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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.
JJT	1-2-09	All calculations checked and each calculation sheet initialed by checker.
JJT	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		Has this calculation been superseded?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 - 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	$C_{v(Max)}$ (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

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

AJT 12-2-09

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 unable to be determined. OR Final OCR
- 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

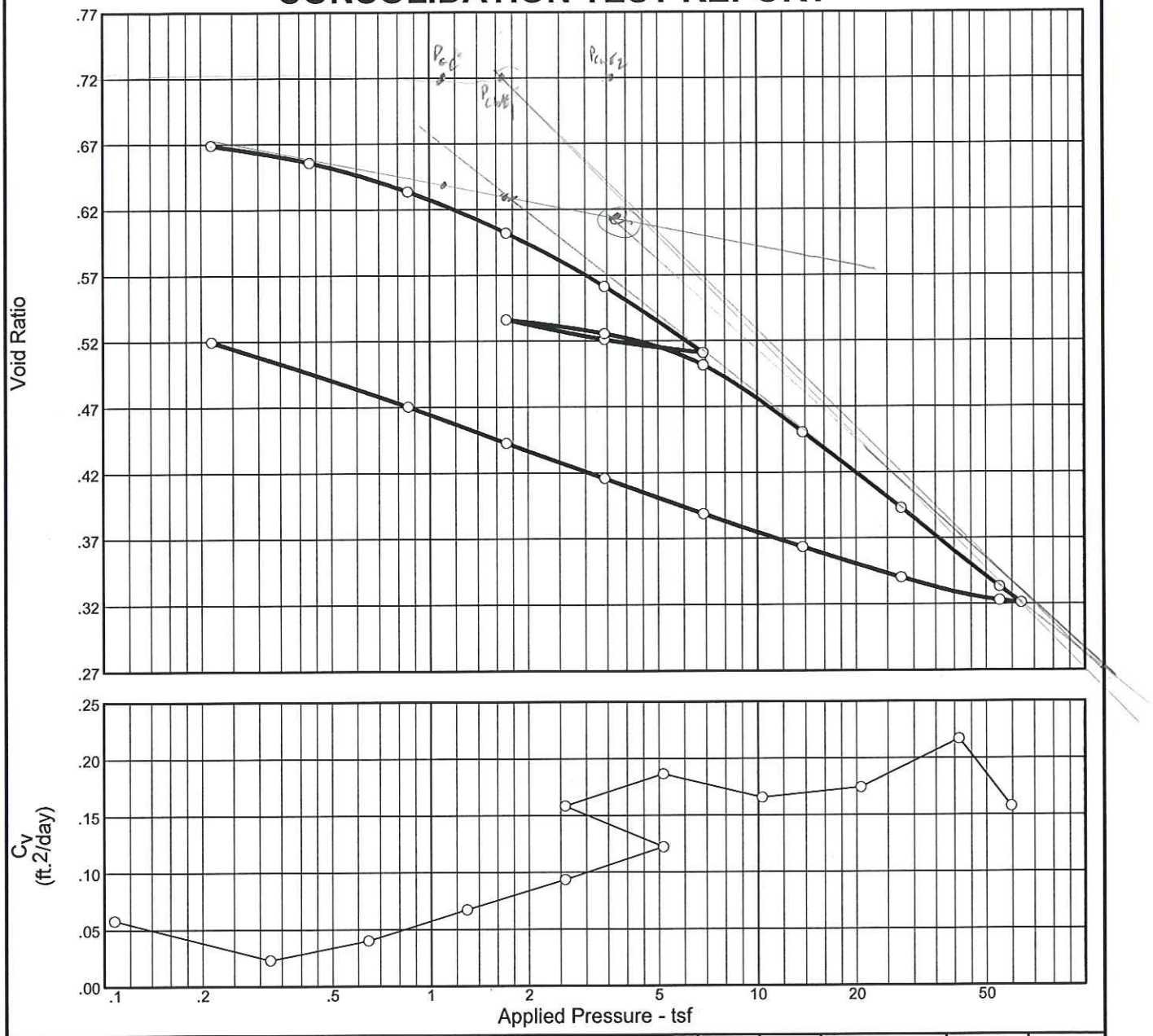
P_0 = Effective overburden stress
Pc_{cas} = Consolidation Test P_c
Pc_{WE} = Work Energy P_c
OCR_c = OCR from Pc_c
OCR_{WE} = OCR from Pc_{WE}
Final P_c = P_c to use for design based on evaluation of Pc_c + Pc_{WE}

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

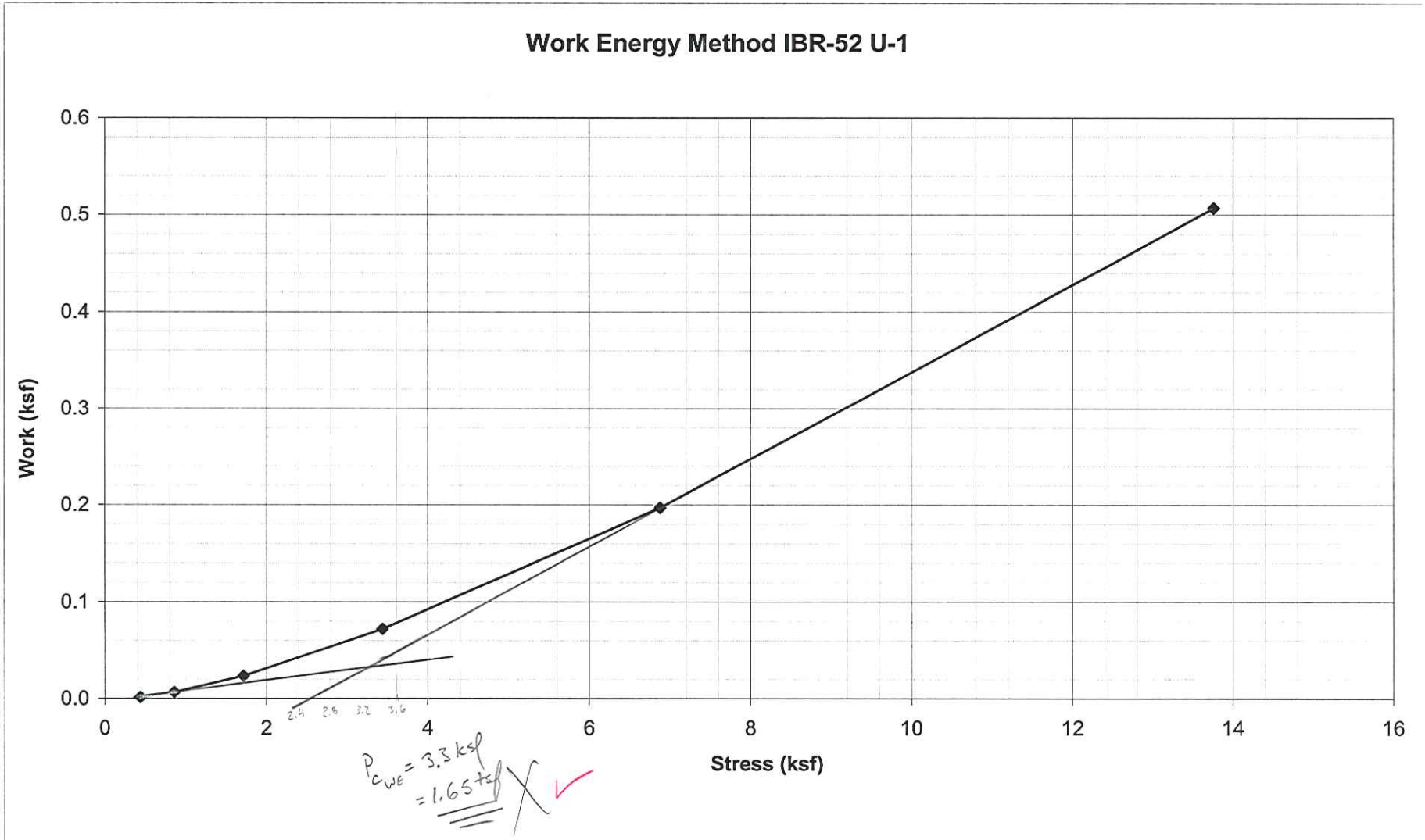
Remarks:

CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Figure

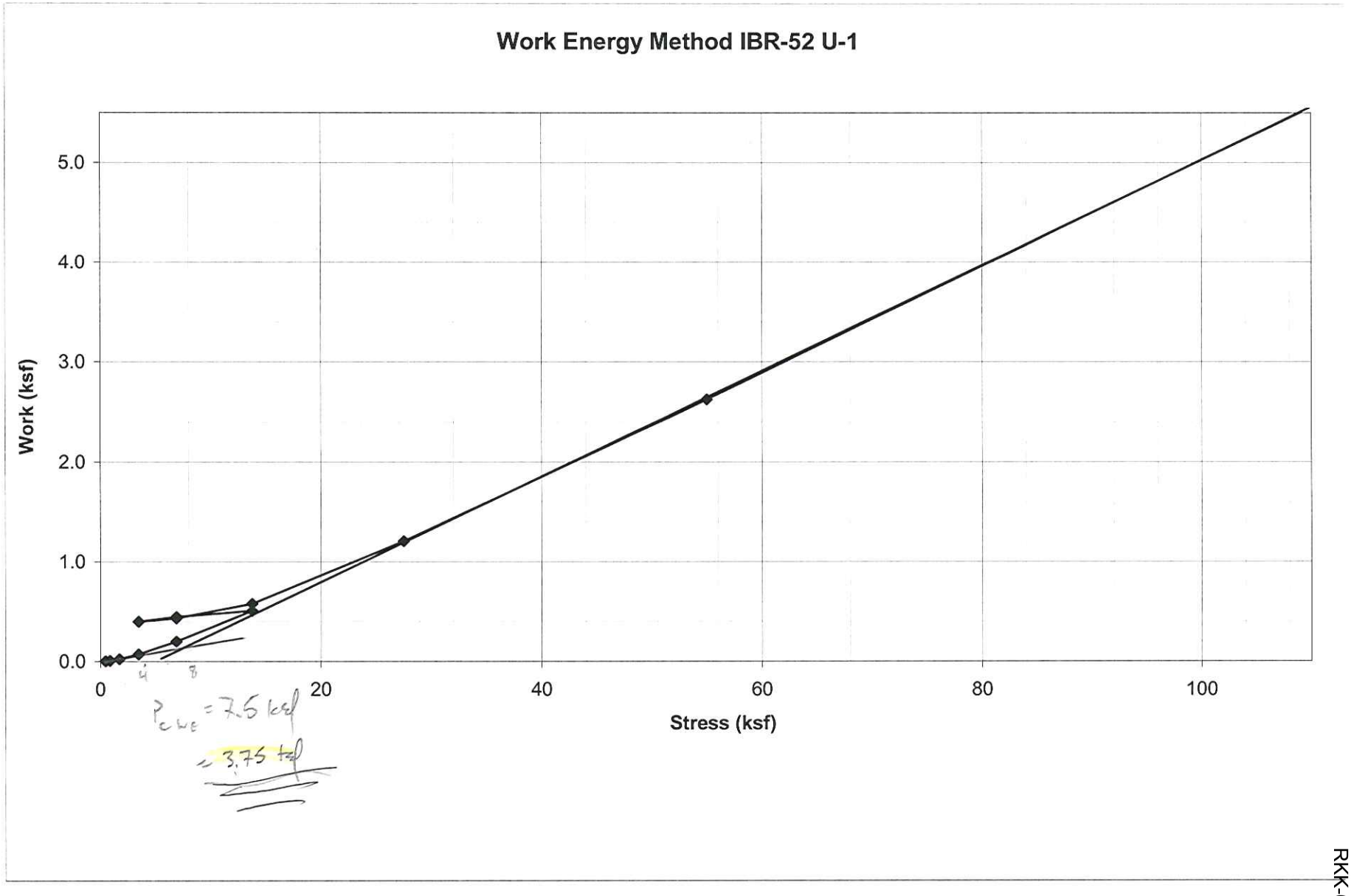
Delaware Turnpike Improvements
SR-1 Interchange



RKK-5

JGT 1-2-09

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



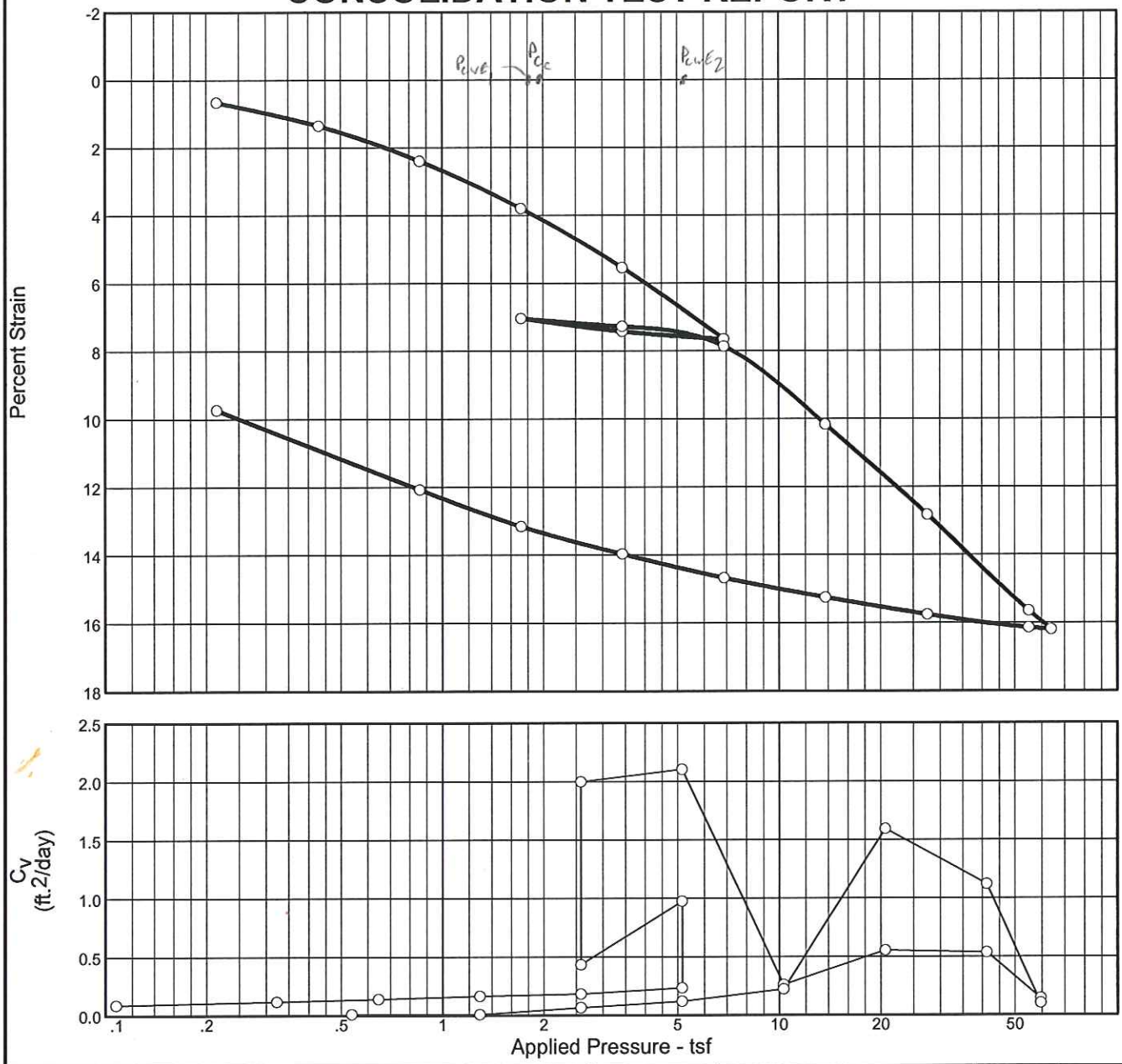
RKK-6

Apr 1-2-09

JJT
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)

$P_{c,ve}$ = 1.83 tsf / 5.25 tsf

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

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

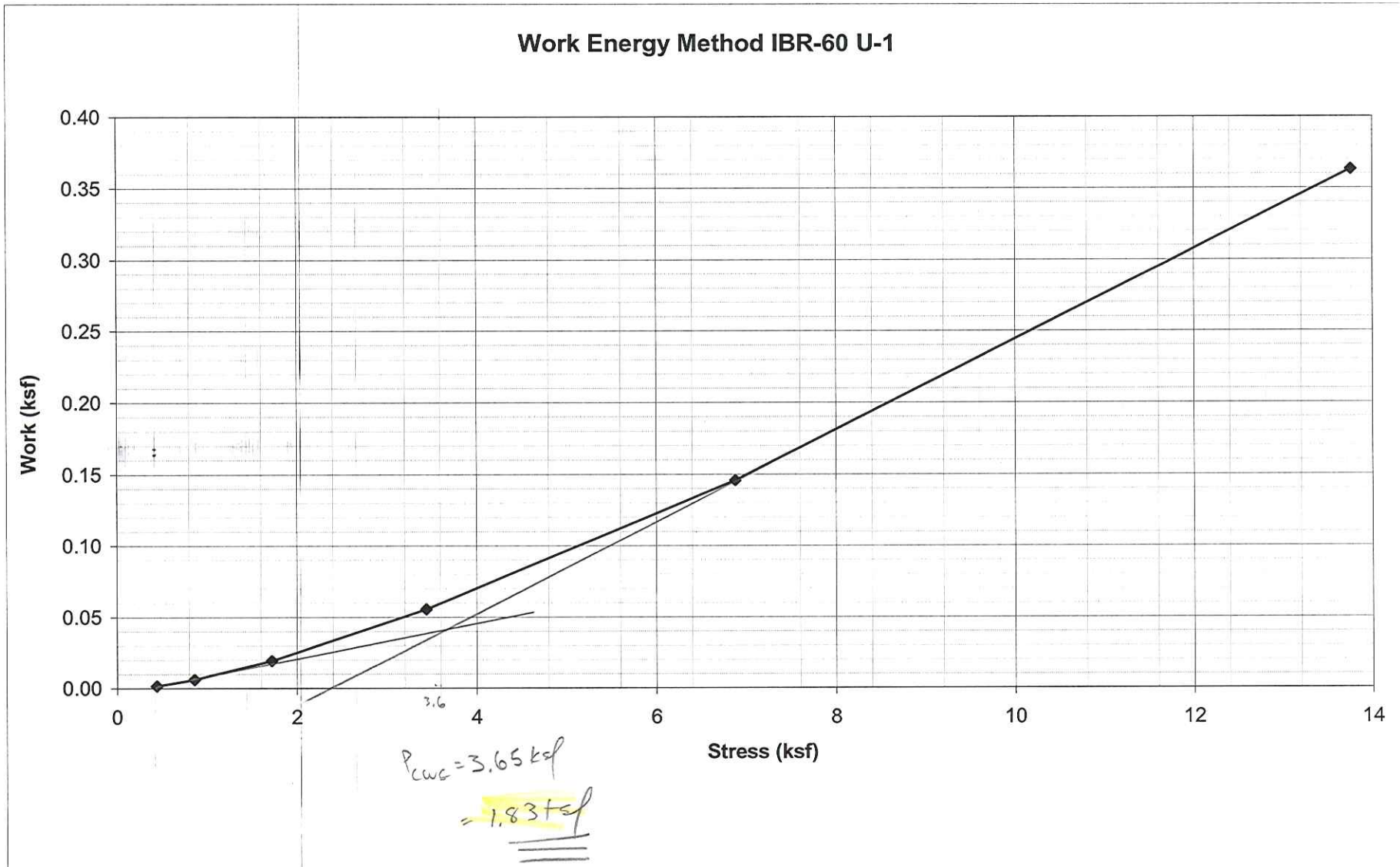
Source: IBR # 60 **Sample No.:** U-1 **Elev./Depth:** 18.0

