5	5836	82.009305	94.837715	322.12609	1817.5235	0	2000
6	5836	84.29236	93.76456	389.09062	1991.5602	0	2000
7	5836	86.575415	92.84504	446.47955	2131.3135	0	2000
8	5836	88.85847	92.069065	494.88565	2235.124	0	2000
9	5836	91.25	91.404865	536.32988	2292.8617	0	2000

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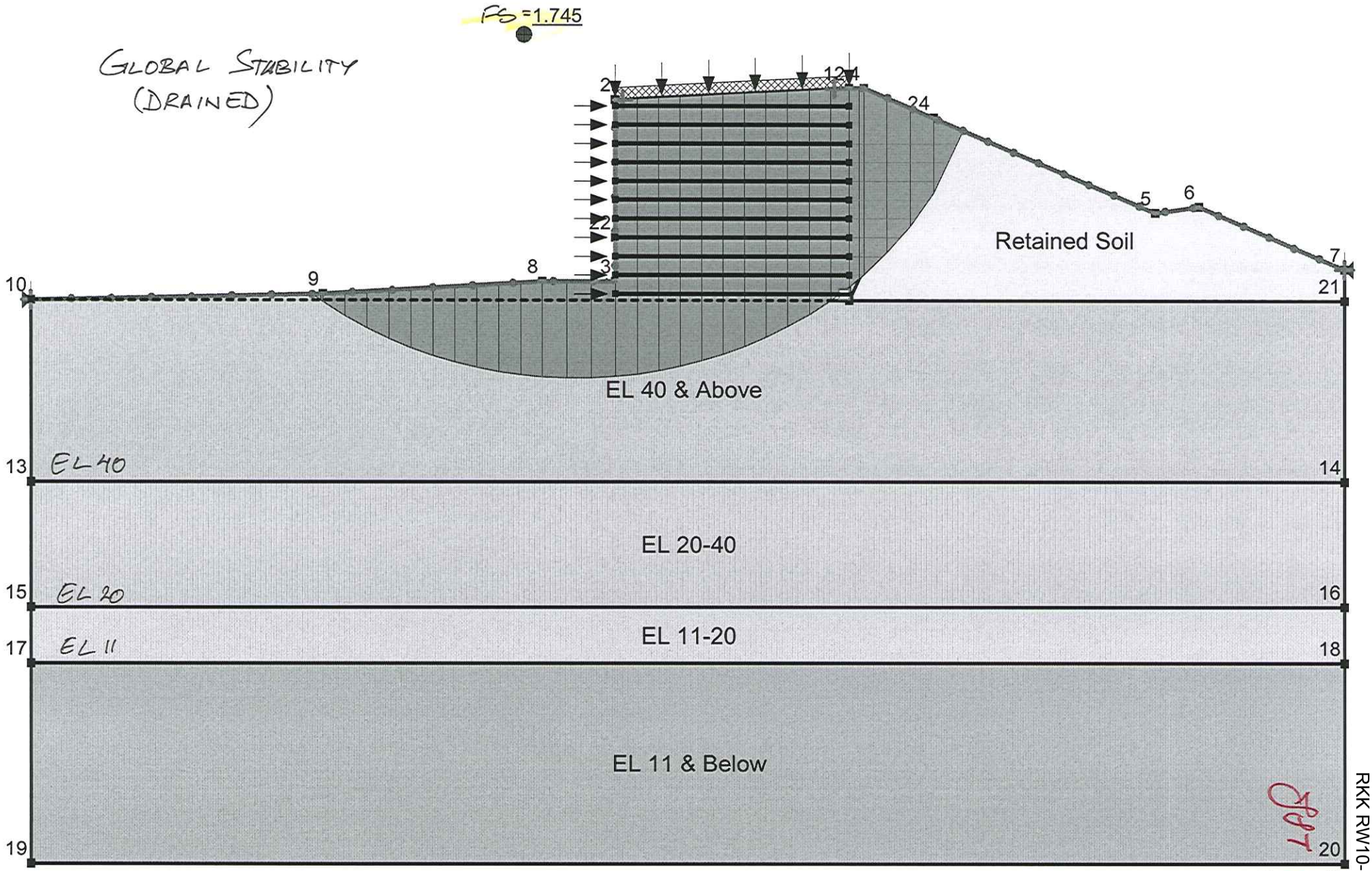
10	5836	93.75	90.85881	570.40244	2301.6584	0	2000
11	5836	96.25	90.462195	595.16962	2270.7925	0	2000
12	5836	98.75	90.210965	610.83017	2203.6965	0	2000
13	5836	101.24165	90.102515	617.61302	5347.0897	0	2000
14	5836	103.72495	90.13485	615.59186	5182.6397	0	2000
15	5836	106.20825	90.307445	604.80922	4992.0506	0	2000
16	5836	108.69155	90.621965	585.2037	4781.6637	0	2000
17	5836	111.17485	91.081525	556.52345	4556.1297	0	2000
18	5836	113.6582	91.69084	518.47481	4320.3	0	2000
19	5836	116.14155	92.456485	470.73093	4076.8219	0	2000
20	5836	118.62485	93.38729	412.62404	3826.5839	0	2000
21	5836	121.10815	94.494905	343.5183	3570.6554	0	2000
22	5836	123.59145	95.794695	262.4103	3307.1204	0	2000
23	5836	126.07475	97.307075	168.03894	3032.7886	0	2000
24	5836	128.55805	99.059665	58.675748	2741.9468	0	2000
25	5836	130.89985	100.95805	-59.783965	2502.8859	1955.4687	0
26	5836	132.61375	102.5099	-156.61768	2649.3091	1786.9815	0
27	5836	133.61375	103.502	-218.52014	2630.6588	1398.7461	0
28	5836	135.19465	105.2726	-328.99691	2387.9207	1269.6799	0
29	5836	137.5839	108.28655	-517.07256	1979.3861	1052.4582	0
30	5836	139.97315	111.96925	-746.87419	1525.9895	811.38303	0
31	5836	142.36245	116.77635	-1046.8493	987.14119	524.87228	0
32	5836	144.60705	123.85695	-1488.6958	304.13488	161.71139	0


FS =1.745
GLOBAL STABILITY
(DRAINED)
2
12
4
24
5
6
7
22
3
8
9
10
21
Retained Soil
EL 40 & Above
13
EL 40
14
EL 20-40
15
EL 20
16
EL 11-20
17
EL 11
18
EL 11 & Below
19
20
RETAINING WALL 10
RAMP C STA 1114+00
RKK RW10-52
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EMC
2/8/09

Slope Stability

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File Information

Revision Number: 44
Date: 1/20/2009
Time: 8:50:45 AM
File Name: RW-10 wo CLSM (Drained).gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Retaining Wall 10\Global Stability\
Last Solved Date: 1/20/2009
Last Solved Time: 8:51:06 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Slope Stability

Description: Retaining Wall 10
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
    Apply Phreatic Correction: No
    Side Function
        Interslice force function option: Half-Sine
    PWP Conditions Source: Piezometric Line
    Use Staged Rapid Drawdown: No
SlipSurface
    Direction of movement: Right to Left
    Allow Passive Mode: No
    Slip Surface Option: Entry and Exit
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: No
    Tension Crack
        Tension Crack Option: (none)

FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1

Materials

Retained Soil

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Reinforced Soil

Model: Mohr-Coulomb
Unit Weight: 105 pcf
Cohesion: 0 psf
Phi: 38 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

EL 40 & Above

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: spline
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

EL 20-40

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: spline
Phi-B: 0 °
Pore Water Pressure

Piezometric Line: 1

EL 11-20

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: spline
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

EL 11 & Below

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 32 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Type B

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (20, 100) ft
Left-Zone Right Coordinate: (101, 132.0625) ft
Left-Zone Increment: 20
Right Projection: Range
Right-Zone Left Coordinate: (129.96124, 133.87258) ft
Right-Zone Right Coordinate: (200, 105) ft
Right-Zone Increment: 20
Radius Increments: 20

Slip Surface Limits

Left Coordinate: (20, 100) ft
Right Coordinate: (200, 105) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	20	100
	200	100

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	100	134
	132	136

for 2' = 250 psf.

Reinforcements

Reinforcement 1

Type: Fabric
Outside Point: (100, 101) ft
Inside Point: (132, 101) ft
Slip Surface Intersection: (130.6, 101) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs

Fabric Load Used: 738.43 lbs
Resisting Force Used: 528.32 lbs/ft
Available Bond Length: 1.3977 ft
Required Bond Length: 1.3977 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (100, 104) ft
Inside Point: (132, 104) ft
Slip Surface Intersection: (133.87, 104) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 539.08 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (100, 107) ft
Inside Point: (132, 107) ft
Slip Surface Intersection: (136.6, 107) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice

Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 488.04 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (100, 110) ft
Inside Point: (132, 110) ft
Slip Surface Intersection: (138.96, 110) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 390.34 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (100, 113) ft
Inside Point: (132, 113) ft
Slip Surface Intersection: (141.04, 113) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1

Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 276.78 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (100, 116) ft
Inside Point: (132, 116) ft
Slip Surface Intersection: (142.85, 116) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 276.78 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (100, 119) ft
Inside Point: (132, 119) ft
Slip Surface Intersection: (144.3, 119) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1

Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 107.63 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (100, 122) ft
Inside Point: (132, 122) ft
Slip Surface Intersection: (145.53, 122) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 107.63 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (100, 125) ft
Inside Point: (132, 125) ft
Slip Surface Intersection: (146.76, 125) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °

Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 107.63 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (100, 128) ft
Inside Point: (132, 128) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (100, 131) ft
Inside Point: (132, 131) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 32 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 12000 lbs
Fabric Safety Factor: 1
Fabric Load: 12000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 12000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Shear/Normal Strength Functions

spline

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 27 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (1000, 775.3)
Data Point: (2000, 1233.6)
Data Point: (3000, 1618.8)
Data Point: (4000, 1963)
Data Point: (5000, 2279)
Data Point: (10000, 3627)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft^2)
Region 1	Reinforced Soil	2,12,23,22	736
Region 2	EL 40 & Above	3,8,9,10,13,14,21,11,1	5330

Region 3	Retained Soil	24,5,6,7,21,11	1113.7513
Region 4	EL 20-40	13,15,16,14	3600
Region 5	EL 11-20	15,17,18,16	1620
Region 6	EL 11 & Below	17,18,20,19	5760
Region 7	Reinforced Soil	22,23,11,1,3	320
Region 8	Type B	12,4,24,11,23	201.24874

Points

	X (ft)	Y (ft)
Point 1	100	100
Point 2	100	132
Point 3	100	103
Point 4	134	134
Point 5	174	114
Point 6	180	115
Point 7	200	105
Point 8	90	103
Point 9	60	101
Point 10	20	100
Point 11	132	100
Point 12	132	134
Point 13	20	71
Point 14	200	71
Point 15	20	51
Point 16	200	51
Point 17	20	42
Point 18	200	42
Point 19	20	10
Point 20	200	10
Point 21	200	100
Point 22	100	110
Point 23	132	110
Point 24	143.55707	129.22146

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	3208	1.745	(94.557, 143.057)	55.415	(147.648, 127.176)	(58.5163, 100.963)

Slices of Slip Surface: 3208

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	3208	59.094345	100.48145	-30.042685	116.70121	104.82403	0.40674
2	3208	59.83618	99.8683	8.2180773	256.42837	218.38065	3.9116
3	3208	61.5	98.62071	86.068909	516.24764	358.10624	20.341
4	3208	64.5	96.53567	216.17485	944.9863	509.88338	98.951
5	3208	67.5	94.726755	329.0441	1309.1086	523.94337	240.86
6	3208	70.5	93.16373	426.56849	1617.2792	586.6769	285.04
7	3208	73.5	91.823955	510.18788	1876.7934	643.19228	313.21
8	3208	76.5	90.690205	580.93237	2085.4322	684.3403	335.86
9	3208	79.5	89.74928	639.6399	2242.3966	712.31992	352.08
10	3208	82.5	88.99107	686.95798	2348.5406	728.58841	361.76
11	3208	85.5	88.40795	723.33301	2406.2431	734.44097	365.26
12	3208	88.5	87.99434	749.14731	2419.2057	730.91528	363.17
13	3208	91.666665	87.74223	764.88624	2372.5824	713.64171	352.94
14	3208	95	87.668455	769.47538	2269.0374	682.85252	335.12
15	3208	98.333335	87.795665	761.54423	2131.9587	644.2547	313.94
16	3208	101.4721	88.094755	742.89949	5211.5857	1415.9199	698.35
17	3208	104.4163	88.546215	714.70923	4979.3014	1373.0706	676.02
18	3208	107.36055	89.162185	676.27049	4732.7368	1326.798	654.75
19	3208	110.3048	89.948405	627.20598	4476.8328	1281.3467	631.93
20	3208	113.249	90.9126	567.06913	4214.0117	1236.6216	608.54
21	3208	116.1932	92.06491	495.14098	3946.495	1192.3059	585.96
22	3208	119.1374	93.418495	410.69343	3673.8084	1148.1641	564.42
23	3208	122.0816	94.990435	312.60648	3395.1669	1104.5056	543.99
24	3208	125.02585	96.803125	199.48406	3107.2769	1063.4681	521.79
25	3208	127.9701	98.88642	69.48833	2805.7542	1023.1568	498.7

26	3208	130.7211	101.1024	-68.790618	2420.109	1890.7964	0
27	3208	132.69795	102.8672	-178.91029	2531.5357	1707.5424	0
28	3208	133.69795	103.83095	-239.04662	2541.5182	1351.3492	0
29	3208	135.59285	105.891	-367.60468	2254.0942	1198.5231	0
30	3208	138.77855	109.7655	-609.36216	1738.0302	924.12703	0
31	3208	141.96425	114.52815	-906.54891	1176.4742	625.54243	0
32	3208	145.60265	122.17545	-1383.7615	409.10366	217.52427	0

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Subject SR-1 INTERCHANGE
RETAINING WALL 10

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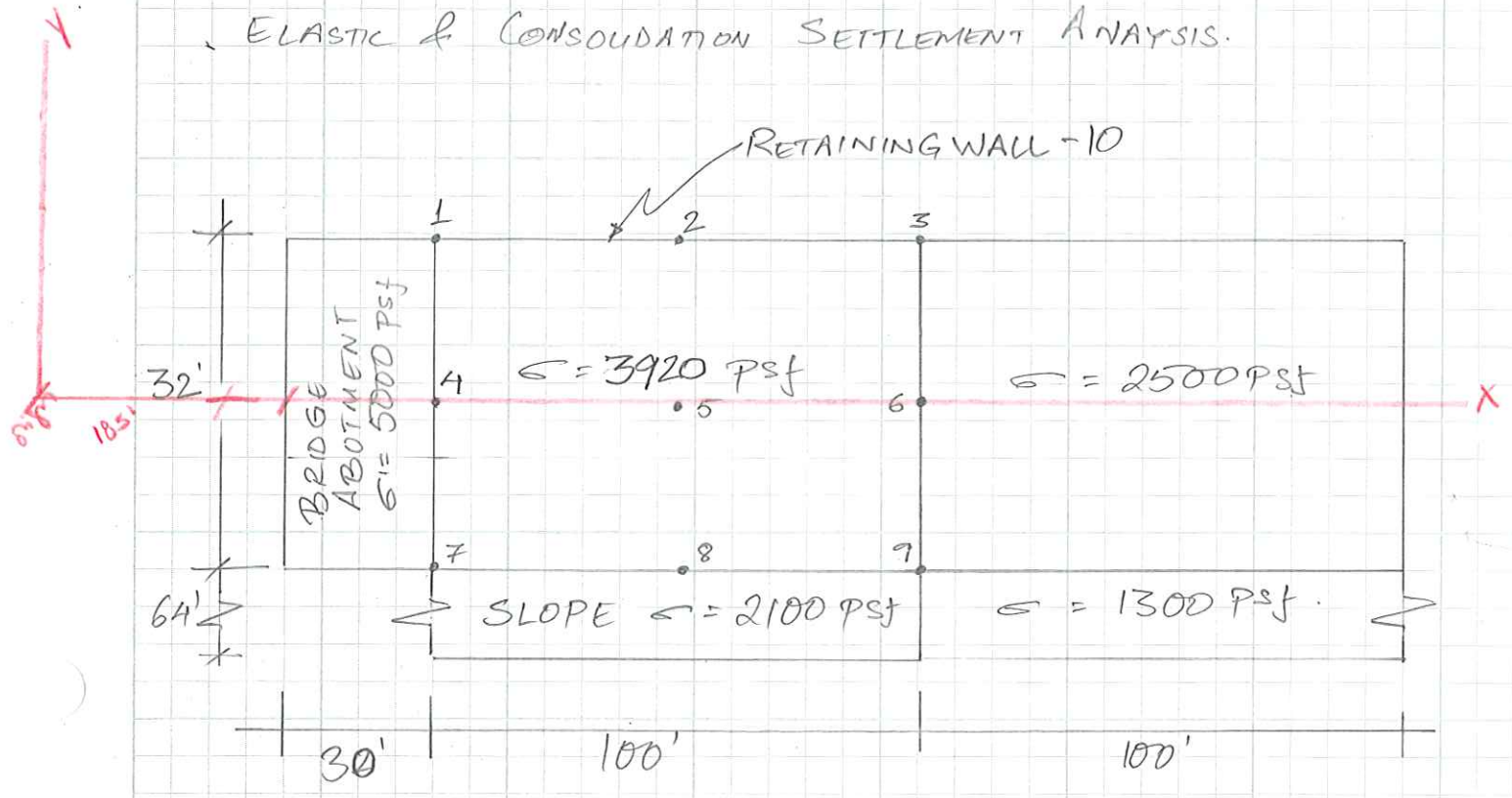
Cm. No. 103-057

Prepared By BBS Date 10-1-08 Checked By JST Date 1-20-09
EM 2/6/09

ELASTIC & CONSOLIDATION SETTLEMENT ANAYSIS.



STRESS DUE TO ABUTMENT & WING WALLS ESTIMATED @ 5000-psf (URS TO DESIGN THEM)

SIDE SLOPES STRESS = $\frac{1}{2}$ γH = 2100 psf

FIRST 100-ft DESIGNED FOR MAX HEIGHT = 32-ft

SECOND 100-ft DESIGNED FOR HT = 24-ft.
STRESS = 2500 ft

CONSOLIDATION SETTLEMENT DUE TO LACK OF CONSOLIDATION TEST FOR THE SPECIFIC STRUCTURE USE P_c = 9000 psf FROM TEST EMBANKMENT. USE BACK CALCULATED SOIL PARAMETERS.

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Subject SR-1/I-95 INTERCHANGE RETAINING WALL 10 Page 65 of 82
Cm. No. 103-059
Prepared By BBS Date 12/16/08 Checked By JST Date 1-20-09
EMK 2/8/09

CONSOLIDATION SOIL PARAMETERS

FOUNDATION LEVEL TO EL 40

AVG LL = 35 PL = 22 PI = 14

COMPRESSION INDEX C_c

$C_c = 0.007 (LL-10)$ SKEMPTON (1944)

$= 0.175$

RECOMPRESSION INDEX C_r (BACK CALCULATED)

$C_r = 0.015$ $1/12\ C_c$

EL 40 to EL 20

AVG LL = 32 PL = 21 PI = 13

COMPRESSION INDEX C_c

$C_c = 0.007 (LL-10)$

$= 0.154$

RECOMPRESSION INDEX C_r (BACK CALCULATED)

$C_r = 0.015 = 1/10 C_c$

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Subject SR-1/I-95 INTERCHANGE RETAINING WALL 10 Page 66 of 82
Cm. No. 103-059
Prepared By BBS Date 12/16/08 Checked By JST Date 1-20-09
CM 2/8/09

EL 20 to EL 11

AVG LL = 21 PL = 14 PI = 7

$C_c = 0.007 (LL - 10)$

$= 0.077$

C_r = RECOMPRESSION INDEX (BACK CALCULATED)

$C_r = 0.015 = 1/5\, C_c$

CLOSEST BORING FROM STRUCTURE WITH CONSOLIDATION

IBR-15 $e_o = 0.772$

$C_v = 0.015$ ft²/day.

ELASTIC MODULUS (BACK CALCULATED)

FOUNDATION LEVEL TO EL 40 STRATUM 2a

$E_s = 818$ ksf

EL 40 TO EL 20 STRATUM 2a

$E_s = 818$ ksf

EL 20 & BELOW STRATUM 2a

$E_s = 1364$ ksf

STRATUM 2b

$E_s = 1364$ ksf

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Subject SR-1 INTERCHANGE RW-10 Page 67 of 82
Cm. No. 103-059
Prepared By BBS Date 10-1-08 Checked By BJT Date 1-20-09

ELASTIC SETTLEMENT δ_E

Max δ_E = 0.8 inch.

CONSOLIDATION SETTLEMENT δ_c

Max δ_c = 3.0 inch

TOTAL SETTLEMENT = 0.8 + ~~2.9~~ 3.0

S_T = ~~3.7~~ 3.8 inch

* location of pb on PS 6B.

MAX DIFFERENTIAL SETTLEMENT

BETWEEN POINTS 2 & 5 Middle RW 10 + Front Face

Δ_{ST} = 3.7 − 2.9

= 0.8 inch.

DISTANCE BETWEEN 2 & 5 is 16-ft

RATIO = $\frac{0.8}{16 \times 12} = \frac{1}{240}$ ALONG CROSS SECTION.

1/240 < 1/100 ; OK

DIFFERENTIAL SETTLEMENT ALONG FACE OF WALL

BETWEEN POINTS 2 & 3

Δ_{ST} = 2.9 − 2.6 = 0.3

DISTANCE BETWEEN 2 & 3 = 50 ft

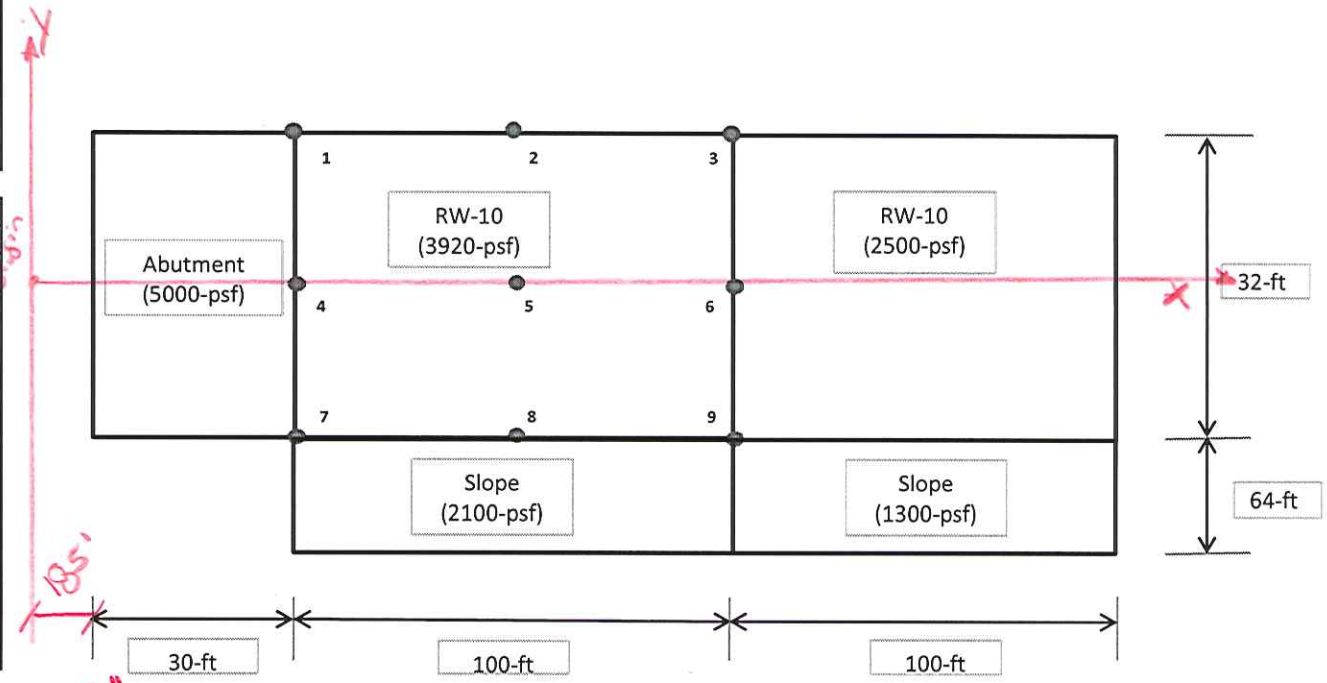
RATIO = $\frac{0.3}{50 \times 12} = \frac{1}{2000} < \frac{1}{100}$ OK

I-95/SR 1 Interchange 103-059-27U 1/20/2009
Retaining Wall 10 Settlement Results

	Settlement (ft)		
Point	Elastic	Consolidation	Total
1	0.04	0.20	0.24
2	0.05	0.19	0.24
3	0.05	0.17	0.22
4	0.05	0.26	0.31
5	0.06	0.25	0.31
6	0.05	0.23	0.28
7	0.05	0.22	0.27
8	0.06	0.24	0.30
9	0.06	0.22	0.28
10			
11			
12			
13			
14			
15			

	Settlement (in)		
Point	Elastic	Consolidation	Total
1	0.5	2.4	2.9
2	0.6	2.3	2.9
3	0.5	2.0	2.6
4	0.6	3.1	3.7
5	0.7	3.0	3.7
6	0.7	2.8	3.4
7	0.6	2.6	3.2
8	0.8	2.9	3.7
9	0.7	2.6	3.3
10			
11			
12			
13			
14			
15			

	RW 10 Differential Settlement						
	Along Front RW 10		Along Center RW 10		Along Back RW 10		Front to Back
	1 to 3	2 to 3	4 to 6	5 to 6	7 to 9	7 to 8	2 to 5
Inches	0.3	-0.3	0.3	0.3	-0.1	-0.4	-0.8
Ratio	1/3846	- 1/1992	1/4184	1/1938	-0	- 1/1441	- 4/921



Max 3.7"
Min 2.4"

* NTS

RKK RW10-70

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Retaining Wall 10\Settlement\RW 10 Settlement Results.xls

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JST 1-20-09
JM 2/2/09

SR-1 Interchange Retaining Wall 100

Report created by FoSSA(2.0): Copyright (c) 2003-2006, ADAMA Engineering, Inc.

PROJECT IDENTIFICATION

Title:	SR-1 Interchange Retaining Wall 100
Project Number:	103-059 -
Client:	DelDot
Designer:	BBS
Station Number:	

Description:
Settlement Analysis of Retaining Wall 10

Company's information:

Name:	Rummel, Klepper & Kahl
Street:	81 Mosher Street Baltimore, MD 21217
Telephone #:	
Fax #:	
E-Mail:	

Original file path and name: M:\project ..... on\Retaining Wall 10\Settlement\RW-10(revised).2ST
Original date and time of creating this file: Wed Oct 01 10:37:17 2008

GEOMETRY: Analysis of a Multiple Footings

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JDT 1-20-09

INPUT DATA – FOUNDATION LAYERS – 4 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	130.00	0.40	
2	130.00	0.40	
3	130.00	0.40	
4	125.00	0.30	

INPUT DATA – MULTIPLE FOOTINGS – 5 footings

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	300.00	169.00

actual EL = Z-100

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RKK RW10-73

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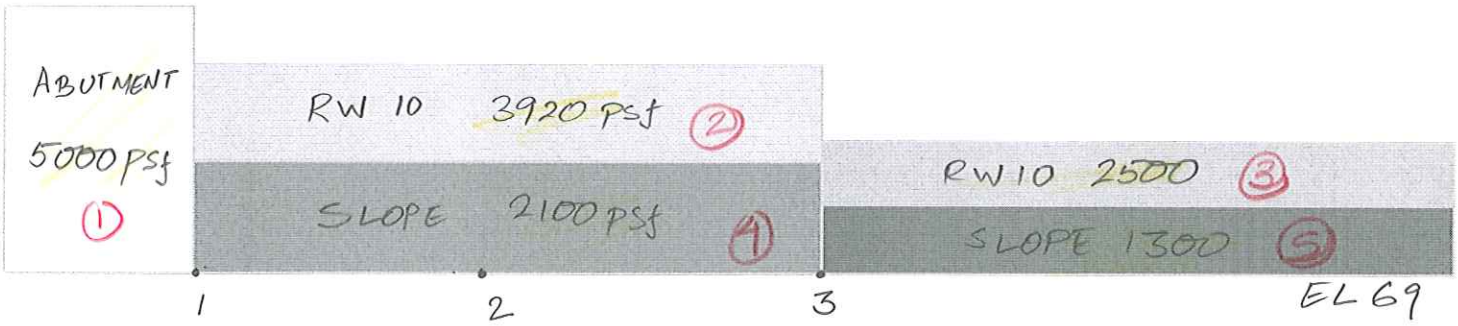
JJ 7-1-20-09

DRAWING OF SPECIFIED GEOMETRY



STRATUM 2a

$\gamma = 130$ pcf

$C = 2000$ PSF

EL 40

STRATUM 2a

$\gamma = 130$ pcf

$C = 3000$ PSF

EL 20

STRATUM 2a

$\gamma = 130$ pcf $C = 4000$ PSF

EL 11

STRATUM 2b

$\gamma = 125$ pcf

$\phi = 32°$

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INPUT DATA FOR CONSOLIDATION -- $\alpha = 1/2$

JLT 1-20-09

Layer # Undergoing Consolidation [Yes/No]		$(\sigma'_p - \sigma'_o)$ given at layer's boundaries in [lb/ft²] at Top	Bottom	Cc	Cr	e0	Cv [ft²/day]	Drains at :
1	Yes	9000.0	7000.0	0.17	0.01	0.77	0.1500	Top
2	Yes	7000.0	5650.0	0.15	0.01	0.77	0.1500	Top
3	Yes	5650.0	5050.0	0.08	0.01	0.77	0.1500	Top
4	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

$P_c = 9000$ psf CALCULATION FOR $(\sigma_p' - \sigma_o')$

WT @ FOUNDATION LEVEL

LAYER 1

TOP = 9000 psf

BOTTOM = $9000 - (130 - 62.4) \times 29 = 7039 \approx 7000$ psf (29 = THICKNESS OF LAYER)

LAYER 2

TOP = 7000 psf

BOTTOM = $7039 - (130 - 62.4) \times 20 = 5687 \approx 5650$ psf

LAYER 3

TOP = 5650

BOTTOM = $5687 - (130 - 62.4) \times 9 = 5079.2 \approx 5050$ psf

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	215.00	16.00	1	818000	0.4000	~~0.0428~~	169.00	168.88	~~0.12~~ 0.0418
			2	818000	0.4000	~~0.0306~~			
			3	1364000	0.4000	~~0.0072~~			
			4	1364000	0.3000	0.0418			
2	265.00	16.00	1	818000	0.4000	~~0.0334~~	169.00	168.88	~~0.12~~ 0.0509
			2	818000	0.4000	~~0.0289~~			
			3	1364000	0.4000	~~0.0078~~			
			4	1364000	0.3000	0.0509			
3	315.00	16.00	1	818000	0.4000	~~0.0276~~	169.00	168.90	~~0.10~~ 0.0458
			2	818000	0.4000	~~0.0236~~			
			3	1364000	0.4000	~~0.0065~~			
			4	1364000	0.3000	0.0458			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

Figure elastic Settlement in Strata II a

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SJT 1-20-09

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
~~14~~	215.00	0.00	1	818000	0.4000	~~0.0862~~	169.00	168.81	~~0.19~~ 0.0485
			2	818000	0.4000	~~0.0447~~			
			3	1364000	0.4000	~~0.0094~~			
			4	1364000	0.3000	0.0485			
~~25~~	265.00	0.00	1	818000	0.4000	~~0.0709~~	169.00	168.81	~~0.19~~ 0.0604
			2	818000	0.4000	~~0.0445~~			
			3	1364000	0.4000	~~0.0106~~			
			4	1364000	0.3000	0.0604			
~~36~~	315.00	0.00	1	818000	0.4000	~~0.0591~~	169.00	168.84	~~0.16~~ 0.0546
			2	818000	0.4000	~~0.0366~~			
			3	1364000	0.4000	~~0.0089~~			
			4	1364000	0.3000	0.0546			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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SST 1-20-09

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
X 7	215.00	-16.00	1	818000	0.4000	~~0.0527~~	169.00	168.85	~~0.15~~ 0.0496
			2	818000	0.4000	~~0.0385~~			
			3	1364000	0.4000	~~0.0091~~			
			4	1364000	0.3000	0.0496			
28	265.00	-16.00	1	818000	0.4000	~~0.0543~~	169.00	168.83	~~0.17~~ 0.0643
			2	818000	0.4000	~~0.0446~~			
			3	1364000	0.4000	~~0.0113~~			
			4	1364000	0.3000	0.0643			
29	315.00	-16.00	1	818000	0.4000	~~0.0447~~	169.00	168.85	~~0.15~~ 0.0585
			2	818000	0.4000	~~0.0368~~			
			3	1364000	0.4000	~~0.0095~~			
			4	1364000	0.3000	0.0585			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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SST, 1-20-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	215.00	16.00	169.00	0.20	168.80
2	265.00	16.00	169.00	0.19	168.81
3	315.00	16.00	169.00	0.17	168.83

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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JST 1-20-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
4 ~~1~~	215.00	0.00	169.00	0.26	168.74
5 ~~2~~	265.00	0.00	169.00	0.25	168.75
6 ~~3~~	315.00	0.00	169.00	0.23	168.77

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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JST 1-20-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	215.00	-16.00	169.00	0.22	168.78
2	265.00	-16.00	169.00	0.24	168.76
3	315.00	-16.00	169.00	0.22	168.78

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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JJT 1-20-09

TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	300.00	169.00	
2	1	300.00	140.00	actual EL = Z - 100
3	1	300.00	120.00	
4	1	300.00	111.00	

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JJT 1-20-09

TABULATED GEOMETRY: INPUT OF MULTIPLE FOOTINGS – 5 footings

Footing #	L (in X direction) [ft]	B (in Y direction) [ft]	X of center [ft]	Y of center [ft]	q [ft]l [lb/ft²]	
1	30.00	32.00	200.00	0.00	5000.00	Abutment
2	100.00	32.00	265.00	0.00	3920.00	RW 10
3	100.00	32.00	365.00	0.00	2500.00	RW 10
4	100.00	64.00	265.00	-48.00	2100.00	Slope
5	100.00	64.00	365.00	-48.00	1300.00	Slope

For footing locations see sheet 71

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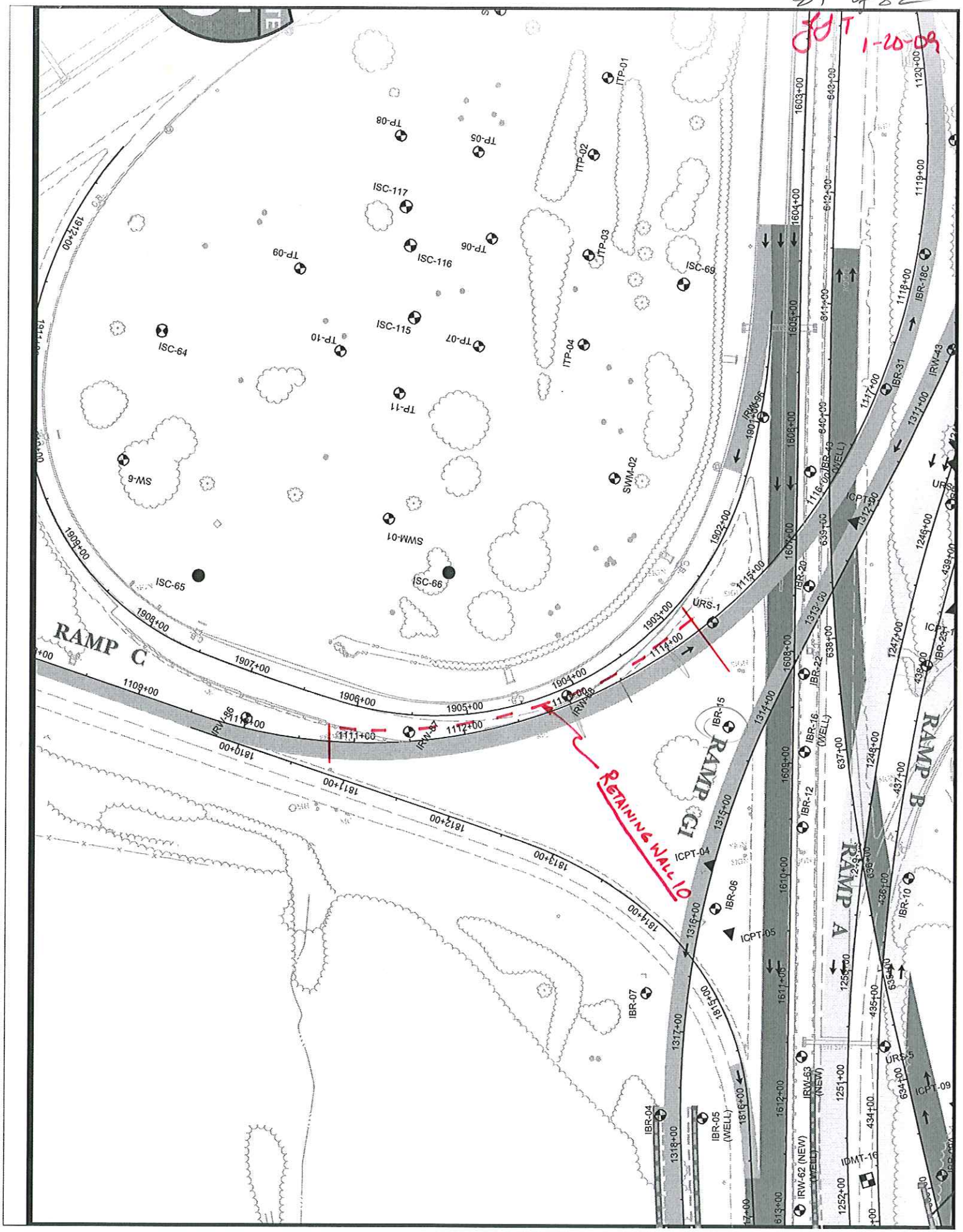
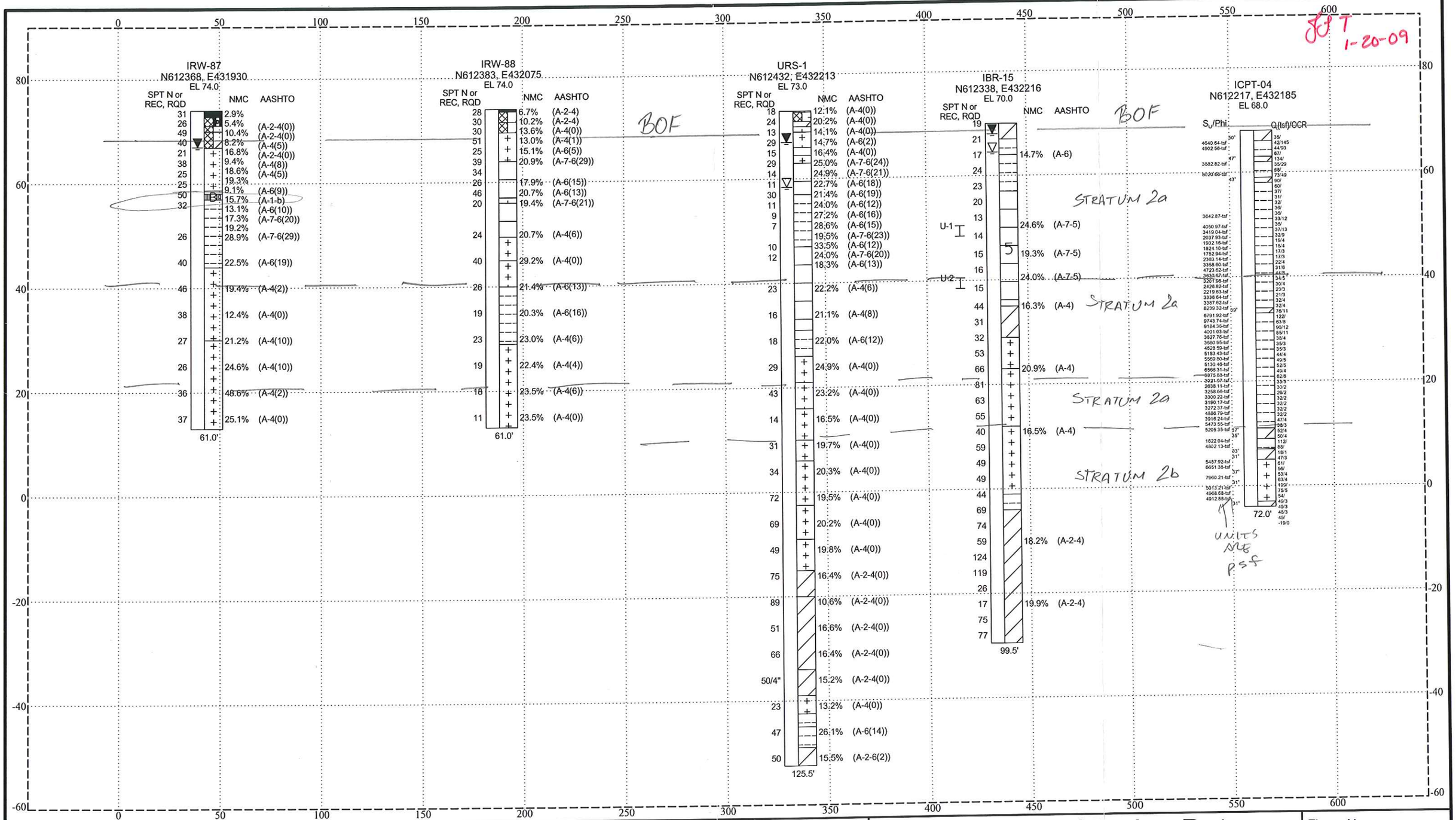
RKK RW10-83


RAMP C
RAMP G1
RAMP A
RAMP B
RETAINING WALL 10
ISC-64
ISC-65
ISC-66
ISC-69
ISC-115
ISC-116
ISC-117
SW-6
SWM-01
SWM-02
TP-01
TP-02
TP-03
TP-04
TP-05
TP-06
TP-07
TP-08
TP-09
TP-10
TP-11
URS-1
URS-5
IBR-04
IBR-05 (WELL)
IBR-06
IBR-07
IBR-10
IBR-12
IBR-15
IBR-16 (WELL)
IBR-18C
IBR-20
IBR-22
IBR-23
IBR-31
IBR-43
IRW-62 (NEW) (WELL)
IRW-63 (NEW)
ICPT-04
ICPT-05
ICPT-09
IDMT-16

RKK RW10-84

82-482

SOT 1-20-09



AASHTO SOIL KEY

A	A-1-a	5	A-2-5		A-5		A-8
B	A-1-b		A-2-6		A-6		Asphalt
	A-3	7	A-2-7	5	A-7-5		FILL
	A-2-4	+ + + + + +	A-4		A-7-6		Decomposed Rock

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data
Retaining Wall 10

Figure No. A-1

Drawn: BBS | Approved: EMK | Date: 12/15/08 | Comm. No 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 12/15/08

CALCULATION CHECKLIST

Project: **SR 1/I-95 Interchange** Comm. No.: **103-059-27U**

Title of Calculation Set: **RW 12 and 13 Analysis – Final Design**

Project Manager: **EMK/JLT**

Calculations Prepared By: **SAB**

Calculation Checked By:

Computer Programs / Files: MSEW 3.0, RSlope/w, FoSSA 2.0

Initial	Date	
		Subsurface Characterization approved by Project Manager
SAB	1/15/09	Calculations are neat, legible and understandable.
SAB	1/15/09	Table of Contents is provided.
SAB	1/15/09	Heading on each page filled out
SAB	1/15/09	The first page contains purpose of the calculation.
SAB	1/15/09	Symbols are defined.
SAB	1/15/09	References for data, methods, formulas and computer program names and version numbers are given.
SAB	1/15/09	Assumptions are listed and those that need to be verified later are Flagged.
SAB	1/15/09	Headings on front sheet of each set of computer input and output.
SAB	1/15/09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JLT	1-18-09	All calculations checked and each calculation sheet initialed by checker.
MM	2/6/09	Calculation set reviewed by Project Manager.
		Has this calculation been superseded? Reference new calculation, if applicable.

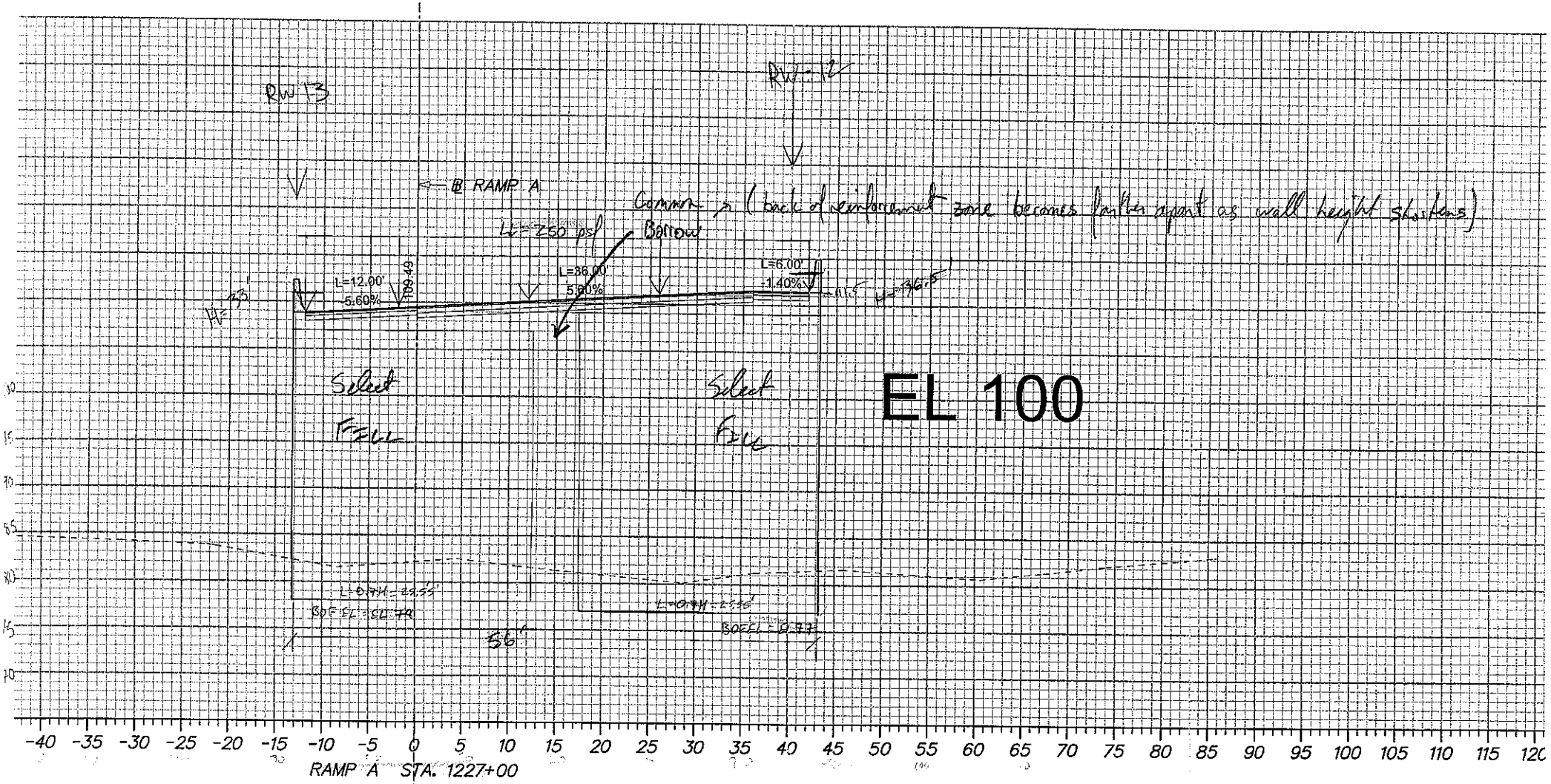
This sheet is to be prepared by the originator of the calculation and attached to the front of the calculation set.

SR1/I-95 Interchange
RW 12 & 13 Analysis

103-0059.270

RKK RW12 & 13-2

JPT
1-2-09



PROPOSED CONSTRUCTION

JPT
1-8-09

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Subject I-95/SR1 Interchange Ramp A Retaining Wall 12 & 13 Stability
Page 1 of 12
Cm. No. 107-059-270
Prepared By SAB Date 9/22/08 REV 11/13/08 Checked By JJT Date 9-30-08 JJT 1-2-09

Objective: To evaluate the external & global stability of Retaining Wall 12 & 13. These walls are proposed to be mechanically stabilized earth walls.

References: 1) AASHTO LRFD Bridge Design Specifications, 4th ed.
2) FHWA Publication No. FHWA-NHI-00-043 "Mechanically Stabilization Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines."

SUMMARY: → AASHTO 2002 / FHWA NHI-043 ASD Method

Foundation Soil
γ = 125 pcf ϕ = 32° c = 0 psf

Bearing Capacity : FS = 2.60 q_R = 6688 psf
Sliding : FS = 2.11   CDR = 2.100
Overturning : FS = 3.38

L/H = 0.7

* Bearing resistance evaluated for H = 36.5' w/ 3' embedment for both wall. Actual wall height will need to be evaluated prior to submission of FFC.

⇒ For Final Design: Conservative evaluation → Both walls evaluated as 36.5' high walls (maximum wall height of RW 12 - greater than max. wall height of RW 13.)

* Check Settlement

* Check Global Stability.

* Dewatering during constr. as GW anticipated to be within 1 to 2' of BOF.

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Subject I-95/SR1 Interchange — RW 12 & 13 Analysis — Page 2 of ____
Cm. No. 103-059-270
Prepared By SAD Date 9/22/08 Checked By SJT Date 9-30-08
REV 11/13/08 SJT 1-2-09
OMM 2/9/09

Wall Details: (See attached cross-section, p. 2a)

→ Tallest section of both walls occurs near Ramp A STA 1227+00. Use this station to evaluate external stability.

RW 12

H = 36.5'
Embedment Depth, E = 3'
Reinforcement Length, L = 25.55' [L/H = 0.7] → assumed
BOF EL = EL 76
Traffic LL = 250 psf

RW 13

H = 33' * [Use H = 36.5' for analysis]
E = 3'
L = 23.1' [Use L = 25.55' for analysis] [L/H = 0.7] → assumed
BOF EL = EL 77
Traffic LL = 250 psf

* H includes height of barrier

⇒ Check if RW 12 & RW 13 should be analyzed as back-to-back walls:

Per FHWA (Rd 2), p. 178 Eqn. 55, reduce the active thrust if $D < H_1 \tan(45 - \phi/2)$

D = Distance between walls H_1 = Wall Height ϕ = Retained Soil friction angle

D = 5' $H_1 \tan(45 - \phi/2) = 36.5 \tan(45 - 29/2) = 21'$ ⇒ D < 21'

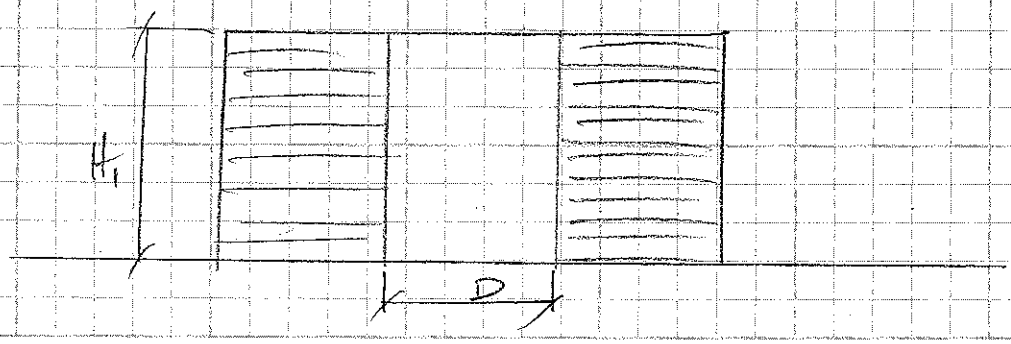
So, → Case I: Back-to-back walls, each behaves independently, but active thrust is reduced.
→ Per AASHTO LRFD, must be designed per AASHTO 2002/FHWA (ASD)

⇒ Analyze as back-to-back walls with MSEW.

⇒ Assumes symmetry, so use taller dimensions for walls:

H_1 = 36.5' D = 5' L = 25.55' E = 3' LL = 250 psf

* Height of RW 13 may be reduced in Final Design based on the final design ground surface EL.



SR1/I-95 Interchange
RW 12 & 13 Analysis

103-059-270

RKK RW12 & 13-5

1-2-09

RW 13

RW 12

℄ RAMP A

L_L = 250 psf

L=12.00'
5.60%

L=36.00'
5.60%

L=6.00'
-1.40%

EL 100

95
90
85
80
75
70

L=0.7H=25.55'
BOF EL = EL 78

L=0.7H=25.55'
BOF EL = EL 77

56'

-40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120

RAMP A STA. 1227+00

* wall height includes height of barrier.

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Subject I-95/SR1 Interchange — Page 3 of
RW 12 & 13 Analysis — Cm. No. 103-059-27U
Prepared By SAB Date 9/22/08 Checked By SBT Date 9-30-08
REV 11/13/08 SBT 1-2-09
EMK 2/9/09

Soils: (See attached fence diagram, p. 3a)

Soil	γ (pcf)	ϕ' (deg)	c' (psf)	S_u (psf)	EL (ft)	
Reinforced Soil	125	34	0	–	–	
Retained Soil	130	28	0	–	–	TYPE F BORROW
Foundation Soil - I	125	32	0	–	78 - 73	SAND
IIb	130	34	0	–	73 - 50	"
IIa	130	17	0	1,500	50 - 40	
IIa	130	17	0	2,500	40 - 20	
IIa	130	17	0	3,500	20 - 0	
~~Notes~~	~~62.4~~				~~75~~	

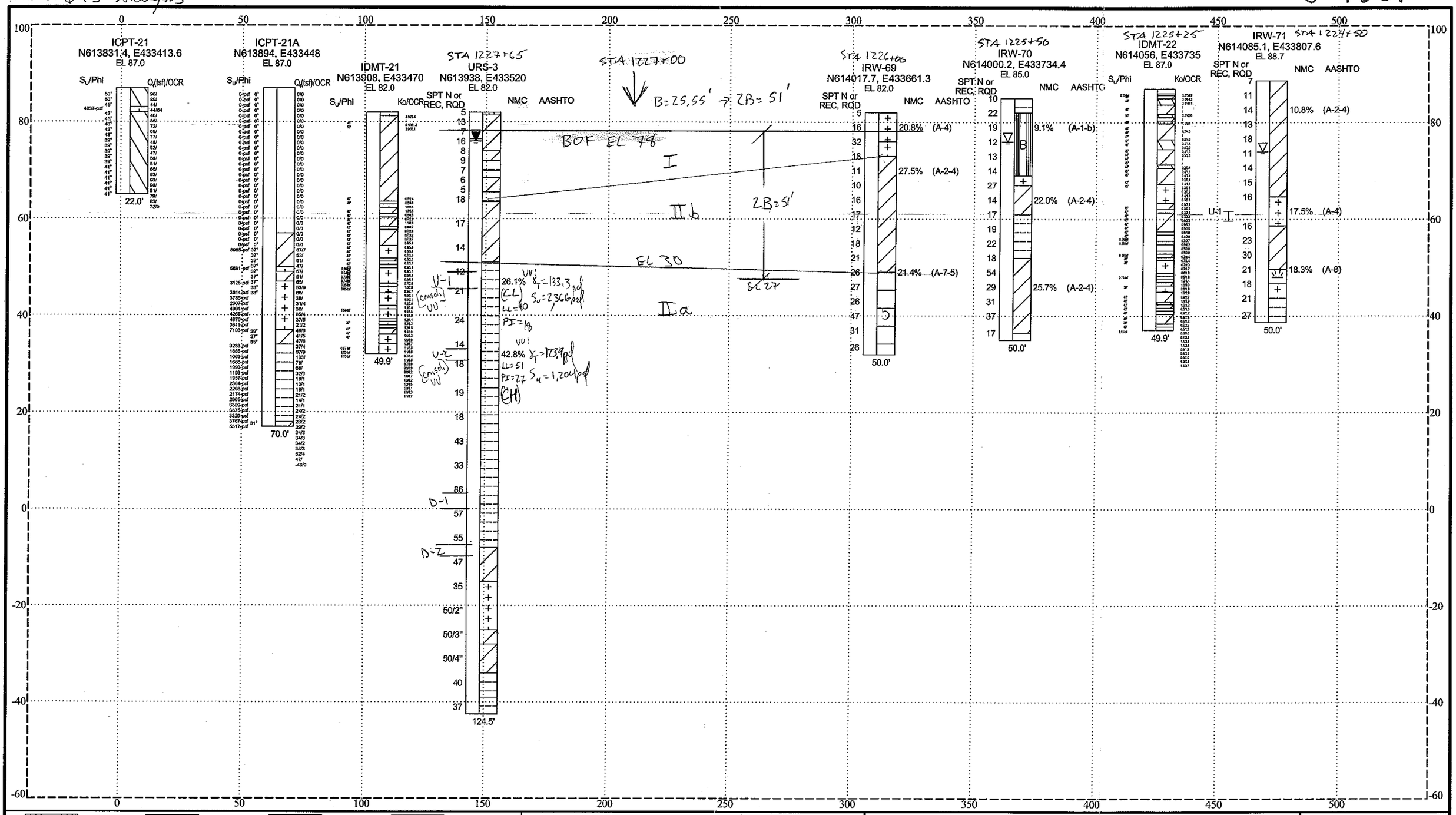
⇒ Analyze Drained case for sand foundation soil.

SR1/I-95 Interchange 103-059-27U 11/13/08

RW 12 & 13 Analysis

RKK RW12 & 13-7

JDT 1-2-09



AASHTO SOIL KEY

A	A-1-a	5	A-2-5		A-5		A-8
B	A-1-b		A-2-6		A-6		Asphalt
	A-3	7	A-2-7	5	A-7-5		FILL
	A-2-4	+ + + + + +	A-4		A-7-6		Decomposed Rock

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data

Retaining Walls 12 and 13

Figure No.

Drawn: SAB | Approved: | Date: 11/13/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 11/13/08

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Subject SR1/I-95 Interchange
RW 12 & 13 Analysis

Page 4 of _____

Cm. No. 103-059-270

Prepared By SAB Date 11/13/08 Checked By SDT Date 1-2-09
EMK 2/9/09

External Stability Analysis: Performed using MSEW 3.0, AASHTO 2002/NHI-043 procedure.
→ See attached MSEW outputs, p. 5 – 12

From Analysis: q_{ult} = 17,374 psf, Maximum Stress, σ_v = 6688 psf, eccentricity, e = 3.58'

⇒ Bearing capacity FS = 2.60 > 2.5 √OK

⇒ Sliding FS = 2.11 > 1.5 √OK

⇒ Overturning FS = 3.38 > 2.0 √OK

→ So walls can be designed as back-to-back walls using L/H = 0.7.

5

JT 1-2-09
EMR 2/9/09

AASHTO DESIGN METHOD
SR 1/I-95 Interchange

PROJECT IDENTIFICATION

Title: SR 1/I-95 Interchange
Project Number: 103-059-27U
Client: DelDOT
Designer: SAB
Station Number: Ramp A STA 1227+00

Description:

Retaining Wall 12 & 13 - Ramp A RW 12: H=36.5' L/H = 0.7 RW 13: H=33' L/H = 0.7

Company's information:

Name: RK&K Engineers, LLP
Street: 81 Mosher St

Baltimore, MD 21224
Telephone #: 410-728-2900
Fax #:
E-Mail:

Original file path and name: M:\projects\2003\03059 deltrnpk\Geotech\INTERCHANGE FIN..... .....a 1227+00 L=pt7H.BEN
Original date and time of creating this file:

PROGRAM MODE:

ANALYSIS
of BACK to BACK WALL
using METAL STRIPS as reinforcing material.

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License number MSEW-301874

JJT 1-2-09
EM 2/9/09

SOIL DATA

REINFORCED SOIL

Unit weight, γ		125.0 lb/ft^3	Select Fill
Design value of internal angle of friction,	ϕ	34.0 °	

RETAINED SOIL

Unit weight, γ		130.0 lb/ft^3	Common Borrow Type F
Design value of internal angle of friction,	ϕ	28.0 °	

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight,	$\gamma_{equiv.}$	125.0 lb/ft^3	Strata I
Equivalent internal angle of friction,	$\phi_{equiv.}$	32.0°	
Equivalent cohesion,	$c_{equiv.}$	0.0 lb/ft^2	

Water table is at wall base elevation ✓

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3610 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 35.49 N γ= 30.21

SEISMICITY

Not Applicable

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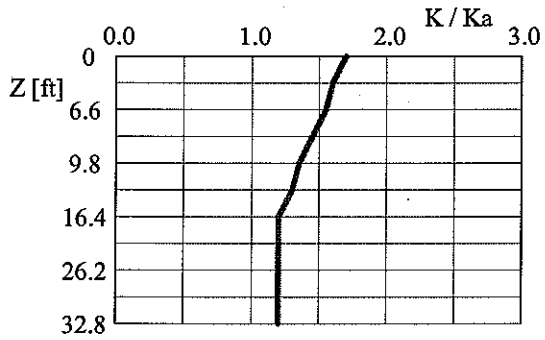
SB T 1-2-09

INPUT DATA: Metal strips
(Analysis)

D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.23	N/A	N/A	N/A	N/A
Ribbed steel strips.					
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0					
Friction angle along reinforcement-soil interface, ρ					
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



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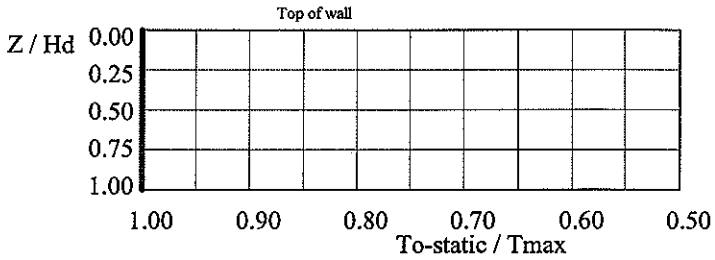
JDT 1-2-09

INPUT DATA: Facia and Connection
(Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.00 ft. Horizontal distance to Center of Gravity of panel is 0.50 ft.
Average unit weight of panel is $\gamma_f = 150.00$ lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

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JST 1-2-09

INPUT DATA: Geometry and Surcharge loads (of BACK to BACK wall)

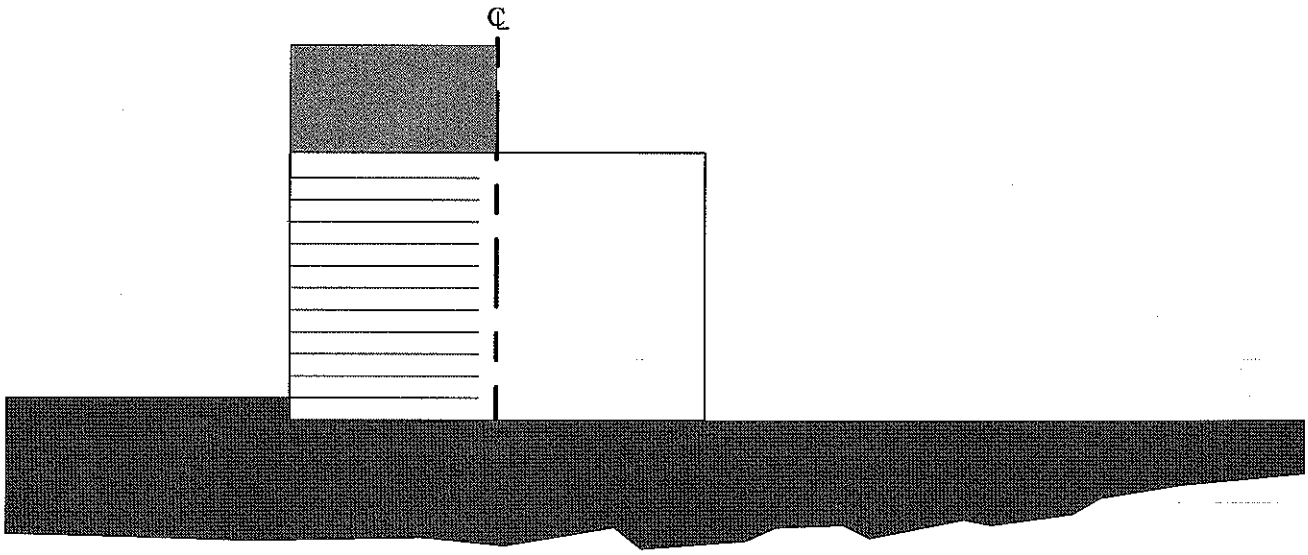
Design height, Hd	36.50	[ft]	{ Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 33.50 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

Distance between walls (Back to Back) = 56.0 ft, and Reinforcement length, L = 25.6 ft. → 0.7 H

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 5 10 15 20 25 30 [ft]

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JT 1-2-09

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, Fs = 2.60, Meyerhof stress = 6688 lb/ft².