Remarks:

CONSOLIDATION TEST REPORT

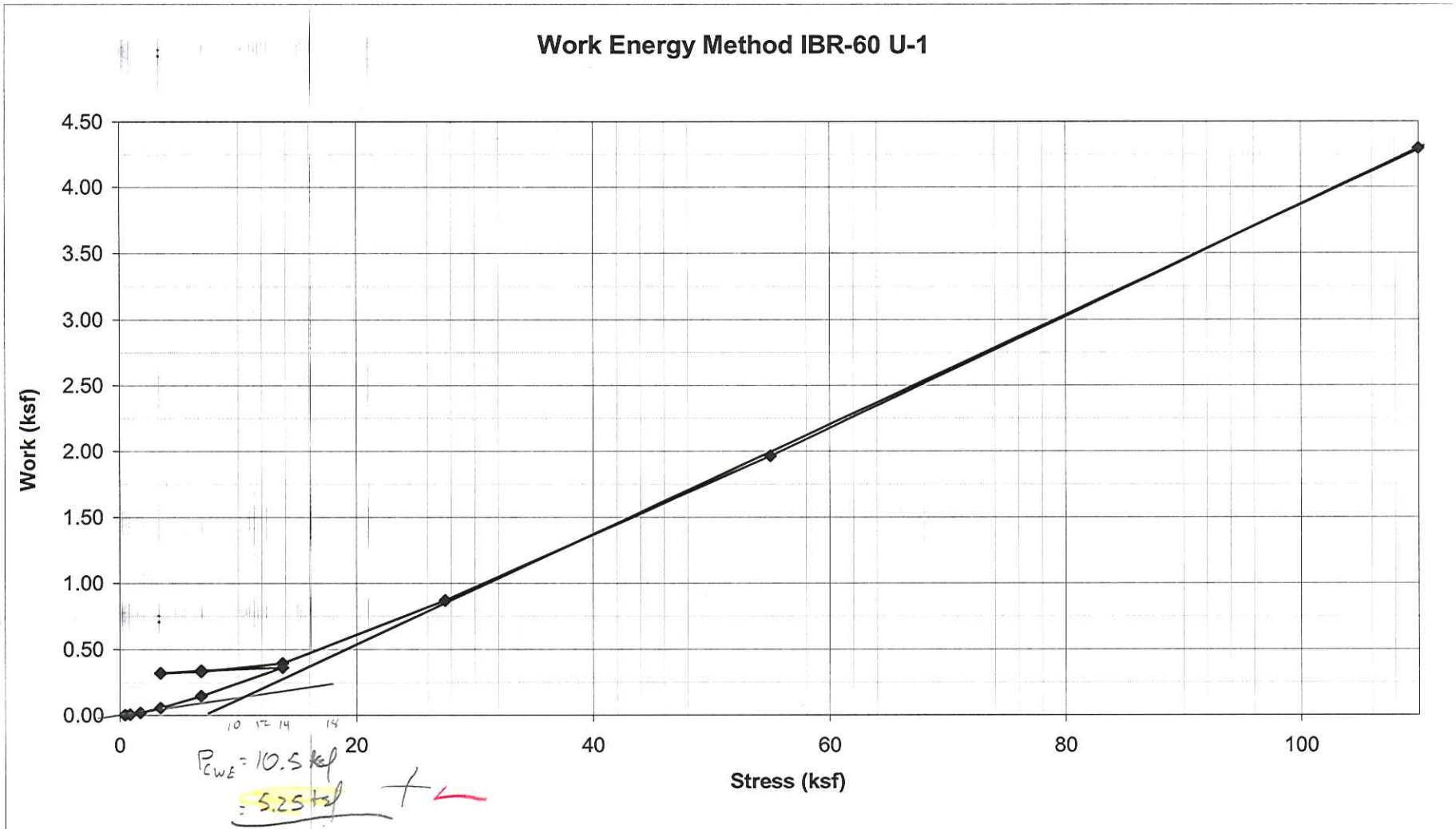
Delaware Department of Transportation
Materials and Research Laboratory

Figure



RKK-8

JDT 1-2-09

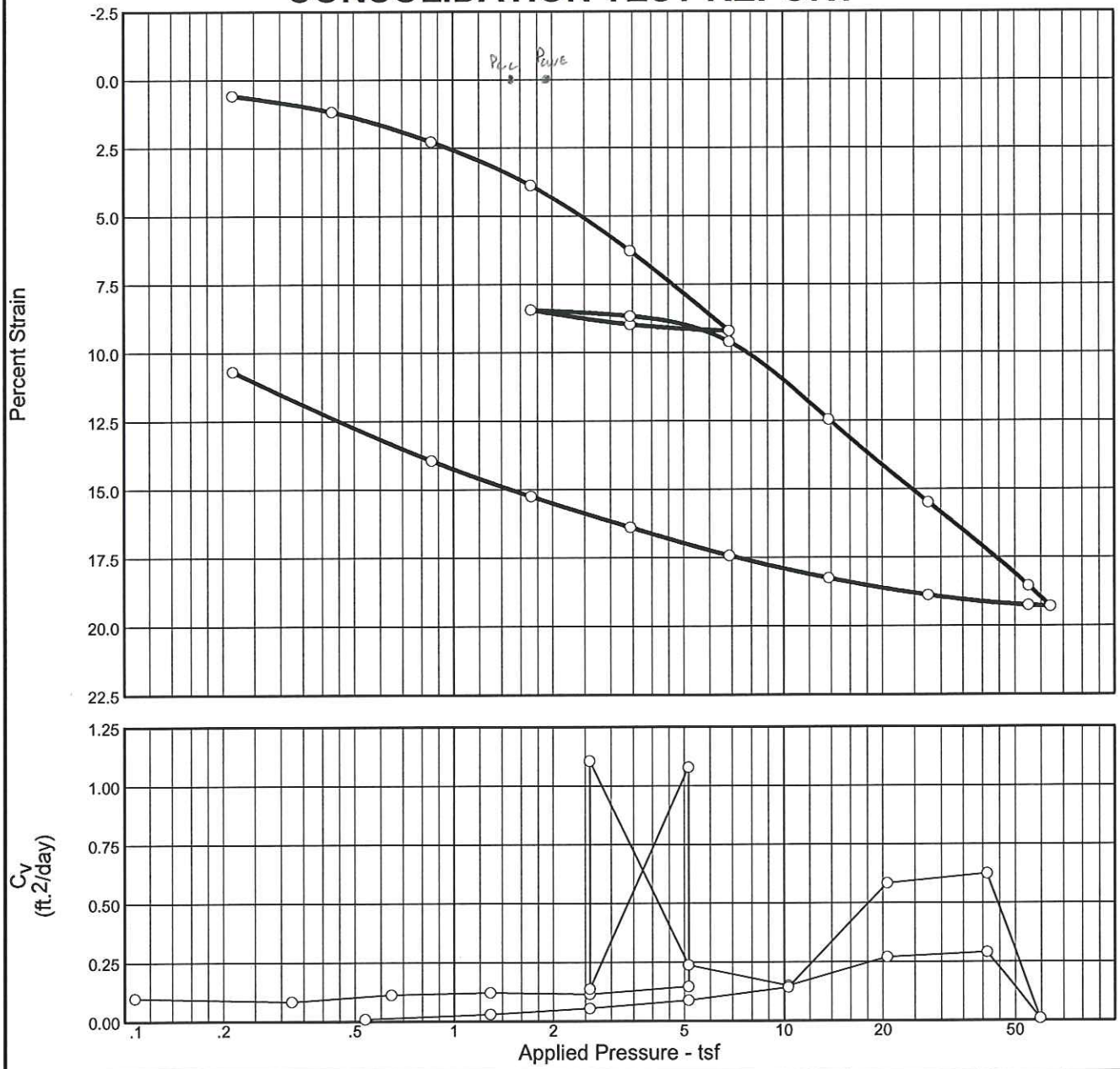

Work Energy Method IBR-60 U-1
Work (ksf)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
20
40
60
80
100
Stress (ksf)
10 12 14 16
$P_{c_{WE}}$ = 10.5 ksf
= 5.25 tsf

RKK-9

JOT
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 $P_{c/E}$ = 1.95 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

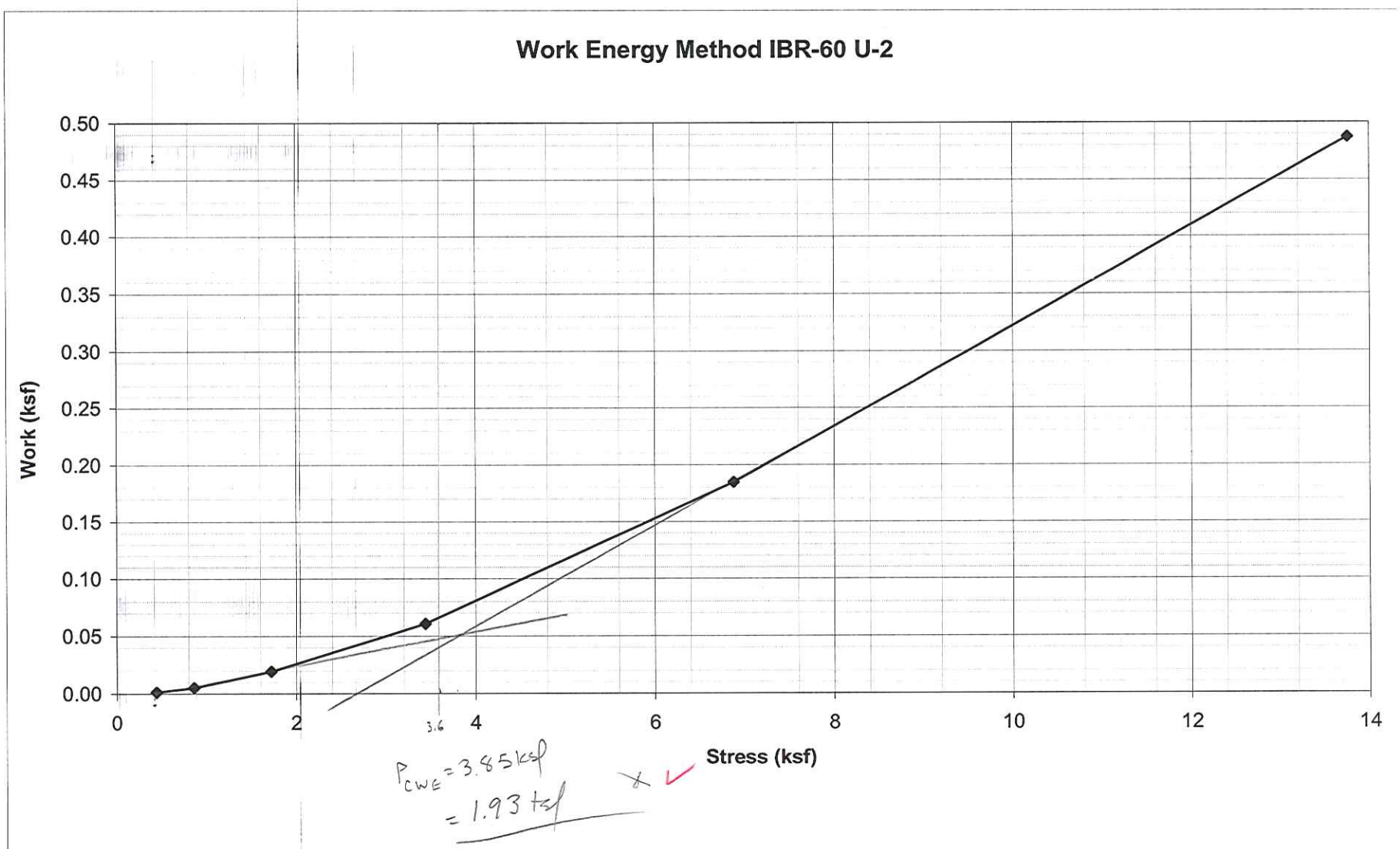
Source: IBR # 60 **Sample No.:** U-2 **Elev./Depth:** 46.0

Remarks:

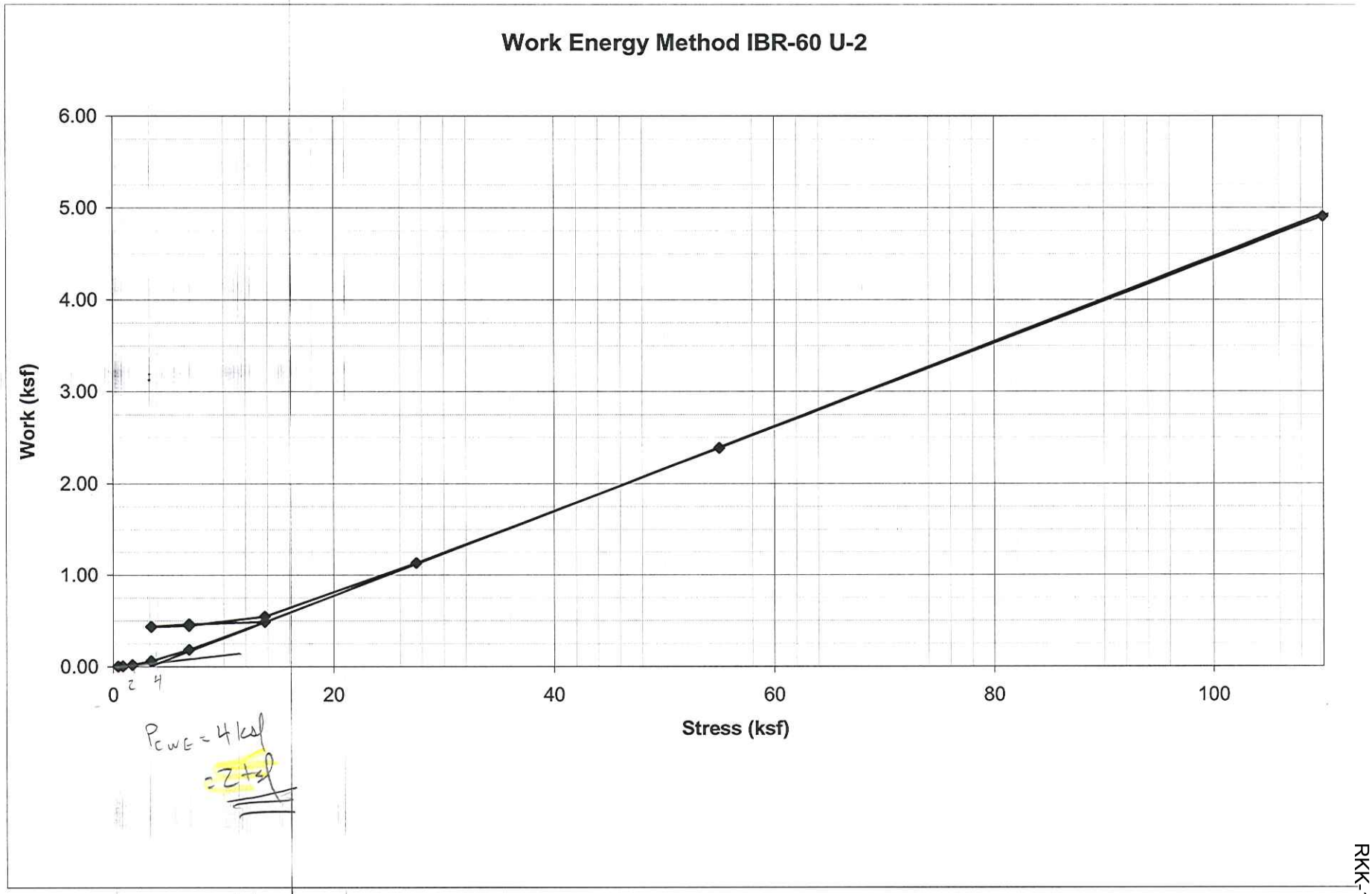
CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Figure


Work Energy Method IBR-60 U-2
Work (ksf)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
2
3.6
4
6
8
10
12
14
Stress (ksf)
P_{CWE} = 3.85 ksf
= 1.93 tsf

RKK-11



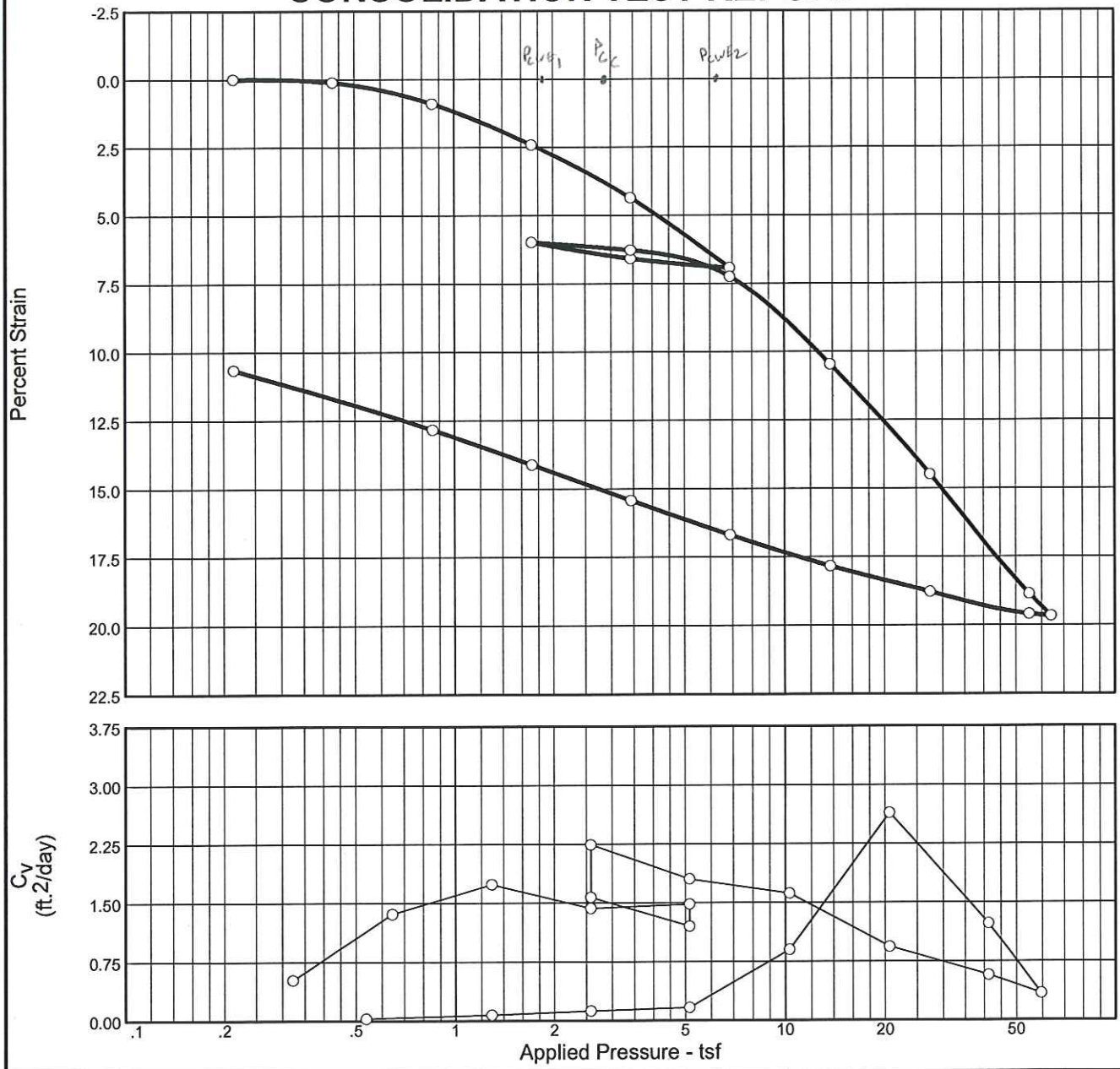
RKK-12

JCT 1-2-09

JBT
1-2-09

RKK-13

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf) 0.81	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)