Foundation Interface: Direct sliding, Fs = 2.108, Eccentricity, e/L = 0.1479, Fs-overturning = 3.38

METAL STRIP				CONNECTION							
#	Elevation [ft]	Length [ft]	Type #	Fs-overall [pullout resistance]	Fs-overall [connection break]	Fs-overall [metal strip strength]	Metal strip strength Fs	Pullout resistance Fs	Direct sliding Fs	Eccentricity e/L	Product name
1	0.00	25.55	1	N/A	1.90	2.11	2.106	3.313	2.266	0.1479	---
2	3.00	25.55	1	N/A	1.01	1.12	1.120	1.503	2.448	0.1261	---
3	6.00	25.55	1	N/A	1.10	1.22	1.223	1.381	2.662	0.1060	---
4	9.00	25.55	1	N/A	1.21	1.35	1.348	1.259	2.917	0.0877	---
5	12.00	25.55	1	N/A	1.35	1.50	1.500	1.137	3.225	0.0711	---
6	15.00	25.55	1	N/A	1.52	1.69	1.692	1.015	3.607	0.0562	---
7	18.00	25.55	1	N/A	1.69	1.88	1.880	0.963	4.106	0.0430	---
8	21.00	25.55	1	N/A	1.88	2.09	2.086	1.116	4.745	0.0316	---
9	24.00	25.55	1	N/A	2.16	2.40	2.399	1.247	5.616	0.0219	---
10	27.00	25.55	1	N/A	2.57	2.85	2.852	1.319	6.878	0.0139	---
11	30.00	25.55	1	N/A	3.29	3.66	3.659	1.326	8.873	0.0076	---
12	33.00	25.55	1	N/A	3.57	3.97	3.971	0.873	12.496	0.0031	---

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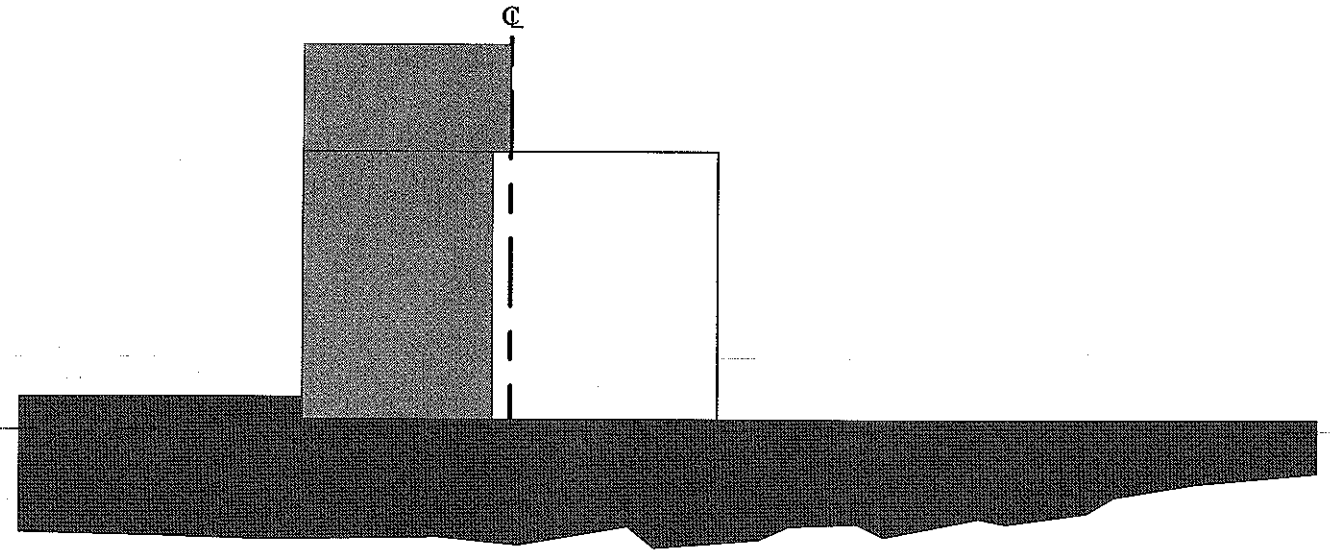
JAT 1-2-09

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table is at wall base elevation)			
Ultimate bearing capacity, q-ult	17374	N/A	[lb/ft ²]
Meyerhof stress, σ_V	6688.0	N/A	[lb/ft ²]
Eccentricity, e	3.58	N/A	[ft]
Eccentricity, e/L	0.140	N/A	
Fs calculated	2.60	N/A	
Base length	25.55	N/A	[ft]

$q_{ult} > \sigma_V$ ∴ OK



SCALE:

0 5 10 15 20 25 30 [ft]

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JPT 1-2-09

DIRECT SLIDING for GIVEN LAYOUT
(for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: Fs-static = 2.108

#	Metal strip Elevation [ft]	Metal strip Length [ft]	Fs Static	Fs Seismic	Metal strip Type #	Product name
1	0.00	25.55	2.266	N/A	1	---
2	3.00	25.55	2.448	N/A	1	---
3	6.00	25.55	2.662	N/A	1	---
4	9.00	25.55	2.917	N/A	1	---
5	12.00	25.55	3.225	N/A	1	---
6	15.00	25.55	3.607	N/A	1	---
7	18.00	25.55	4.106	N/A	1	---
8	21.00	25.55	4.745	N/A	1	---
9	24.00	25.55	5.616	N/A	1	---
10	27.00	25.55	6.878	N/A	1	---
11	30.00	25.55	8.873	N/A	1	---
12	33.00	25.55	12.496	N/A	1	---

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1479; Overturning: Fs-static = 3.38

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	0.00	25.55	0.1479	N/A	1	---
2	3.00	25.55	0.1261	N/A	1	---
3	6.00	25.55	0.1060	N/A	1	---
4	9.00	25.55	0.0877	N/A	1	---
5	12.00	25.55	0.0711	N/A	1	---
6	15.00	25.55	0.0562	N/A	1	---
7	18.00	25.55	0.0430	N/A	1	---
8	21.00	25.55	0.0316	N/A	1	---
9	24.00	25.55	0.0219	N/A	1	---
10	27.00	25.55	0.0139	N/A	1	---
11	30.00	25.55	0.0076	N/A	1	---
12	33.00	25.55	0.0031	N/A	1	---

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Subject I-95/SR1 Interchange — Page 1 of 31
Rpt A Retg Wall 12 & 13 Global Stability — Cm. No. 103-059-274
Prepared By SAB Date 9/22/09 Checked By JJT Date 9-30-08
Checked: 11/13/08 JJT 1-2-09
QMR 2/9/09

Global Stability Analysis: Performed using Slope/w

⇒ Back-to-Back walls RW 12 & 13 analyzed together.

⇒ STA 1224+00 chosen for global stability analysis: (biggest slope in front of RW 13)
2.5(H):1(V)

See attached cross-section, p. 2

Soils: (See attached fence diagram, p. 3)

Soil	γ (pcf)	DRAINED ϕ' (deg)*	DRAINED c' (psf)	UNDRAINED S_u (psf)	EL (ft)	
Reinforced Soil	125	34	0	—	—	Select Borrow (Type F Borrow)
Retained Soil	130	28	0	—	—	
Stratum I	125	32	0	—	91-66	
Stratum IIa	130	17	0	1,500	66-40	
Stratum IIa	130	17	0	2,500	40-20	
Stratum IIa	130	17	0	3,500	20-0	
Water	62.4				75	

*: Calculated using site-specific graph from Mitchell, 1926. (See attached graph, p. 4-5) For Stratum IIa

From LL graph, ϕ' ranges from 17.5° to 19° & averages 18.5°

From PL graph, ϕ' ranges from 15° to 17.5° & averages 16°

⇒ So use ϕ = 17°

⇒ DRAINED soil parameters are critical case → Check global stability for drained case.

→ Morgenstern-Price Method used for analysis. See attached Slope/w reports: Packet 1: RW13
Packet 2: RW12

Summary:

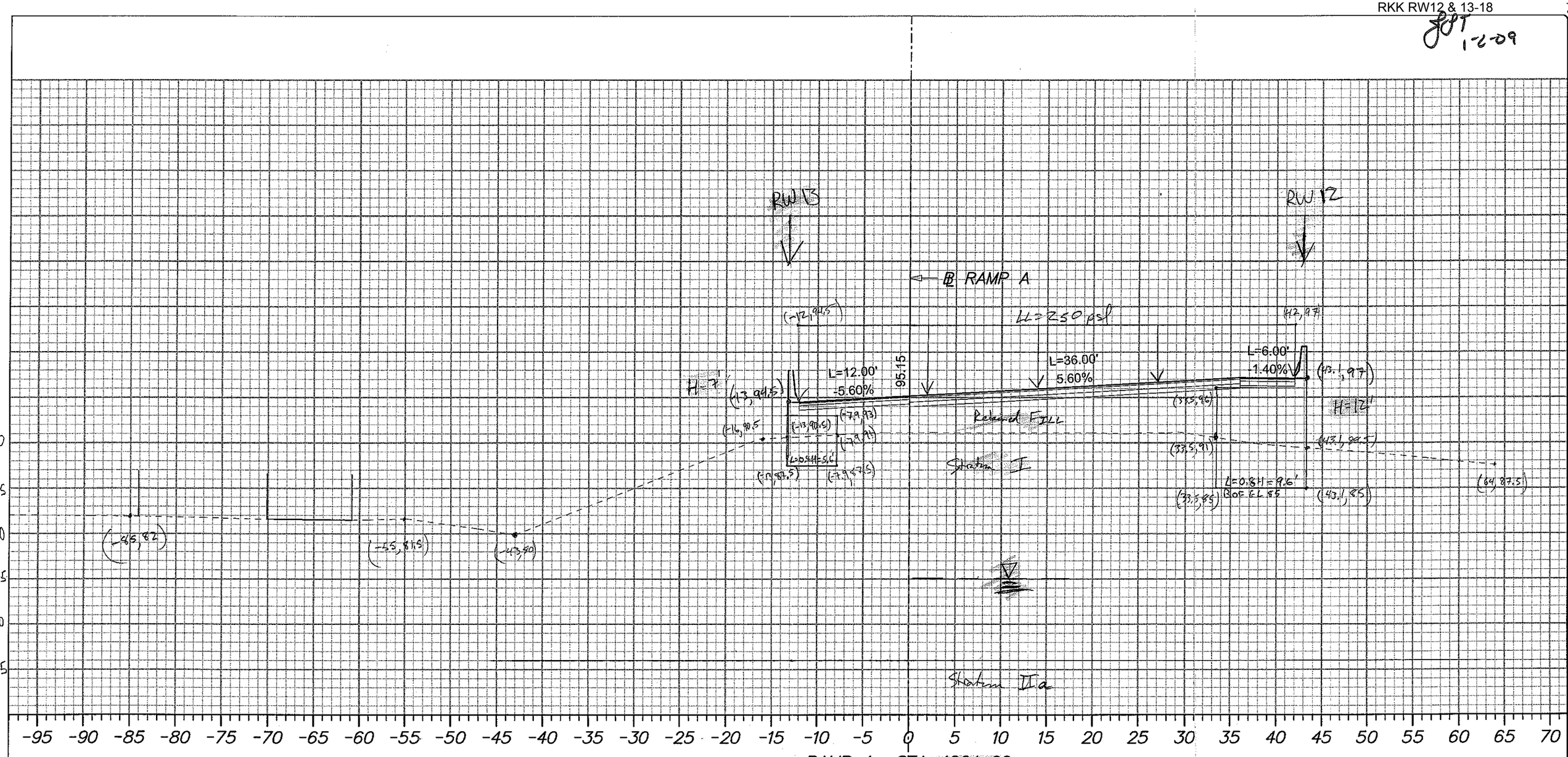
			Factored Resistance	
RW 13:	FS = 1.58	→	0.63	< 0.65 ✓OK
RW 12:	FS = 1.58	→	0.63	< 0.65 ✓OK

FS = 1.59

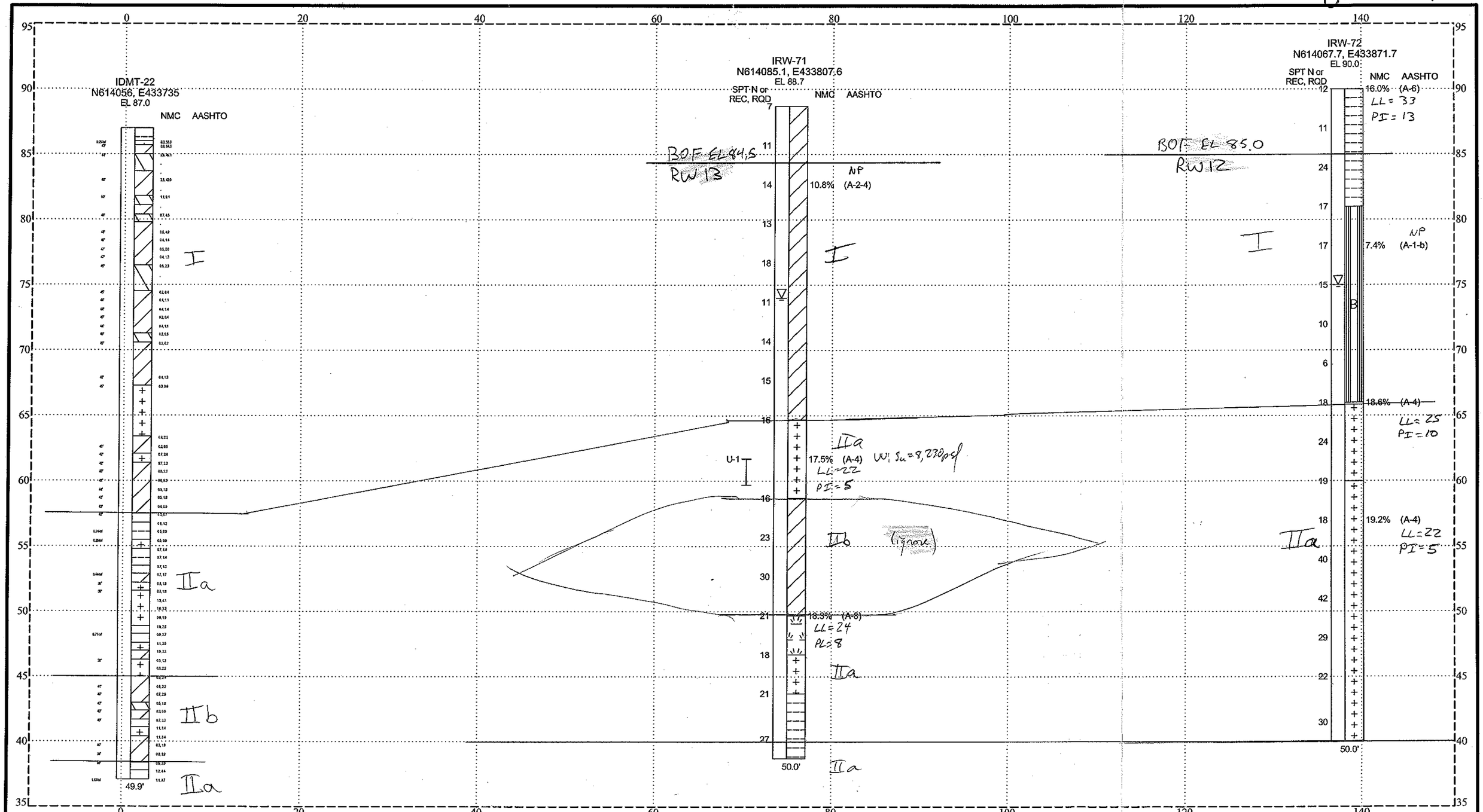
- Wall Manufacturer to verify external Stability

RKK RW12 & 13-18

JBT 1-2-09



* Height of wall does not include barrier *



AASHTO SOIL KEY

A	A-1-a	5	A-2-5		A-5		A-8
B	A-1-b		A-2-6		A-6		Asphalt
	A-3	7	A-2-7	5	A-7-5		FILL
	A-2-4	+ + + + + +	A-4		A-7-6		Decomposed Rock

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data
Retaining Wall 12 and 13 STA 1224+00

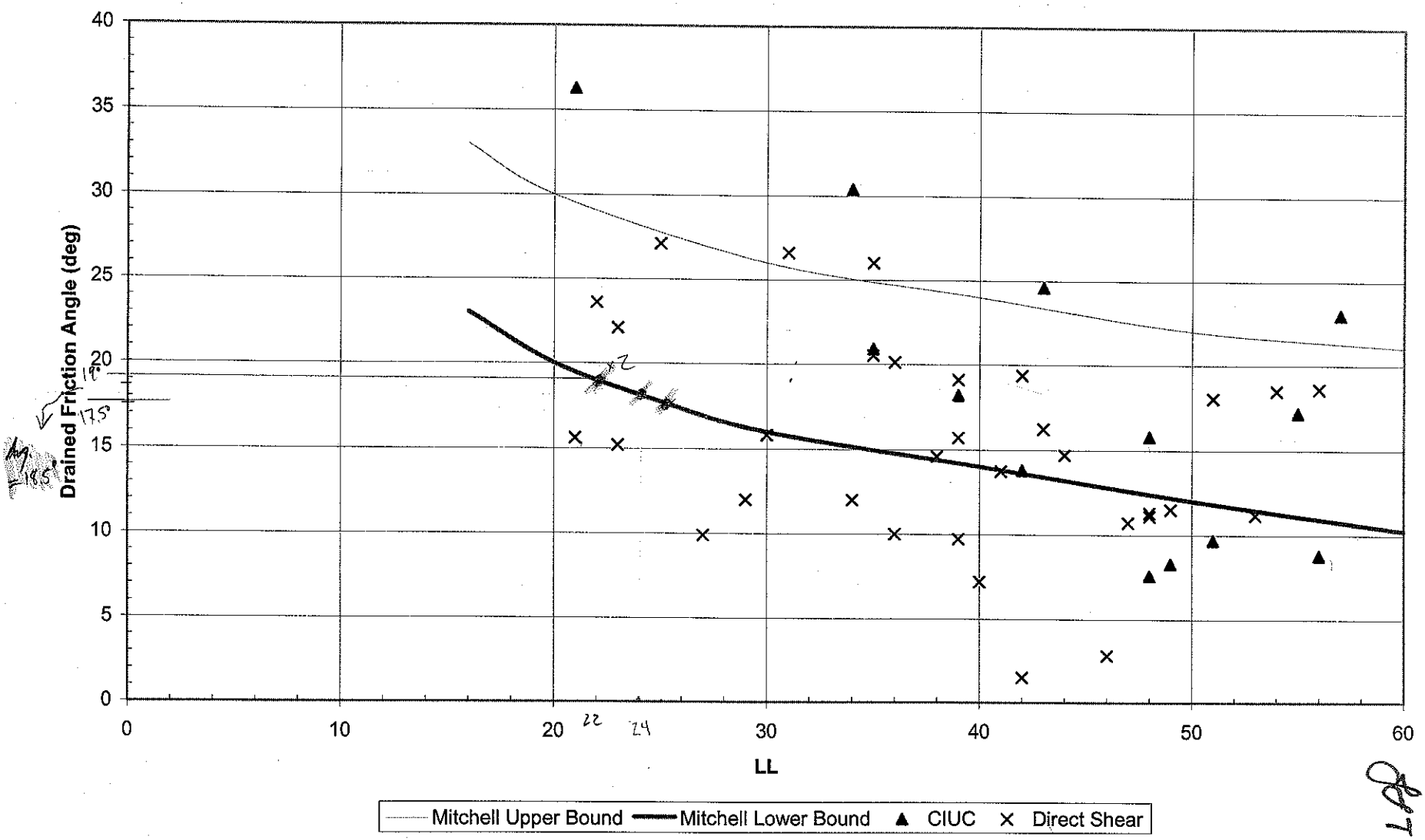
Figure No.

Drawn: SAB | Approved: EMK | Date: 9/22/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE 195 GINT FILE.GPJ RKK_CURRENT.GDT 9/22/08

Drained Friction Angle vs. Liquid Limit

Stratum IIa



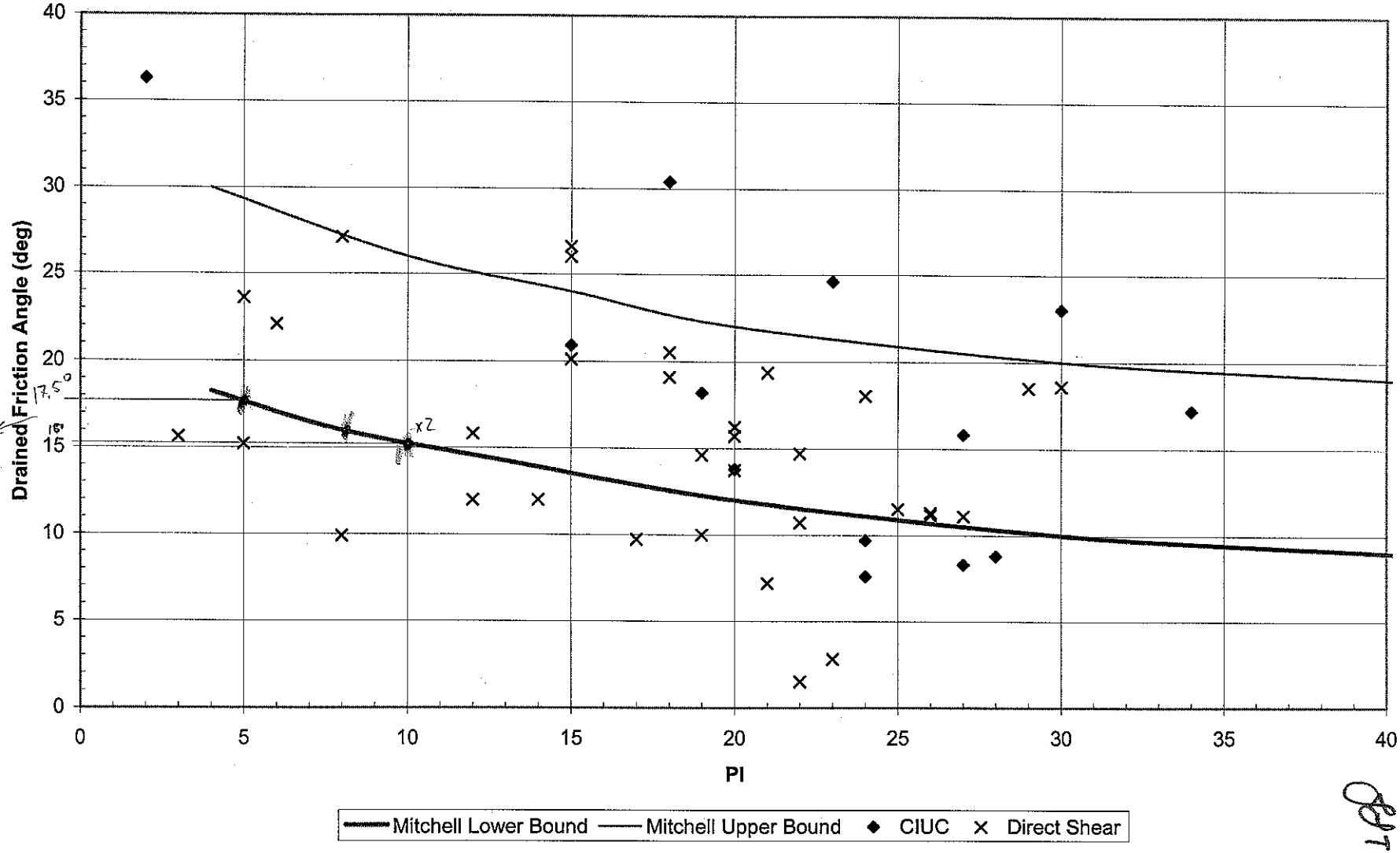
M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Drained Soil Parameters.xls LL Graph

RKK RW12 & 13-20

I-95/SR 1 Interchange 103-059-270 9/18/08

Drained Friction Angle vs. Plasticity Index

Stratum IIa



avg. = 16°

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Site Characterization\Drained Soil Parameters.xls PI Graph

RKK RW12 & 13-21

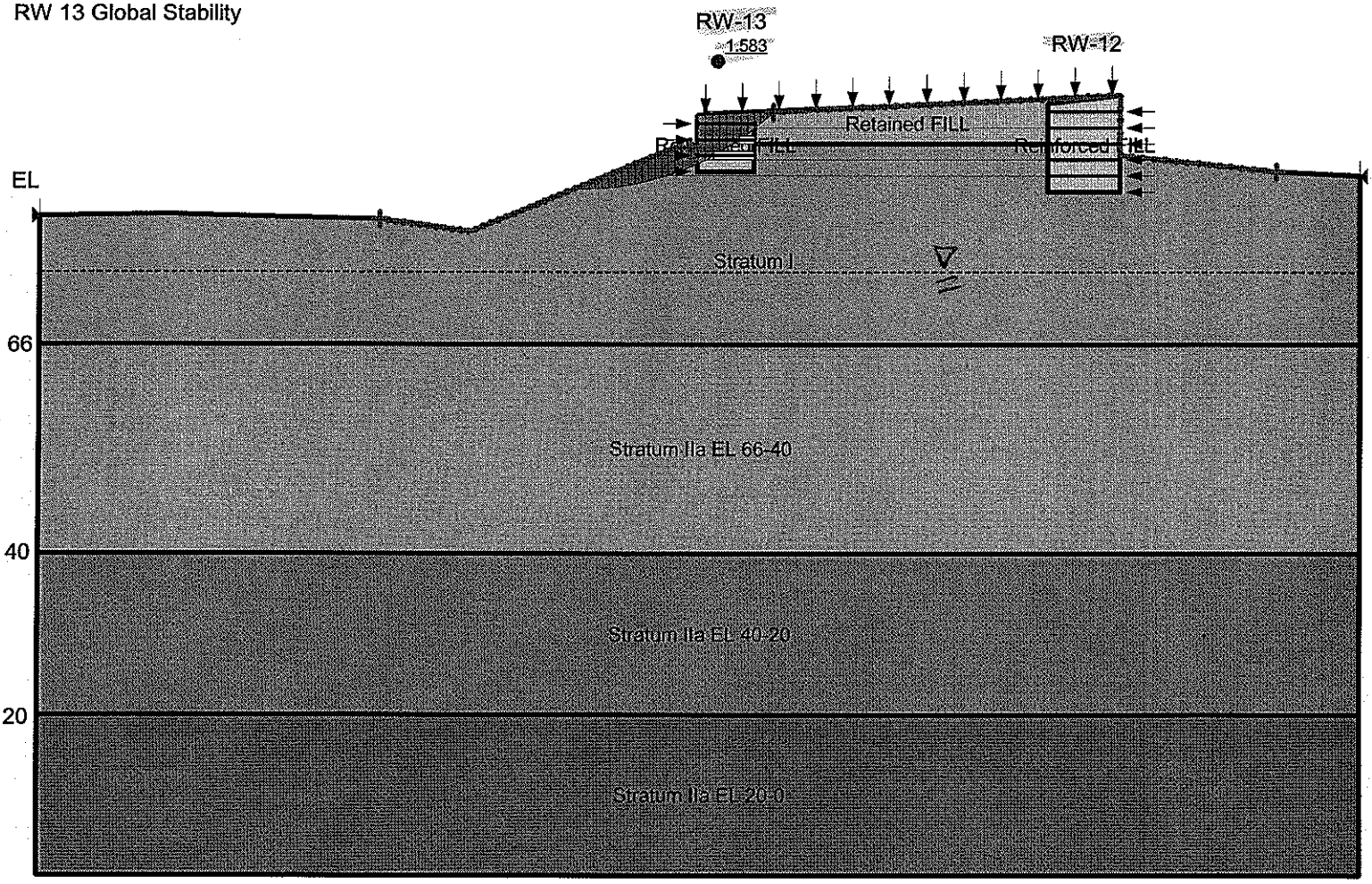
JPT 9-30-08

BPT 1-209

5

JBT
1-2-09
SM
2/9/09

SR1/I-95 Interchange 103-059-27U 11/13/08
RW 13 Global Stability



JJT 1-2-09

SLOPE/W Analysis

Report generated using GeoStudio 2007, version 7.11. Copyright © 1991-2008 GEO-SLOPE International Ltd.

File Information → RW 13 Analysis

Revision Number: 27
Date: 11/13/2008
Time: 11:53:42 AM
File Name: Ramp A STA 1224+00 RW 13.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 12 and 13\
Last Solved Date: 11/13/2008
Last Solved Time: 11:54:08 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Description: I-95/SR 1 Interchange 103-059-27U Ramp A Retaining Wall 13 STA 1224+00
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Apply Phreatic Correction: No
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

SlipSurface
- Direction of movement: Right to Left
- Allow Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: No
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 16
Ending Optimization Points: 32
Complete Passes per Insertion: 1

Materials

Reinforced FILL

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Select Fill

Retained FILL (DelDOT Type F Borrow)

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Stratum I

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 32 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Stratum IIa EL 66-40

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 17 °

Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Stratum IIa EL 40-20

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 17 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Stratum IIa EL 20-0

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 17 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (-55, 81.5) ft
Left-Zone Right Coordinate: (-14, 90.5) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (-3.0000001, 94.945633) ft
Right-Zone Right Coordinate: (64, 87.5) ft
Right-Zone Increment: 50
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (-100, 82) ft
Right Coordinate: (75, 87) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-100	75
	75	75

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	-12	95
	42	97

Reinforcements

Reinforcement 1

Type: Fabric
Outside Point: (-13, 87.5) ft
Inside Point: (-5.5, 87.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 7.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 8000 lbs
Fabric Safety Factor: 1
Fabric Load: 8000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 7.5 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (-13, 89.5) ft
Inside Point: (-5.5, 89.5) ft
Slip Surface Intersection: (-10.927, 89.5) ft
Total Length: 7.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 8000 lbs
Fabric Safety Factor: 1
Fabric Load: 8000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 7.5 lbs
Fabric Load Used: 3.4268 lbs
Resisting Force Used: 0.63144 lbs/ft
Available Bond Length: 5.4269 ft
Required Bond Length: 5.4269 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (-13, 91.5) ft
Inside Point: (-5.5, 91.5) ft
Slip Surface Intersection: (-7.4884, 91.5) ft
Total Length: 7.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 8000 lbs
Fabric Safety Factor: 1
Fabric Load: 8000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 7.5 lbs
Fabric Load Used: 1.2555 lbs

Resisting Force Used: 0.63144 lbs/ft
Available Bond Length: 1.9884 ft
Required Bond Length: 1.9884 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (-13, 93.5) ft
Inside Point: (-5.5, 93.5) ft
Slip Surface Intersection: (-4.7157, 93.5) ft
Total Length: 7.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 8000 lbs
Fabric Safety Factor: 1
Fabric Load: 8000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 7.5 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0.63144 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (43.1, 85) ft
Inside Point: (33.5, 85) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 9.6 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 9.6 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (43.1, 87) ft
Inside Point: (33.5, 87) ft
Slip Surface Intersection: (-17.092, 87) ft
Total Length: 9.6 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 9.6 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0.63144 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (43.1, 89) ft
Inside Point: (33.5, 89) ft
Slip Surface Intersection: (-11.937, 89) ft
Total Length: 9.6 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 9.6 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 0.63144 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (43.1, 91) ft
Inside Point: (33.5, 91) ft
Slip Surface Intersection: (-8.2698, 91) ft
Total Length: 9.6 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 9.6 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0.63144 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (43.1, 93) ft
Inside Point: (33.5, 93) ft
Slip Surface Intersection: (-5.3621, 93) ft
Total Length: 9.6 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 9.6 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 0.63144 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (43.1, 95) ft
Inside Point: (33.5, 95) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 9.6 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 9.6 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Regions

	Material	Points	Area (ft^2)
Region 1	Stratum IIa EL 20-0	25,26,24,23	3500
Region 2	Stratum IIa EL 40-20	23,21,22,24	3500
Region 3	Stratum IIa EL 66-40	21,19,20,22	4550
Region 4	Stratum I	1,28,3,4,5,7,8,9,10,16,15,14,13,18,27,20,19	3507.9088
Region 5	Reinforced FILL	6,7,8,9,10,11	48.75
Region 6	Reinforced FILL	15,16,17,12,13,14	110.4

Region 7	Retained FILL	6,11,10,16,17,12	191.175

Points

RW-13

Point 8 @ Toe of Wall
Point 6 @ Top of Wall
So, wall Height = pt. 6 − pt. 8

	X (ft)	Y (ft)	
Point 1	-100	82	
Point 2	-85	82	
Point 3	-55	81.5	
Point 4	-43	80	
Point 5	-16	90.5	
Point 6	-13	94.5	← EL 94.5
Point 7	-13	90.5	
Point 8	-13	87.5	← EL 87.5
Point 9	-5.5	87.5	
Point 10	-5.5	91	
Point 11	-5.5	93.5	
Point 12	43.1	97	
Point 13	43.1	89.5	
Point 14	43.1	85	
Point 15	33.5	85	
Point 16	33.5	91	
Point 17	33.5	96	
Point 18	64	87.5	
Point 19	-100	66	
Point 20	75	66	
Point 21	-100	40	
Point 22	75	40	
Point 23	-100	20	
Point 24	75	20	
Point 25	-100	0	
Point 26	75	0	
Point 27	75	87	
Point 28	-82.956857	82.088801	

= 94.5 − 87.5

H = 7'

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	6377	1.583	(-28.082, 122.951)	37.595	(-3, 94.9456)	(-29.1867, 85.3719)

Slices of Slip Surface: 6377

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	6377	-28.747095	85.36408	-646.72318	22.985554	14.362968	0
2	6377	-27.867985	85.3588	-646.39309	68.784342	42.981227	0
3	6377	-26.988875	85.37409	-647.34689	113.3201	70.810258	0
4	6377	-26.109765	85.40997	-649.58005	155.90875	97.422602	0
5	6377	-25.230655	85.466495	-653.10505	195.83737	122.37277	0
6	6377	-24.351545	85.543765	-657.92773	232.40154	145.2206	0
7	6377	-23.472435	85.64191	-664.05914	264.99371	165.58645	0
8	6377	-22.593325	85.76109	-671.49221	293.1132	183.15745	0
9	6377	-21.714215	85.90151	-680.25754	316.42362	197.72343	0
10	6377	-20.835105	86.063415	-690.35575	334.78626	209.19767	0
11	6377	-19.955995	86.247085	-701.82328	348.21283	217.58753	0
12	6377	-19.076885	86.45285	-714.65403	356.87421	222.99976	0
13	6377	-18.197775	86.681085	-728.89785	361.09609	225.63788	0
14	6377	-17.318665	86.932225	-744.57038	361.26638	225.74429	0

15	6377	-16.439555	87.20675	-761.69611	357.8319	223.59819	0
16	6377	-15.5	87.527515	-781.71365	328.91792	205.53073	0
17	6377	-14.5	87.89885	-804.88826	276.2654	172.62978	0
18	6377	-13.5	88.303025	-830.10816	222.77422	139.20478	0
19	6377	-12.5	88.7412	-857.45175	585.52176	394.93941	0
20	6377	-11.535715	89.196535	-885.85942	619.92753	418.1464	0
21	6377	-10.607145	89.6679	-915.27298	563.31166	379.95851	0
22	6377	-9.678573	90.17234	-946.74045	505.17552	340.74519	0
23	6377	-8.75	90.711415	-980.40121	448.7125	302.6604	0
24	6377	-7.8214285	91.2869	-1016.3335	392.60918	264.81823	0
25	6377	-6.892857	91.90082	-1054.6297	335.52277	226.31297	0
26	6377	-5.9642855	92.55551	-1095.4429	277.57895	187.22937	0
27	6377	-5.0833335	93.21563	-1136.6775	232.11002	123.41509	0
28	6377	-4.25	93.879475	-1178.1236	172.34291	91.636351	0
29	6377	-3.4166665	94.58334	-1221.9583	108.04198	57.446939	0

RW 12 Global Stability

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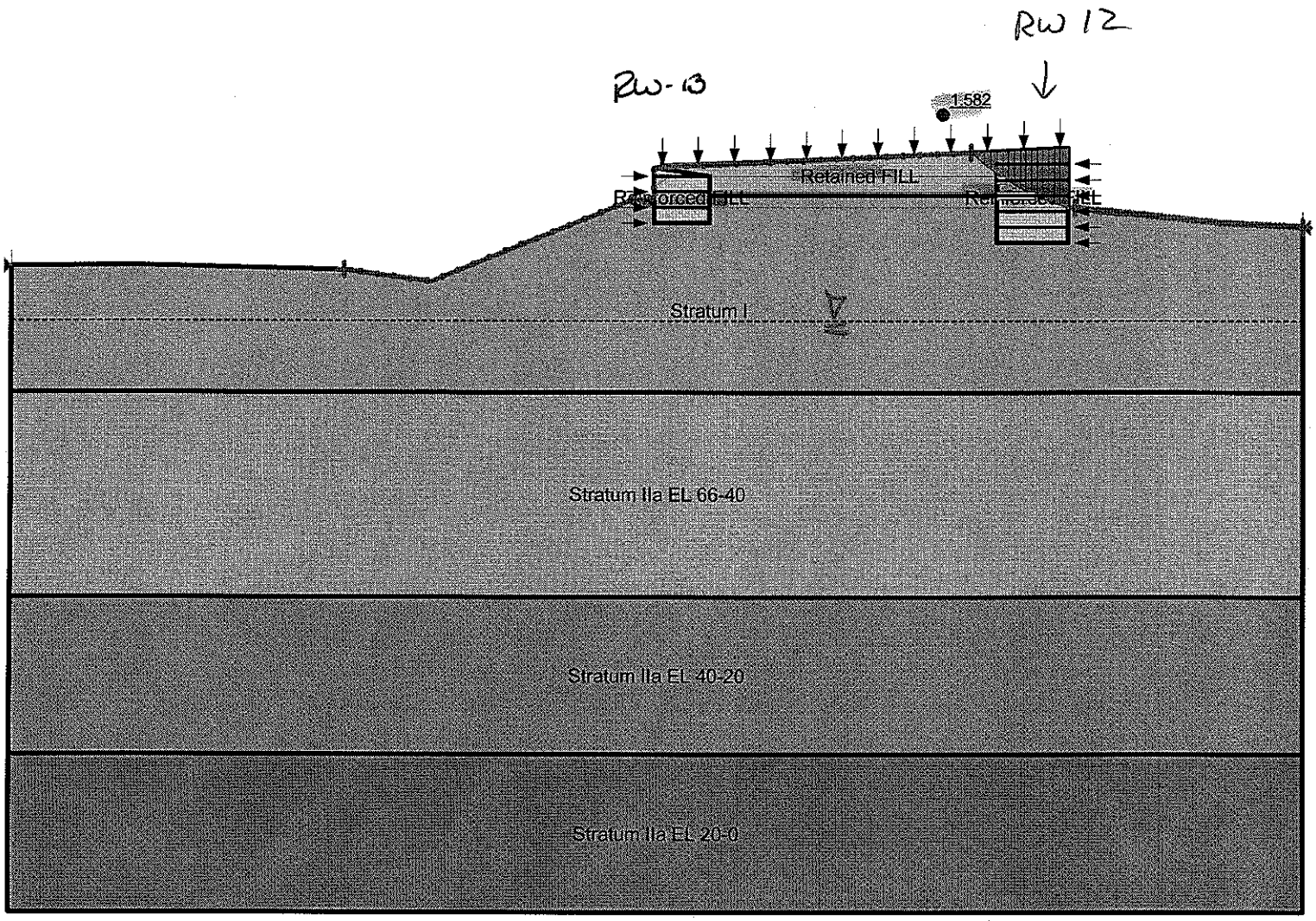
JJT 1-2-09



JJT 9-30-08
JJT 1-2-09

SLOPE/W Analysis

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File Information

RW-12

Revision Number: 31
Date: 9/22/2008
Time: 1:56:48 PM
File Name: Ramp A STA 1224+00 RW 12.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 12 and 13\
Last Solved Date: 9/22/2008
Last Solved Time: 1:57:07 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Description: I-95/SR 1 Interchange 103-059-27U Ramp A Retaining Wall 12 STA 1224+00
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Apply Phreatic Correction: No
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

SlipSurface
- Direction of movement: Left to Right
- Allow Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: No
- Tension Crack
  - Tension Crack Option: (none)

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FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 16
Ending Optimization Points: 32
Complete Passes per Insertion: 1

Materials

Reinforced FILL

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Select Fill

Retained FILL

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Type F Borrow

Stratum I

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 32 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Stratum IIa EL 66-40

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 17 °

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Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Stratum IIa EL 40-20

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 17 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Stratum IIa EL 20-0

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 17 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (-55, 81.5) ft
Left-Zone Right Coordinate: (30, 96.416221) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (44, 89.413876) ft
Right-Zone Right Coordinate: (75, 87) ft
Right-Zone Increment: 50
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (-100, 82) ft
Right Coordinate: (75, 87) ft

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Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	-100	75
	75	75

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 250 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	-12	95
	42	97

Reinforcements

Reinforcement 1

Type: Fabric
Outside Point: (-13, 87.5) ft
Inside Point: (-5.5, 87.5) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 7.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 8000 lbs
Fabric Safety Factor: 1
Fabric Load: 8000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 7.5 lbs
Fabric Load Used: 0 lbs

Used Fabric for reinforcement in Models. May be metal straps for design. OK

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Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (-13, 89.5) ft
Inside Point: (-5.5, 89.5) ft
Slip Surface Intersection: (43.07, 89.5) ft
Total Length: 7.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 8000 lbs
Fabric Safety Factor: 1
Fabric Load: 8000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 7.5 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0.63222 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (-13, 91.5) ft
Inside Point: (-5.5, 91.5) ft
Slip Surface Intersection: (37.585, 91.5) ft
Total Length: 7.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 8000 lbs
Fabric Safety Factor: 1
Fabric Load: 8000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 7.5 lbs
Fabric Load Used: 0 lbs

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Resisting Force Used: 0.63222 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (-13, 93.5) ft
Inside Point: (-5.5, 93.5) ft
Slip Surface Intersection: (33.935, 93.5) ft
Total Length: 7.5 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 8000 lbs
Fabric Safety Factor: 1
Fabric Load: 8000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 7.5 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0.63222 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (43.1, 85) ft
Inside Point: (33.5, 85) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 9.6 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 9.6 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (43.1, 87) ft
Inside Point: (33.5, 87) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 9.6 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 9.6 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (43.1, 89) ft
Inside Point: (33.5, 89) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 9.6 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 9.6 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (43.1, 91) ft
Inside Point: (33.5, 91) ft
Slip Surface Intersection: (38.707, 91) ft
Total Length: 9.6 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 9.6 lbs
Fabric Load Used: 3.2918 lbs
Resisting Force Used: 0.63222 lbs/ft
Available Bond Length: 5.2067 ft
Required Bond Length: 5.2067 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (43.1, 93) ft
Inside Point: (33.5, 93) ft
Slip Surface Intersection: (34.751, 93) ft
Total Length: 9.6 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 9.6 lbs
Fabric Load Used: 0.79084 lbs

Resisting Force Used: 0.63222 lbs/ft
Available Bond Length: 1.2509 ft
Required Bond Length: 1.2509 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (43.1, 95) ft
Inside Point: (33.5, 95) ft
Slip Surface Intersection: (31.757, 95) ft
Total Length: 9.6 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Bond Skin Friction: 1 psf
Bond Safety Factor: 1
Bond Resistance: 1 lbs/ft
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 9.6 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0.63222 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Regions

	Material	Points	Area (ft^2)
Region 1	Stratum IIa EL 20-0	25,26,24,23	3500
Region 2	Stratum IIa EL 40-20	23,21,22,24	3500
Region 3	Stratum IIa EL 66-40	21,19,20,22	4550
Region 4	Stratum I	1,28,3,4,5,7,8,9,10,16,15,14,13,18,27,20,19	3507.9088
Region 5	Reinforced FILL	6,7,8,9,10,11	48.75
Region 6	Reinforced FILL	15,16,17,12,13,14	110.4

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Region 7	Retained FILL	6,11,10,16,17,12	191.175

Points

	X (ft)	Y (ft)	
Point 1	-100	82	
Point 2	-85	82	
Point 3	-55	81.5	
Point 4	-43	80	
Point 5	-16	90.5	
Point 6	-13	94.5	
Point 7	-13	90.5	
Point 8	-13	87.5	
Point 9	-5.5	87.5	
Point 10	-5.5	91	
Point 11	-5.5	93.5	
Point 12	43.1	97	← EL 97
Point 13	43.1	89.5	
Point 14	43.1	85	← EL 85
Point 15	33.5	85	
Point 16	33.5	91	
Point 17	33.5	96	
Point 18	64	87.5	
Point 19	-100	66	
Point 20	75	66	
Point 21	-100	40	
Point 22	75	40	
Point 23	-100	20	
Point 24	75	20	
Point 25	-100	0	
Point 26	75	0	
Point 27	75	87	
Point 28	-82.956857	82.088801	

RW 12

Wall Height = Point 12 - Point 14

(Point 12 = Top of Wall EL)

(Point 14 = Toe of Wall EL

H = 97 - 85 = 12'

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	10282	1.582	(51.58, 121.388)	33.004	(30, 96.4162)	(53.9076, 88.4658)

Slices of Slip Surface: 10282

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesi Streng (psf)
1	10282	30.4375	96.05114	-1313.5831	64.111103	34.088478	0
2	10282	31.3125	95.34557	-1269.5229	134.88906	71.721786	0
3	10282	32.1875	94.687325	-1228.4592	200.23376	106.46618	0
4	10282	33.0625	94.072975	-1190.1215	261.73023	139.16443	0
5	10282	33.886365	93.530975	-1156.2939	300.29777	202.55341	0
6	10282	34.65909	93.054825	-1126.6123	350.99419	236.74857	0
7	10282	35.431815	92.6073	-1098.6958	401.19609	270.61018	0
8	10282	36.204545	92.18708	-1072.4701	451.96294	304.85285	0
9	10282	36.977275	91.793	-1047.8778	503.3685	339.52634	0
10	10282	37.75	91.42403	-1024.8559	555.57383	374.73928	0
11	10282	38.522725	91.07925	-1003.3445	610.32629	411.67028	0
12	10282	39.295455	90.75784	-983.29427	662.41591	446.80518	0
13	10282	40.068185	90.459075	-964.64914	716.55249	483.32076	0
14	10282	40.84091	90.182305	-947.37481	770.63838	519.80215	0

15	10282	41.613635	89.926945	-931.43917	824.02141	555.80946	0
16	10282	42.55	89.648075	-914.00181	875.44113	590.4925	0
17	10282	43.485985	89.39395	-898.18686	10.245474	6.4020825	0
18	10282	44.257955	89.208475	-886.60661	25.191233	15.741229	0
19	10282	45.02993	89.042485	-876.24868	38.099811	23.807404	0
20	10282	45.801905	88.89568	-867.08877	48.738432	30.455152	0
21	10282	46.573875	88.767805	-859.10541	56.884027	35.545085	0
22	10282	47.345845	88.658635	-852.29368	62.341551	38.955325	0
23	10282	48.11782	88.56798	-846.64124	64.968291	40.596694	0
24	10282	48.889795	88.495695	-842.1279	64.690482	40.4231	0
25	10282	49.661765	88.441655	-838.76528	61.51592	38.439413	0
26	10282	50.433735	88.405765	-836.52	55.537129	34.70345	0
27	10282	51.205705	88.387975	-835.40387	46.924841	29.321895	0
28	10282	51.97768	88.38825	-835.42274	35.914487	22.441862	0
29	10282	52.749655	88.40659	-836.57677	22.784425	14.237289	0
30	10282	53.521625	88.44303	-838.84663	7.8307353	4.8931865	0

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject I-95/SR 1 Interchange
RW 12 & 13 Settlement Calculations
Page 1 of 22
Cm. No. 103-059-274
Prepared By SAB Date 9/22/08 Checked By [illegible] Date 9-30-08
REV 12/18/08 [illegible] 1-18-09

Objective: To estimate the settlement anticipated to occur during and following the construction of Ramp A Retaining Walls 12 & 13.

Wall Details: (See p. 2 for cross-section)

Retaining Wall 12 is 358' long.
Retaining Wall 13 is 348' long.

Length of wall to be analyzed, say L = 100' [~STA 1227+50 to ~STA 1226+50]

→ This section of the MSE Walls was chosen to be analyzed because the walls are the tallest here generally the highest bearing stress. The walls adjoin to Ramp A, Bridge S-1 @ STA 1227+50.

→ From MSEW Analysis, Maycroff Stress, σ_v: RW 12: 6,688 psf RW13: 6,688 psf
eccentricity, e = 3.58', B = 25.55'
$B' = B - 2e$
$= 25.55 - 2(3.58)$
$= 18.4'$ B' = 18.4'

Distance between walls = 56'

→ To estimate differential settlement, model STA 1226+50 to 1225+50 in MSEW using the average wall height between these stations.

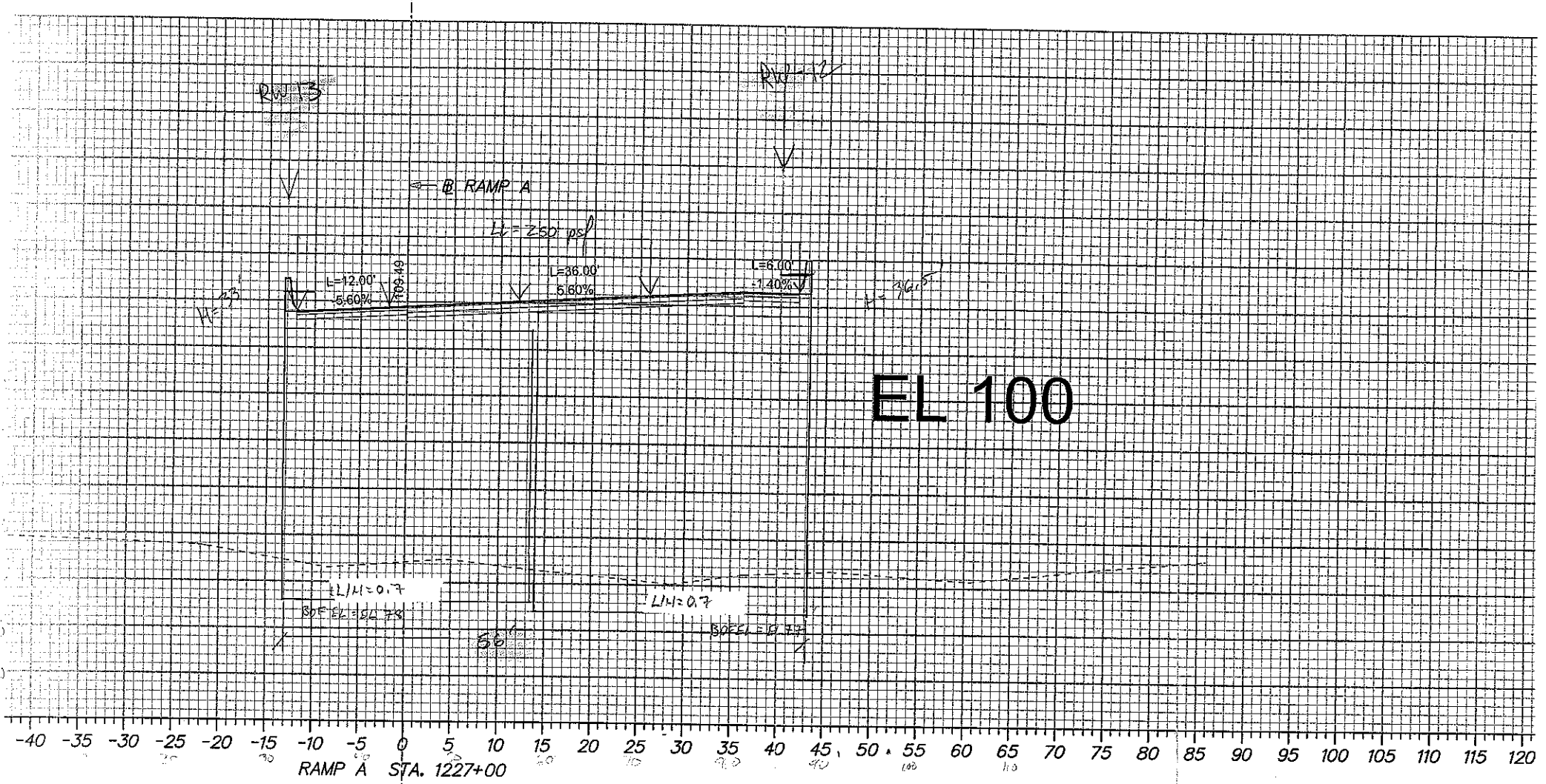
⇒ Average Height = 23' Average Width = 56' ⇒ $\sigma_v = 130 pcf (23') = 2,990 psf$

⇒ So for RW12 & 13, use 100' long, 18.4' wide footings with $\sigma_v = 6,688 psf$ (from MSEW)

↳ Area b/t walls: Fill: $130 pcf \times 35' = 4,550 psf$, Width = $56' - (2)(18.4') = 19.2'$

⇒ From URS, Ramp A Abutment: Bearing Stress = 4,980 psf & B = 38'

I-95/SR 1 Interchange 103-059-ZZU 9/22/08
RW 12 & 13 Settlement REV 12/16/08



RKK RW 12 & 13-49
1-18-09
2

RUMMEL, KLEPPER & KAHL, LLP
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Subject I-95/SR 1 Interchange
RW12 & 13 Settlement
Page 3 of
Cm. No. 103-059-270
Prepared By SAB Date 9/22/08 Checked By JJT Date 9-13-08
REV 1/6/08 JJT 1-18-09
CKM 1/9/09

Soils: (See attached fence, page 8)
- Assume BOF EL = EL 78 → Water table @ EL 76

Stratum	EL	γ_t (pcf)	μ	E (ksf) (3)*	C_s (1)	C_r (1)	e_o (1)	C_v (ft²/day) (1)	OCR (1)	P_c (psf) (2)	P_o @ Bottom (psf)	Avg. N-value
I	78-73	125	0.3	1,500	–	–	–	–	–	–	438	18
IIb	73-50	130	0.3	1,364	–	–	–	–	–	–	1,993	15
IIa	50-11	130	0.4	818	0.02	0.02	0.614	0.2086	3	7,800	6,117	31
IIb	-11--36	130	0.3	1,364	–	–	–	–	–	–	7,801	–
IIa	-36-146	130	0.4	1,364	0.016	0.016	0.654	0.2086	1			

↳ Assume no consolidation from Main Stratum (2B = 112', so consol. estimated from EL 78 to EL -34)

(1): Consolidation parameters from general site parameters & Consol. Tests from URS-3 (see p. 4)
* Use $C_c = C_r$ in analysis since $\Delta\sigma < P_c$; $C_r = 10\%/6_c \leq 0.015$ ✓

(2): P_c estimated based on graph of K_o values ~ 60' FILL x 130 pcf = 7,800 psf (See page 5)

P_o: I: 2'(125) + 3'(125-62.4) = 438 psf
IIb: 438 + 23'(130-62.4) = 1,993 psf
IIa EL 50-11: 1,993 + 61'(130-62.4) = 6,117 psf
IIb EL -11--36: 6,117 + 25'(67.6) = 7,801 psf
IIa EL -36--146: 7,801 + 110'(67.6) = 15,243 psf

$P_c - P_o$ = 7,800 - 1,993 = 5,807 psf
→ $P_c - P_o$ = 7,800 - 6,117 = 1,683 psf
→ $P_c - P_o$ =

(3): Calculate Young's Modulus (E) based on: *IGNORE BELOW. USE GENERAL SITE PARAMETERS*

1) DMT Testing - see page 6. From DMT 21 (closed):

Stratum	E (ksf)
I	787
IIb	628
IIa (50-0)	326

2) SPT N-values (from Boring IRW-69): (Gen. Bowles, 4th ed., attached, page 7)

Stratum I: Table 2-7; For Medium Clay, E = 300-1,000 ksf. So, 787 ksf OK.

Stratum IIb: Table 5-5; OC Sand; $E_s = [18,000 + 750N]/50$ = 585 ksf vs. 628 ksf → So use E = 600 ksf

Stratum IIa: Table 2-7; Med to Hard Clay, E = ~1,000 ksf.
Table 5-5: For PI < 30/stiff, E_s = 500 to 1,500 s_u = 500(1.5 ksf) to 1,500(1.5 ksf) = 750 to 2250 ksf

=> So use E = 700 ksf for EL 50-0 and E = 1,000 below EL 0.

* E-values for all Strata are from Correlations w/ SPT N-Values @ Borings A, B, C, + G1.

SR 1/I-95 Interchange - Consolidation Soil Parameters - Stratum 2a

PointID	Sample	GS EL	GWL (ft)	Depth (ft)	Sample EL	γ_T (pcf)	NMC (%)	LL	PL	PI	LI	P_0 (tsf)	$Pc_{Casagrande}$ (tsf)	$Pc_{Work\ Energy}$ (tsf)	OCR_C	$OCR_{W.E.}$	FINAL P_c (tsf)	FINAL OCR	e_0	c_c	c_r	$C_{v(Max)}$ (ft^2/d)	$C_{v(Min)}$ (ft^2/d)	cr/cc	CC	CR
IEB-15	U-1	83	52.0	12	71	129.5	26.7	49	26	23	0.03	0.78	3.53	6.00	4.5	7.7	3.53	4.5	0.669	0.19	0.05	3.17	0.02	26	11.384	0.030
IBR-61	U-1	84	24.0	14	70	123.6	30.7	34	21	13	0.75	0.87	2.91	1.85	3.4	2.1	2.91	3.4	0.748	0.24	0.05	2.64	0.03	21	13.730	0.029
IEB-13A	T-1	84	9.6	15	69	77.8	18.7	33	19	14	-0.02	0.82	2.95	3.30	3.6	4.0	3.13	3.8	0.554	0.12	0.02	0.23		17	7.722	0.013
IBR-60	U-1	86	11.4	18	68	133.3	20.5	30	19	11	0.14	0.94	1.97	1.83	2.1	2.0	1.97	2.1	0.521	0.13	0.03	2.10	0.01	23	8.547	0.020
ICPT-15A	T-1	80.19	3.0	19	61.19	101.5	24.4	49	23	26	0.05	0.69	2.30	3.10	3.3	4.5	2.7	3.9	0.666	0.12	0.03	0.19	0.09	25	7.203	0.018
IRW-33A	T-1	80	15.0	24	56	107.8	23.3	42	21	21	0.11	1.10	1.25	0.90	1.1	0.8	1.08	1.0	0.685	0.19	0.07	0.41	0.01	37	11.276	0.042
IRW-44	T-1	81	10.0	25	56	103.6	20.1	40	19	21	0.05	1.11	2.91	3.93	2.6	3.5	3.42	3.1	0.657	0.17	0.05	0.11	0	29	10.260	0.030
URS-4	U-1	77	14.0	22	55	123.9	34.7	53	28	25	0.27	1.12	1.78	3.10	1.6	2.8	3.1	2.8	0.851	0.25	0.09	2.50	0.01	36	13.506	0.049
IRW-51	T-1	80	10.7	25	55	105.8	21.6	38	19	19	0.14	1.17	1.94	2.75	1.7	2.4	2.35	2.0	0.64	0.23	0.09	0.2	0.03	39	14.024	0.055
IRW-32	T-1	79	13.4	25	54	114.2	19.5	39	19	20	0.03	1.24	6.50	4.60	5.3	3.7	NV	NV	0.545	0.11	0.04	0.24	0.05	29	9.061	0.026
ICPT-16A	T-1	84.87	14.4	31	53.87	134.1	16.4	34	19	15	-0.17	1.90	3.90	5.00	2.1	2.6	4.45	2.3	0.474	0.07	0.01	2.27	0.29	14	4.749	0.007
IRW-52	T-2	88	15.2	35	53	108.3	22.3	44	19	25	0.13	1.63	2.56	2.60	1.6	1.6	2.58	1.6	0.628	0.16	0.05	0.47	0.24	31	9.828	0.031
IRW-50	T-1	77.69	5.2	25	52.69	111.2	19.9	NP	NP	NP		1.02	8.28	5.25	8.1	5.2	NV	NV	0.563	0.19	0.03	1.0	0	16	12.156	0.019
IEB-15	U-2	83	52.0	31	52	132.8	22.6	36	20	16	0.16	2.02	5.29	1.91	2.6	0.9	5.29	2.6	0.527	0.17	0.05	1.10	0.01	29	11.133	0.033
IRW-33	T-1	79	DRY	27	52	100.5	26.1	47	22	25	0.16	1.30	1.12	1.40	0.9	1.1	1.26	1.0	0.801	0.20	0.07	0.16	0.02	35	11.105	0.039
ICPT-15A	T-2	80.19	3.0	29	51.19	72.3	36.7	50	24	26	0.49	1.00	11.00	12.00	11.0	12.0	11.5	11.5	1.333	0.15	0.02	6.74	2.36	13	6.429	0.009
IBR-15	T-1	70	2.0	19.5	50.5	96.9	24.6	42	20	22	0.21	0.72	1.63	2.30	2.3	3.2	1.97	2.7	0.772	0.22	0.06	0.15	0.03	27	12.415	0.034
URS-1	U-1	73	6.0	24	49	126.0	33.5	48	24	24	0.40	0.95	0.67	0.70	0.7	0.7	NV	NV	0.792	0.23	0.07	0.17	0.03	30	12.835	0.039
IEB-13B	T-2	81.64	7.0	33	48.64	115.9	16.1	28	17	11	-0.08	1.40	5.70	7.25	4.1	5.2	6.48	4.6	0.454	0.04	0.01	6.87	2.47	25	2.751	0.007
IRW-53	T-1	63.39	18.5	15	48.39	107.6	19.9	39	17	22	0.13	0.96	1.96	4.00	2.0	4.2	NV	NV	0.539	0.15	0.04	0.32	0.04	27	9.747	0.026
URS-3	U-1	82	6.0	35	47	132.3	26.1	40	22	18	0.23	1.33	2.59	2.40	1.9	1.8	2.59	1.9	0.614	0.20	0.07	1.92	0.02	35	12.392	0.043
IBR-04	T-1	65	2.0	18	47	115.5	12.6	22	17	5	-0.88	0.67	3.00	2.75	4.5	4.1	2.88	4.3	0.487	0.05	0.01	1.5	0	20	3.362	0.007
IRW-49	T-2	77	2.6	30	47	113.4	20.7	60	19	41	0.04	1.12	5.11	4.00	4.5	3.6	4.56	4.1	0.475	0.09	0.03	0.3	0.08	33	6.102	0.020
IRW-42	T-2	75	1.0	30	45	114.7	26.1	44	22	22	0.19	1.18	3.96	4.38	3.4	3.7	4.17	3.5	0.541	0.18	0.04	0.22	0.01	22	11.681	0.026
IEB-13B	T-3	81.64	7.0	39	42.64	116.9	15.5	27	14	13	0.12	1.63	10.00	7.25	6.1	4.5	8.63	5.3	0.447	0.05	0.03	4.99	1.59		3.455	0.021
IBR-52	U-1	57	11.5	16	41	126.9	29.8	43	23	20	0.34	0.88	1.10	3.75	1.3	4.3	3.75	4.3	0.678	0.18	0.07	0.22	0.02	39	10.727	0.042
IBR-60	U-2	86	11.4	46	40	132.3	24.2	36	21	15	0.21	1.90	1.23	2.00	0.6	1.1	2.00	1.1	0.602	0.16	0.04	1.11	0.01	25	9.988	0.025
URS-4	U-2	77	14.0	37	40	131.2	26.9	42	22	20	0.25	1.64	1.01	1.12	0.6	0.7	NV	NV	0.458	0.20	0.06	2.35	0.01	30	13.717	0.041
														Above EL 40 Averages:			3.75	3.37	0.633	0.16	0.05	1.56	0.28	27	9.689	0.028
ICPT-16A	T-2	84.87	14.4	45	39.87	134.1	16.7	41	18	23	-0.06	2.45	4.20	3.90	1.7	1.6	4.05	1.7	0.304	0.07	0.01	0.99	0.23	14	5.368	0.008
IBR-32	T-3	89		50	39	132.7	16.7	31	18	13	-0.10	2.11	3.00	3.38	1.4	1.6	3.19	1.5	0.519	0.16	0.05	0.02		31	10.533	0.033
IRW-23	T-2	60	36.7	24.5	35.5	108.7	18.4	36	21	15	-0.17	0.81	4.96	3.63	6.1	4.5	4.29	5.3	0.522	0.13	0.03	0.38	0.06	23	8.541	0.020
ICPT-15A	T-3	80.19	3.0	45	35.19	97.3	22.3	53	22	31	0.01	1.47	3.50	2.20	2.4	1.5	2.85	1.9	0.739	0.12	0.04	0.09	0.05	33	6.901	0.023
IBR-05	T-2	66	36.0	31.5	34.5	119.0	16.0	21	18	3	-0.67	1.17	4.75	2.70	4.1	2.3	NV	NV	0.661	0.15	0.02	1.0		13	9.031	0.012
URS-3	U-2	82	6.0	50	32	117.0	42.8	51	24	27	0.70	1.74	0.84	1.20	0.5	0.7	NV	NV	0.987	0.27	0.08	0.33	0.01	30	13.588	0.040
ICPT-16A	T-3	84.87	14.4	55	29.87	134.1	13.2	64	26	38	-0.34	3.39	5.00	5.40	1.5	1.6	5.20	1.5	0.872	0.19	0.04	1.08	0.08	21	10.150	0.021
URS-5	U-1	63	4.0	35.5	27.5	121.5	34.5	55	29	26	0.21	1.24	2.01	1.60	1.6	1.3	2.01	1.6	0.786	0.23	0.09	1.61	0.01	39	12.878	0.050
IEB-15	U-3	83	52.0	56	27	132.8	25.5	47	25	22	0.02	3.56	2.40	4.05	0.7	1.1	4.05	1.1	0.582	0.20	0.06	1.70	0.01	30	12.642	0.038
IBR-61	U-2	84	24.0	59	25	123.3	33.3	46	24	22	0.42	2.55	0.69	2.50	0.3	1.0	2.50	1.0	0.839	0.22	0.06	0.56	0.01	27	11.963	0.033
IRW-09	T-2	59	DRY	35	24	110.9	17.5	23	18	5	-0.10	1.39	3.92	2.30	2.8	1.7	NV	NV	0.536	0.11	0.03	2.8	0.2	27	7.161	0.020
IEB-13B	T-4	81.64	7.0	59	22.64	104.1	22.1	NP	NP	NP		2.13	8.00	9.60	3.8	4.5	8.8	4.1	0.505	0.04	0.01	1.76	0.34	25	2.658	0.007
														EL 40 to 20 Averages:			4.10	2.2	0.654	0.16	0.04	1.03	0.10	26	9.285	0.025
														Total Average:			3.85	3.0	0.639	0.16	0.05	1.40	0.23	27	9.567	0.027

NV: Consolidation Test Not Valid

RKK RW12 & 13-51
JGT 1-18-09

I-95/SR1 Interchange
103-059-270
RW12 & 13 Settlement

= ~60'