$P_{c\,w/t_1}$ = 1.85 tsf / 6.25 tsf

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

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

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

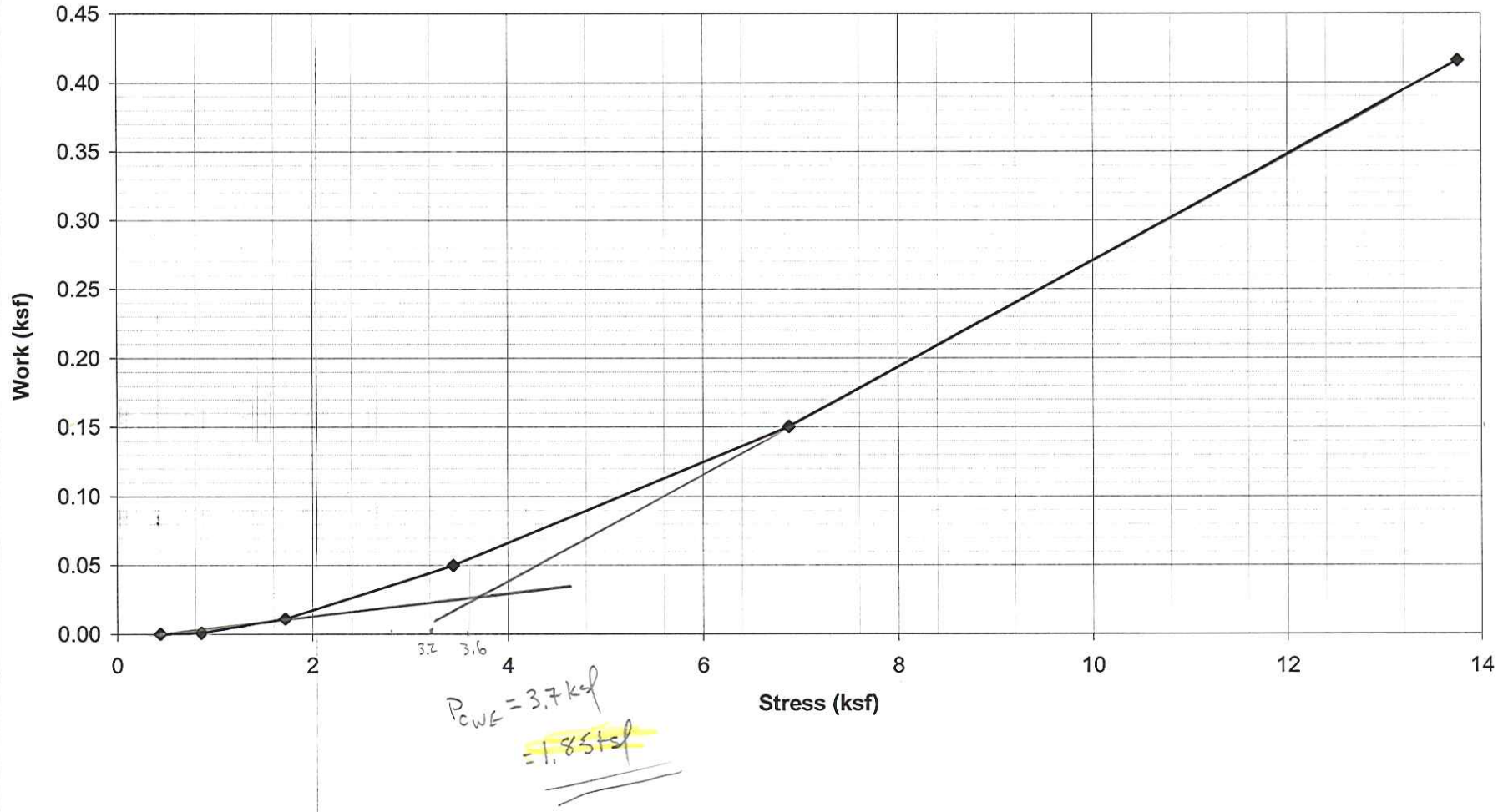
Remarks:

CONSOLIDATION TEST REPORT

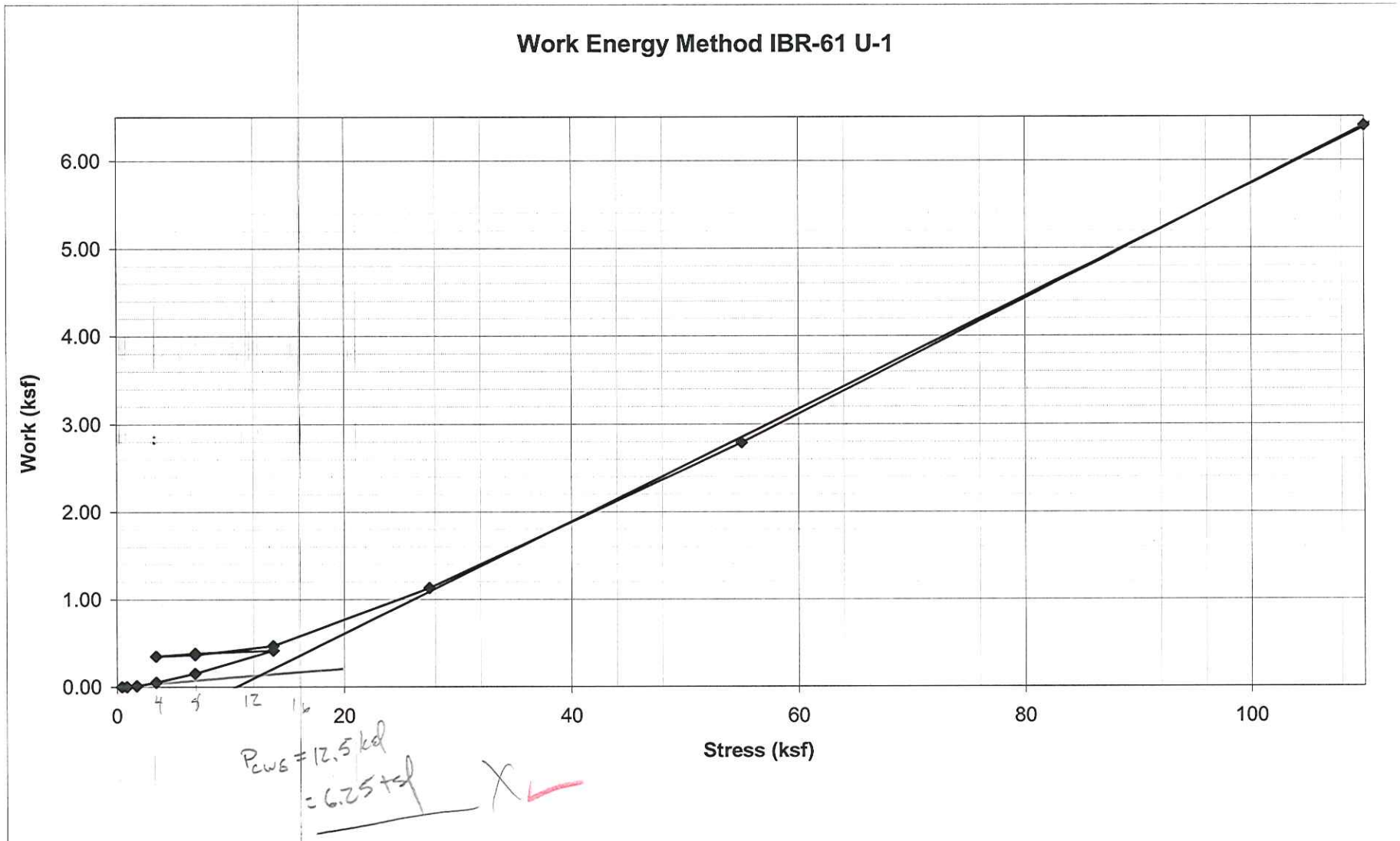
Delaware Department of Transportation
Materials and Research Laboratory

Figure

Work Energy Method IBR-61 U-1



RKK-14

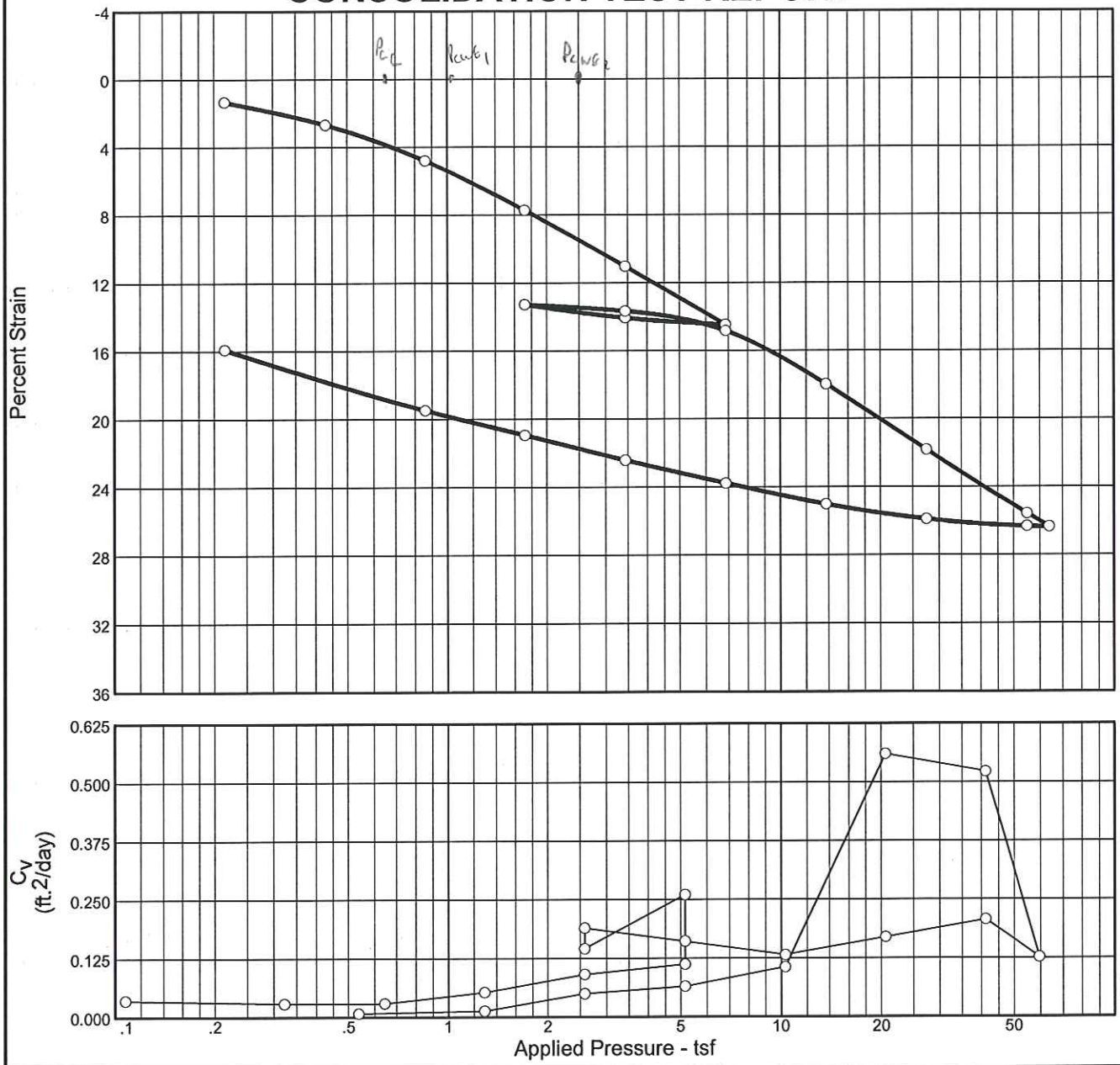

Work Energy Method IBR-61 U-1
Work (ksf)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
20
40
60
80
100
Stress (ksf)
4
8
12
16
P_{cwg} = 12.5 ksf
= 6.25 tsf

RKK-15

JJT 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

$P_{c/ve}$ = 2.5 tsf

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

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

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

Remarks:

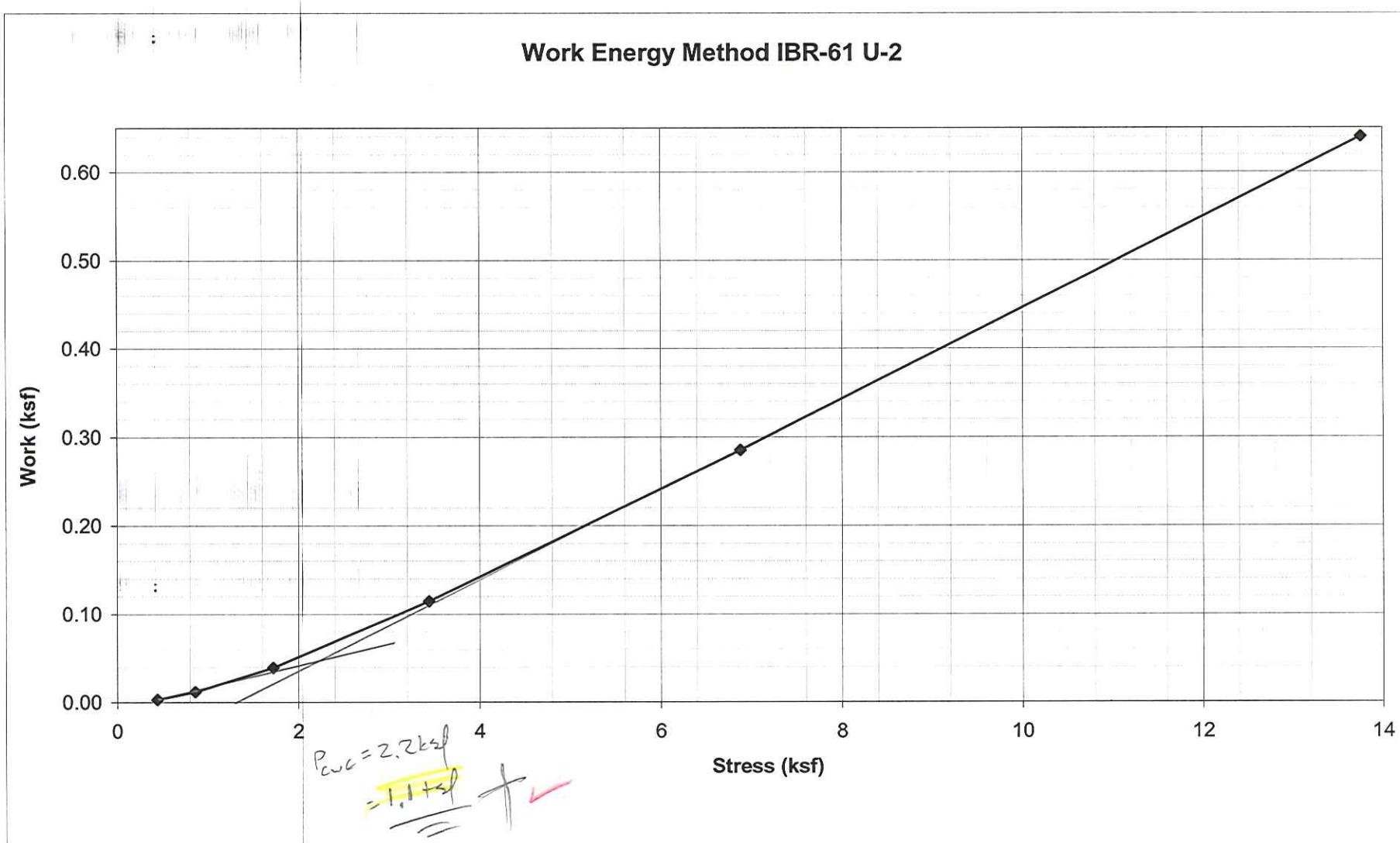
CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Figure