So $P_c \approx 60'$ FILL

6'(125 pcf) = 7500 psf

JJT 9-30-08

JJT 1-18-09

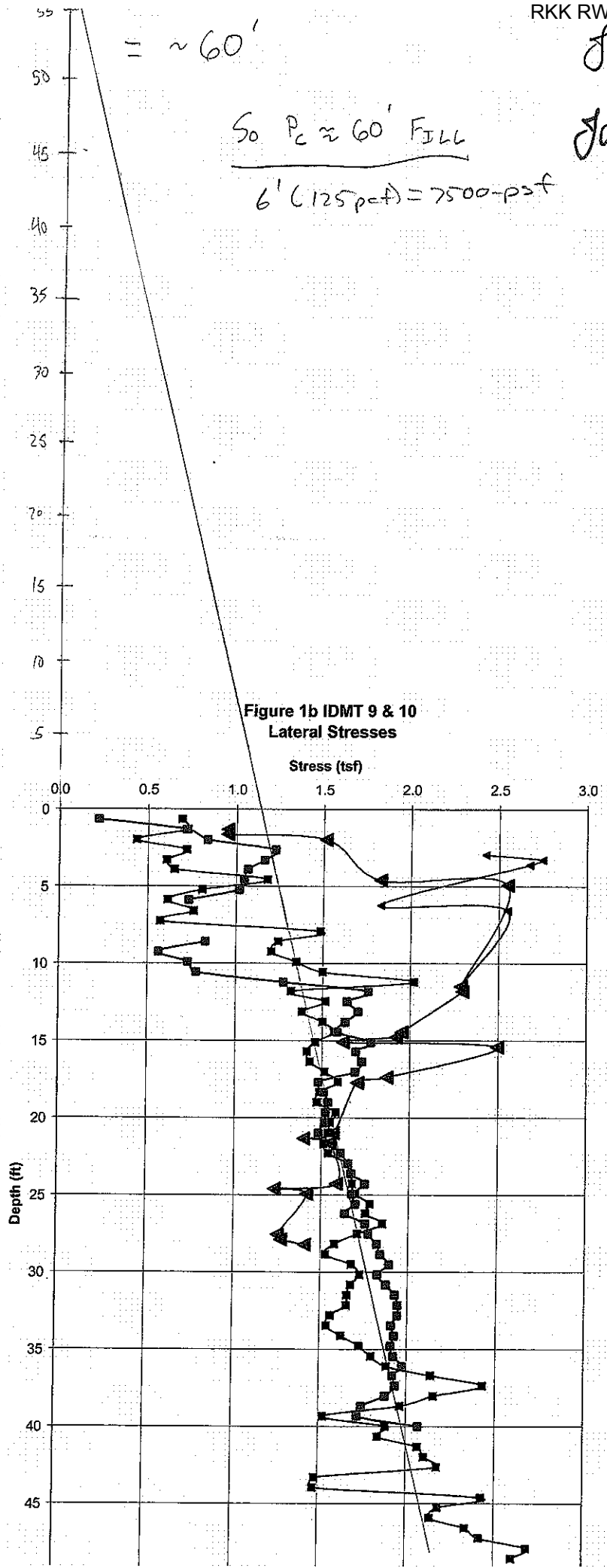


Figure 1b IDMT 9 & 10
Lateral Stresses

JDT 9-30-08

JDT 1-15-09

I-95/SR 1 Interchange 103-059-27U 9/23/08
RW 12 and 13 Settlement Parameters

IDMT-21 EL 82							IDMT-22 EL 87						
Depth	EL	OCR	M (ksf)	E (ksf)	E avg	Stratum/EL	Depth	EL	OCR	M (ksf)	E (ksf)	E avg	Stratum/EL
0.7	81.3	73.4	166	123			1	86	56.9	69	51		
1.3	80.7		501	372			1.3	85.7	64.3	348	259		
2	80	161.3	1905	1415			2	85	49.1	476	354		
2.6	79.4	58.1	1667	1238	787	I	2.6	84.4		1192	885		
							3.3	83.7		924	686		
							3.9	83.1	42	1454	1080		
							4.6	82.4		880	654		
							5.2	81.8	9.1	826	614		
							5.9	81.1		522	388		
							6.6	80.4	4.5	648	481		
							7.2	79.8		545	405		
							7.9	79.1	4.9	746	554		
							8.5	78.5	1.4	598	444		
							9.2	77.8	2	548	407		
							9.8	77.2	1.3	547	406		
							10.5	76.5	2.3	582	432		
							11.2	75.8		231	172		
							11.8	75.2		301	224		
							12.5	74.5	0.4	307	228		
							13.1	73.9	1.1	357	265		I
							13.8	73.2	1.4	345	256	460	EL 73
							14.4	72.6	0.4	322	239		
							15.1	71.9	1.1	414	308		
							15.7	71.3	0.6	416	309		
17.7	64.3	2.4	473	351			16.4	70.6	0.2	349	259		
18.4	63.6	4.8	718	533			19	68	1.3	354	263		
19	63	8.5	646	480			19.7	67.3	0.6	252	187		
19.7	62.3	5.5	234	174									
20.3	61.7	4.8	722	536									
21	61	2.8	760	565									
21.7	60.3	8.6	864	642									
22.3	59.7	4.7	779	579									
23	59	2.9	722	536									
23.6	58.4	3.2	657	488			23.6	63.4	2.2	160	119		
24.3	57.7	3.7	687	510			24.3	62.7	0.5	350	260		
24.9	57.1	5.9	1131	840			24.9	62.1	3.4	996	740		
25.6	56.4	5.6	1187	882			25.6	61.4	3.3	640	475		
26.2	55.8	3.1	990	735			26.2	60.8	2.3	847	629		
26.9	55.1	3.9	1018	756			26.9	60.1	5.3	1195	888		
27.6	54.4	2.6	840	624			27.6	59.4	1.9	857	637		
28.2	53.8	3.7	748	556			28.2	58.8	1.8	759	564		
28.9	53.1	5.4	982	729			28.9	58.1	0.9	404	300		2b
29.5	52.5	5.7	1113	827			29.5	57.5	0.7	204	152	396	EL 57
30.2	51.8	6.3	1194	887			30.2	56.8	1.2	69	51		
30.8	51.2	6.4	1641	1219		2b	30.8	56.2	0.9	8	6		
31.5	50.5	2.8	500	371	628	EL 50	31.5	55.5	0.9	43	32		
32.2	49.8	2.8	87	65			32.2	54.8	1.4	125	93		
32.8	49.2	2.7	127	94			32.8	54.2	1.4	91	68		
33.5	48.5	3.1	126	94			33.5	53.5	1.3	84	62		
34.1	47.9	3.1	156	116			34.1	52.9	1.7	86	64		
34.8	47.2	3.6	213	158			34.8	52.2	1.9	373	277		
35.4	46.6	3.6	210	156			35.4	51.6	1.8	309	230		
36.1	45.9	3.5	281	209			36.1	50.9	4.1	516	383		
36.7	45.3	3.8	444	330			36.7	50.3	3.3	389	289		
37.4	44.6	4.1	467	347			37.4	49.6	1.9	175	130		
38.1	43.9	5.3	409	304			38.1	48.9	2.8	331	246		
38.7	43.3	4.6	404	300			38.7	48.3	2.7	122	91		
39.4	42.6	5.9	583	433			39.4	47.6	3.9	337	250		
40	42	7.3	680	505			40	47	3.2	375	279		
40.7	41.3	6.9	455	338			40.7	46.3	1.3	337	250		
41.3	40.7	5.7	459	341			41.3	45.7	2.2	234	174		2a
42	40	3.8	322	239			42	45	2.4	323	240	169	EL 45
42.7	39.3	3.8	381	283			42.7	44.3	2.2	874	649		
43.3	38.7	3.4	570	423			43.3	43.7	2.9	932	692		
44	38	3.8	448	333			44	43	1.8	706	524		
44.6	37.4	3	741	550			44.6	42.4	0.6	620	461		
45.3	36.7	1.9	992	737			45.3	41.7	3.3	945	702		
45.9	36.1	4.2	1161	862			45.9	41.1	3.4	367	273		
46.6	35.4	8.7	852	633			46.6	40.4	3.4	404	300		
47.2	34.8	5.2	567	421			47.2	39.8	1.8	674	501		
47.9	34.1	4.5	490	364			47.9	39.1	3.9	1139	846		
48.6	33.4	3.1	219	163			48.6	38.4	2	730	542		
49.2	32.8	3.3	203	151			49.2	37.8	4.4	367	273		
49.9	32.1	3.7	235	175	326	2a	49.9	37.1	3.7	266	198		

Avg: 4.2

BOWLES, 4th ED

TABLE 5-5 Equations for stress-strain modulus E_s by several test methods

E_s in kPa for SPT and units of q_c for CPT; divide kPa by 50 to obtain ksf. The N values should be estimated as N_{55} and not N_{70}

Soil	SPT	CPT
Sand (normally consolidated)	$E_s = 500(N + 15)$ $E_s = (15\,000 \text{ to } 22\,000) \ln N$ $E_s§ = (35\,000 \text{ to } 50\,000) \log N$	$E_s = 2 \text{ to } 4q_c$ $E_s† = (1 + D_r^2)q_c$
Sand (saturated)	$E_s = 250(N + 15)$	
Sand (overconsolidated)	$E_{s‡} = 18\,000 + 750N$ $E_{s(OCR)} = E_{s(nc)}(OCR)^{1/2}$	$E_s = 6 \text{ to } 30q_c$
Gravelly sand and gravel	$E_s = 1200(N + 6)$ $E_s = 600(N + 6) \quad N \leq 15$ $E_s = 600(N + 6) + 2000 \quad N > 15$	
Clayey sand	$E_s = 320(N + 15)$	$E_s = 3 \text{ to } 6q_c$
Silty sand	$E_s = 300(N + 6)$	$E_s = 1 \text{ to } 2q_c$
Soft clay	—	$E_s = 3 \text{ to } 8q_c$
Clay	Using the undrained shear strength s_u in units of s_u $I_P > 30$ or organic $I_P < 30$ or stiff $E_{s(OCR)} = E_{s(nc)}(OCR)^{1/2}$	$E_s = 100 \text{ to } 500s_u$ $E_s = 500 \text{ to } 1500s_u$

† Vesić (1970).
‡ Author's equation from plot of D'Appolonia et al. (1970).
§ USSR (and may not be standard blow count N).
General sources: European Conference on Standard Penetration Testing (1974), vol. 2.1, pp. 150–151; CGJ, November 1983, pp. 726–737; Use of In Situ Tests in Geotechnical Engineering, ASCE (1986), p. 1173; Mitchel and Gardner (1975).

CLAYS

AND	s_u (ksf)
VERY STIFF	2–4
STIFF	1–2
MEDIUM	0.5–1
SOFT	0.25–0.5
VERY SOFT	0–0.25

TRIAXIAL $E = 2.5q_c$

PLANE-STRAIN $E = 3.5q_c$

TABLE 2-7 Typical range of values for the static stress-strain modulus E_s for selected soils

Field values depend on stress history, water content, density, etc.

Soil	E_s ksf	E_s Mpa
Clay		
Very soft	50–250	2–15
Soft	100–500	5–25
Medium	300–1000	15–50
Hard	1000–2000	50–100
Sandy	500–5000	25–250
Glacial till		
Loose	200–3200	10–150
Dense	3000–15 000	150–720
Very dense	10 000–30 000	500–1440
Loess	300–1200	15–60
Sand		
Silty	150–450	5–20
Loose	200–500	10–25
Dense	1000–1700	50–81
Sand and gravel		
Loose	1000–3000	50–150
Dense	2000–4000	100–200
Shale	3000–300 000	150–5000
Silt	40–400	2–20

TABLE 2-8 Values or value ranges for Poisson's ratio μ

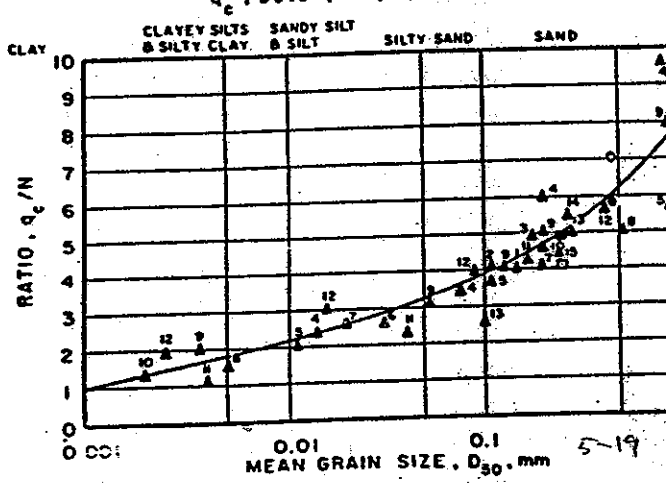
Type of soil	μ
Clay, saturated	0.4–0.5
Clay, unsaturated	0.1–0.3
Sandy clay	0.2–0.3
Silt	0.3–0.35
Sand, gravelly sand	0.1–1.00
commonly used	0.3–0.4
Rock	0.1–0.4 (depends somewhat type of rock)
Loess	0.1–0.3
Ice	0.36
Concrete	0.15

$\mu = \frac{1 - \sin\phi}{2 - \sin\phi}$

$\mu = 0.1 + 0.3\phi_r$

$\phi_r = \frac{\phi - 25°}{45° - 25°}$

FAIR $\phi \geq 40$



SR1/I-95 Interchange 103-059-270 11/13/08

RW 12 & 13 Analysis

RKK RW12 & 13.55

1-18-09

ICPT-21
N613831.4, E433413.6
EL 87.0
S_u/Phi Q_t(tsf)/OCR
22.0'

ICPT-21A
N613894, E433448
EL 87.0
S_u/Phi Q_t(tsf)/OCR
70.0'

IDMT-21
N613908, E433470
EL 82.0
S_u/Phi Ko/OCR
49.9'

STA 1227+65
URS-3
N613938, E433520
EL 82.0
SPT N or REC, RQD NMC AASHTO

STA 1227+00
B=25.55' → ZB=51'

BOF EL 78

I

II.b

ZB=51'

EL 30

II.a

EL 27

U-1 (consol) UU: γ_T=133.3 pcf, 26.1% (CL), LL=40, PI=19, S_u=2,366 psf

U-2 (consol) UU: γ_T=123.9 pcf, 42.8% (CH), LL=51, PI=27, S_u=1,204 psf

D-1

D-2

EL -11

II.b

EL -36

124.5'

STA 1226+00
IRW-69
N614017.7, E433661.3
EL 82.0
SPT N or REC, RQD NMC AASHTO
20.8% (A-4)
27.5% (A-2-4)
21.4% (A-7-5)
50.0'

STA 1225+50
IRW-70
N614000.2, E433734.4
EL 85.0
SPT N or REC, RQD NMC AASHTO
9.1% (A-1-b)
22.0% (A-2-4)
25.7% (A-2-4)
50.0'

STA 1225+25
IDMT-22
N614056, E433735
EL 87.0
S_u/Phi Ko/OCR
49.9'

STA 1224+50
IRW-71
N614085.1, E433807.6
EL 88.7
SPT N or REC, RQD NMC AASHTO
10.8% (A-2-4)
17.5% (A-4)
U-1 UU: S_u = 8,320 psf
18.3% (A-8)
50.0'

AASHTO SOIL KEY

A-1-a	A-2-5	A-5	A-8		
A-1-b	A-2-6	A-6	Asphalt		
A-3	A-2-7	A-7-5	FILL		
A-2-4	A-4	A-7-6	Decomposed Rock		

Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data
Retaining Walls 12 and 13

Figure No.

Drawn: SAB | Approved: | Date: 11/13/08 | Comm. No 103-059-27

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 11/13/08

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject I-95/SR1 Interchange — RW12 & 13 Settlement
Page 9 of
Cm. No. 103-059-270
Prepared By SAS Date 9/23/08 Checked By GDT Date 9-30-08
REV 1/6/08 GDT 1-18-09 EMM 2/9/09

Analyses: Performed using FoSSA (See attached output, p. 10-21)

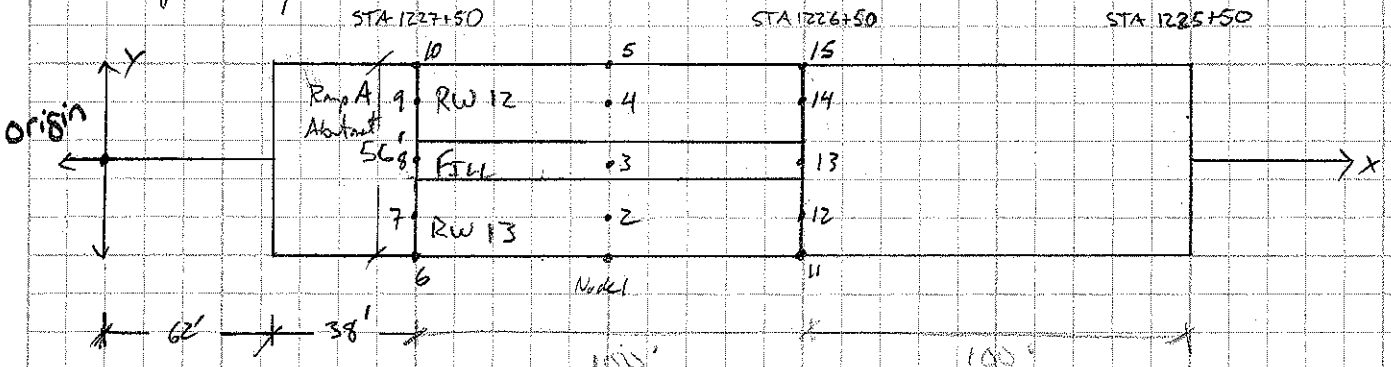
→ Calculate Elastic settlement to a depth of 4B below the BOF EL.

⇒ Full "footing" width for both walls = 56', 4B = 224'

BOF EL = EL 78 78 - 224 = EL -146

* Assume no elastic settlement in CLAY (Stratum IIa); only consolidation.

Bird's Eye View of Settlement Points:



Summary:

Maximum Elastic Settlement = 0.17' = 2.1" @ Nodes 2 & 4

Maximum Consolidation Settlement = 0.20' = 2.4" @ Node 3

⇒ Maximum Total Settlement = 0.36'

= 4.4" @ Nodes 2, 3, 4

↓

Time-rate Settlement:

⇒ See page 22 for differential settlement. (AASHTO Tolerance = 1/100)

JJT 1-18-09

SR 1/I-95 Interchange

Report created by FoSSA(2.0): Copyright (c) 2003-2006, ADAMA Engineering, Inc.

PROJECT IDENTIFICATION

Title:	SR 1/I-95 Interchange
Project Number:	103-059-27U -
Client:	DelDOT
Designer:	SAB
Station Number:	1227+00

RW 12 + 13

Description:
Retaining Wall 12 and 13

Company's information:

Name:	RK&K Engineers, LLP
Street:	81 Mosher Street Baltimore, MD 21217
Telephone #:	410-728-2900
Fax #:	410-728-0282
E-Mail:	

Original file path and name: M:\project ..... aining Wall 12 and 13\Final Design\RW12 and 13.2ST
Original date and time of creating this file: Thu Jan 08 08:28:58 2009

GEOMETRY: Analysis of a Multiple Footings

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JGT 1-18-09

INPUT DATA – FOUNDATION LAYERS – 5 layers

	Wet Unit Weight, γ [lb/ft³]	Poisson's Ratio μ	Description of Soil
1	125.00	0.30	Stratum I
2	130.00	0.30	Stratum IIb
3	130.00	0.40	Stratum IIa EL 50
4	130.00	0.30	Stratum IIb EL -11
5	130.00	0.40	IIa EL -36

INPUT DATA – MULTIPLE FOOTINGS – 5 footings

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	0.00	376.00
2	100.00	376.00
3	150.00	376.00
4	200.00	376.00
5	300.00	376.00

actual EL = Z - 300

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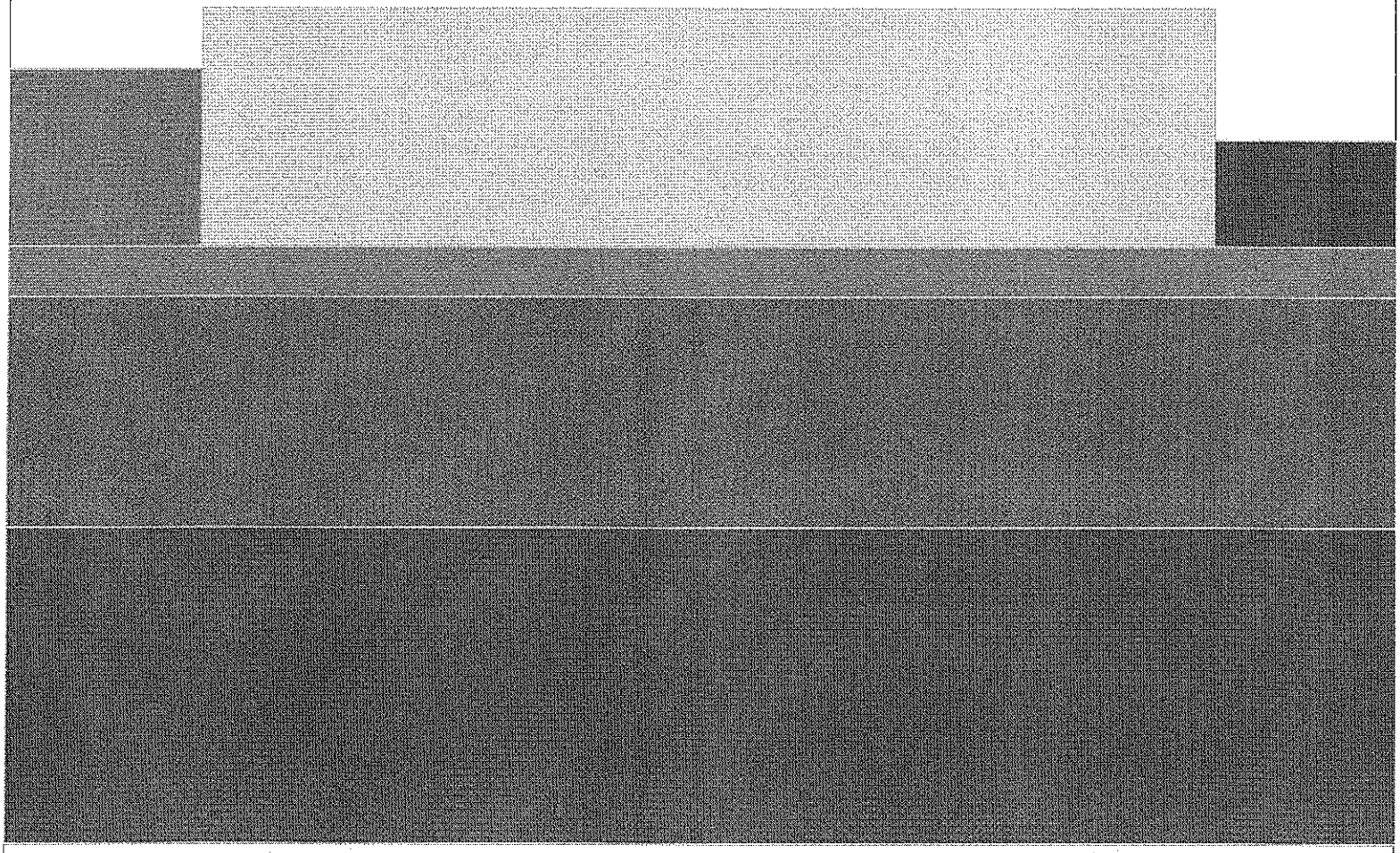
JST 1-18-09

DRAWING OF SPECIFIED GEOMETRY



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INPUT DATA FOR CONSOLIDATION -- $\alpha = 1/6$

Layer # Underging Consolidation [Yes/No]		$(\sigma'_p - \sigma'_o)$ given at layer's boundaries in [lb/ft²] at Top	Bottom	Cc	Cr	e0	Cv [ft ²/day]	Drains at :
1	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	Yes	5807.0	1683.0	0.02	0.02	0.61	0.2086	Top & Bot.
4	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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JJT 1-18-09

TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	0.00	378.00	Stratum I
	2	100.00	378.00	
	3	150.00	378.00	
	4	200.00	378.00	
	5	300.00	378.00	
2	1	0.00	373.00	Stratum IIb
	2	100.00	373.00	
	3	150.00	373.00	
	4	200.00	373.00	
	5	300.00	373.00	
3	1	0.00	350.00	Stratum IIa EL 50
	2	100.00	350.00	
	3	150.00	350.00	
	4	200.00	350.00	
	5	300.00	350.00	
4	1	0.00	289.00	Stratum IIb EL -11
	2	100.00	289.00	
	3	150.00	289.00	
	4	200.00	289.00	
	5	300.00	289.00	
5	1	0.00	164.00	IIa EL -36
	2	100.00	164.00	
	3	150.00	164.00	
	4	200.00	164.00	
	5	300.00	164.00	

Actual EL = Z - 350

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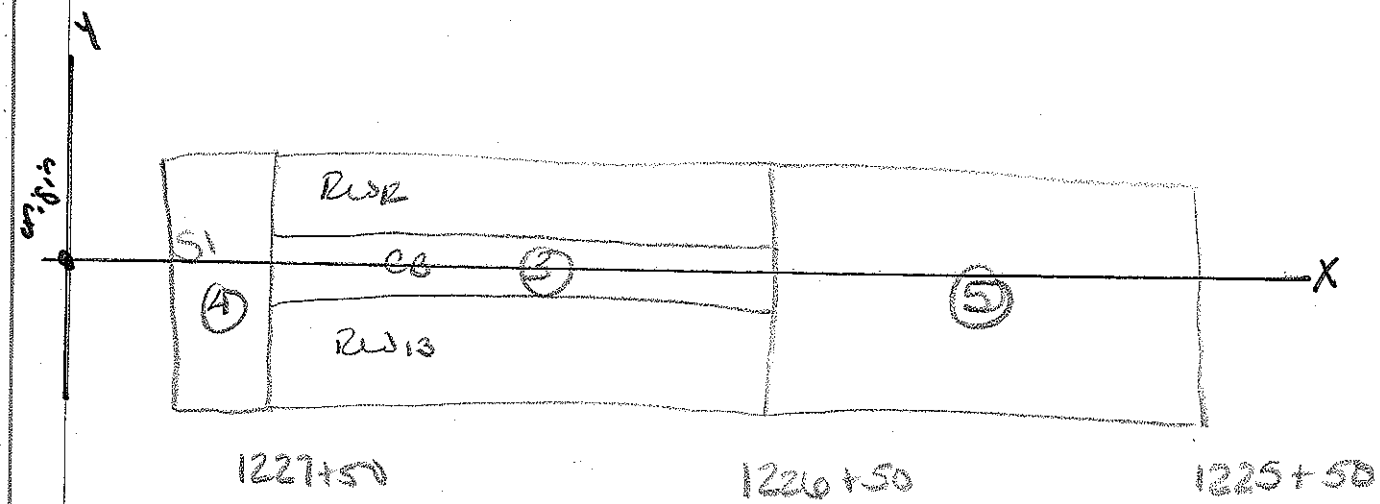
SOT 1-18-09

TABULATED GEOMETRY: INPUT OF MULTIPLE FOOTINGS – 5 footings

Footing #	L (in X direction) [ft]	B (in Y direction) [ft]	X of center [ft]	Y of center [ft]	q [ft]l [lb/ft²]	
1	100.00	18.40	150.00	18.80	6688.00	
2	100.00	18.40	150.00	-18.80	6688.00	CB between 12+15
3	100.00	19.20	150.00	0.00	4550.00	
4	38.00	56.00	81.00	0.00	4980.00	S1
5	100.00	56.00	250.00	0.00	2990.00	ΔTA 1226+50 to 1225+50

See Pg 9 for plan view



* NTS

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1-18-09

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	150.00	-28.00	1	1500000	0.3000	0.0065	378.00	~~377.68~~	~~0.32~~
			2	1364000	0.3000	0.0379			
			3	818000	0.4000	~~0.1336~~			0.1298'
			4	1364000	0.3000	0.0854			
			5	1364000	0.4000	~~0.0572~~			
2	150.00	-14.00	1	1500000	0.3000	0.0138	378.00	~~377.59~~	~~0.41~~
			2	1364000	0.3000	0.0687			
			3	818000	0.4000	~~0.1790~~			
			4	1364000	0.3000	0.0921			0.1746'
			5	1364000	0.4000	~~0.0592~~			
3	150.00	0.00	1	1500000	0.3000	0.0085	378.00	~~377.58~~	~~0.42~~
			2	1364000	0.3000	0.0596			
			3	818000	0.4000	~~0.1940~~			
			4	1364000	0.3000	0.0946			0.1627'
			5	1364000	0.4000	~~0.0585~~			
4	150.00	14.00	1	1500000	0.3000	0.0138	378.00	~~377.59~~	~~0.41~~
			2	1364000	0.3000	0.0687			
			3	818000	0.4000	~~0.1790~~			
			4	1364000	0.3000	0.0921			0.1746'
			5	1364000	0.4000	~~0.0592~~			
5	150.00	28.00	1	1500000	0.3000	0.0069	378.00	~~377.68~~	~~0.32~~
			2	1364000	0.3000	0.0379			
			3	818000	0.4000	~~0.1336~~			
			4	1364000	0.3000	0.0854			0.144'
			5	1364000	0.4000	~~0.0572~~			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

Ignore elastic Settlement in Strata Ia

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JST 1-18-09

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
6	100.00	-28.00	1	1500000	0.3000	0.0058	378.00	~~377.72~~	~~0.28~~
			2	1364000	0.3000	0.0341			0,1129'
			3	818000	0.4000	~~0.1168~~			
			4	1364000	0.3000	0.0730			
			5	1364000	0.4000	~~0.0526~~			
7	100.00	-14.00	1	1500000	0.3000	0.0122	378.00	~~377.63~~	~~0.37~~
			2	1364000	0.3000	0.0639			
			3	818000	0.4000	~~0.1591~~			0,1549'
			4	1364000	0.3000	0.0788			
			5	1364000	0.4000	~~0.0535~~			
8	100.00	0.00	1	1500000	0.3000	0.0095	378.00	~~377.62~~	~~0.38~~
			2	1364000	0.3000	0.0610			
			3	818000	0.4000	~~0.1738~~			0.1522'
			4	1364000	0.3000	0.0808			
			5	1364000	0.4000	~~0.0538~~			
9	100.00	14.00	1	1500000	0.3000	0.0122	378.00	~~377.63~~	~~0.37~~
			2	1364000	0.3000	0.0639			
			3	818000	0.4000	~~0.1591~~			0,1549'
			4	1364000	0.3000	0.0788			
			5	1364000	0.4000	~~0.0535~~			
10	100.00	28.00	1	1500000	0.3000	0.0060	378.00	~~377.72~~	~~0.28~~
			2	1364000	0.3000	0.0341			
			3	818000	0.4000	~~0.1168~~			0,1131'
			4	1364000	0.3000	0.0730			
			5	1364000	0.4000	~~0.0526~~			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

Ignore elastic settlement in Strata IIa

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JJT 1-18-09

IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
11	200.00	-28.00	1	1500000	0.3000	0.0048	378.00	~~377.78~~	~~0.22~~
			2	1364000	0.3000	0.0277			
			3	818000	0.4000	~~0.1042~~			0.1095'
			4	1364000	0.3000	0.0770			
			5	1364000	0.4000	~~0.0556~~			
12	200.00	-14.00	1	1500000	0.3000	0.0103	378.00	~~377.66~~	~~0.34~~
			2	1364000	0.3000	0.0519			
			3	818000	0.4000	~~0.1407~~			0.1451'
			4	1364000	0.3000	0.0829			
			5	1364000	0.4000	~~0.0566~~			
13	200.00	0.00	1	1500000	0.3000	0.0074	378.00	~~377.65~~	~~0.35~~
			2	1364000	0.3000	0.0482			
			3	818000	0.4000	~~0.1599~~			0.1406'
			4	1364000	0.3000	0.0850			
			5	1364000	0.4000	~~0.0569~~			
14	200.00	14.00	1	1500000	0.3000	0.0103	378.00	~~377.66~~	~~0.34~~
			2	1364000	0.3000	0.0519			
			3	818000	0.4000	~~0.1407~~			0.1451'
			4	1364000	0.3000	0.0829			
			5	1364000	0.4000	~~0.0566~~			
15	200.00	28.00	1	1500000	0.3000	0.0051	378.00	~~377.73~~	~~0.27~~
			2	1364000	0.3000	0.0277			
			3	818000	0.4000	~~0.1042~~			0.1098'
			4	1364000	0.3000	0.0770			
			5	1364000	0.4000	~~0.0556~~			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

Ignore elastic settlement in Strata IIa

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JST 1-18-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	150.00	-28.00	378.00	0.16	377.84
2	150.00	-14.00	378.00	0.19	377.81
3	150.00	0.00	378.00	0.20	377.80
4	150.00	14.00	378.00	0.19	377.81
5	150.00	28.00	378.00	0.16	377.84

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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JST 1-18-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
#6	100.00	-28.00	378.00	0.14	377.86
#7	100.00	-14.00	378.00	0.17	377.83
#8	100.00	0.00	378.00	0.18	377.82
#9	100.00	14.00	378.00	0.17	377.83
#10	100.00	28.00	378.00	0.14	377.86

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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JDT 1-18-09

ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	200.00	-28.00	378.00	0.13	377.87
2	200.00	-14.00	378.00	0.16	377.84
3	200.00	0.00	378.00	0.17	377.83
4	200.00	14.00	378.00	0.16	377.84
5	200.00	28.00	378.00	0.13	377.87

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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SR 1/I-95 Interchange 103-059-27U 1/15/2009
Retaining Wall 12 13 Settlement Results

	Settlement (ft)		
Point	Elastic	Consolidation	Total
1	0.13	0.16	0.29
2	0.17	0.19	0.36
3	0.16	0.20	0.36
4	0.17	0.19	0.36
5	0.14	0.16	0.30
6	0.11	0.14	0.25
7	0.15	0.17	0.32
8	0.15	0.18	0.33
9	0.15	0.17	0.32
10	0.11	0.14	0.25
11	0.11	0.13	0.24
12	0.15	0.16	0.31
13	0.14	0.17	0.31
14	0.15	0.16	0.31
15	0.11	0.13	0.24

	Settlement (in)		
Point	Elastic	Consolidation	Total
1	1.6	1.9	3.5
2	2.1	2.3	4.4
3	2.0	2.4	4.4
4	2.1	2.3	4.4
5	1.7	1.9	3.6
6	1.4	1.7	3.0
7	1.9	2.0	3.9
8	1.8	2.2	4.0
9	1.9	2.0	3.9
10	1.4	1.7	3.0
11	1.3	1.6	2.9
12	1.7	1.9	3.7
13	1.7	2.0	3.7
14	1.7	1.9	3.7
15	1.3	1.6	2.9

Max 4.4"
Min 2.9"

	RW 12 & 13 Differential Settlement							
	Front RW 13		Front RW 12		Between Walls		Front to Front	
	6 to 1	1 to 11	10 to 5	5 to 15	8 to 3	3 to 13	1 to 3	3 to 5
Inches	0.4	0.6	0.6	0.8	0.4	0.6	0.9	0.7
Ratio	1/1355	1/994	1/982	1/779	3/4918	1/960	1/686	1/852

All differential settlements are within the allowable AASHTO tolerance of 1/100.

See point locations on PG 9.

RKK RW12 & 13-69
1-18-09
SMW 2/9/09

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Retaining Wall 12 and 13\Final Design\RW 12 and 13 Settlement Results Final.xls

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CALCULATION CHECKLIST

Project: SR-1/I-95 INTERCHANGE Comm. No.: 108-059

Title of Calculation Set: RETAINING WALL 14 & 15

Project Manager: EMK

Calculations Prepared By: BBS

Calculation Checked By:

Computer Programs / Files: SLOPE W, GSTABL, FOSSA

Initial	Date	
BBS	1-21-09	Subsurface Characterization approved by Project Manager
BBS	1-21-09	Calculations are neat, legible and understandable.
BBS	1-21-09	Table of Contents is provided.
BBS	1-21-09	Heading on each page filled out
BBS	1-21-09	The first page contains purpose of the calculation.
BBS	1-21-09	Symbols are defined.
BBS	1-21-09	References for data, methods, formulas and computer program names and version numbers are given.
BBS	1-21-09	Assumptions are listed and those that need to be verified later are Flagged.
BBS	1-21-09	Headings on front sheet of each set of computer input and output.
BBS	1-21-09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JPT	1-22-09	All calculations checked and each calculation sheet initialed by checker.
EMK	2/6/09	Calculation set reviewed by Project Manager.
		Has this calculation been superseded? Reference new calculation, if applicable.

This sheet is to be prepared by the originator of the calculation and attached to the front of the calculation set.

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Cm. No. 103-059
Prepared By BBS Date 1-20-09 Checked By JBT Date 1-22-09
EM 2/5/09

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SOIL PARAMETERS	3
WALL DESIGN	6
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GLOBAL STABILITY	15
SETTLEMENT	65
CROSS-SECTION	80
FENCE	81
LOCATION PLAN	82

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RETAINING WALL RW-14&15 Cm. No. 103-059
Prepared By RBS Date 9-26-08 Checked By JPT Date 1-22-09
QM 2/5/09

PURPOSE : DESIGN OF RETAINING WALL 14 & 15
BACK TO BACK WALLS.

REFERENCE: AASHTO LRFD BRIDGE DESIGN SPECIFICATION
CUSTOMARY US UNITS 14TH EDITION 2009.

SOFTWARE: FOSSA 2.0.
GSTABL 7 by STEDWIN
SLOPE/W

SYMBOLS:

UNIT WEIGHT → γ
FRICTION ANGLE → ϕ
UNDRAINED SHEAR STRENGTH → S_u
MODULUS OF ELASTICITY → E_s
POISSON'S RATIO → μ
COMPRESSION INDEX → C_c
COEFFICIENT OF CONSOLIDATION → C_R

WALL 14

LENGTH OF WALL = 814-ft.
MAX HEIGHT OF WALL = 35-ft.
DEPTH OF EMBEDMENT = 3-ft.
EXPOSED HEIGHT OF WALL = 32-ft (MAX)

WALL 15

LENGTH OF WALL = 1204-ft.
MAX HEIGHT OF WALL = 35-ft
DEPTH OF EMBEDMENT = 3-ft.
EXPOSED HEIGHT OF WALL = 32-ft. (MAX)

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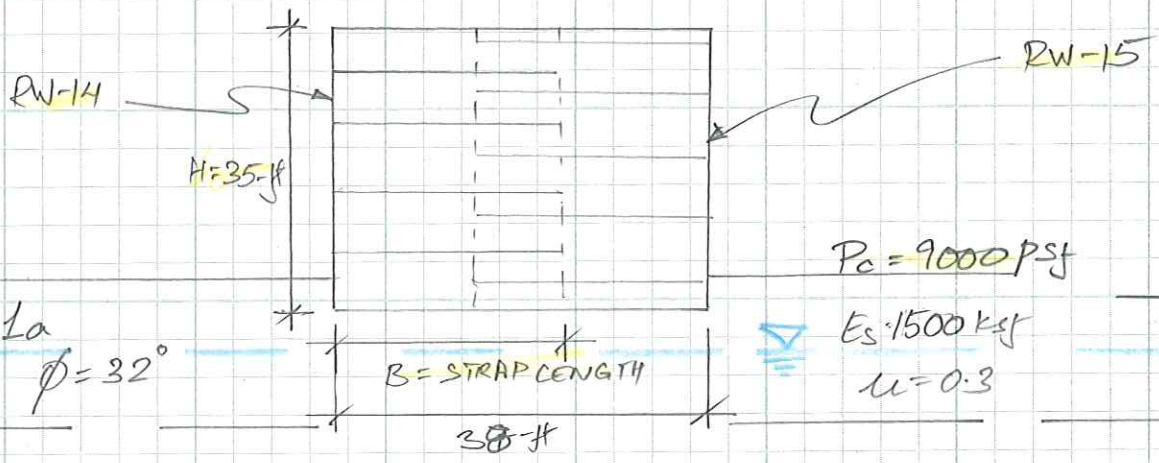
QM 7/5/09

SOIL PARAMETERS FOUNDATION @ EL-79



STRATUM 1a
$\gamma = 125$ pcf $\phi = 32°$
$E_s = 1500$ ksf
$\mu = 0.3$

STRATUM 2a
$\gamma = 130$ pcf $\phi = 0$
$S_u = 1700$ psf.
$E_s = 818$ ksf
$C_c = 0.24$ OCR = 3.3
$e_o = 0.748$
$C_r = 0.015$

STRATUM 2a (ii)
$\gamma = 130$ pcf $\phi = 0$
$S_u = 2500$ psf
$E_s = 818$ ksf
$\mu = 0.4$ OCR = 3.3
$e_o = 0.839$
$C_c = 0.22$ $C_r = 0.015$

STRATUM 2a (iii)
$\gamma = 130$ pcf $\phi = 0$
$S_u = 3500$ psf
$E_s = 818$ ksf
$\mu = 0.4$ OCR = 2.1
$e_o = 0.839$
$C_c = 0.22$ $C_r = 0.015$

STRATUM 2a (iv)
$\gamma = 130$ pcf $\phi = 0$
$S_u = 5000$ psf
$E_s = 1364$ ksf OCR = 2.1
$\mu = 0.4$
$e_o = 0.839$
$C_c = 0.22$ $C_r = 0.015$

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EM 2/5/09

SOIL PARAMETERS.

STRATUM 1A EL 70 & ABOVE

$\gamma = 125$ pcf $\phi = 32°$

$E_s = 1500$ ksf (BACK CALCULATED)

STRATUM 2A EL 40 & ABOVE

$\gamma = 130$ pcf $\phi = 0$ $c = 1700$ psf (LAB RESULT)

$E_s = 818$ ksf (BACK CALCULATED)

$C_c = 0.24$
$e_o = 0.748$
} CONSOLIDATION TEST RESULT (IBR61)

$C_r = 0.015$ (BACK CALCULATED)

STRATUM 2A EL 20 TO EL 40

$\gamma = 130$ pcf $\phi = 0$ $c = 2500$ psf

$E_s = 818$ ksf (BACK CALCULATED)

$C_c = 0.22$
$e_o = 0.839$
} CONSOLIDATION TEST RESULT (IBR 61)

$C_r = 0.015$ (BACK CALCULATED)

C_r & E_s BACK CALCULATED FROM SETTLEMENT PLATE DATA.

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GM 1/5/09

STRATUM 2A ELO TO EL 20

$\gamma = 130$ pcf $\phi = 0$ $c = 3500$ psf

$E_s = 818$ ksf

$C_c = 0.22$

$e_o = 0.839$

$C_r = 0.015$

STRATUM 2A ELO & BELOW

$\gamma = 130$ pcf $\phi = 0$ $c = 5000$ psf

$E_s = 1364$ ksf

$C = 0.22$

$e_o = 0.839$

$C_r = 0.015$

STRATUM 2A DRAINED PARAMETERS

$\phi = 24°$ $C = 0$ FOR BEARING ANALYSIS

SHEAR STRENGTH = $0.7753\,(\text{SHEAR STRESS})^{0.6701}$
USING SPLINE CURVE

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JST 1-22-09

SOIL PARAMETERS

REINFORCED SOIL

$\gamma = 125$ pcf $\quad \phi = 34°$

RETAINED SOIL

$\gamma = 125$ pcf $\quad \phi = 34°$ (BACK TO BACK WALL reinforcement zones overlap

FOUNDATION SOIL

$\gamma = 125$ pcf $\quad \phi = 32°$

ACTIVE EARTH PRESSURE COEFFICIENT FOR REINFORCED SOIL

COULUMB'S

$$K_a = \frac{\sin^2(\phi+\theta)}{\sin^2\theta \sin(\theta-\delta)\left[1+\sqrt{\frac{\sin(\delta+\phi)\sin(\phi-\alpha)}{\sin(\theta-\delta)\sin(\theta+\alpha)}}\right]^2}$$

Where

$\theta = 90$ SLOPE OF WALL

$\alpha = 0$ HORIZONTAL BACKFILL

$\delta = \phi = 34°$ FRICTION ANGLE BETWEEN SOIL & WALL

$\phi = 34°$ FRICTION ANGLE OF REINFORCED SOIL (BACK TO BACK WALL WITH OVERLAPING REINFORCED ZONE)

$$K_a = \frac{\sin^2 124}{\sin^2 90 \sin 56\left[1+\sqrt{\frac{\sin 68 \sin 34}{\sin 56 \sin 90}}\right]^2}$$

$= 0.312$

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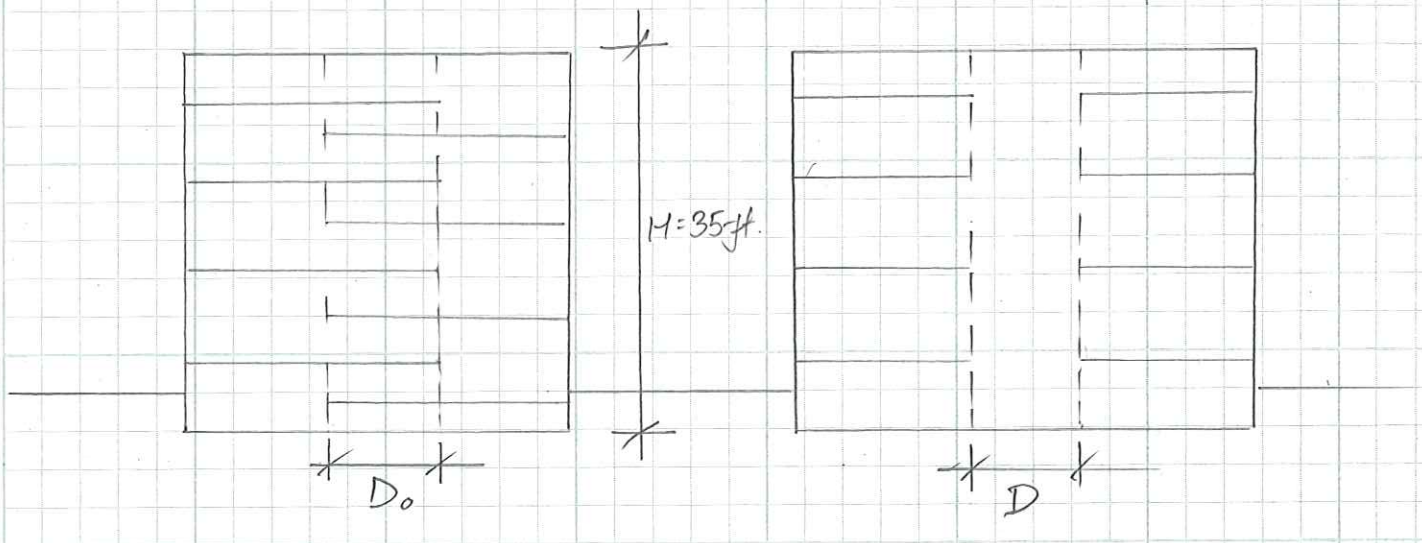
BACK TO BACK WALLS

HEIGHT OF WALLS = 35-ft.

MIN STRAP LENGTH = 0.7 H = 25-ft

DISTANCE BETWEEN WALLS = 38-ft

OVERLAP OF REINFORCEMENT $D_o = 25 - \frac{38}{2} = 6\text{-ft.}$



IF $D_o > 0.3H$ NO LATERAL PRESSURE

$0.3H = 10.5 > D_o$ ∴ THERE IS REDUCED LATERAL PRESSURE

IF $D > H \tan(45 - \phi/2)$ where, ϕ = FRICTION ANGLE OF RETAINED SOIL
TOTAL LATERAL FORCE ACTS = 28° (IF THE STRAPS DIDNOT OVERLAP)

$H\tan(45 - \phi/2) = 35 \tan(45 - \frac{28}{2})$

$= 21\text{-ft.}$

BETWEEN D & D_o LINEAR INTERPOLATION.

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LINEAR INTERPOLATION

LATERAL FORCE 0% @ $D_o = -10.5$ ft

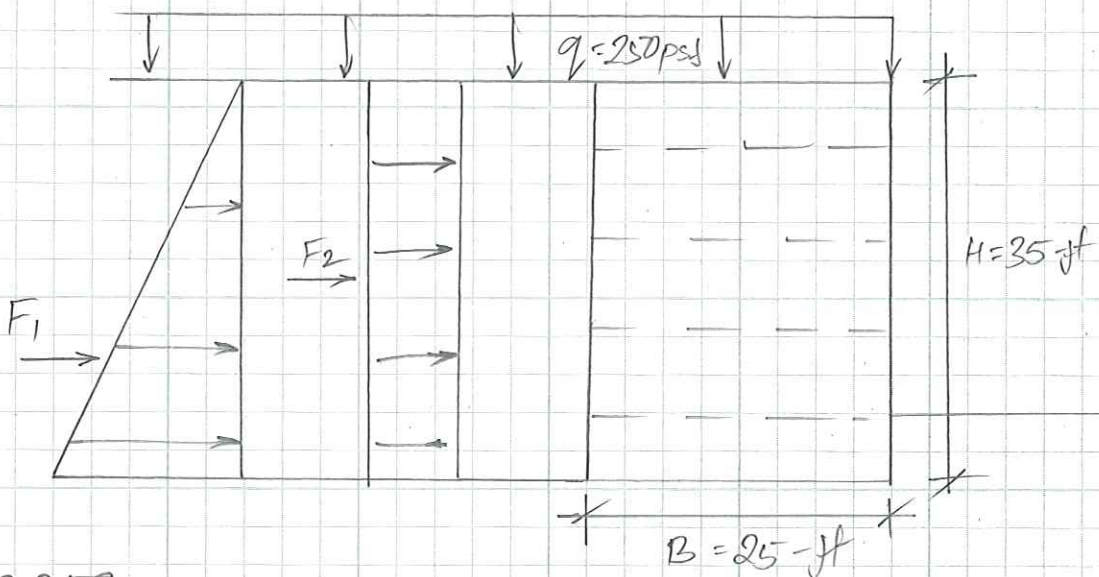
100% @ D = 21 ft

TOTAL DIFFERENCE = 21 + 10.5 = 31.5

$D_o = -6$ ft ; $-6 + 10.5 = 4.5$

∴ % of LATERAL FORCE = $\frac{4.5}{31.5} = 14.3\%$

CONSIDER ONE SIDE WALL-15



$K_a = 0.259$

$F_1 = 14.3\% \frac{1}{2} K_a \gamma H^2 = 3416$ lb/ft

$F_2 = 14.3\% \gamma_{SOIL} K_a H = 390$ lb/ft ✓

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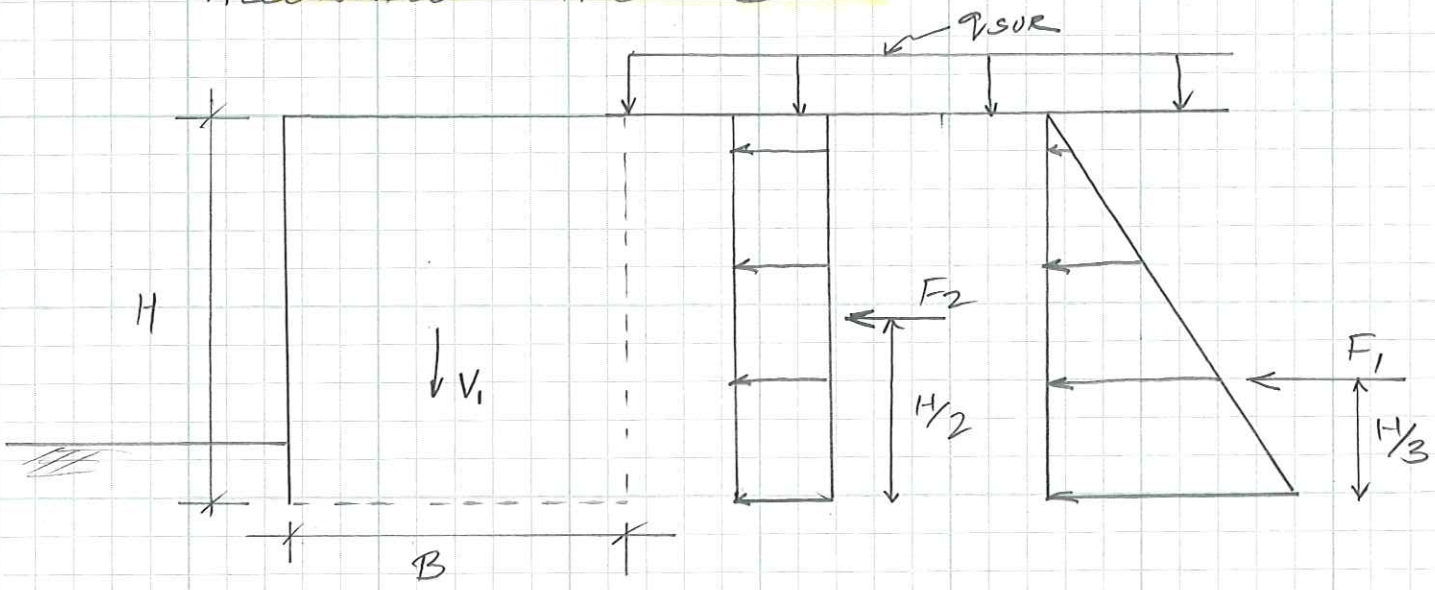
ALLOWABLE STRESS DESIGN

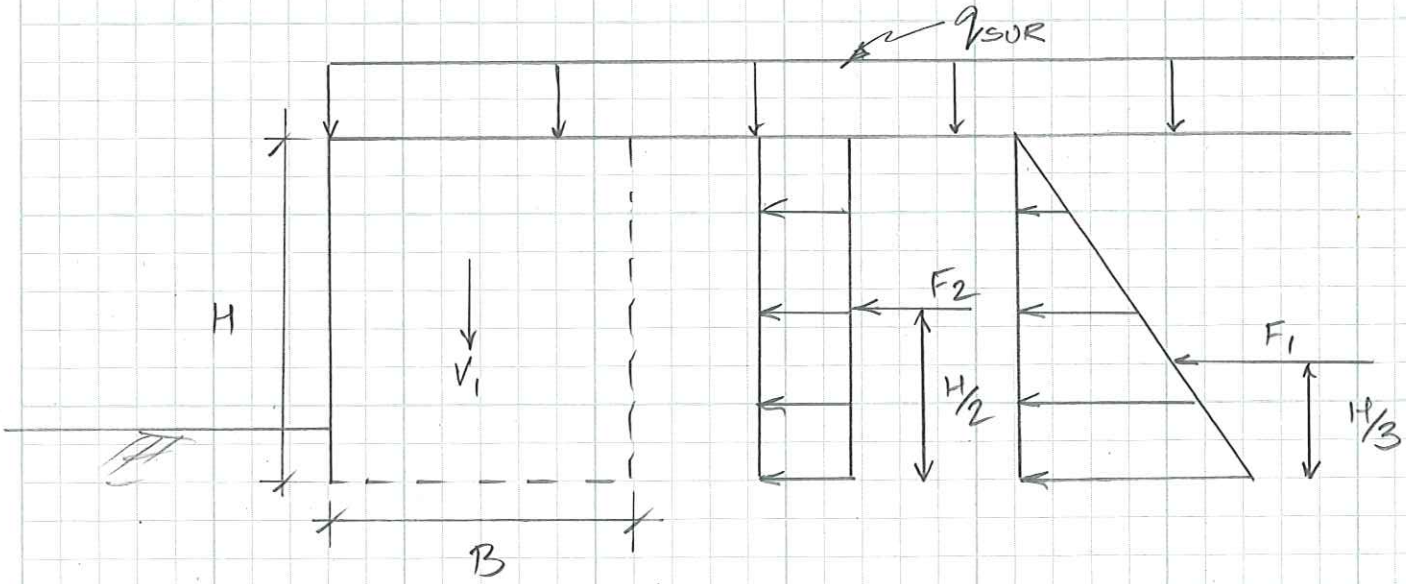


FOR SLIDING & ECCENTRICITY

$F_1 = \frac{1}{2} K_a \gamma H^2$

$F_2 = K_a q_{SUR} H$

$V_1 = \gamma_R H B$



FOR BEARING CAPACITY

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WALL ANALYZED WITH ALLOWABLE STRESS DESIGN (ASD) BECAUSE THE WALL GEOMETRY – BACK TO BACK WALL

ECCENTRICITY FOR SLIDING & OVERTURNING.

$$e = \frac{F_1 \cos\alpha \, H/3 + F_2 \cos\alpha \, H/2}{V_1}$$

$$= \frac{3416 \times \cos 0 \times 35/3 + 390 \times \cos 0 \times 35/2}{125 \times 35 \times 25}$$

$$= \frac{46678.3}{109375}$$

$$= 0.43 \text{ ft}.$$

OVERTURNING CHECK

ECCENTRICITY SHOULD BE WITHIN CENTER 1/3 OF BASE WIDTH

$$\frac{1}{2} \text{ BASE WIDTH} = \frac{25}{2} = 12.5$$

$$e < \frac{12.5}{3}$$

$0.43 < 4.17$ OK.

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CHECK FOR SLIDING.

RESISTANCE AGAINST SLIDING

$R_R = \Sigma V \tan\delta$

δ = Smaller of ϕ_f & ϕ_R

ϕ_f = FOUNDATION SOIL = 32°

ϕ_R = REINFORCED SOIL = 34°

$R_R = (125 \times 25 \times 35) \tan 32$

$= 68345$ lb/ft

HORIZONTAL DRIVING FORCE

$R_{DR} = F_1 + F_2$

$= 3416 + 390$

$= 3806$ lb/ft.

$FS = \frac{R_R}{R_{DR}} = \frac{68345}{3806} = 17.9 > 1.5$ OK

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BEARING CAPACITY CHECK

ECCENTRICITY

$$e = \frac{F_1 \cos\alpha \, H/3 + F_2 \cos\alpha \, H/2}{V_1 + q_{SUR} B}$$

$$= \frac{3416 \times \cos 0 \times 35/3 + 390 \times \cos 0 \times 35/2}{125 \times 35 \times 25 + 250 \times 25}$$

$$= \frac{46678.3}{115625}$$

$$= 0.40 \text{ ft.}$$

EFFECTIVE FOOTING WIDTH

$$B' = B - 2e$$

$$= 25 - 2 \times 0.4 = 24.2 \text{ ft}$$

EQUIVALENT UNIFORM BEARING PRESSURE

$$\sigma_V = \frac{V_1 + q_{SUR} B}{B - 2e}$$

$$= \frac{125 \times 35 \times 25 + 250 \times 25}{24.2}$$

$$= 4777.9 \text{ psf}$$

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CM 1/5/09

BEARING CAPACITY CHECK

ULTIMATE BEARING CAPACITY

$$q_{ULT} = cN_c S_c i_c + \gamma D_f N_q S_q d_q i_q C_{wq} + \frac{1}{2}\gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$$

FOR LAYERED SYSTEM (STRONG COHESIONLESS LAYER OVER WEAK LAYER)

$$q_{ULT} = q_2 e^{0.67\left[1+\left(\frac{B}{L}\right)\right]\frac{H}{B}} \rightarrow (C10.6.3.1.2f\text{-}1)$$

q_2 = BEARING RESISTANCE OF A FICTICIOUS FOOTING OF THE SAME SIZE & SHAPE AS THE ACTUAL FOOTING SUPPORTED ON THE LOWER WEAK LAYER

B = FOOTING WIDTH

L = LENGTH OF FOOTING

H = THICKNESS OF TOP LAYER BELOW FOUNDATION ELEVATION

$$q_L = cN_c S_c i_c + \gamma D_f N_q \cancel{S_q d_q} i_q C_{wq} + \frac{1}{2}\gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$$

$N_q = 0$ FOR MSE WALL BEARING RESISTANCE

DRAINED CONDITION

$\phi = 24°$ $c = 0$ SEE PG 4 OF 82

$N_c = 19.3$ $N_\gamma = 9.4$

$C_{w\gamma} = 0.5$

$S_\gamma = 1 - 0.4\frac{B}{L}$

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FOR BACK TO BACK WALL WITH OVERLAPPING STRAPS

CONSIDER SINGLE FOOTING

$B = 38\text{-ft}$ (DISTANCE BETWEEN BACK TO BACK WALLS)

$$q_2 = \frac{1}{2} \times 130 \times 38 \times 9.4 \times \left(1 - 0.4 \times \frac{38}{500}\right) \times \frac{1}{2}$$

$$= 11256 \text{ psf}$$

$$q_{ULT} = q_2 \, e^{0.67\left[1+\frac{B}{L}\right]H/B}$$

$B = 38\text{-ft}$

$L = \text{SAY } 500\text{-ft}$

$H = 8\text{-ft}$ (WORST CASE FOR HIGHEST PORTION OF WALL)

$$q_{ULT} = 11256 \; e^{0.67\left[1+\frac{38}{500}\right]\frac{8}{38}}$$

$$= 11256 \cdot e^{0.15}$$

$$= 11256 \times 1.16$$

$$= 13100 \text{ psf}$$

FACTOR OF SAFETY

$$FS = \frac{q_{ULT}}{\sigma_V} = \frac{13100}{4777.9} = 2.74 > 2.0 \text{ OK}$$

WELL CHARACTERIZED SITE

σ_V from P8 11

* Check Undrained

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EMK 2/5/09

UNDRAINED CONDITION

$\phi = 0$ $c = 1700$ psf

CONSIDER SINGLE FOOTING

$B = 38$-ft. (DISTANCE BETWEEN BACK TO BACK WALLS)

$q_2 = cN_c S_c i_c + \frac{1}{2}\gamma B N_\gamma S_\gamma i_\gamma C_{wr}$

$N_c = 5.14$ $N_q = 0$ FOR $\phi = 0$

$S_c = \left(1 + \frac{B}{5L}\right) = 1 + \frac{\times 38}{5 \times 500} = 1.01$

BACK TO BACK WALL NEGLECT ECCENTRICITY

$q_2 = 1700 \times 5.14 \times 1.01$ psf

$= 8825.38$ psf.

$q_{ULT} = q_2 e^{0.67\left[1 + \frac{B}{L}\right]\frac{H}{B}}$ (C10.6.3.1.2f-1)

$= 8825.38 \times e^{0.67\left[1 + \frac{38}{500}\right]\frac{8}{38}}$

$= 8825.38 \times 1.164$

$= 10272.7$ psf.

$F.S = \frac{q_{ULT}}{\sigma_v} = \frac{10272.7}{4777.9} = 2.15 > 2.0$ OK

σ_v from pg 11

WELL CHARACTERIZED SITE

* Undrained Case governs.