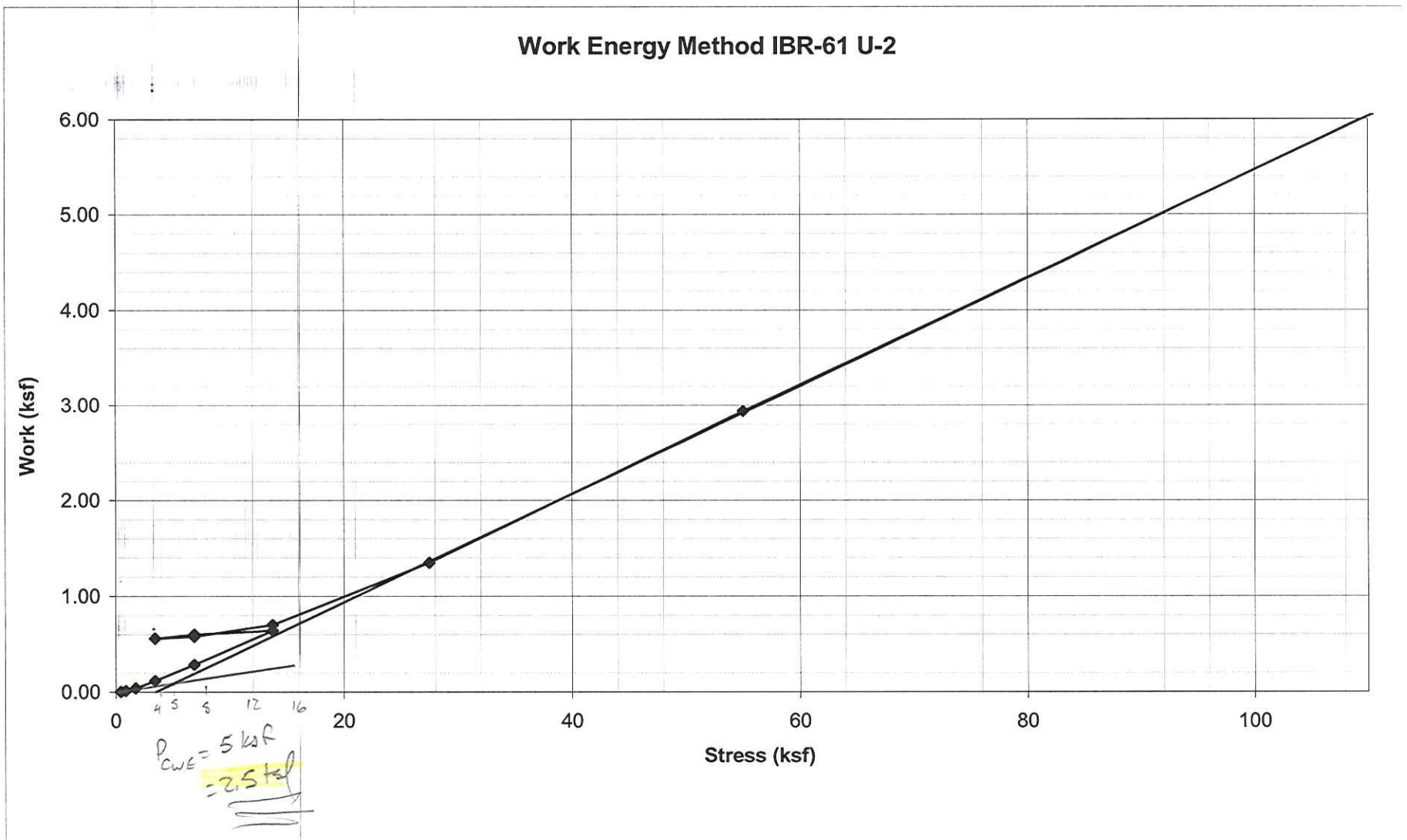
103-059-27U

SR1 / I-95 Interchange



RKK-17

DPT 1-2-09

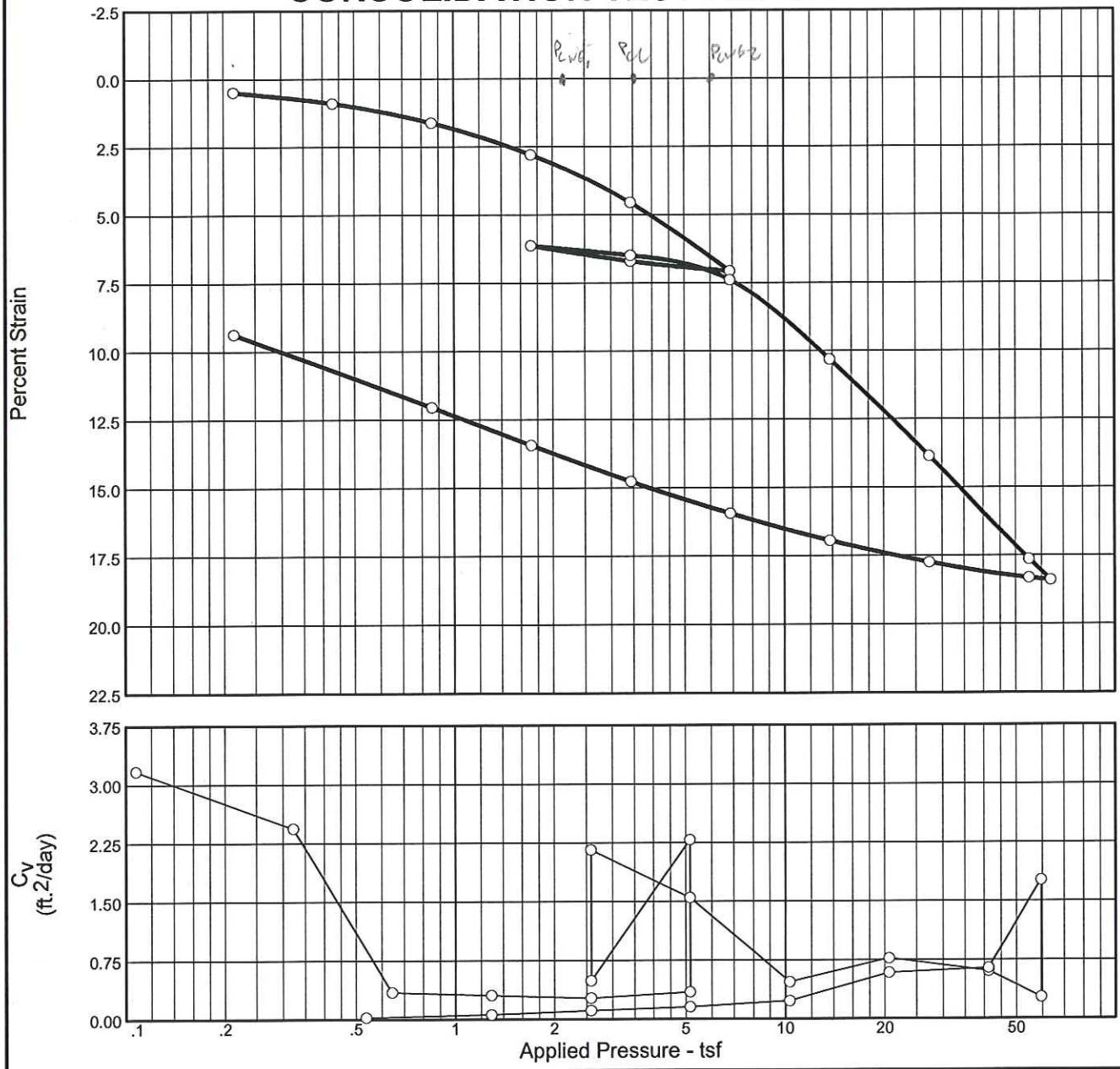

Work Energy Method IBR-61 U-2
Work (ksf)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
20
40
60
80
100
Stress (ksf)
4 5 8 12 16
P_{CWE} = 5 ksf
= 2.5 tsf

RKK-18

JJT
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

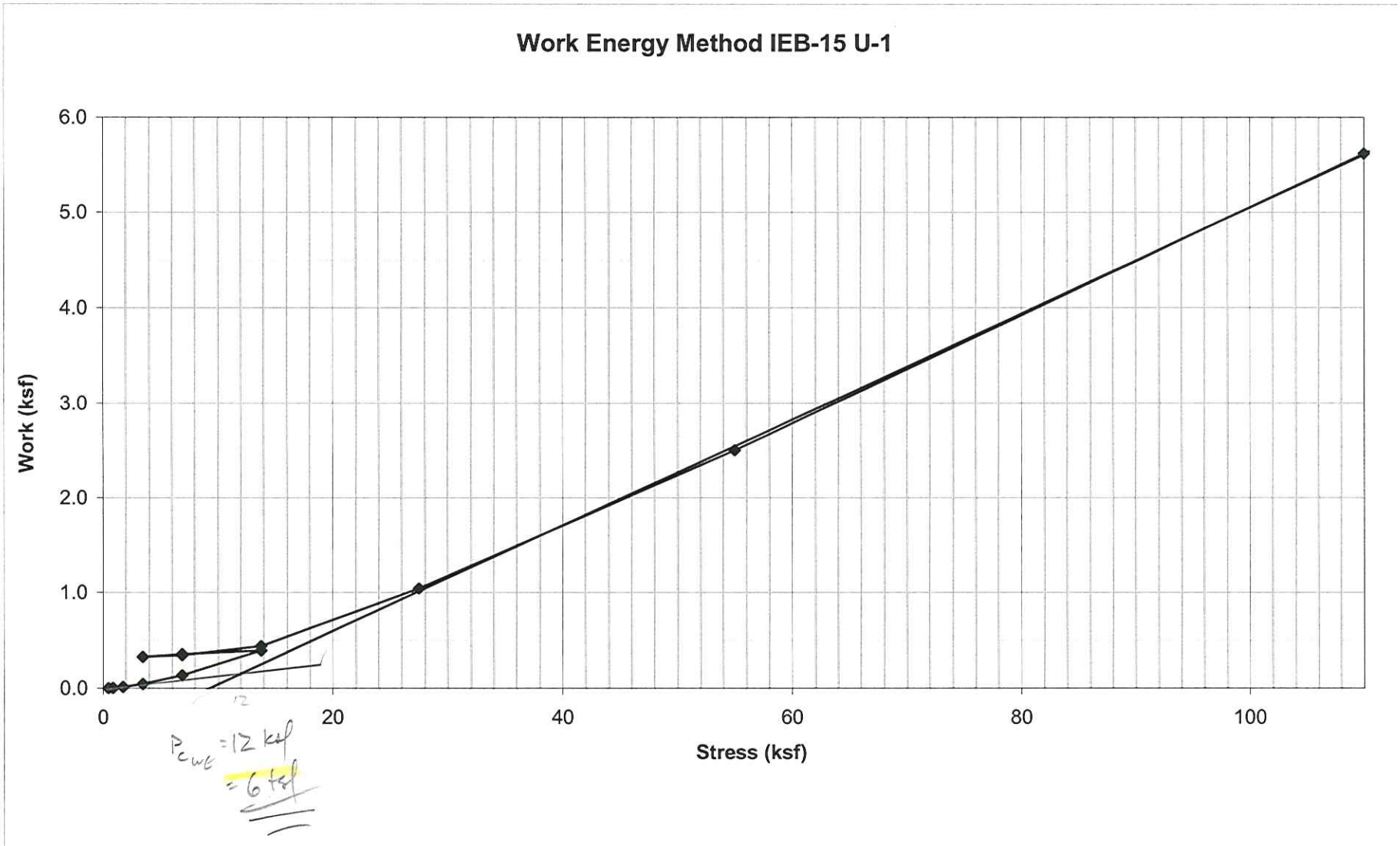
Source: IEB # 15 **Sample No.:** U-1 **Elev./Depth:** 12.0

Remarks:

CONSOLIDATION TEST REPORT

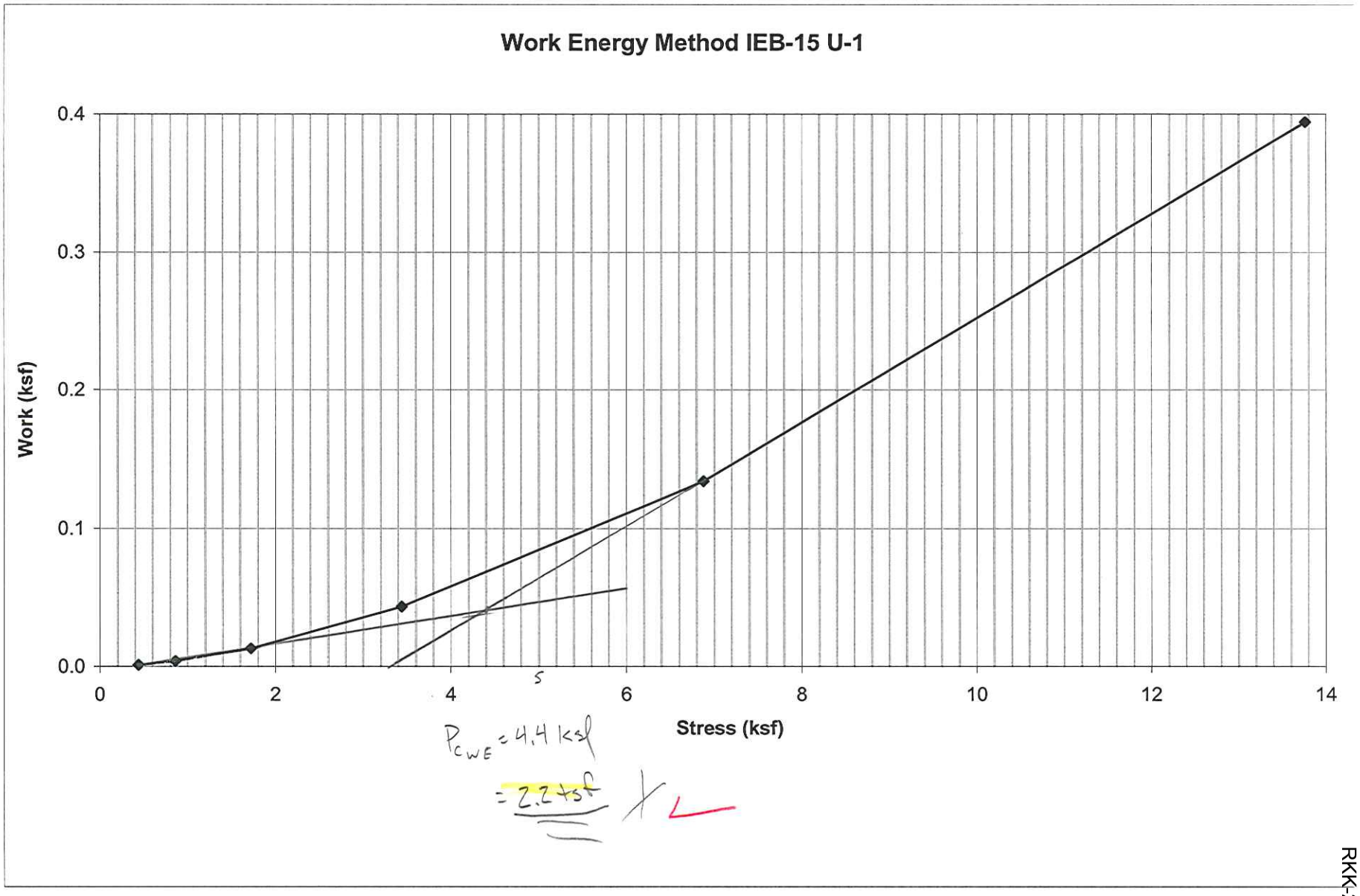
Delaware Department of Transportation
Materials and Research Laboratory

Figure



RKK-20

JPT 1-2-09

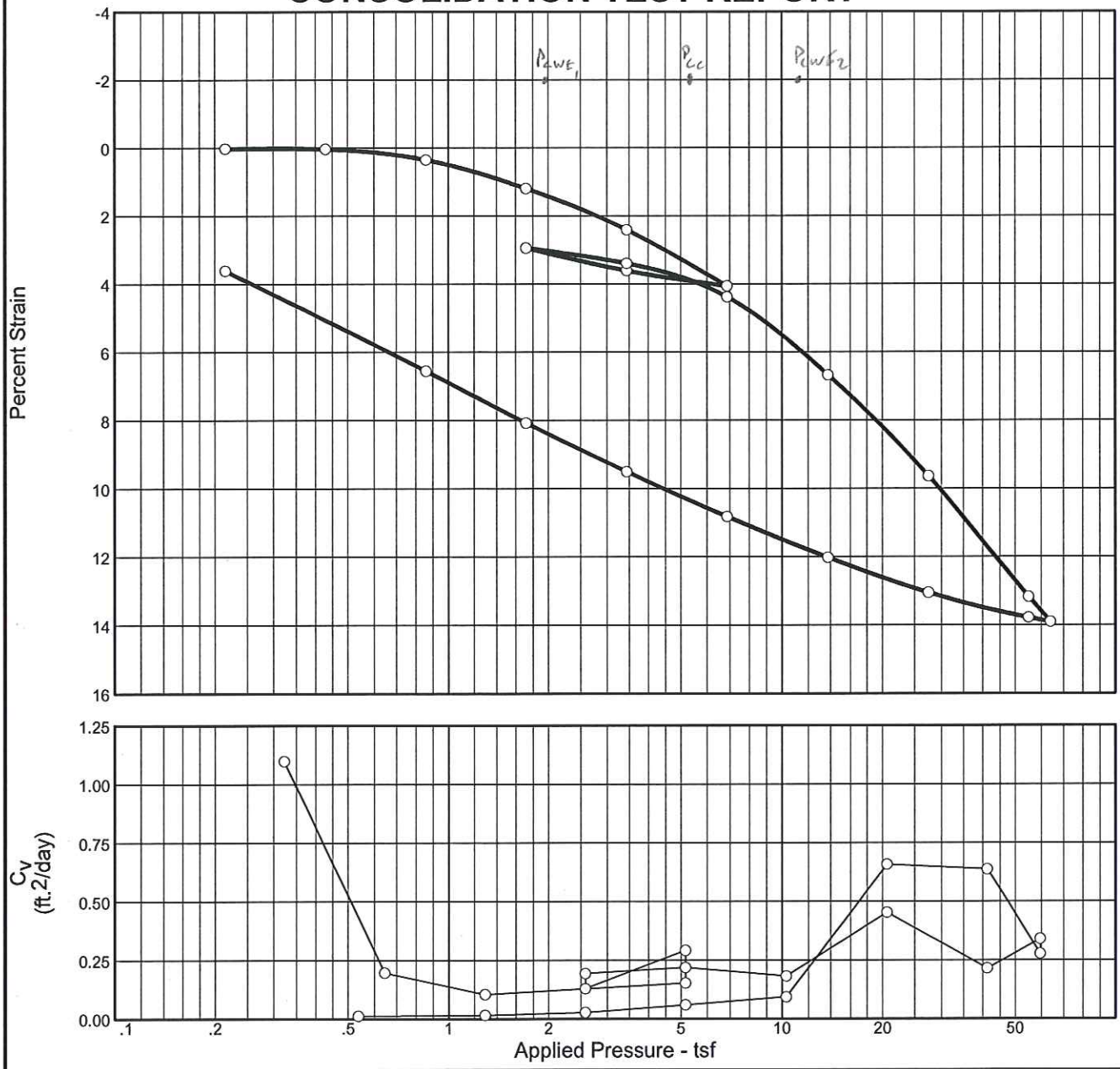

Work Energy Method IEB-15 U-1
Work (ksf)
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
Stress (ksf)
P_{cWE} = 4.4 ksf
= 2.2 tsf

RKK-21

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~~ 2.02	5.29	0.17	0.05			0.527

MATERIAL DESCRIPTION	USCS	AASHTO
Saturated gray clay w/trace of fine to coarse sand. $P_{c_{WE}}$ = 1.91 tsf / 11.25 tsf	CL	A-6(16)

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

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

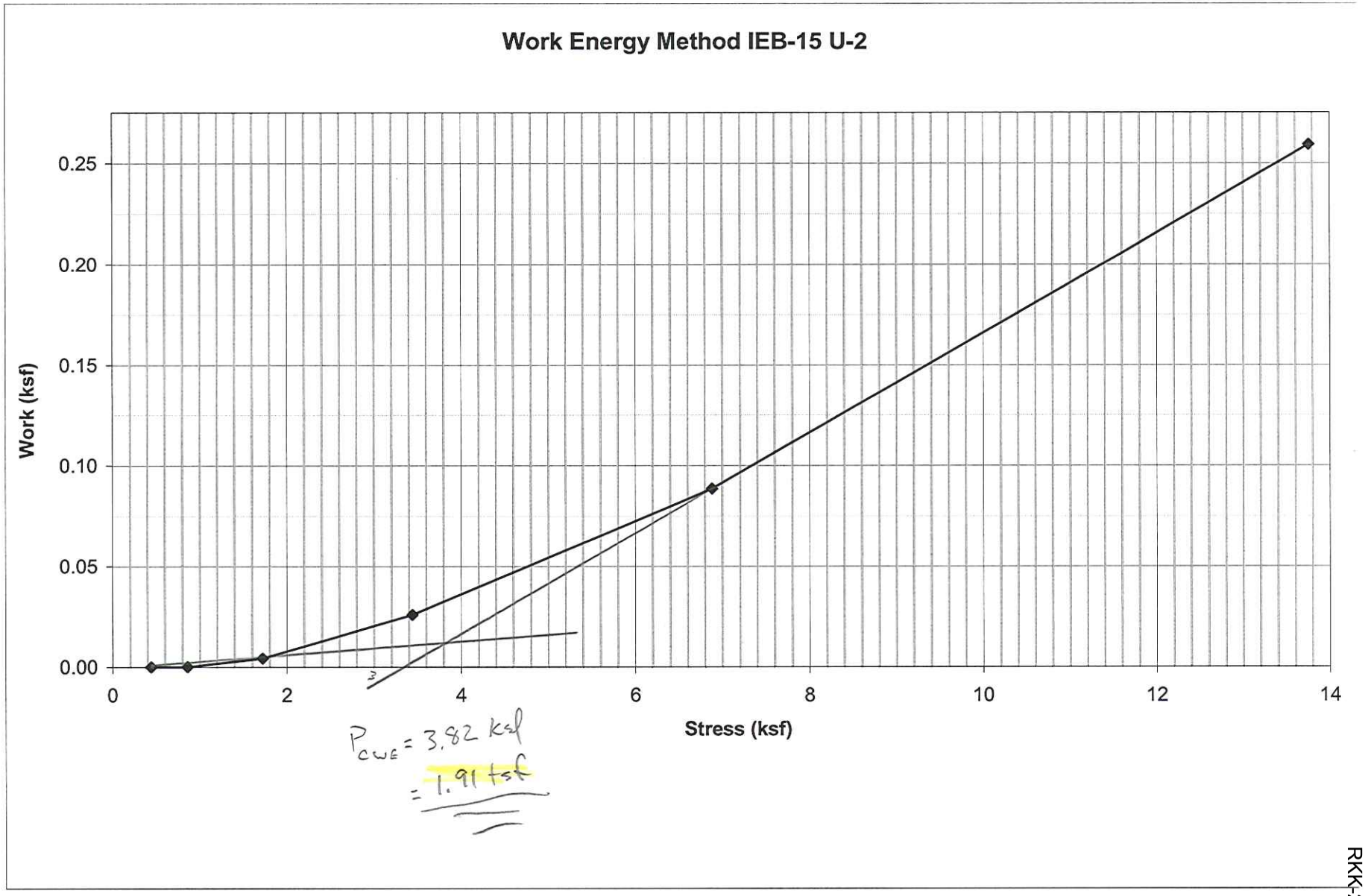
Source: IEB # 15 **Sample No.:** U-2 **Elev./Depth:** 31.0

Remarks:

CONSOLIDATION TEST REPORT

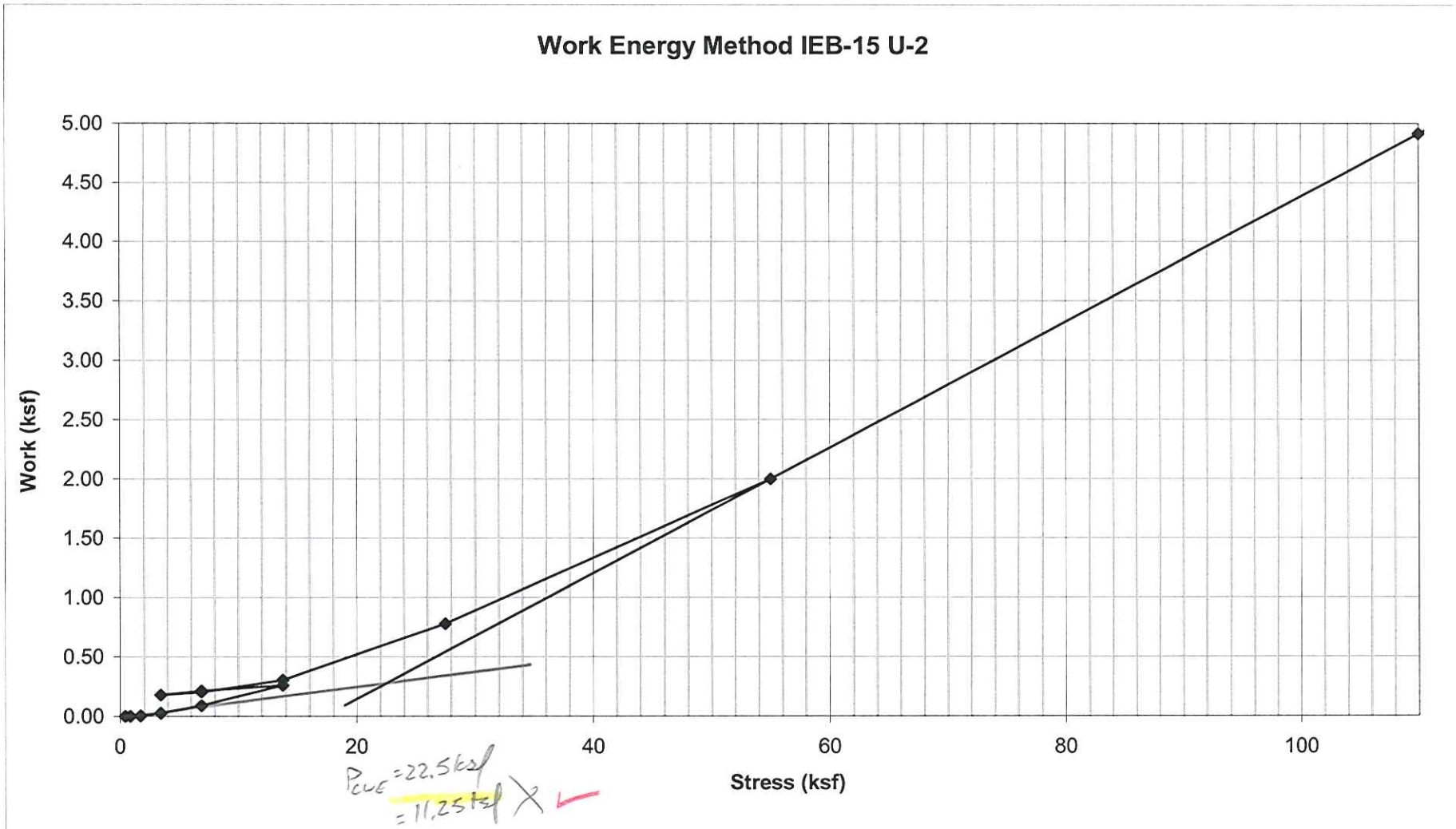
Delaware Department of Transportation
Materials and Research Laboratory

Figure



RKK-23

JVPT 1-2-09

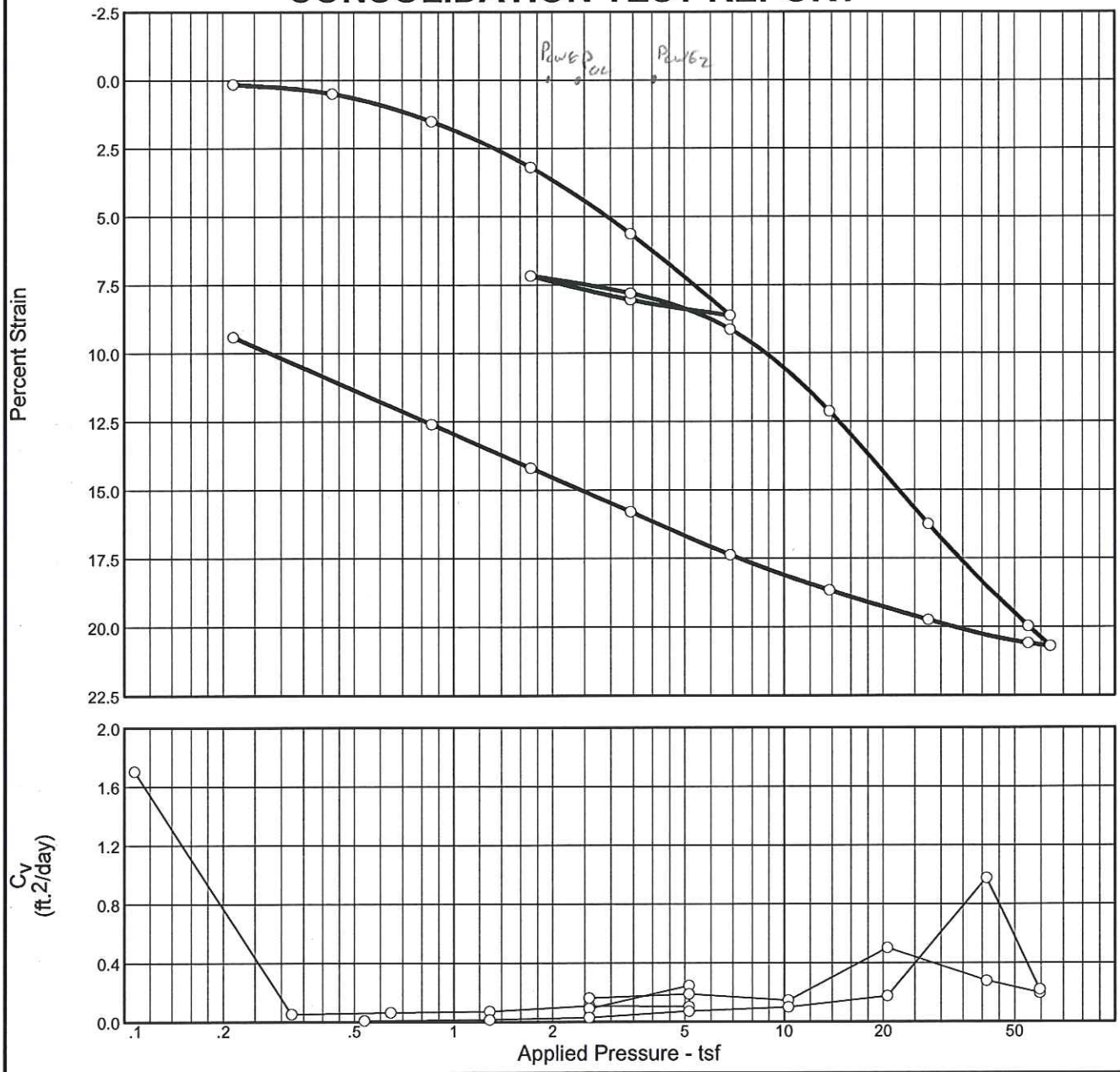

Work Energy Method IEB-15 U-2
Work (ksf)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
20
40
60
80
100
Stress (ksf)
P_{ave} = 22.5 ksf
= 11.25 ksf

RKK-24

JPT 1-2-09

RKK-25

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf) 3.54	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 $P_{c\,WE}$ = 1.8 tsf (4.05 t/ft²)	USCS	AASHTO
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

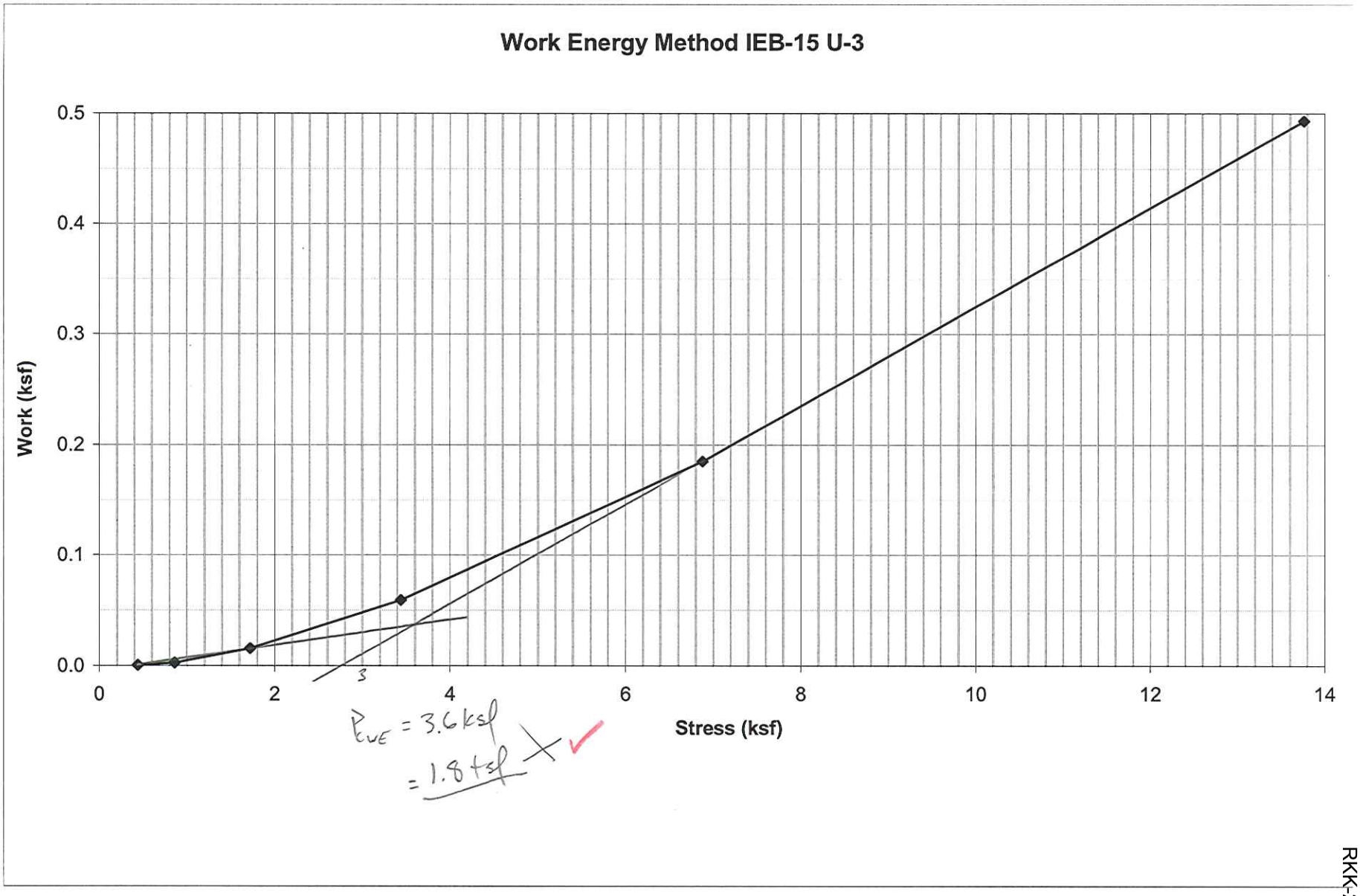
Source: IEB # 15 **Sample No.:** U-3 **Elev./Depth:** 56.0

Remarks:

CONSOLIDATION TEST REPORT

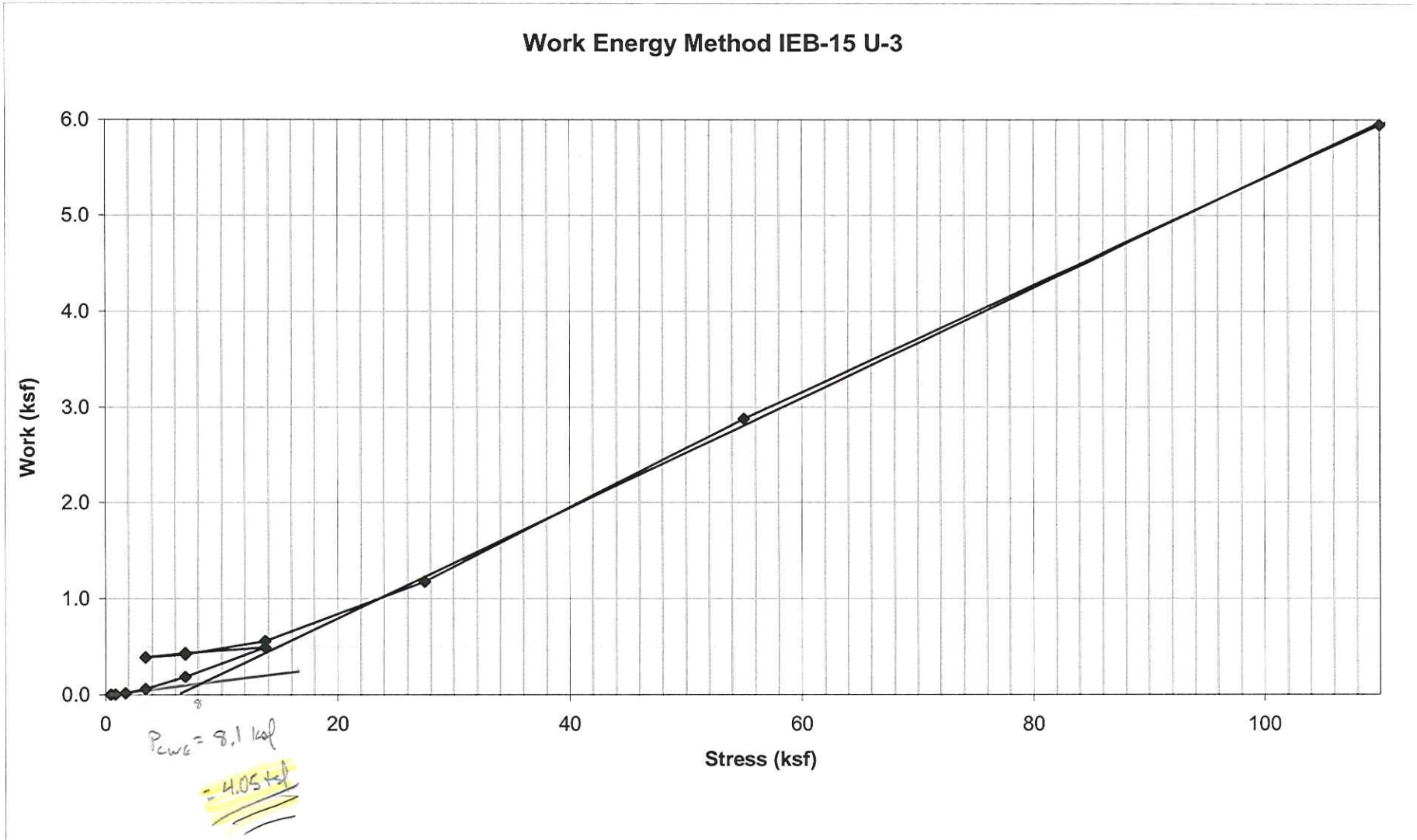
Delaware Department of Transportation
Materials and Research Laboratory