RUMMEL, KLEPPER & KAHL, LLP
"A Tradition Of Excellence" since 1923

Subject SR-1 INTERCHANGE RETAINING WALLS 14 & 15 Page 15 of 82
Cm. No. 103-059-27U
Prepared By BBS Date 10-28-08 Checked By JPT Date 1-22-09
EML 2/5/09

GLOBAL STABILITY

CHECK FOR GLOBAL STABILITY FOR HIGHEST PORTION OF WALL
SEE CROSS SECTION @ RAMP B STA 458+50

SOIL PARAMETERS

STRATA	UNIT WEIGHT (pcf)	UNDRAINED SHEAR STRENGTH (PSF)	DRAINED ϕ	DRAINED C (PSF)
EL 70 & ABOVE	125	—	32	0
EL 60 TO 70	130	1700		
EL 50 TO 60	125	1700		
EL 40 TO 50	130	1700		
EL 20 TO 40	130	2500		
EL 20 & BELOW	130	3500		

SPLINE FUNCTION $y = 0.7753 x^{0.6701}$ (y = shear strength, x = normal stress)

$y = 0.7753 x^{0.6701}$ (SPLINE FUNCTION)

WATER TABLE @ EL 75.0 ≈ 4' ↓ BOF

ASSUME FAILURE SURFACE DOESNOT DEVELOP IN REINFORCED ZONE

SUMMARY OF RESULTS

CONDITION	FACTOR OF SAFETY	FACTORED RESISTANCE
UNDRAINED (SLOPEW)	1.761	0.568 < 0.65 OK
DRAINED (SLOPE W)	1.734	0.577 < 0.65 OK
UNDRAINED (GSTABL)	1.700	0.588 < 0.65 OK

≈ 1.53

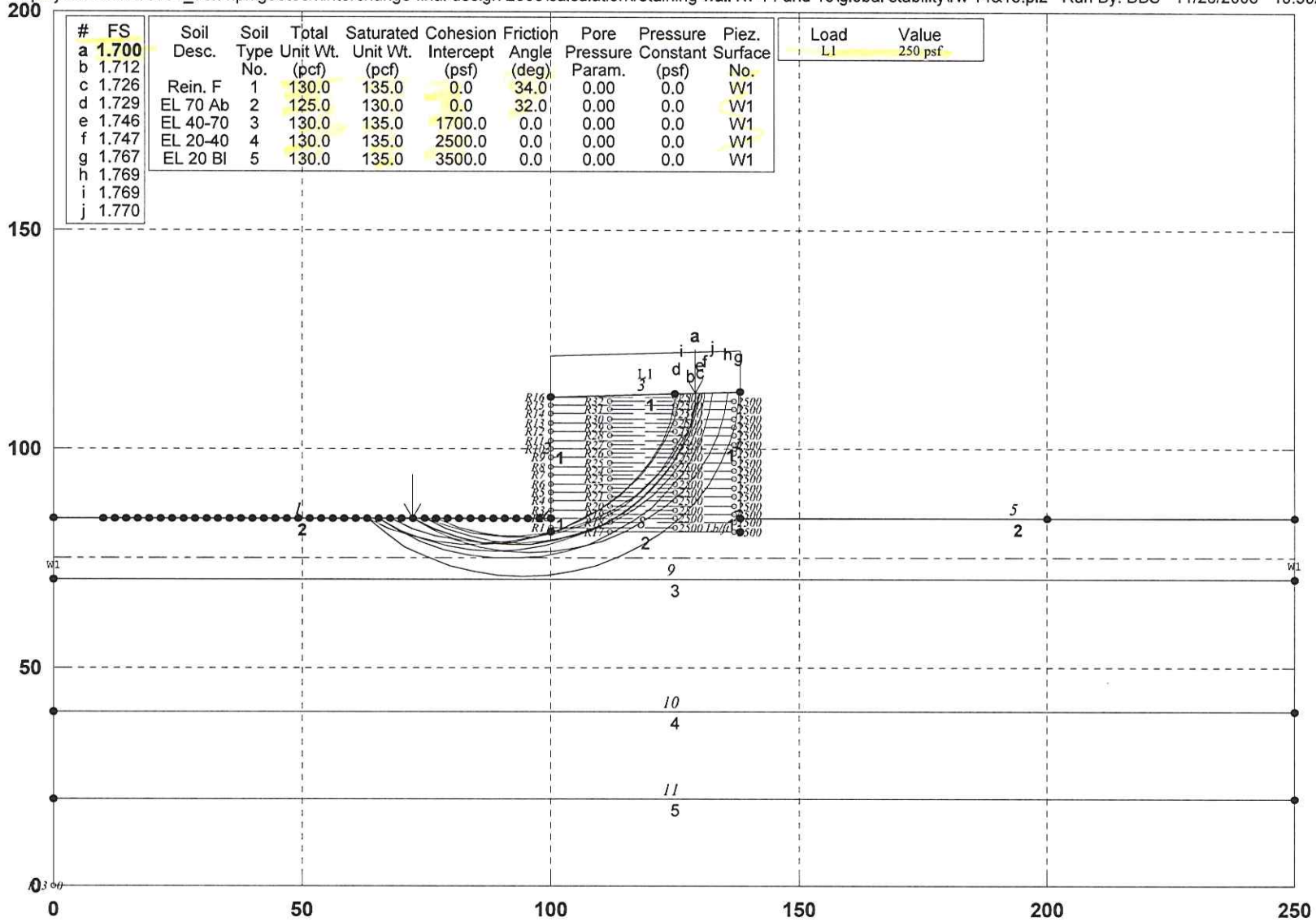
SR-1 I-95 Interchange Ret. Wall 14 & 15 (Ramp B STA 458+50)

m:\projects\2003\03059_deltrnpk\geotech\interchange final design 2008\calculation\retaining wall rw-14 and 15\global stability\rw 14&15.pl2 Run By: BBS 11/26/2008 10:50AM

#	FS
a	1.700
b	1.712
c	1.726
d	1.729
e	1.746
f	1.747
g	1.767
h	1.769
i	1.769
j	1.770

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
Rein. F	1	130.0	135.0	0.0	34.0	0.00	0.0	W1
EL 70 Ab	2	125.0	130.0	0.0	32.0	0.00	0.0	W1
EL 40-70	3	130.0	135.0	1700.0	0.0	0.00	0.0	W1
EL 20-40	4	130.0	135.0	2500.0	0.0	0.00	0.0	W1
EL 20 Bl	5	130.0	135.0	3500.0	0.0	0.00	0.0	W1

Load	Value
L1	250 psf



GSTABL7 v.2 FSmin=1.700

Safety Factors Are Calculated By The Simplified Janbu Method

(UNDRAINED CONDITION)

GSTABL7

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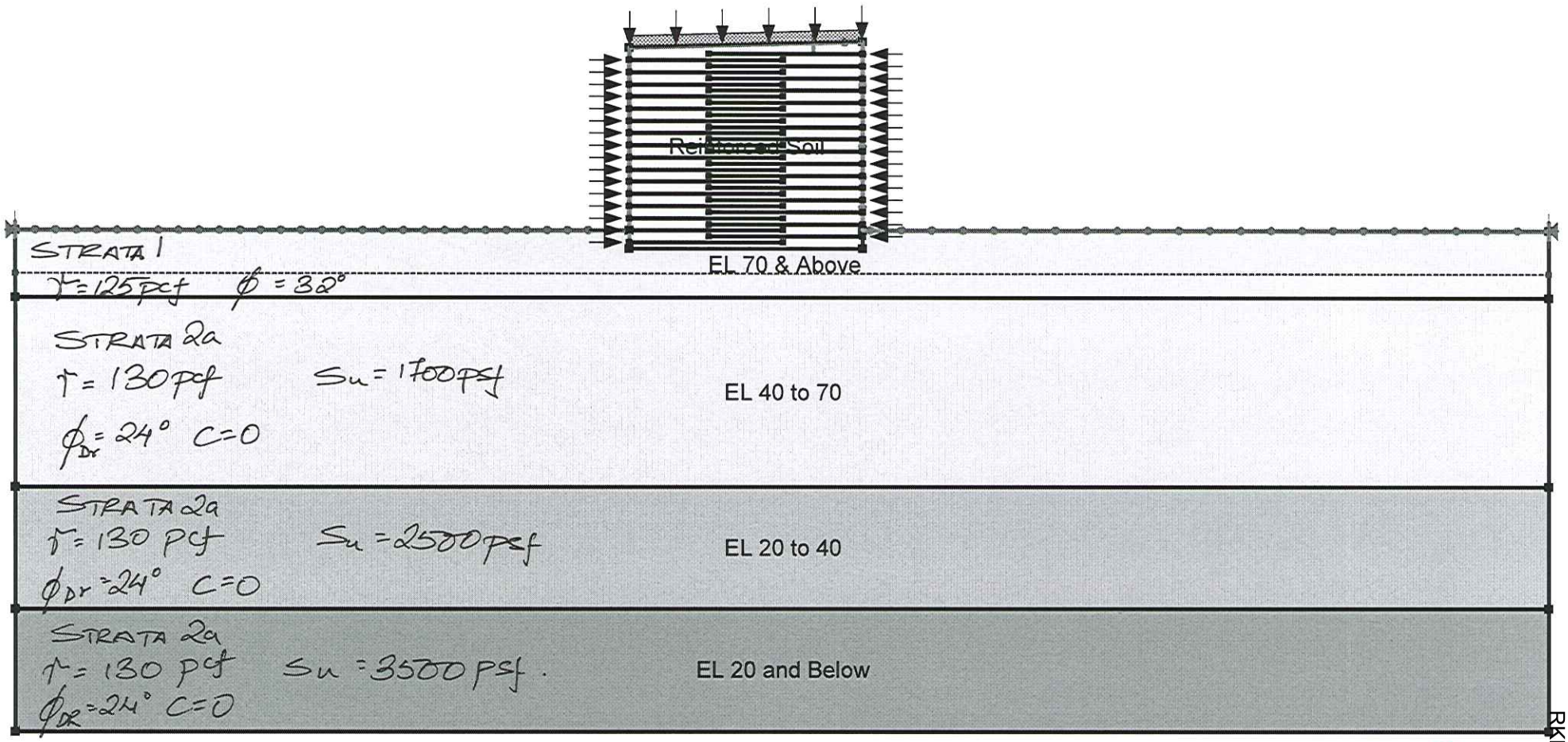
JJT 1-22-09

RKK RW14 & 15-18

GLOBAL STABILITY



SLOPE/W

RETAINING WALL 14 & 15
RAMP B STA 458+50

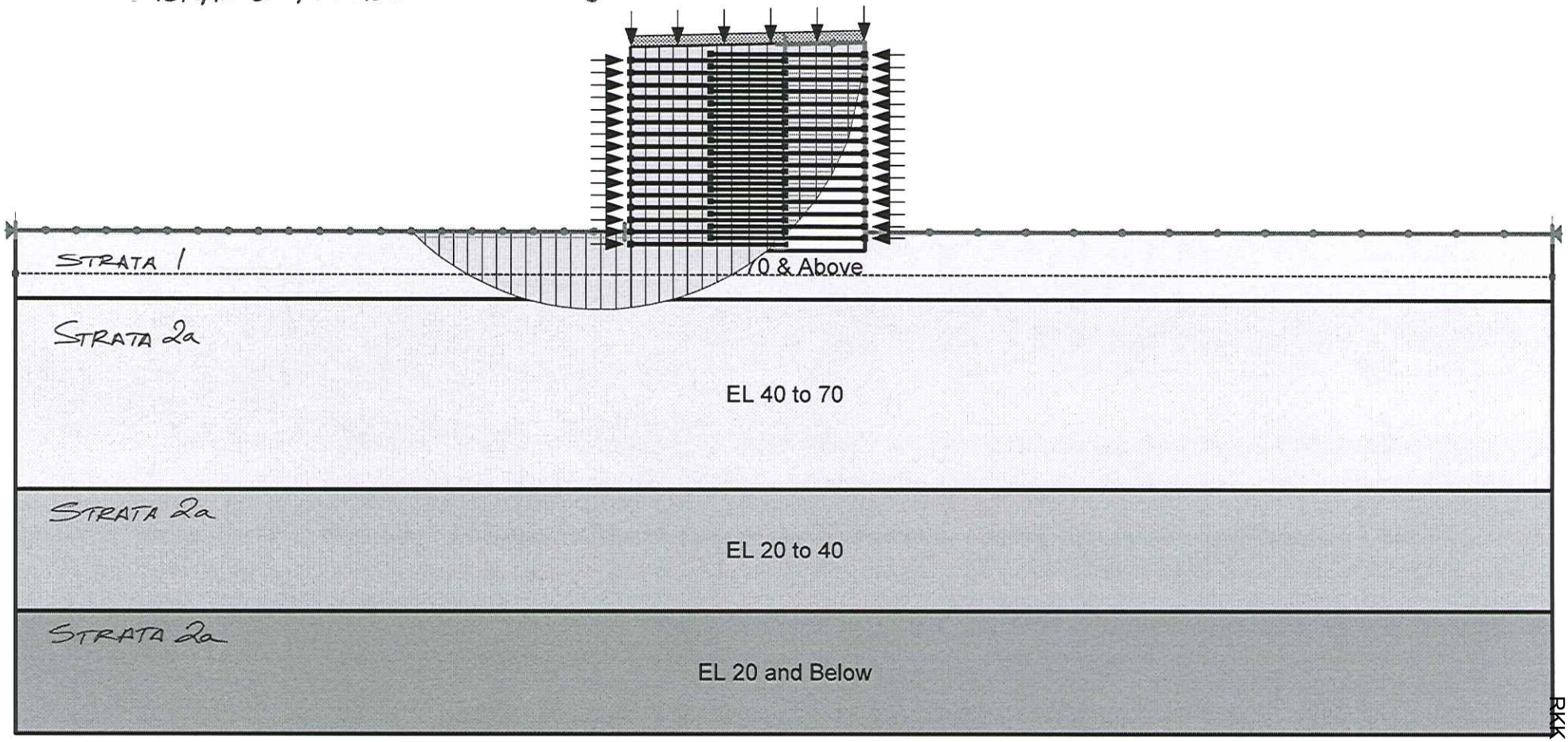
1-22-09

RKK RW14 & 15-19

GLOBAL STABILITY

.DRAINED ANALYSIS

F.S = 1.734



RETAINING WALL 14 & 15

RAMP B STA 458+50

16 of 82

JPT

1.22.09

RKK RW14 & 15-20

SLOPE/W Analysis

Report generated using GeoStudio 2007, version 7.11. Copyright © 1991-2008 GEO-SLOPE International Ltd.

File Information

Revision Number: 29
Date: 11/26/2008
Time: 10:03:22 AM
File Name: RW-14&15 (Drained) alt.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Retaining Wall RW-14 and 15\Global Stability\
Last Solved Date: 11/26/2008
Last Solved Time: 10:03:51 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Description: Retaining Wall 14 & 15 STA 458+50
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- **Apply Phreatic Correction:** No
- **Side Function**
  - **Interslice force function option:** Half-Sine
- **PWP Conditions Source:** Piezometric Line
- **Use Staged Rapid Drawdown:** No

SlipSurface
- **Direction of movement:** Right to Left
- **Allow Passive Mode:** No
- **Slip Surface Option:** Entry and Exit
- **Critical slip surfaces saved:** 1
- **Optimize Critical Slip Surface Location:** No
- **Tension Crack**
  - **Tension Crack Option:** (none)

FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1

Materials

Reinforced Soil

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Select Fill

EL 70 & Above

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 32 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Strata IIa

EL 40 to 70

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: SPLINE
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

EL 20 to 40

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: SPLINE
Phi-B: 0 °
Pore Water Pressure

Piezometric Line: 1

EL 20 and Below

Model: Shear/Normal Fn.
Unit Weight: 130 pcf
Strength Function: SPLINE
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0, 82) ft
Left-Zone Right Coordinate: (99, 82) ft
Left-Zone Increment: 20
Right Projection: Range
Right-Zone Left Coordinate: (125, 112.65789) ft
Right-Zone Right Coordinate: (250, 82) ft
Right-Zone Increment: 20
Radius Increments: 14

Slip Surface Limits

Left Coordinate: (0, 82) ft
Right Coordinate: (250, 82) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	75
	250	75

≃ 4' ↓ BOF

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

22 of 82

Coordinates

	X (ft)	Y (ft)
	100.1	114
	137.9	115

> 2' w/ 125 pcf
∴ 250-pcf

Reinforcements

Reinforcement 1

Type: Fabric
Outside Point: (100, 80) ft
Inside Point: (125, 80) ft
Slip Surface Intersection: (123.28, 80) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 1104 lbs
Resisting Force Used: 643.16 lbs/ft
Available Bond Length: 1.7166 ft
Required Bond Length: 1.7166 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (138, 81) ft
Inside Point: (113, 81) ft
Slip Surface Intersection: (65.421, 81) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1

Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (100, 82) ft
Inside Point: (125, 82) ft
Slip Surface Intersection: (125.42, 82) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 597.02 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (100, 84) ft
Inside Point: (125, 84) ft
Slip Surface Intersection: (127.33, 84) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °

Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 597.02 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (100, 86) ft
Inside Point: (125, 86) ft
Slip Surface Intersection: (128.93, 86) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 541.53 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (100, 88) ft
Inside Point: (125, 88) ft
Slip Surface Intersection: (130.41, 88) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 472.84 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (100, 90) ft
Inside Point: (125, 90) ft
Slip Surface Intersection: (131.67, 90) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 472.84 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (100, 92) ft
Inside Point: (125, 92) ft
Slip Surface Intersection: (132.86, 92) ft
Total Length: 25 ft
Reinforcement Direction: 180 °

Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 382.12 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (100, 94) ft
Inside Point: (125, 94) ft
Slip Surface Intersection: (133.78, 94) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 382.12 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (100, 96) ft
Inside Point: (125, 96) ft
Slip Surface Intersection: (134.71, 96) ft

Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 382.12 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (100, 98) ft
Inside Point: (125, 98) ft
Slip Surface Intersection: (135.45, 98) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 221.43 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 12

Type: Fabric
Outside Point: (100, 100) ft

Inside Point: (125, 100) ft
Slip Surface Intersection: (135.9, 100) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 221.43 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 13

Type: Fabric
Outside Point: (100, 102) ft
Inside Point: (125, 102) ft
Slip Surface Intersection: (136.35, 102) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 221.43 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 14

Type: Fabric
Outside Point: (100, 104) ft
Inside Point: (125, 104) ft
Slip Surface Intersection: (136.8, 104) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 221.43 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 15

Type: Fabric
Outside Point: (100, 106) ft
Inside Point: (125, 106) ft
Slip Surface Intersection: (137.25, 106) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 221.43 lbs/ft
Available Bond Length: 0 ft

Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 16

Type: Fabric
Outside Point: (100, 108) ft
Inside Point: (125, 108) ft
Slip Surface Intersection: (137.7, 108) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 221.43 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 17

Type: Fabric
Outside Point: (100, 110) ft
Inside Point: (125, 110) ft
Slip Surface Intersection: (137.97, 110) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 62.866 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 18

Type: Fabric
Outside Point: (138, 83) ft
Inside Point: (113, 83) ft
Slip Surface Intersection: (126.38, 83) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 13.379 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 19

Type: Fabric
Outside Point: (138, 85) ft
Inside Point: (113, 85) ft
Slip Surface Intersection: (128.14, 85) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0

Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 15.135 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 20

Type: Fabric
Outside Point: (138, 87) ft
Inside Point: (113, 87) ft
Slip Surface Intersection: (129.72, 87) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 16.716 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 21

Type: Fabric
Outside Point: (138, 89) ft
Inside Point: (113, 89) ft
Slip Surface Intersection: (131.04, 89) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs

Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 18.04 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 22

Type: Fabric
Outside Point: (138, 91) ft
Inside Point: (113, 91) ft
Slip Surface Intersection: (132.3, 91) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 19.301 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 23

Type: Fabric
Outside Point: (138, 93) ft
Inside Point: (113, 93) ft
Slip Surface Intersection: (133.32, 93) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs

Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 20.319 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 24

Type: Fabric
Outside Point: (138, 95) ft
Inside Point: (113, 95) ft
Slip Surface Intersection: (134.24, 95) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 21.244 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 25

Type: Fabric
Outside Point: (138, 97) ft
Inside Point: (113, 97) ft
Slip Surface Intersection: (135.17, 97) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1

Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 22.169 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 26

Type: Fabric
Outside Point: (138, 99) ft
Inside Point: (113, 99) ft
Slip Surface Intersection: (135.67, 99) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 22.674 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 27

Type: Fabric
Outside Point: (138, 101) ft
Inside Point: (113, 101) ft
Slip Surface Intersection: (136.13, 101) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf

Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 23.125 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 28

Type: Fabric
Outside Point: (138, 103) ft
Inside Point: (113, 103) ft
Slip Surface Intersection: (136.58, 103) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 23.576 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 29

Type: Fabric
Outside Point: (138, 105) ft
Inside Point: (113, 105) ft
Slip Surface Intersection: (137.03, 105) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable

F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 24.027 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 30

Type: Fabric
Outside Point: (138, 107) ft
Inside Point: (113, 107) ft
Slip Surface Intersection: (137.48, 107) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 24.478 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 31

Type: Fabric
Outside Point: (138, 109) ft
Inside Point: (113, 109) ft
Slip Surface Intersection: (137.91, 109) ft
Total Length: 25 ft

Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 24.908 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 32

Type: Fabric
Outside Point: (138, 111) ft
Inside Point: (113, 111) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Shear/Normal Strength Functions

SPLINE

Model: Spline Data Point Function
Function: Shear Stress vs. Normal Stress
Curve Fit to Data: 100 %
Segment Curvature: 27 %
Y-Intercept: 0
Data Points: Normal Stress (psf), Shear Stress (psf)
Data Point: (0, 0)
Data Point: (1000, 775.3)
Data Point: (2000, 1233.6)
Data Point: (3000, 1618.8)
Data Point: (4000, 1963)
Data Point: (5000, 2279)
Data Point: (10000, 3627)
Estimation Properties
Intact Rock Param.: 10
Geological Strength: 100
Disturbance Factor: 0
SigmaC: 600000 psf
Sigma3: 300000 psf
Num. Points: 20

Regions

	Material	Points	Area (ft²)
Region 1	Reinforced Soil	3,2,7,8,5,4	1273
Region 2	EL 70 & Above	1,2,7,8,5,6,10,9	2636
Region 3	EL 20 to 40	15,13,14,16	5000
Region 4	EL 20 and Below	11,15,16,12	5000
Region 5	EL 40 to 70	9,13,14,10	7750

Points

	X (ft)	Y (ft)
Point 1	0	82
Point 2	100	82
Point 3	100	112
Point 4	138	113
Point 5	138	82
Point 6	250	82

Point 7	100	79
Point 8	138	79
Point 9	0	71
Point 10	250	71
Point 11	0	0
Point 12	250	0
Point 13	0	40
Point 14	250	40
Point 15	0	20
Point 16	250	20

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	4140	1.734	(94.909, 112.448)	43.139	(138, 113)	(64.35, 82)

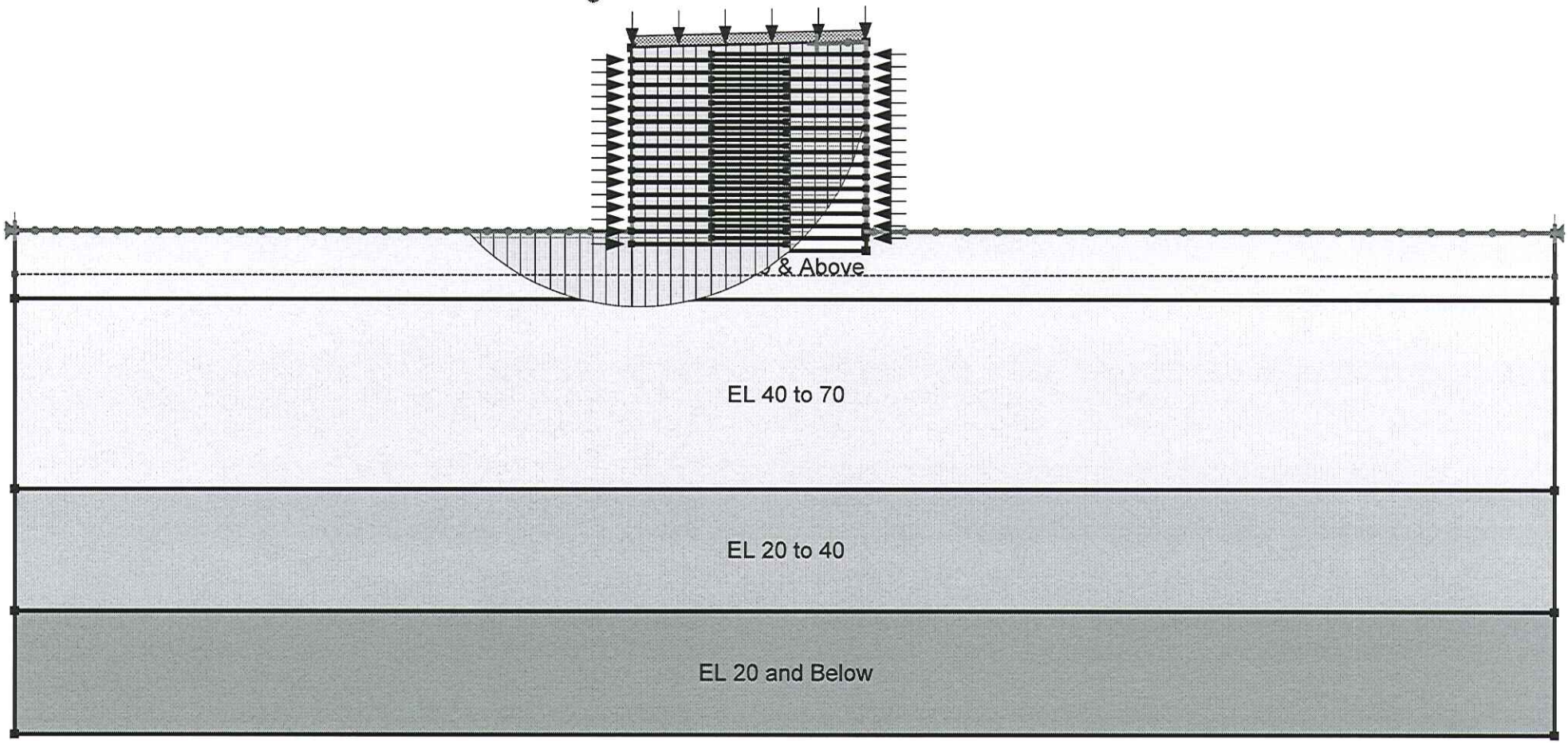
Slices of Slip Surface: 4140

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	4140	65.49304	80.933075	-370.23299	217.65338	136.00493	0
2	4140	67.779125	78.94065	-245.8957	637.83979	398.56654	0
3	4140	70.06521	77.209275	-137.85946	1025.8394	641.0156	0
4	4140	72.35129	75.7017	-43.787805	1375.8899	859.75146	0
5	4140	74.676315	74.37191	39.193068	1669.3662	1018.6452	0
6	4140	77.040285	73.2056	111.9724	1901.2017	1118.0346	0
7	4140	79.404255	72.211895	173.97819	2077.6255	1189.5308	0
8	4140	81.768225	71.378205	225.99985	2195.9785	1230.9793	0
9	4140	84.168055	70.68676	269.14522	2253.1156	813.84734	413.18
10	4140	86.60374	70.13447	303.61008	2265.4023	808.07171	409.83
11	4140	89.03942	69.728075	328.96765	2229.6294	792.14233	400.4
12	4140	91.475105	69.46343	345.48339	2152.4519	767.53376	385.58
13	4140	93.91079	69.337915	353.31319	2041.0149	735.51538	366.26
14	4140	96.346475	69.350305	352.54286	1902.4332	697.16618	343.58
15	4140	98.78216	69.500725	343.15574	1743.3592	653.2529	318.92
16	4140	100.05	69.616545	335.92937	5613.2195	1570.8218	791.44

17	4140	101.22815	69.78965	325.12523	5710.0893	1592.0326	802.23
18	4140	103.4844	70.18564	300.41716	5416.4828	1538.7872	775.24
19	4140	105.74065	70.707265	267.86576	5120.1619	1489.5172	744.45
20	4140	108.05075	71.378205	225.99985	4841.9907	2884.3912	0
21	4140	110.4147	72.211895	173.97819	4505.7651	2706.8009	0
22	4140	112.7787	73.2056	111.9724	4180.5341	2542.3195	0
23	4140	115.1427	74.37191	39.193068	3865.5153	2390.9515	0
24	4140	117.7817	75.91212	-56.917723	3527.107	2203.9811	0
25	4140	120.6957	77.91212	-181.71719	3172.3859	1982.3267	0
26	4140	123.465	80.16059	-322.02824	2865.5176	1932.816	0
27	4140	126.08955	82.696455	-480.27111	2464.8516	1662.5634	0
28	4140	128.7141	85.732195	-669.69443	2121.4905	1430.9634	0
29	4140	131.33865	89.47343	-903.14655	1740.8666	1174.2293	0
30	4140	133.9632	94.39262	-1210.1027	1277.8014	861.88793	0
31	4140	136.58775	103.05167	-1750.4563	527.44971	355.76932	0
32	4140	137.95	109.6382	-2161.4417	62.537704	42.182214	0

GLOBAL STABILITY
UNDRAINED ANALYSIS

FS = 1.761



RETAINING WALL 14 & 15
RAMP B STA 458+50

42 of 82
JPT
1-22-09

RKK RW14 & 15-44

43 of 82

SLOPE/W Analysis

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File Information

Revision Number: 49
Date: 11/26/2008
Time: 9:43:53 AM
File Name: RW-14&15 (UnDrained) alt.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Retaining Wall RW-14 and 15\Global Stability\
Last Solved Date: 11/26/2008
Last Solved Time: 9:44:30 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Description: Retaining Wall 14 & 15 STA 458+50
Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- **Apply Phreatic Correction:** No
- **Side Function**
  - **Interslice force function option:** Half-Sine
- **PWP Conditions Source:** Piezometric Line
- **Use Staged Rapid Drawdown:** No

SlipSurface
- **Direction of movement:** Right to Left
- **Allow Passive Mode:** No
- **Slip Surface Option:** Entry and Exit
- **Critical slip surfaces saved:** 1
- **Optimize Critical Slip Surface Location:** No
- **Tension Crack**
  - **Tension Crack Option:** (none)

FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1

Materials

Reinforced Soil

Model: Mohr-Coulomb
Unit Weight: 130 pcf
Cohesion: 0 psf
Phi: 34 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Select Fill

EL 70 & Above

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 32 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Strata Ia

EL 40 to 70

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 1700 psf
Pore Water Pressure
Piezometric Line: 1

EL 20 to 40

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 2500 psf
Pore Water Pressure
Piezometric Line: 1

EL 20 and Below

Model: Undrained (Phi=0)
Unit Weight: 130 pcf
Cohesion: 3500 psf
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0, 82) ft
Left-Zone Right Coordinate: (99.99, 82) ft
Left-Zone Increment: 30
Right Projection: Range
Right-Zone Left Coordinate: (130, 112.78947) ft
Right-Zone Right Coordinate: (250, 82) ft
Right-Zone Increment: 30
Radius Increments: 15

Slip Surface Limits

Left Coordinate: (0, 82) ft
Right Coordinate: (250, 82) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	75
	250	75

≈ 4' ↓ BOF

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

for 2' ∴ 250 psf

Coordinates

	X (ft)	Y (ft)

	100.1	114
	137.9	115

Reinforcements

Reinforcement 1

Type: Fabric
Outside Point: (100, 80) ft
Inside Point: (125, 80) ft
Slip Surface Intersection: (126.7, 80) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 638.15 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (100, 82) ft
Inside Point: (125, 82) ft
Slip Surface Intersection: (128.67, 82) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs

Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 600.96 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 3

Type: Fabric
Outside Point: (100, 84) ft
Inside Point: (125, 84) ft
Slip Surface Intersection: (130.38, 84) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 556.94 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 4

Type: Fabric
Outside Point: (100, 86) ft
Inside Point: (125, 86) ft
Slip Surface Intersection: (131.89, 86) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs

Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 503.47 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 5

Type: Fabric
Outside Point: (100, 88) ft
Inside Point: (125, 88) ft
Slip Surface Intersection: (133.14, 88) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 503.47 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 6

Type: Fabric
Outside Point: (100, 90) ft
Inside Point: (125, 90) ft
Slip Surface Intersection: (134.26, 90) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1

Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 435.03 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 7

Type: Fabric
Outside Point: (100, 92) ft
Inside Point: (125, 92) ft
Slip Surface Intersection: (135.21, 92) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 435.03 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 8

Type: Fabric
Outside Point: (100, 94) ft
Inside Point: (125, 94) ft
Slip Surface Intersection: (136.05, 94) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf

Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 332.44 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 9

Type: Fabric
Outside Point: (100, 96) ft
Inside Point: (125, 96) ft
Slip Surface Intersection: (136.63, 96) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 332.44 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 10

Type: Fabric
Outside Point: (100, 98) ft
Inside Point: (125, 98) ft
Slip Surface Intersection: (137.22, 98) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable

F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 332.44 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 11

Type: Fabric
Outside Point: (100, 100) ft
Inside Point: (125, 100) ft
Slip Surface Intersection: (137.81, 100) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 332.44 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 12

Type: Fabric
Outside Point: (100, 102) ft
Inside Point: (125, 102) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft

Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 13

Type: Fabric
Outside Point: (100, 104) ft
Inside Point: (125, 104) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 14

Type: Fabric
Outside Point: (100, 106) ft
Inside Point: (125, 106) ft

Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 15

Type: Fabric
Outside Point: (100, 108) ft
Inside Point: (125, 108) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 16

Type: Fabric

Outside Point: (100, 110) ft
Inside Point: (125, 110) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 14 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 17

Type: Fabric
Outside Point: (138, 81) ft
Inside Point: (113, 81) ft
Slip Surface Intersection: (74.319, 81) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 18

Type: Fabric
Outside Point: (138, 85) ft
Inside Point: (113, 85) ft
Slip Surface Intersection: (131.15, 85) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 18.149 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 19

Type: Fabric
Outside Point: (138, 87) ft
Inside Point: (113, 87) ft
Slip Surface Intersection: (132.52, 87) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 19.517 ft

Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 20

Type: Fabric
Outside Point: (138, 89) ft
Inside Point: (113, 89) ft
Slip Surface Intersection: (133.77, 89) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 20.77 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 21

Type: Fabric
Outside Point: (138, 91) ft
Inside Point: (113, 91) ft
Slip Surface Intersection: (134.73, 91) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs

Resisting Force Used: 0 lbs/ft
Available Bond Length: 21.735 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 22

Type: Fabric
Outside Point: (138, 93) ft
Inside Point: (113, 93) ft
Slip Surface Intersection: (135.69, 93) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 22.689 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 23

Type: Fabric
Outside Point: (138, 95) ft
Inside Point: (113, 95) ft
Slip Surface Intersection: (136.34, 95) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0

Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 23.34 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 24

Type: Fabric
Outside Point: (138, 97) ft
Inside Point: (113, 97) ft
Slip Surface Intersection: (136.93, 97) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 23.926 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 25

Type: Fabric
Outside Point: (138, 99) ft
Inside Point: (113, 99) ft
Slip Surface Intersection: (137.51, 99) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs

Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 24.512 ft
Required Bond Length: -1 ft
Governing Component: Bond

Reinforcement 26

Type: Fabric
Outside Point: (138, 101) ft
Inside Point: (113, 101) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 27

Type: Fabric
Outside Point: (138, 103) ft
Inside Point: (113, 103) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs

Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 28

Type: Fabric
Outside Point: (138, 105) ft
Inside Point: (113, 105) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 29

Type: Fabric
Outside Point: (138, 107) ft
Inside Point: (113, 107) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1

Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 30

Type: Fabric
Outside Point: (138, 109) ft
Inside Point: (113, 109) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 31

Type: Fabric
Outside Point: (138, 111) ft
Inside Point: (113, 111) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf

Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 32

Type: Fabric
Outside Point: (138, 83) ft
Inside Point: (113, 83) ft
Slip Surface Intersection: (129.59, 83) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes
Contact Cohesion: 0 psf
Contact Phi: 0 °
Interface Factor: 1
Bond Safety Factor: 1
Fabric Capacity: 10000 lbs
Fabric Safety Factor: 1
Fabric Load: 10000 lbs
Load Distribution: Conc. in 1 slice
Load Orientation: 0
Applied Load: 10000 lbs
Fabric Load Used: 0 lbs
Resisting Force Used: 0 lbs/ft
Available Bond Length: 16.588 ft
Required Bond Length: -1 ft
Governing Component: Bond

Regions

	Material	Points	Area (ft^2)
Region 1	Reinforced Soil	3,2,7,8,5,4	1273
Region 2	EL 70 & Above	1,2,7,8,5,6,10,9	2636
Region 3	EL 20 to 40	15,13,14,16	5000

Region 4	EL 20 and Below	11,15,16,12	5000
Region 5	EL 40 to 70	9,13,14,10	7750

Points

	X (ft)	Y (ft)
Point 1	0	82
Point 2	100	82
Point 3	100	112
Point 4	138	113
Point 5	138	82
Point 6	250	82
Point 7	100	79
Point 8	138	79
Point 9	0	71
Point 10	250	71
Point 11	0	0
Point 12	250	0
Point 13	0	40
Point 14	250	40
Point 15	0	20
Point 16	250	20

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	10990	1.761	(101.021, 107.346)	37.542	(138, 113)	(73.326, 82)

Slices of Slip Surface: 10990

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	10990	74.40578	80.912805	-368.95721	231.37242	144.57754	0
2	10990	76.565345	78.897405	-243.198	671.11384	419.35847	0
3	10990	78.72491	77.171365	-135.49488	1068.7046	667.80073	0
4	10990	80.88447	75.686765	-42.854514	1419.4581	886.97586	0