Figure



RKK-26

DJT 1-2-09



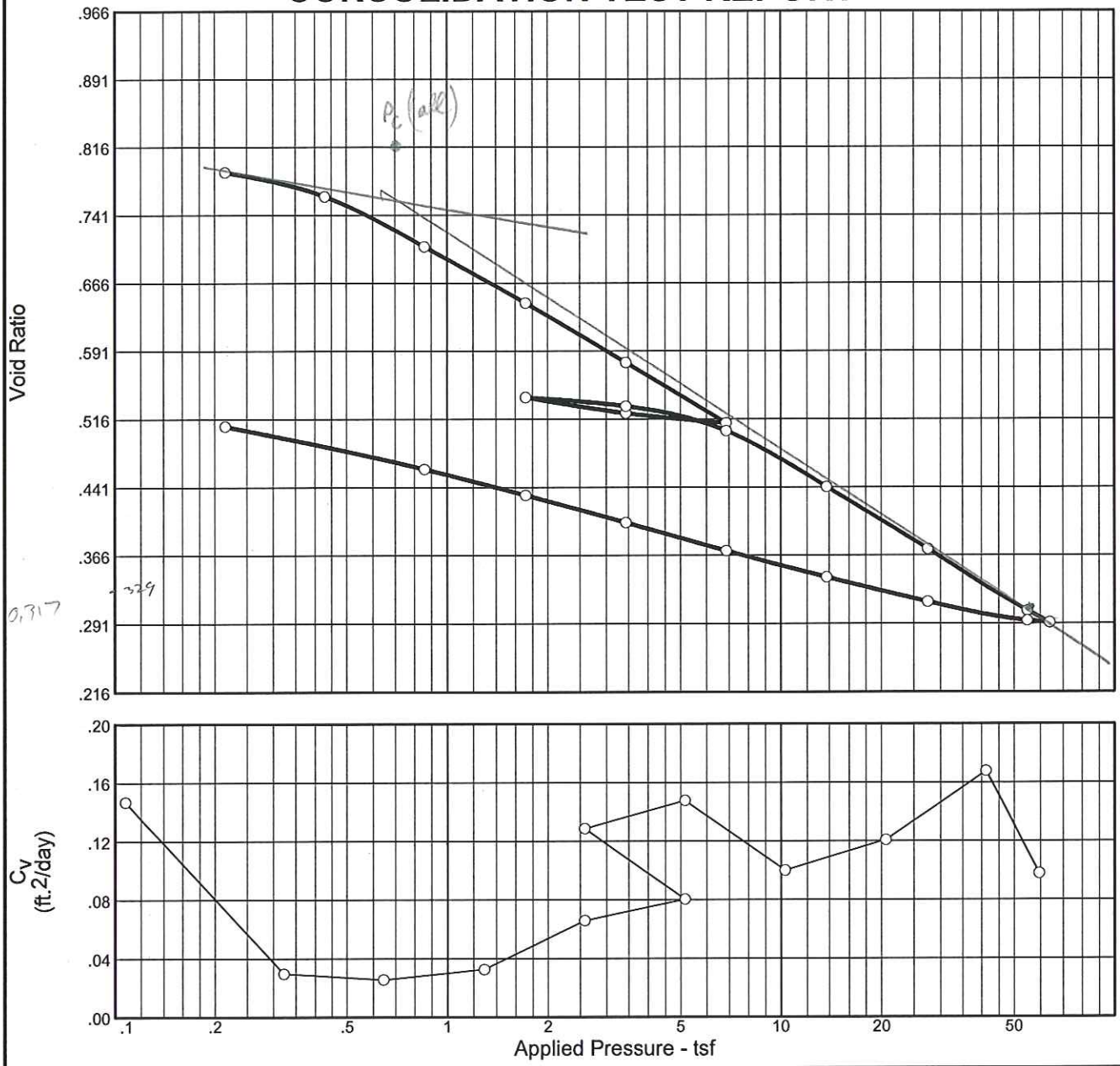
RKK-27

DPT 1-2-09

SDT 1-2-09

RKK-28

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf) 0.95	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 P_{swe} = 0.7 tsf / 1 lod	USCS	AASHTO
Saturated light gray clay w/trace of fine to coarse sand. NV	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

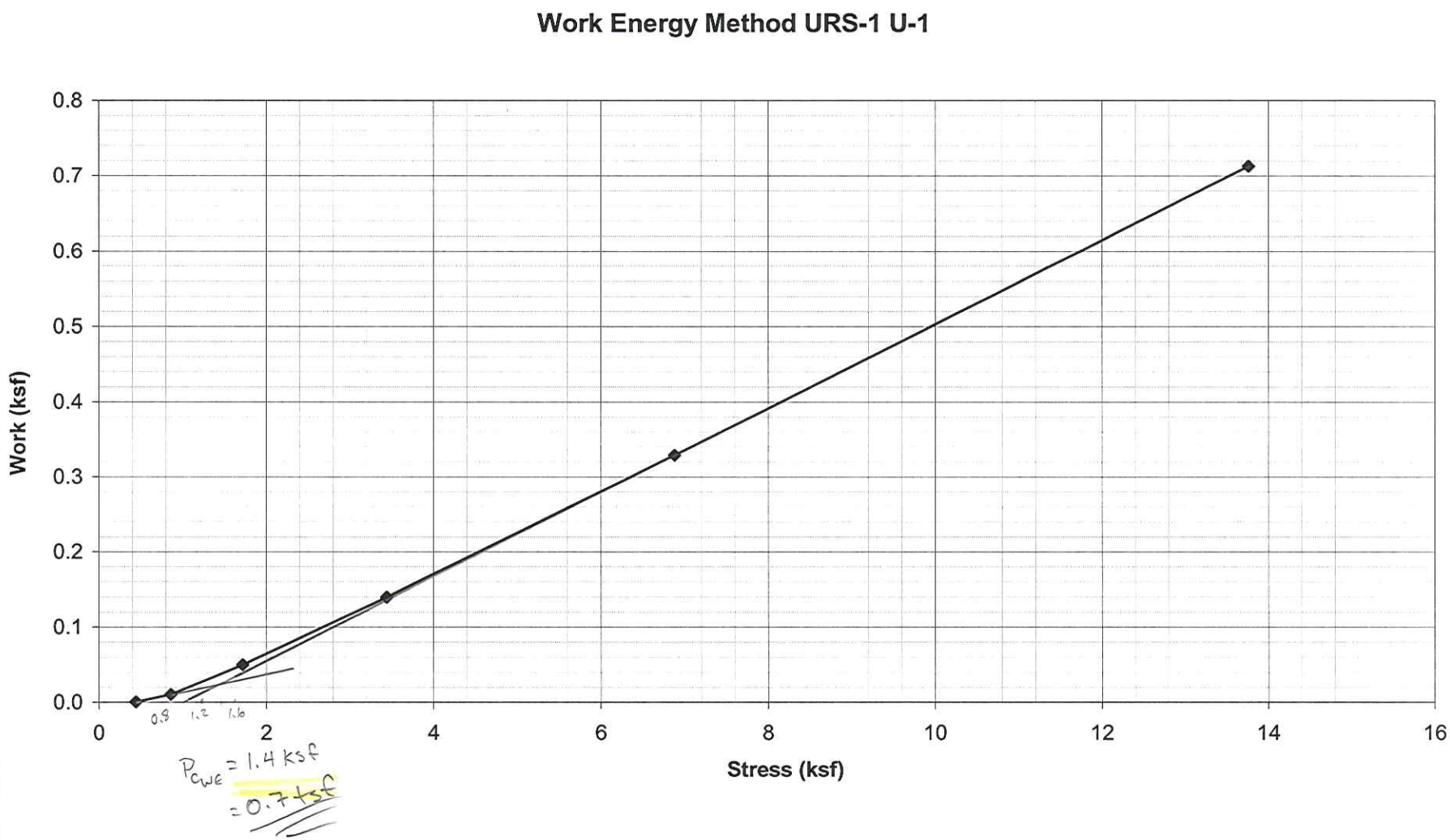
Remarks:

CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Figure

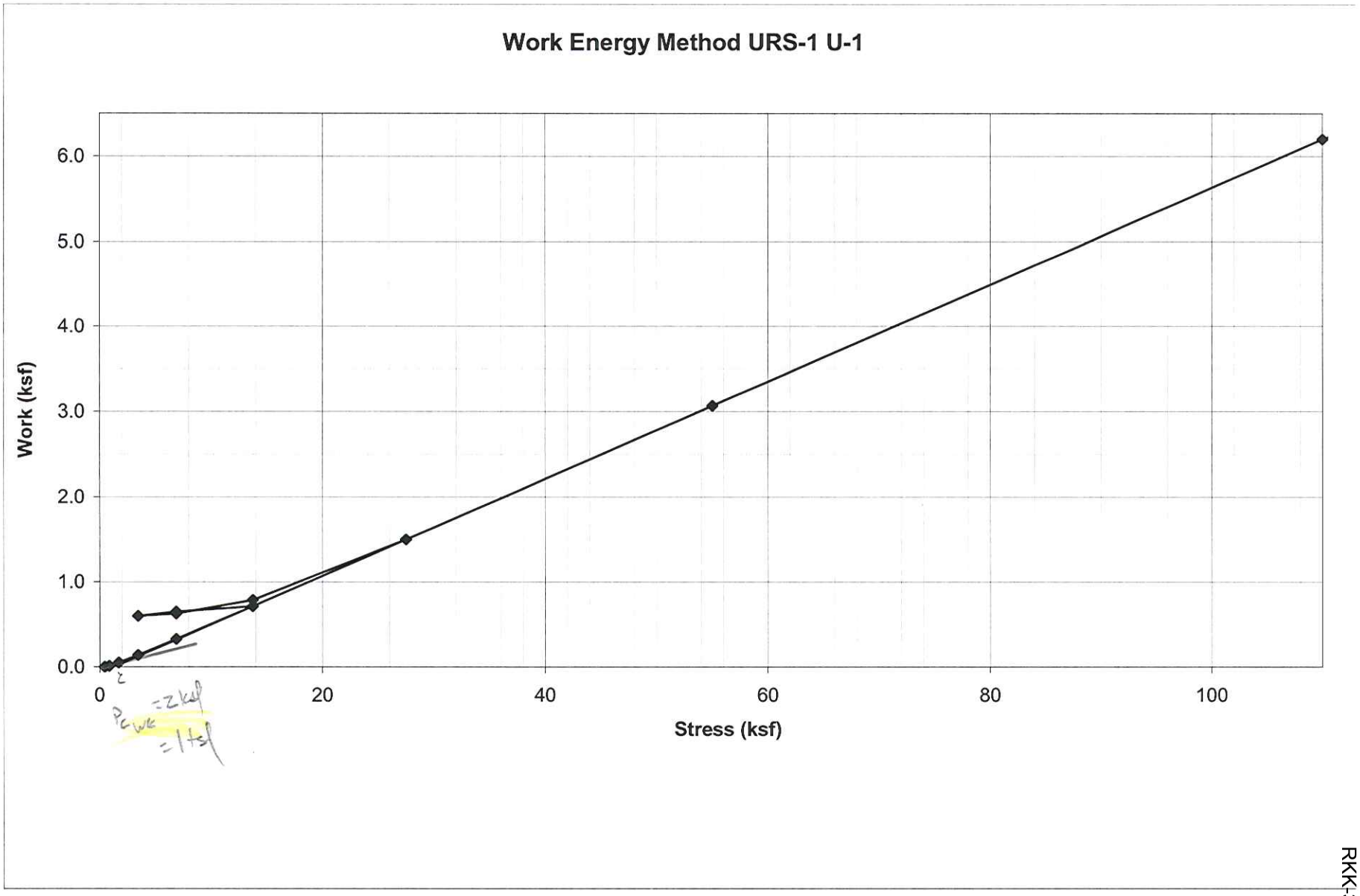
Delaware Turnpike Improvements
SR-1 Interchange



RKK-29

SGT 1-2-09

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



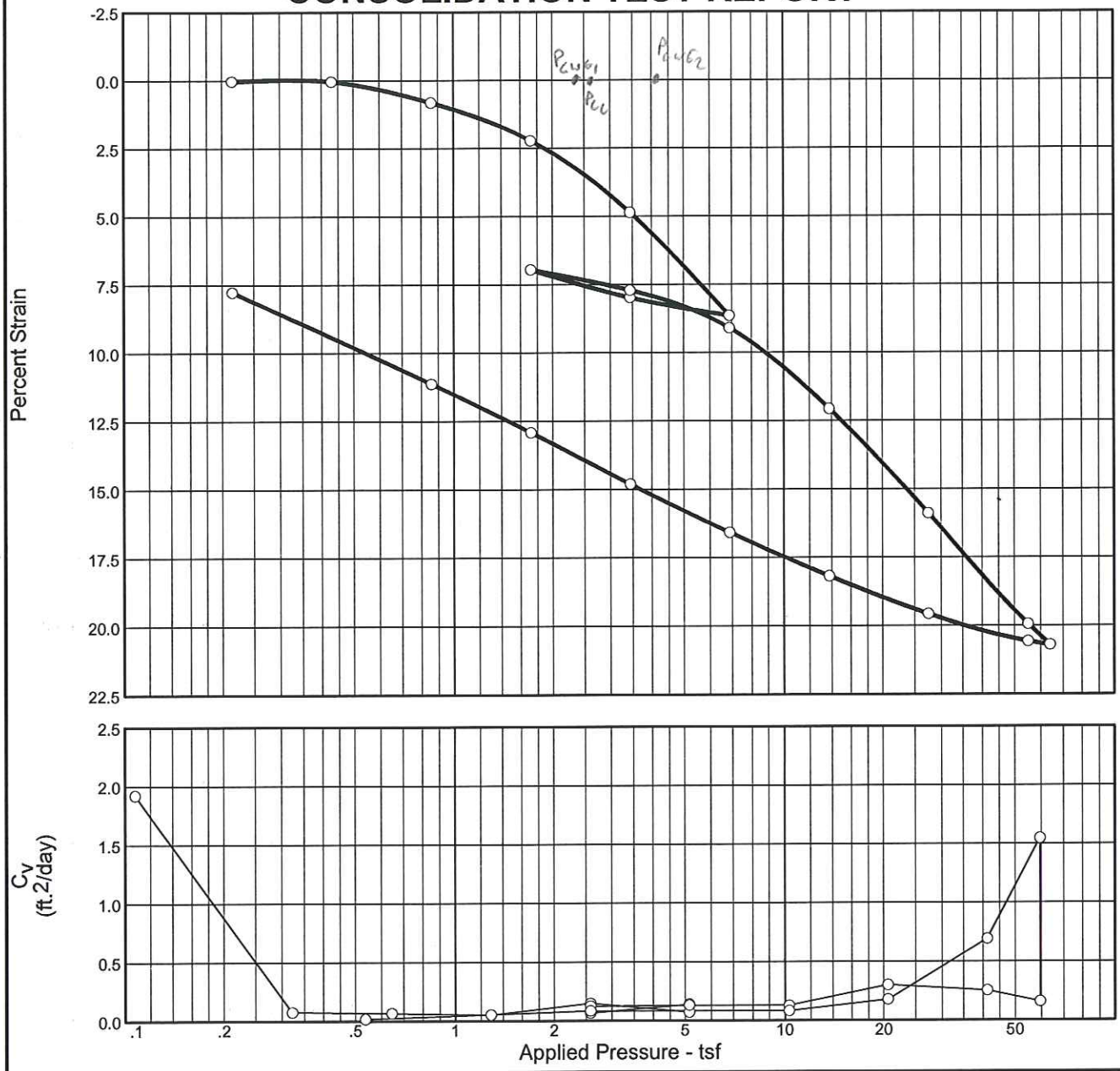
RKK-30

JCP 1-2-09

JOI
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~~ 1.33	2.59	0.20	0.07			0.614

MATERIAL DESCRIPTION P_{CWE} = 2.4 ksf / 4.15 ksf	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

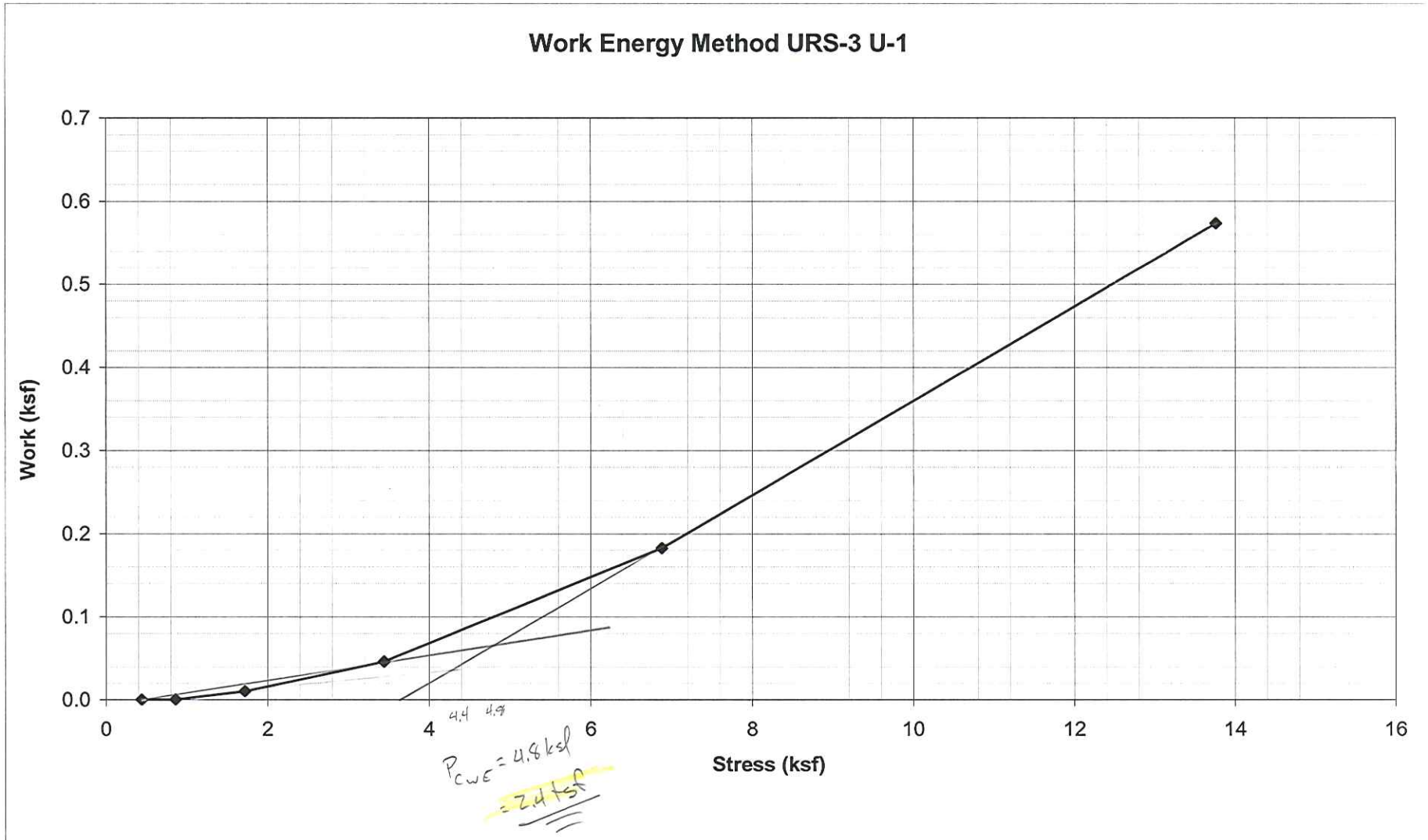
Remarks:

CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Figure

Delaware Turnpike Improvements
SR-1 Interchange



RKK-32

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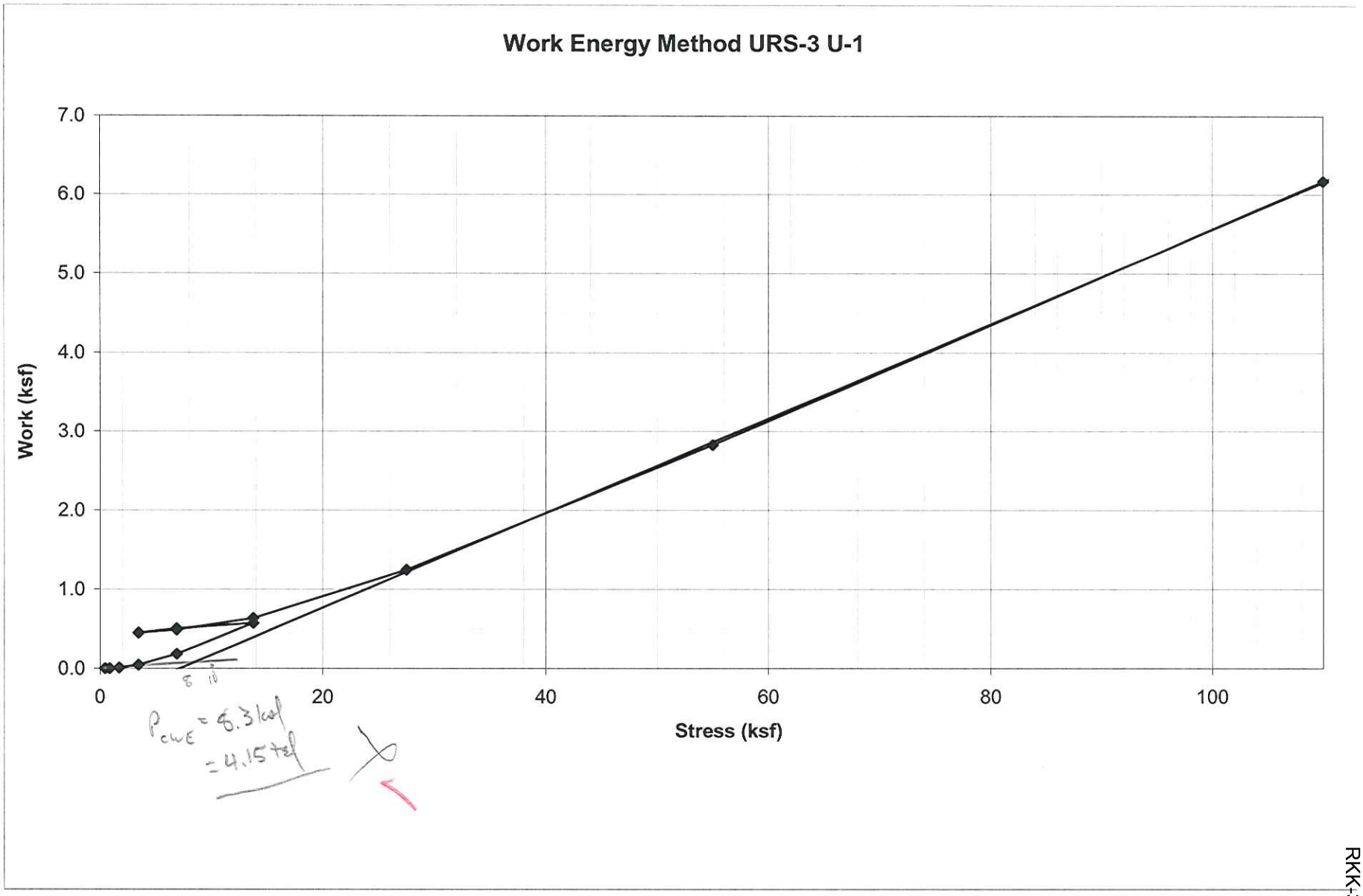


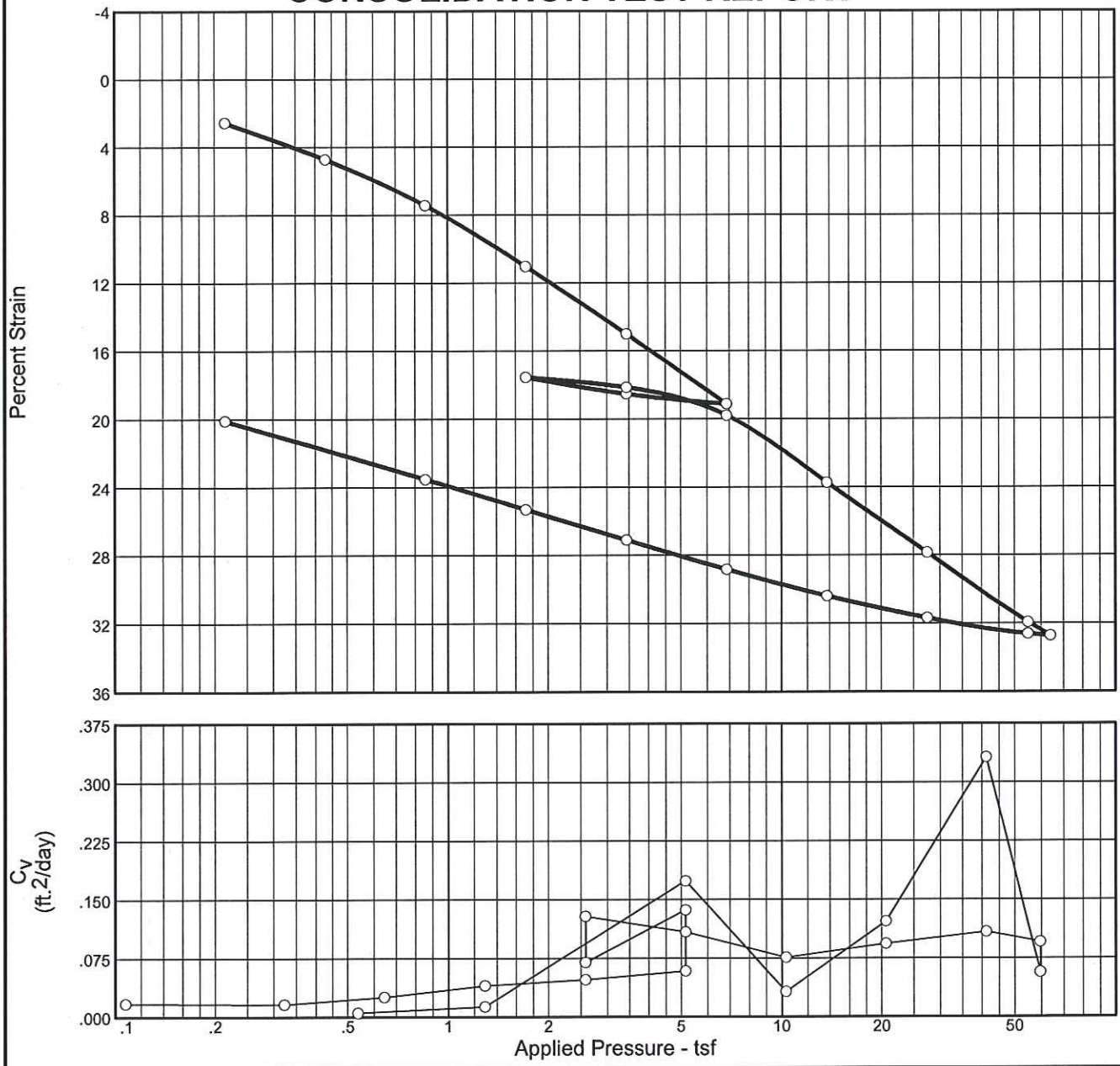
RKK-33

QPT 1-2-09

RJT
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. $P_{c_{WE}}$ = 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

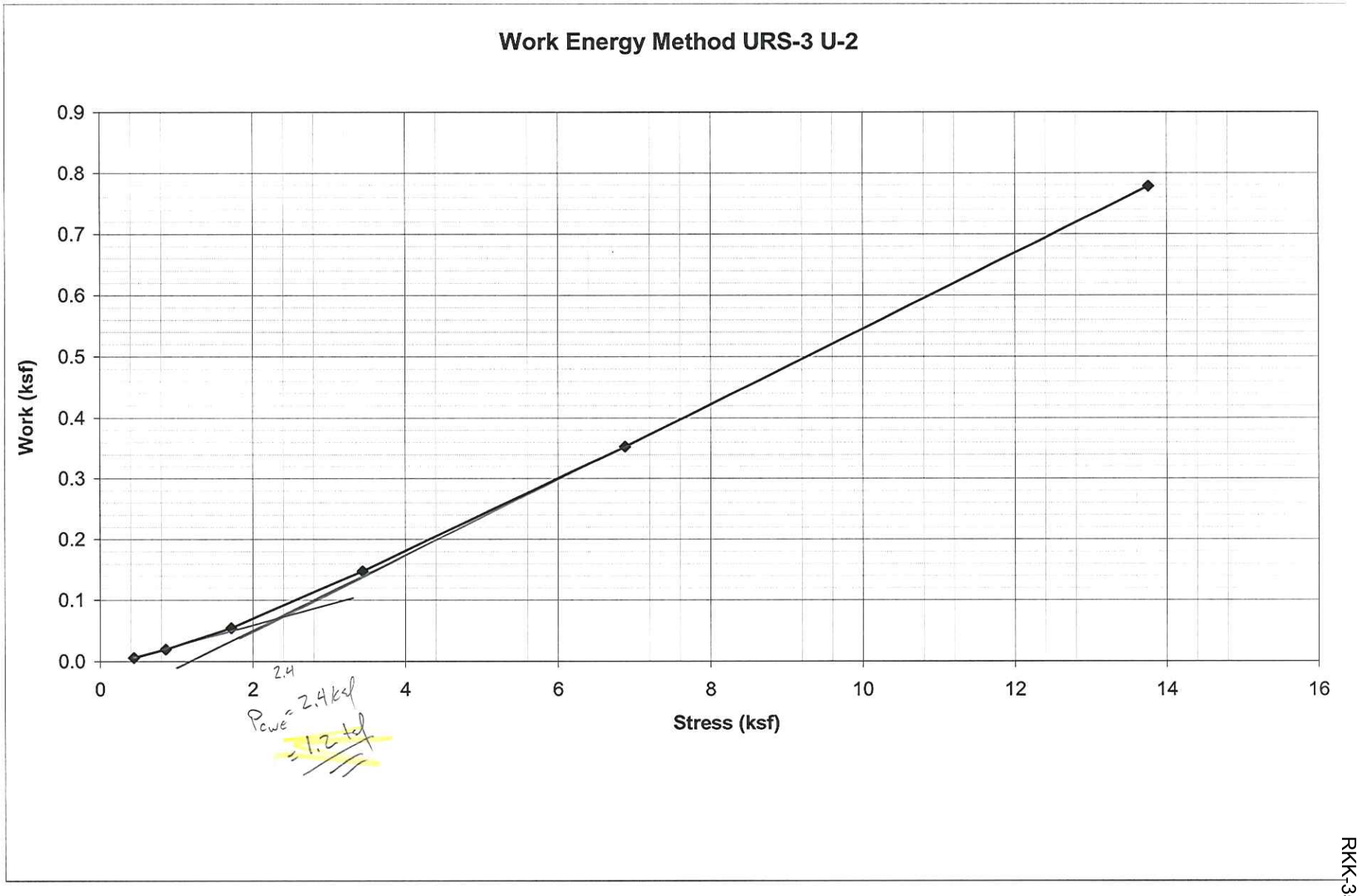
Remarks:

CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Figure

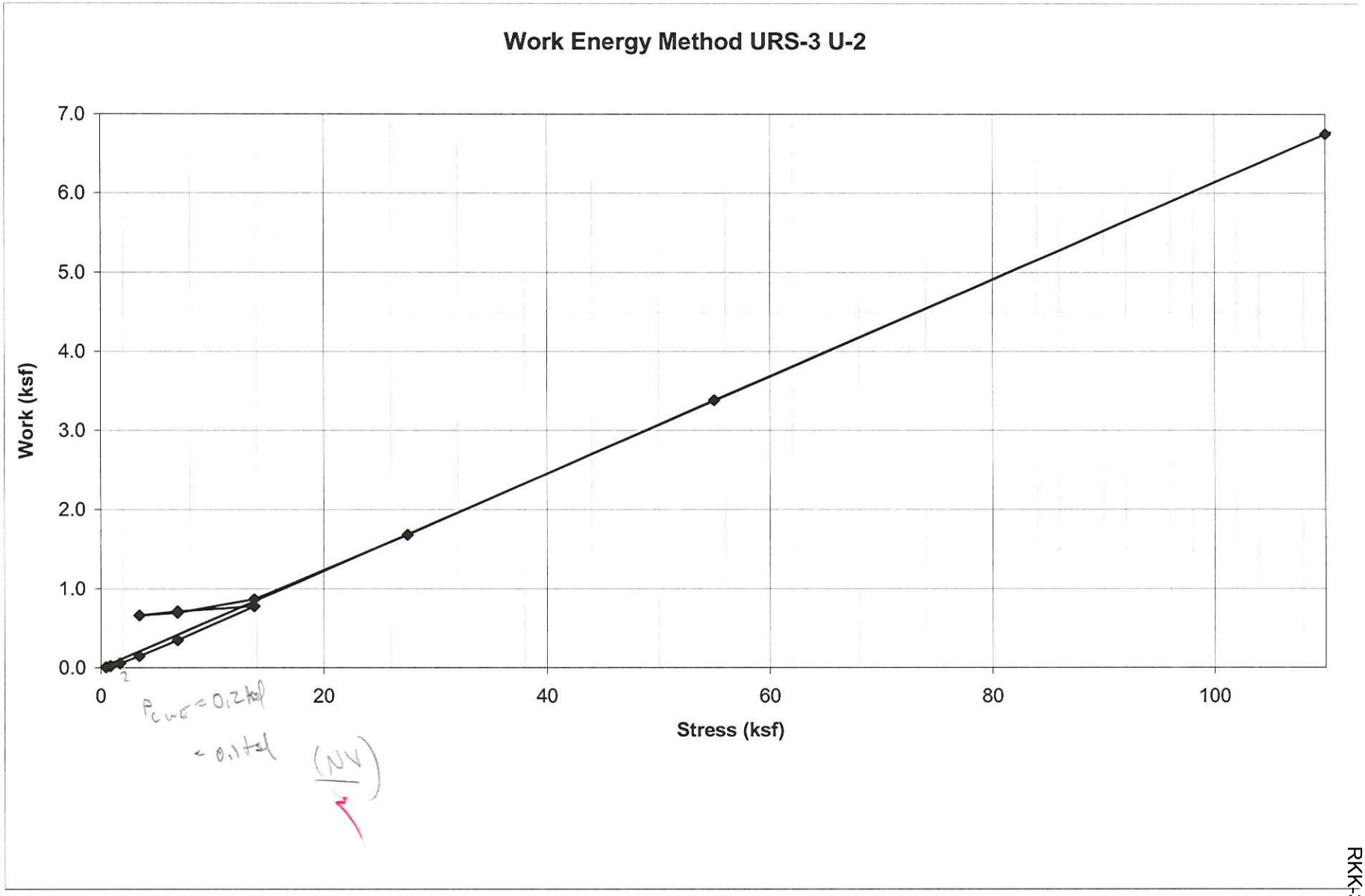
Delaware Turnpike Improvements
SR-1 Interchange



RKK-35

JTT 1-2-09

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



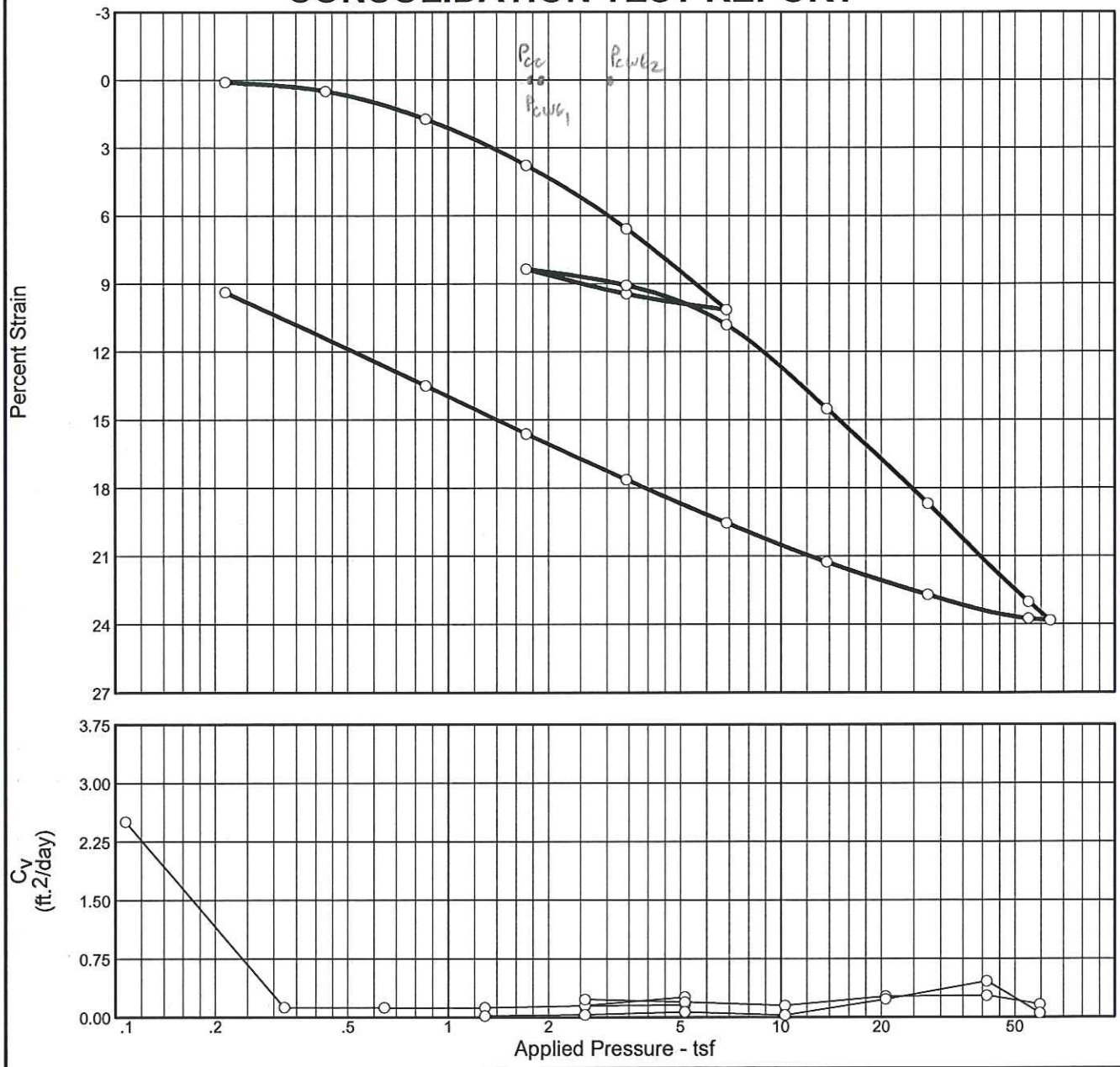
RKK-36

PGT 1-2-09

JJT
1-2-09

RKK-37

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf) 1.12	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 $P_{cwl} = 1.85$ tsf / 3.8 tsf	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