5	10990	83.171195	74.347155	40.737724	1713.9723	1045.553	0
6	10990	85.58508	73.149525	115.46998	1941.6673	1141.1347	0
7	10990	87.99896	72.158105	177.3326	2096.1869	1199.0332	0
8	10990	90.412845	71.355735	227.40278	2177.308	1218.436	0
9	10990	92.667315	70.760825	264.52673	2360.9915	0	1700
10	10990	94.762365	70.344475	290.50611	2332.6332	0	1700
11	10990	96.85742	70.05037	308.85655	2265.726	0	1700
12	10990	98.952475	69.87562	319.76293	2164.7169	0	1700
13	10990	100.05	69.816505	323.45197	6055.8773	0	1700
14	10990	101.13215	69.81828	323.33759	6192.3749	0	1700
15	10990	103.19645	69.88129	319.40504	5958.5585	0	1700
16	10990	105.26075	70.0586	308.34513	5706.084	0	1700
17	10990	107.32505	70.351865	290.04367	5442.5271	0	1700
18	10990	109.38935	70.76388	264.33324	5173.2361	0	1700
19	10990	111.62845	71.355735	227.40278	4925.0004	2935.3848	0
20	10990	114.04235	72.158105	177.3326	4546.4718	2730.1412	0
21	10990	116.45625	73.149525	115.46998	4184.4227	2542.5639	0
22	10990	118.8701	74.347155	40.737724	3838.0184	2372.8043	0
23	10990	121.0035	75.582875	-36.371493	3547.527	2216.7409	0
24	10990	122.8565	76.828675	-114.10707	3306.4674	2066.1101	0
25	10990	124.7095	78.2458	-202.53871	3072.0443	1919.6263	0
26	10990	126.658	79.956615	-309.29275	2783.824	1877.713	0
27	10990	128.702	82.03074	-438.73117	2512.2048	1694.5035	0
28	10990	130.746	84.476615	-591.34174	2226.7051	1501.9315	0
29	10990	132.79	87.435685	-775.99618	1909.7747	1288.1593	0
30	10990	134.834	91.20767	-1011.3507	1526.5723	1029.686	0
31	10990	136.878	96.835475	-1362.5312	964.67669	650.68264	0
32	10990	137.95	100.59555	-1597.1678	519.34026	350.29943	0

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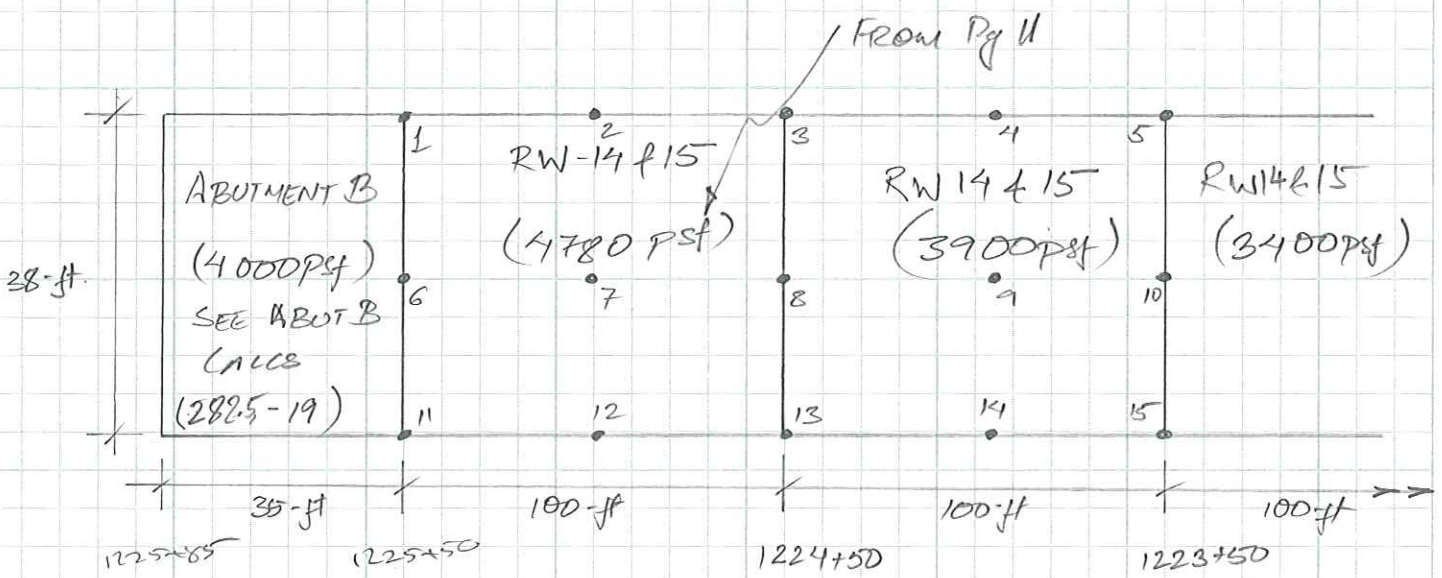
Subject SR-1 INTERCHANGE / RETAINING WALL 14 & 15 Page 65 of 82
Cm. No. 103-059
Prepared By BBS Date 2-6-09 Checked By [illegible] Date 2/6/09

ELASTIC & CONSOLIDATION SETTLEMENT



FOR STRESS DUE TO ABUTMENT SEE ABUTMENT B CALCS

σ_v = 4000 psf

AVG HEIGHT BETWEEN STA 1225+50 & STA 1224+50 IS 35-ft.

SEE RETAINING WALL 14&15 CALCS σ_v = 4780psf.

AVG HEIGHT BETWEEN STA 1224+50 & 1223+50 IS 30-ft

APPROX STRESS = γH = 130x30 = 3900psf

AVG HEIGHT BETWEEN STA 1223+50 & 1222+50 is 26-ft.

APPROX STRESS = γH = 130x26 ≈ 3400psf.

ELASTIC SETTLEMENT FOR COARSE GRAINED SOIL

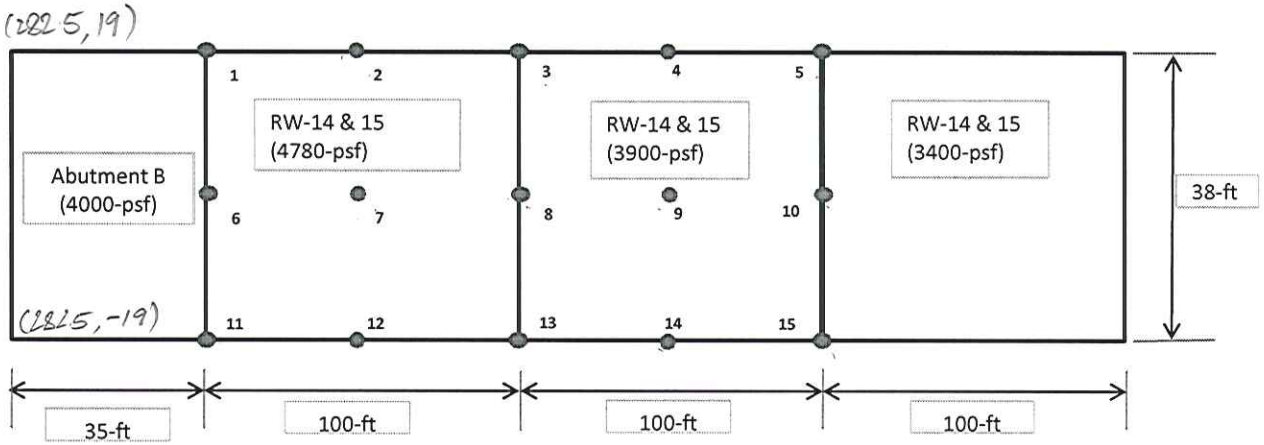
CONSOLIDATION SETTLEMENT FOR FINE GRAINED SOIL.

I-95/SR 1 Interchange 103-059-27U 2/6/2009
Retaining Wall 14 15 Settlement Results

	Settlement (ft)		
Point	Elastic	Consolidation	Total
1	0.01	0.16	0.17
2	0.01	0.19	0.20
3	0.01	0.18	0.19
4	0.01	0.17	0.18
5	0.01	0.16	0.17
6	0.02	0.20	0.22
7	0.02	0.23	0.25
8	0.02	0.23	0.25
9	0.01	0.21	0.22
10	0.01	0.20	0.21
11	0.01	0.16	0.17
12	0.01	0.19	0.20
13	0.01	0.18	0.19
14	0.01	0.17	0.18
15	0.01	0.16	0.17

	Settlement (in)		
Point	Elastic	Consolidation	Total
1	0.1	1.9	2.0
2	0.1	2.3	2.4
3	0.1	2.2	2.3
4	0.1	2.0	2.1
5	0.1	1.9	2.0
6	0.2	2.4	2.6
7	0.2	2.8	3.0
8	0.2	2.8	3.0
9	0.2	2.5	2.7
10	0.2	2.4	2.6
11	0.1	1.9	2.0
12	0.1	2.3	2.4
13	0.1	2.2	2.3
14	0.1	2.0	2.1
15	0.1	1.9	2.0

	RW 14 & 15 Differential Settlement						
	Along Front RW 14		Along Center RW 14 & 15		Along Front RW 15		Front to Back
	1 to 3	1 to 2	6 to 8	6 to 7	11 to 13	11 to 12	3 to 8
Inches	-0.2	0.4	0.4	-0.4	-0.2	-0.4	-0.7
Ratio	1/5051	6/9901	1/3367	- 1/1618	- 1/5051	- 4/6579	- 1/323



RKK RW14 & 15-68

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BPS
CWL
2/6/09

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Retaining Wall RW-14 and 15\RW 14 & 15 Settlement Results.xls

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Subject SR-1 INTERCHANGE Page 67 of 82
RETAINING WALL RW14 & 15 Cm. No. 103-059
Prepared By BBS Date 9-26-08 Checked By JPT Date 1-22-09

MAX ELASTIC SETTLEMENT

δ_E = 0.2 inches

MAX CONSOLIDATION SETTLEMENT

δ_C = 2.8 - inches

TOTAL SETTLEMENT = $\delta_E + \delta_C$ NODE 4

= 0.2 + 2.8

= 3.0 inch.

MAX DIFFERENTIAL SETTLEMENT IS ALONG FACE OF WALL

BETWEEN NODES 1 & 2

$\Delta\delta$ = 0.4 - inch over 100 - ft.

RATIO = $\frac{0.4}{12 \times 50} = \frac{1}{1500}$

BETWEEN NODES 3 & 8

$\Delta\delta$ = 0.7 - inch over 19 - ft

RATIO = $\frac{0.7}{19 \times 12} = \frac{1}{325}$

RKK RW14 & 15-70
SR-1 Interchange Ramp B

6 & 9 & 82

BBS 2-6-09

SR-1 Interchange Ramp B

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PROJECT IDENTIFICATION

Title: SR-1 Interchange Ramp B
Project Number: 103-059 -
Client: DelDot
Designer: BBS
Station Number:

Description:
Retaining Wall 14 & 15 Settlement Analysis

Company's information:

Name: Rummel, Klepper & Kahl
Street: 81 Mosher Street
Baltimore, MD 21217
Telephone #:
Fax #:
E-Mail:

Original file path and name: M:\project ..... Retaining Wall RW-14 and 15\RW-14 RW-15revised.2ST
Original date and time of creating this file: Thu Sep 25 09:30:22 2008

GEOMETRY: Analysis of a Multiple Footings

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INPUT DATA – FOUNDATION LAYERS – 6 layers

	Wet Unit Weight, γ [lb/ft^3]	Poisson's Ratio μ	Description of Soil
1	125.00	0.30	
2	130.00	0.40	
3	130.00	0.40	
4	130.00	0.40	
5	130.00	0.40	
6	125.00	0.30	

INPUT DATA – MULTIPLE FOOTINGS – 4 footings

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	300.00	175.00

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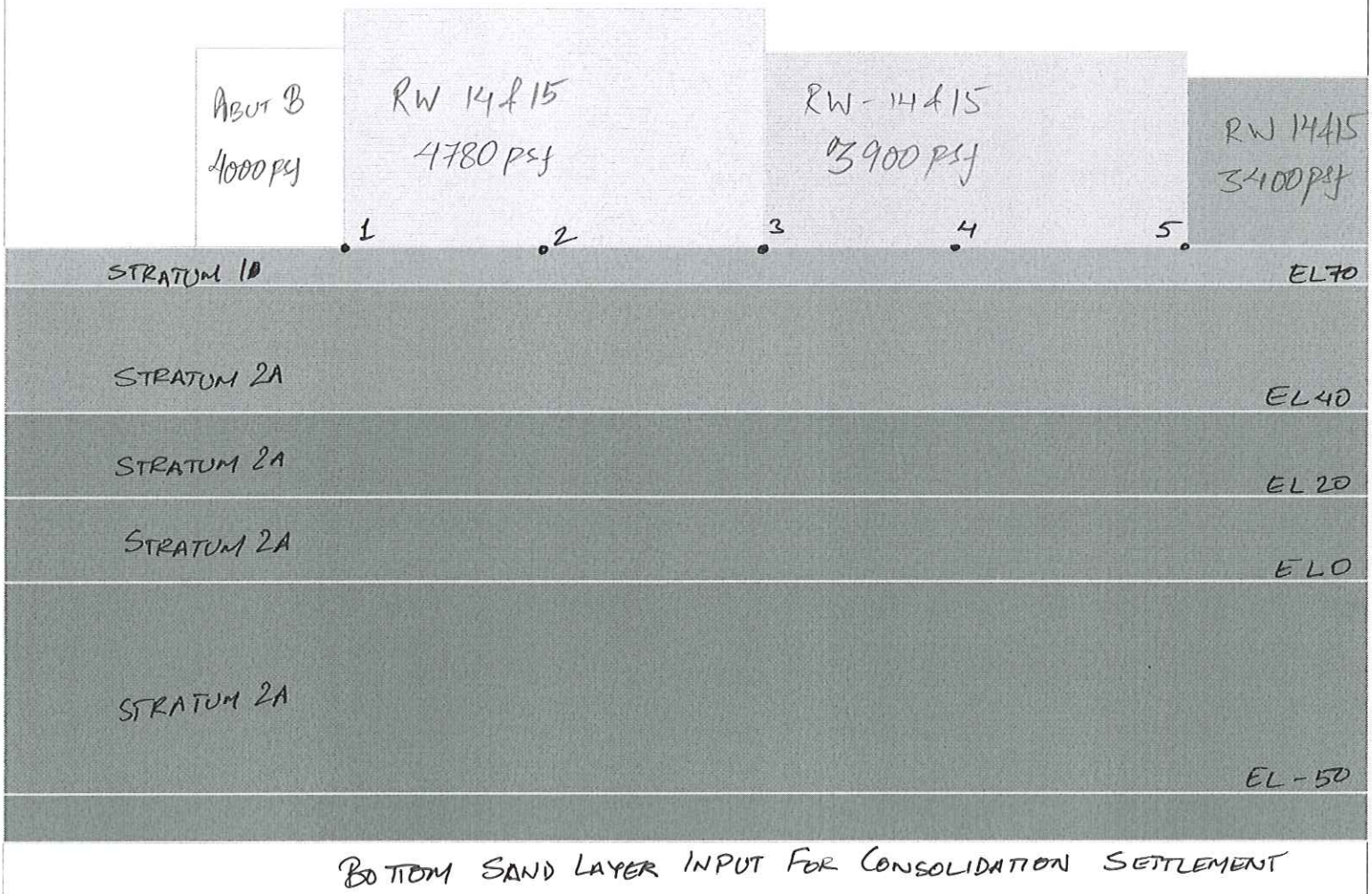
DRAWING OF SPECIFIED GEOMETRY



BOTTOM SAND LAYER INPUT FOR CONSOLIDATION SETTLEMENT

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INPUT DATA FOR CONSOLIDATION -- $\alpha = 1/2$

Layer # Underging Consolidation [Yes/No]	$(\sigma'_p - \sigma'_o)$ given at layer's boundaries in [lb/ft²] at Top	Bottom	Cc	Cr	e0	Cv [ft²/day]	Drains at :
1	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Yes	8150.0	5450.0	0.24	0.01	0.75	1.6500	Top
3	Yes	5450.0	4100.0	0.22	0.01	0.84	1.6500	Top
4	Yes	4100.0	2750.0	0.22	0.01	0.84	0.8400	Bottom
5	Yes	2750.0	0.0	0.22	0.01	0.84	0.8400	Bottom
6	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A

$P_c = 9000$ psf ESTIMATE $(\sigma_f' - \sigma_o')$ WT @ 4 ft BELOW FOUNDATION

LAYER 2

TOP = $9000 - 125 \times 4 - (125 - 62.4) \times 5 = 8187 \approx 8150$ psf

BOTTOM = $8187 - (130 - 62.4) \times 40 = 5483 \approx 5450$ psf

LAYER 3

TOP = 5450 psf

BOTTOM = $5483 - (130 - 62.4) \times 20 = 4131 \approx 4100$ psf

LAYER 4

TOP = 4100 psf

BOTTOM = $4131 - (130 - 62.4) \times 20 = 2779 \approx 2750$ psf

LAYER 5

TOP = 2750

BOTTOM = 0

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
1	317.50	19.00	1	1500000	0.3000	0.0084	179.00	178.86	~~0.14~~ 0.0084
			2	818000	0.4000	~~0.0489~~			
			3	818000	0.4000	~~0.0293~~			
			4	818000	0.4000	~~0.0232~~			
			5	1364000	0.4000	~~0.0241~~			
			6	1364000	0.3000	~~0.0083~~			
2	367.50	19.00	1	1500000	0.3000	0.0087	179.00	178.84	~~0.16~~ 0.0087
			2	818000	0.4000	~~0.0514~~			
			3	818000	0.4000	~~0.0336~~			
			4	818000	0.4000	~~0.0282~~			
			5	1364000	0.4000	~~0.0304~~			
			6	1364000	0.3000	~~0.0106~~			
3	417.50	19.00	1	1500000	0.3000	0.0082	179.00	178.85	~~0.15~~ 0.0082
			2	818000	0.4000	~~0.0469~~			
			3	818000	0.4000	~~0.0309~~			
			4	818000	0.4000	~~0.0266~~			
			5	1364000	0.4000	~~0.0302~~			
			6	1364000	0.3000	~~0.0109~~			
4	467.50	19.00	1	1500000	0.3000	0.0071	179.00	178.86	~~0.14~~ 0.0071
			2	818000	0.4000	~~0.0406~~			
			3	818000	0.4000	~~0.0273~~			
			4	818000	0.4000	~~0.0239~~			
			5	1364000	0.4000	~~0.0278~~			
			6	1364000	0.3000	~~0.0104~~			
5	517.50	19.00	1	1500000	0.3000	0.0068	179.00	178.87	~~0.13~~ 0.0068
			2	818000	0.4000	~~0.0392~~			
			3	818000	0.4000	~~0.0259~~			
			4	818000	0.4000	~~0.0222~~			
			5	1364000	0.4000	~~0.0252~~			
			6	1364000	0.3000	~~0.0093~~			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

IGNORE ELASTIC SETTLEMENT OF STRATUM IIa

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
~~26~~	317.50	0.00	1	1500000	0.3000	0.0173	179.00	178.79	~~0.21~~ 0.0173
			2	818000	0.4000	~~0.0913~~			
			3	818000	0.4000	~~0.0392~~			
			4	818000	0.4000	~~0.0275~~			
			5	1364000	0.4000	~~0.0263~~			
			6	1364000	0.3000	~~0.0087~~			
~~27~~	367.50	0.00	1	1500000	0.3000	0.0182	179.00	178.76	~~0.24~~ 0.0182
			2	818000	0.4000	~~0.0968~~			
			3	818000	0.4000	~~0.0448~~			
			4	818000	0.4000	~~0.0333~~			
			5	1364000	0.4000	~~0.0332~~			
			6	1364000	0.3000	~~0.0110~~			
~~38~~	417.50	0.00	1	1500000	0.3000	0.0170	179.00	178.78	~~0.22~~ 0.017
			2	818000	0.4000	~~0.0890~~			
			3	818000	0.4000	~~0.0413~~			
			4	818000	0.4000	~~0.0315~~			
			5	1364000	0.4000	~~0.0329~~			
			6	1364000	0.3000	~~0.0114~~			
~~49~~	467.50	0.00	1	1500000	0.3000	0.0148	179.00	178.80	~~0.20~~ 0.0148
			2	818000	0.4000	~~0.0776~~			
			3	818000	0.4000	~~0.0365~~			
			4	818000	0.4000	~~0.0282~~			
			5	1364000	0.4000	~~0.0303~~			
			6	1364000	0.3000	~~0.0109~~			
~~510~~	517.50	0.00	1	1500000	0.3000	0.0143	179.00	178.81	~~0.19~~ 0.0143
			2	818000	0.4000	~~0.0746~~			
			3	818000	0.4000	~~0.0346~~			
			4	818000	0.4000	~~0.0263~~			
			5	1364000	0.4000	~~0.0275~~			
			6	1364000	0.3000	~~0.0097~~			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

IGNORE ELASTIC SETTLEMENT OF STRATUM IIa

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IMMEDIATE SETTLEMENT, Si

Node #	Settlement along section: X [ft.]	Y [ft.]	Layer (k)	Young's Modulus, E [lb/ft ²]	Poisson's Ratio, μ	Settlement of each layer, Si(k) [ft.]	Initial Z [ft.]	Final Z * [ft.]	Total Settlement Sum of Si(k), [ft.]
X11	317.50	-19.00	1	1500000	0.3000	0.0081	179.00	178.86	~~0.14~~ 0.0081
			2	818000	0.4000	~~0.0489~~			
			3	818000	0.4000	~~0.0293~~			
			4	818000	0.4000	~~0.0232~~			
			5	1364000	0.4000	~~0.0241~~			
			6	1364000	0.3000	~~0.0083~~			
212	367.50	-19.00	1	1500000	0.3000	0.0085	179.00	178.84	~~0.16~~ 0.0085
			2	818000	0.4000	~~0.0514~~			
			3	818000	0.4000	~~0.0336~~			
			4	818000	0.4000	~~0.0282~~			
			5	1364000	0.4000	~~0.0304~~			
			6	1364000	0.3000	~~0.0106~~			
313	417.50	-19.00	1	1500000	0.3000	0.0079	179.00	178.85	~~0.15~~ 0.0079
			2	818000	0.4000	~~0.0469~~			
			3	818000	0.4000	~~0.0309~~			
			4	818000	0.4000	~~0.0266~~			
			5	1364000	0.4000	~~0.0302~~			
			6	1364000	0.3000	~~0.0109~~			
414	467.50	-19.00	1	1500000	0.3000	0.0069	179.00	178.86	~~0.14~~ 0.0069
			2	818000	0.4000	~~0.0406~~			
			3	818000	0.4000	0.0273			
			4	818000	0.4000	~~0.0239~~			
			5	1364000	0.4000	~~0.0278~~			
			6	1364000	0.3000	~~0.0104~~			
515	517.50	-19.00	1	1500000	0.3000	0.0066	179.00	178.87	~~0.13~~ 0.0066
			2	818000	0.4000	~~0.0392~~			
			3	818000	0.4000	~~0.0259~~			
			4	818000	0.4000	~~0.0222~~			
			5	1364000	0.4000	~~0.0252~~			
			6	1364000	0.3000	~~0.0093~~			

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1	317.50	19.00	179.00	0.16	178.84
2	367.50	19.00	179.00	0.19	178.81
3	417.50	19.00	179.00	0.18	178.82
4	467.50	19.00	179.00	0.17	178.83
5	517.50	19.00	179.00	0.16	178.84

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
~~1~~ 6	317.50	0.00	179.00	0.20	178.80
~~2~~ 7	367.50	0.00	179.00	0.23	178.77
3 8	417.50	0.00	179.00	0.23	178.77
~~4~~ 9	467.50	0.00	179.00	0.21	178.79
~~5~~ 10	517.50	0.00	179.00	0.20	178.80

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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ULTIMATE SETTLEMENT, Sc

Node #	X [ft.]	Y [ft.]	Original Z [ft.]	Settlement Sc [ft.]	Final Z * [ft.]
1 11	317.50	-19.00	179.00	0.16	178.84
2 12	367.50	-19.00	179.00	0.19	178.81
3 13	417.50	-19.00	179.00	0.18	178.82
4 14	467.50	-19.00	179.00	0.17	178.83
5 15	517.50	-19.00	179.00	0.16	178.84

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

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TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

Found. Soil #	Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]	DESCRIPTION
1	1	400.00	179.00	
2	1	300.00	170.00	
3	1	300.00	140.00	
4	1	300.00	120.00	
5	1	300.00	100.00	
6	1	300.00	50.00	

ACTUAL EL=Z-100

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TABULATED GEOMETRY: INPUT OF MULTIPLE FOOTINGS – 4 footings

Footing #	L (in X direction) [ft]	B (in Y direction) [ft]	X of center [ft]	Y of center [ft]	q [ft]l [lb/ft²]
1	35.00	38.00	300.00	0.00	4000.00 — ABUTMENT B
2	100.00	38.00	367.50	0.00	4780.00
3	100.00	38.00	467.50	0.00	3900.00 } RW 14 & 15
4	100.00	38.00	567.50	0.00	3400.00

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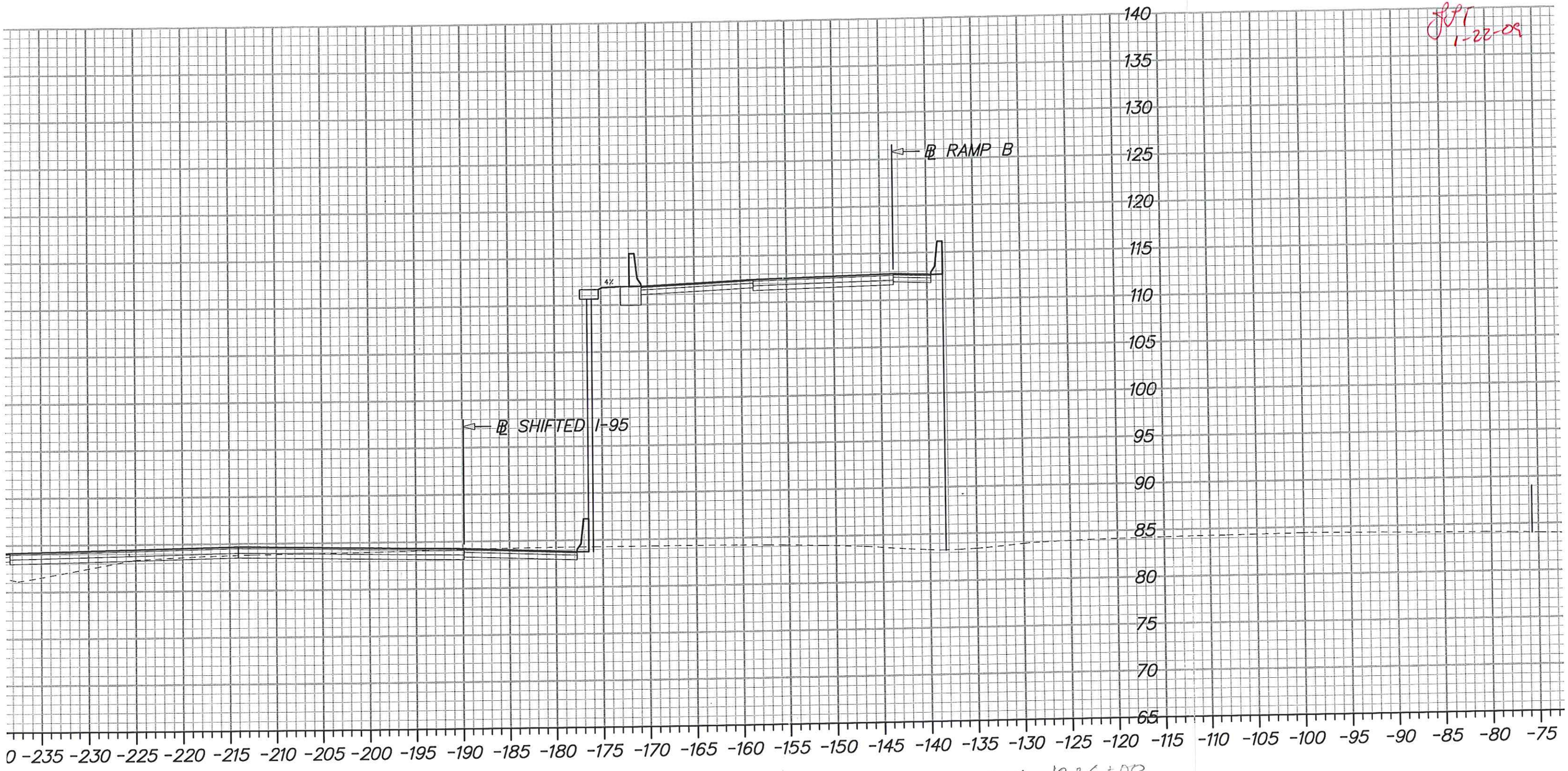
JWT 1-22-09



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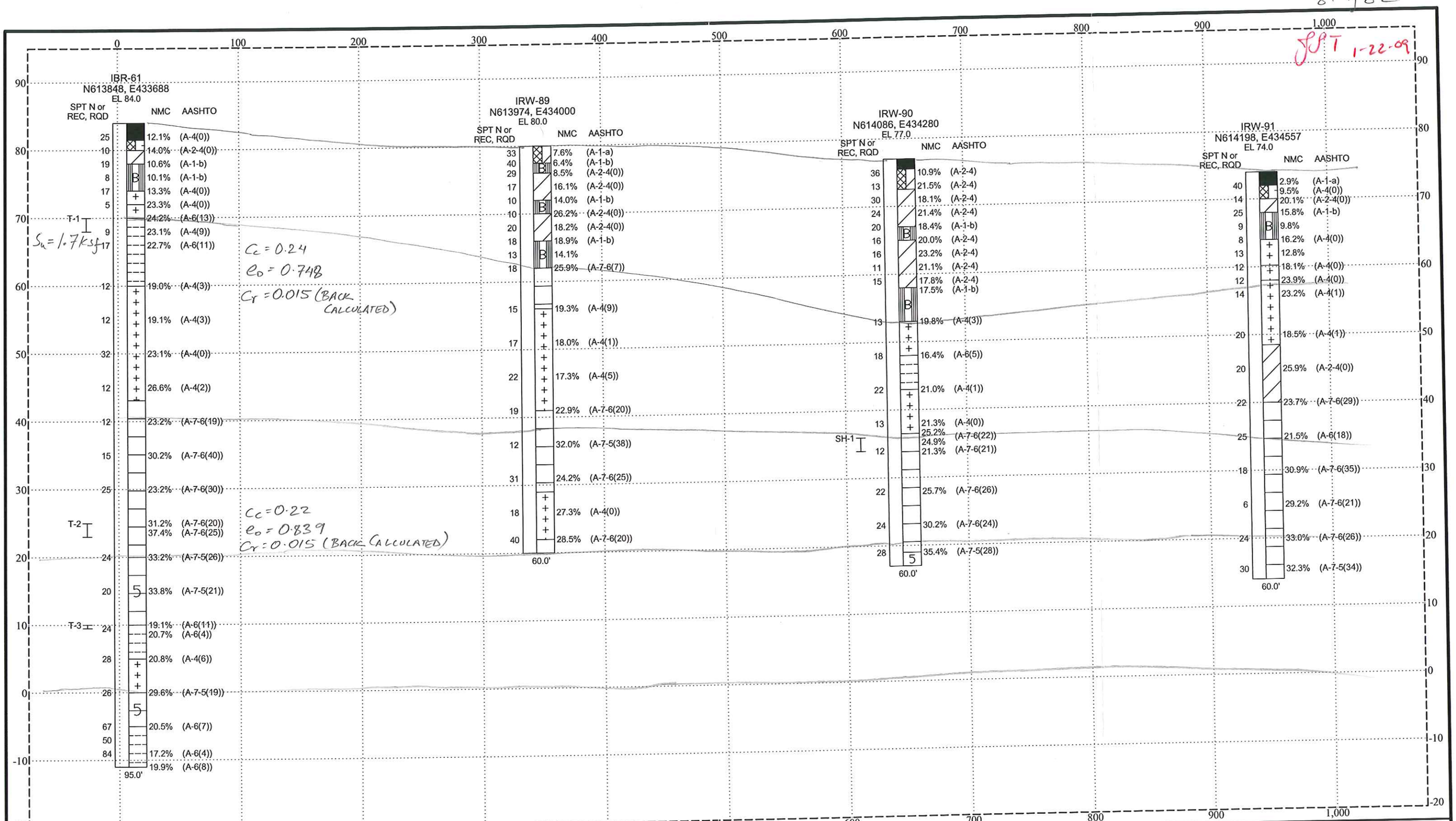
RAMP B STA 458+50

SPT 1-22-09



AASHTO SOIL KEY

A	A-1-a	A-2-5	A-5	A-8	
B	A-1-b	A-2-6	A-6	Asphalt	
A-3	A-2-7	A-7-5	FILL		
A-2-4	A-4	A-7-6	Decomposed Rock		

Rummel, Klepper & Kahl, LLP
Consulting Engineers
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Baltimore, MD 21217
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Title: Summary of Boring Data
Retaining Wall 14 & 15

Figure No. A-1

Drawn: BBS | Approved: EMK | Date: 1/20/09 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 1/20/09

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JPT
1-22-09

WALL 15

WALL 14

WALL 12

WALL 13

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CHURCHMANS ROAD

GENER
GROW