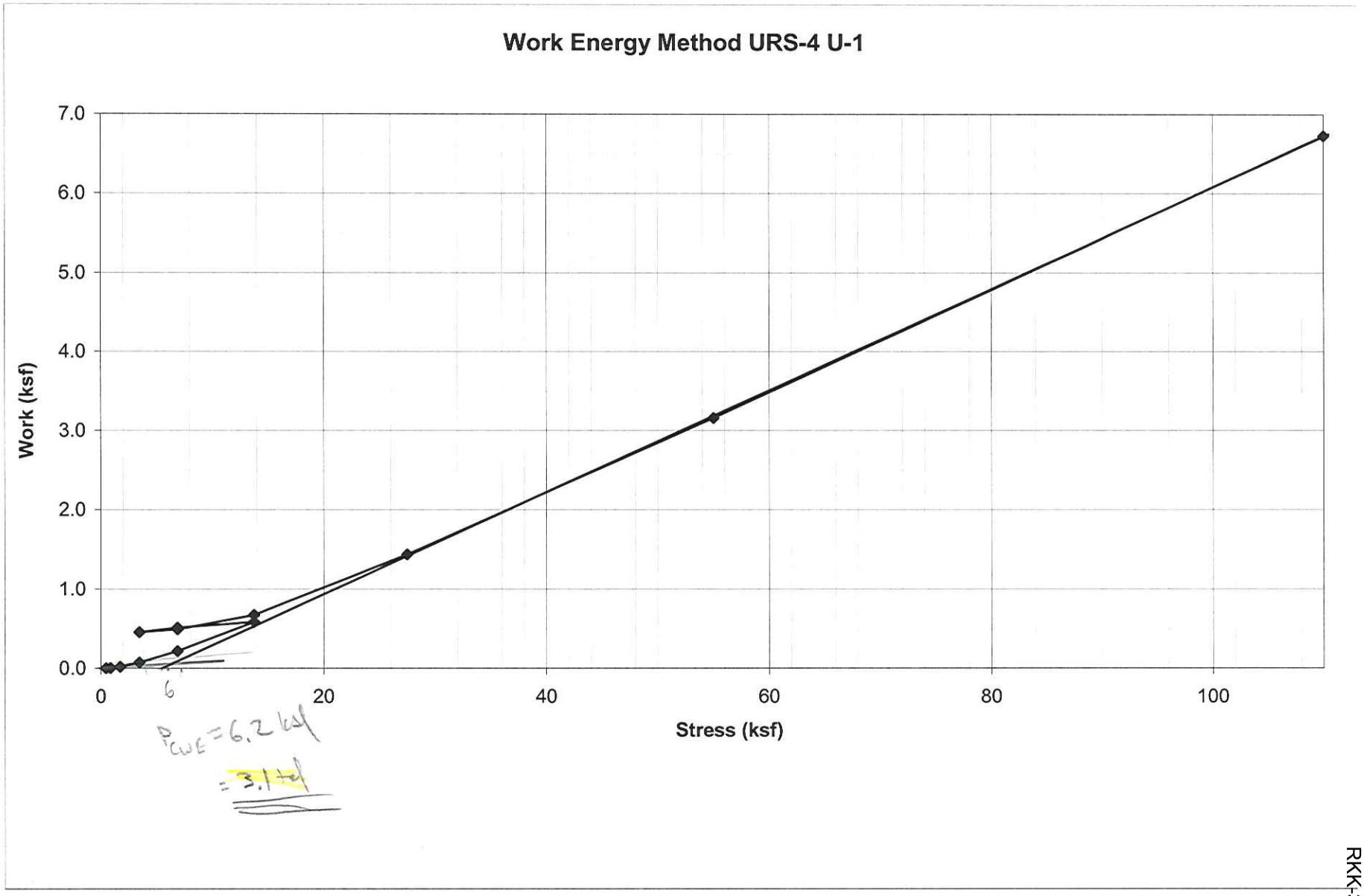
Source: URS # 4 **Sample No.:** U-1 **Elev./Depth:** 22.0

Remarks:

CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

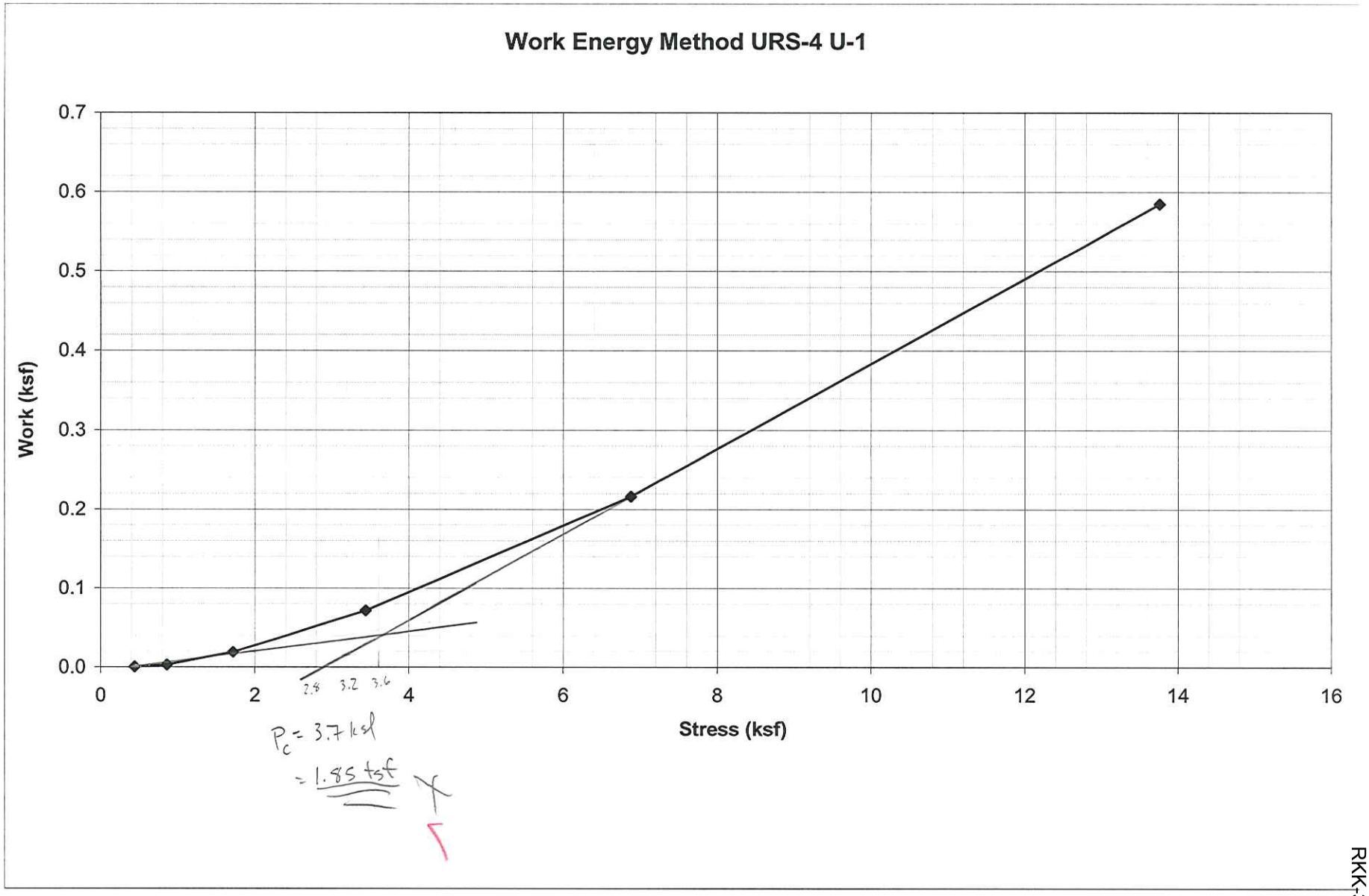
Figure



RKK-38

JOT 1-2-09

Delaware Turnpike Improvements
SR-1 Interchange



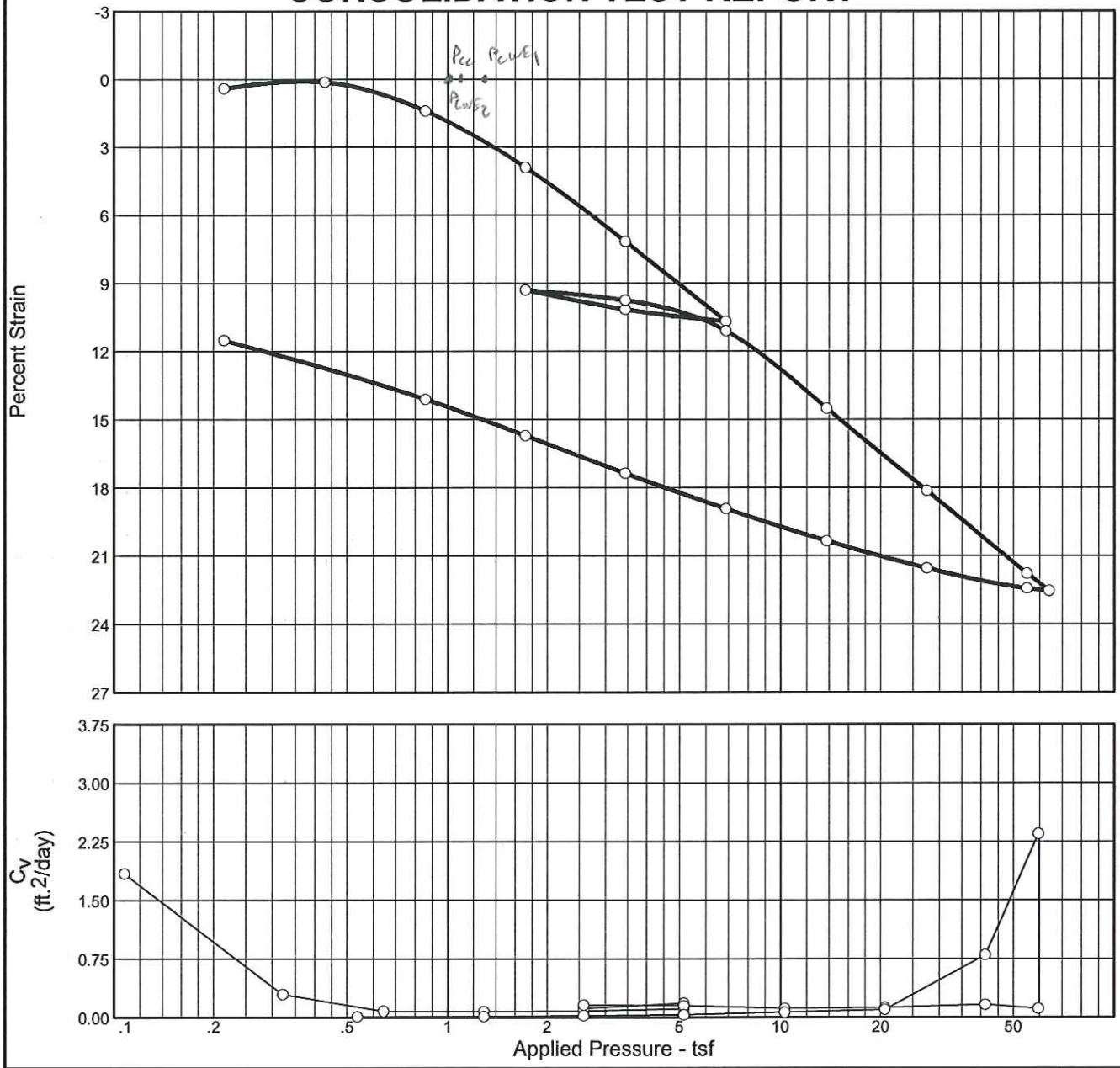
RKK-39

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

JJPT
1-2-09

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_{cwf} = 1.25 tsf / 1.12 tsf	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

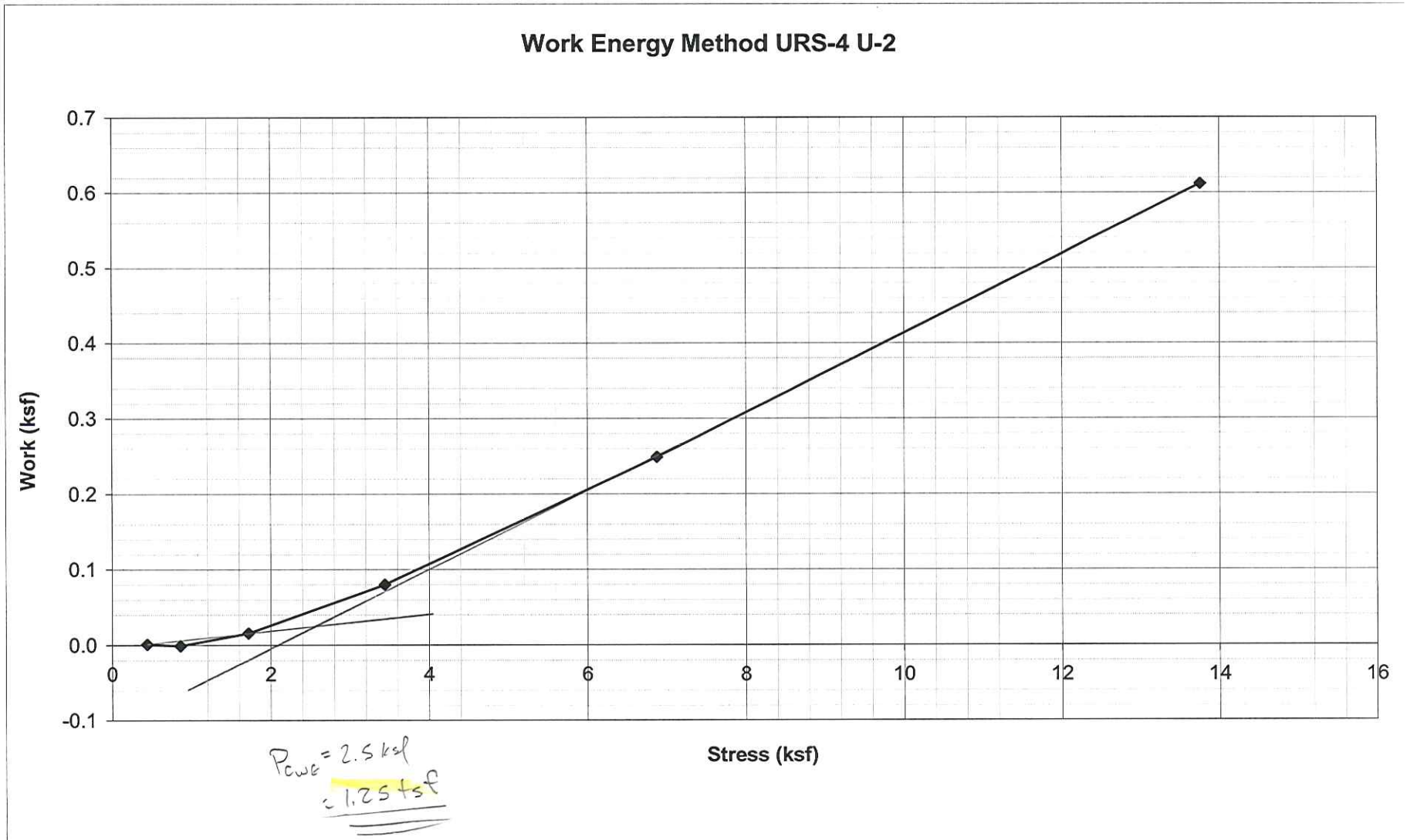
Remarks:

CONSOLIDATION TEST REPORT

Delaware Department of Transportation
Materials and Research Laboratory

Figure

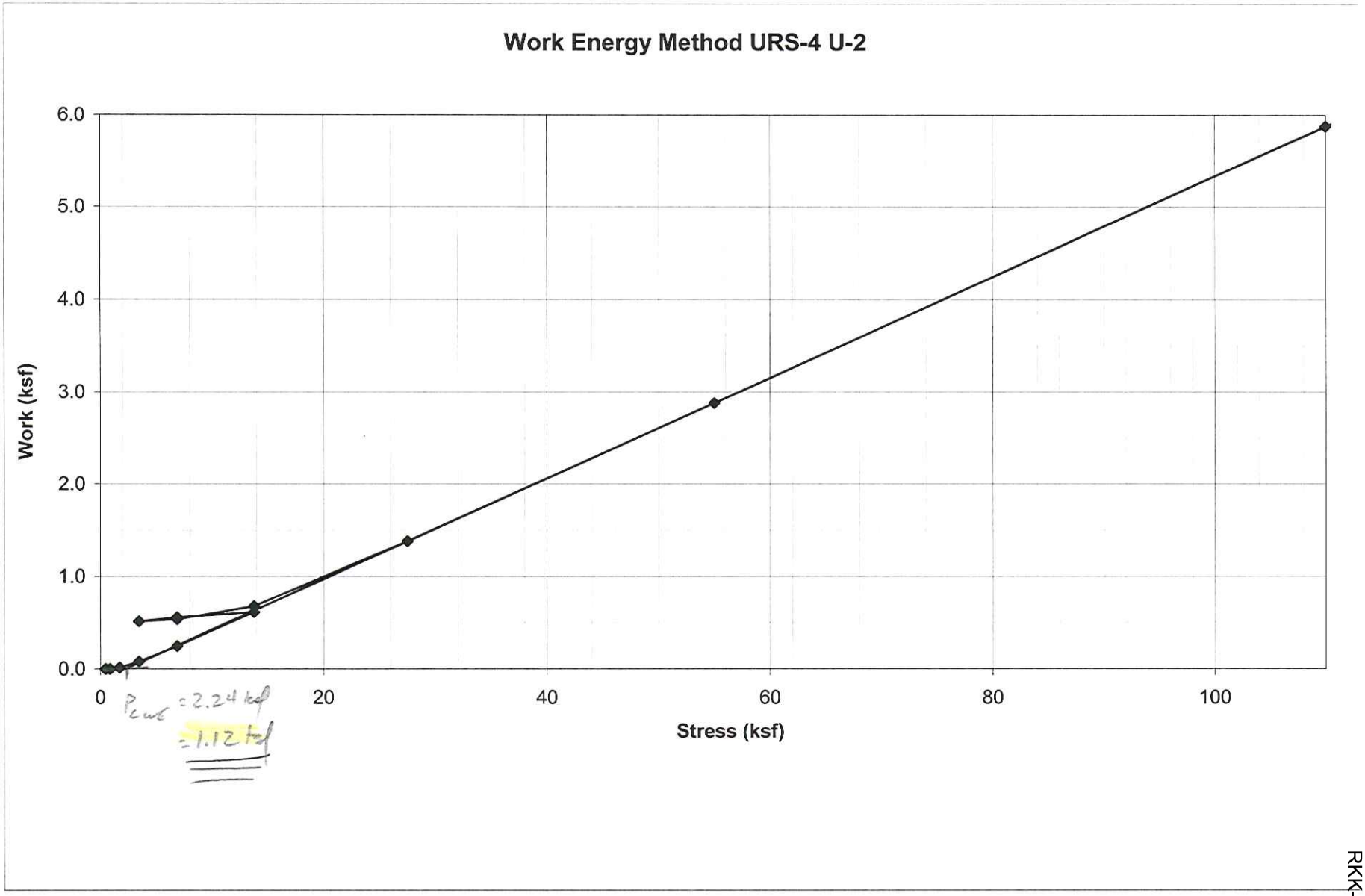
Delaware Turnpike Improvements
SR-1 Interchange



RKK-41

DOT 1-2-09

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



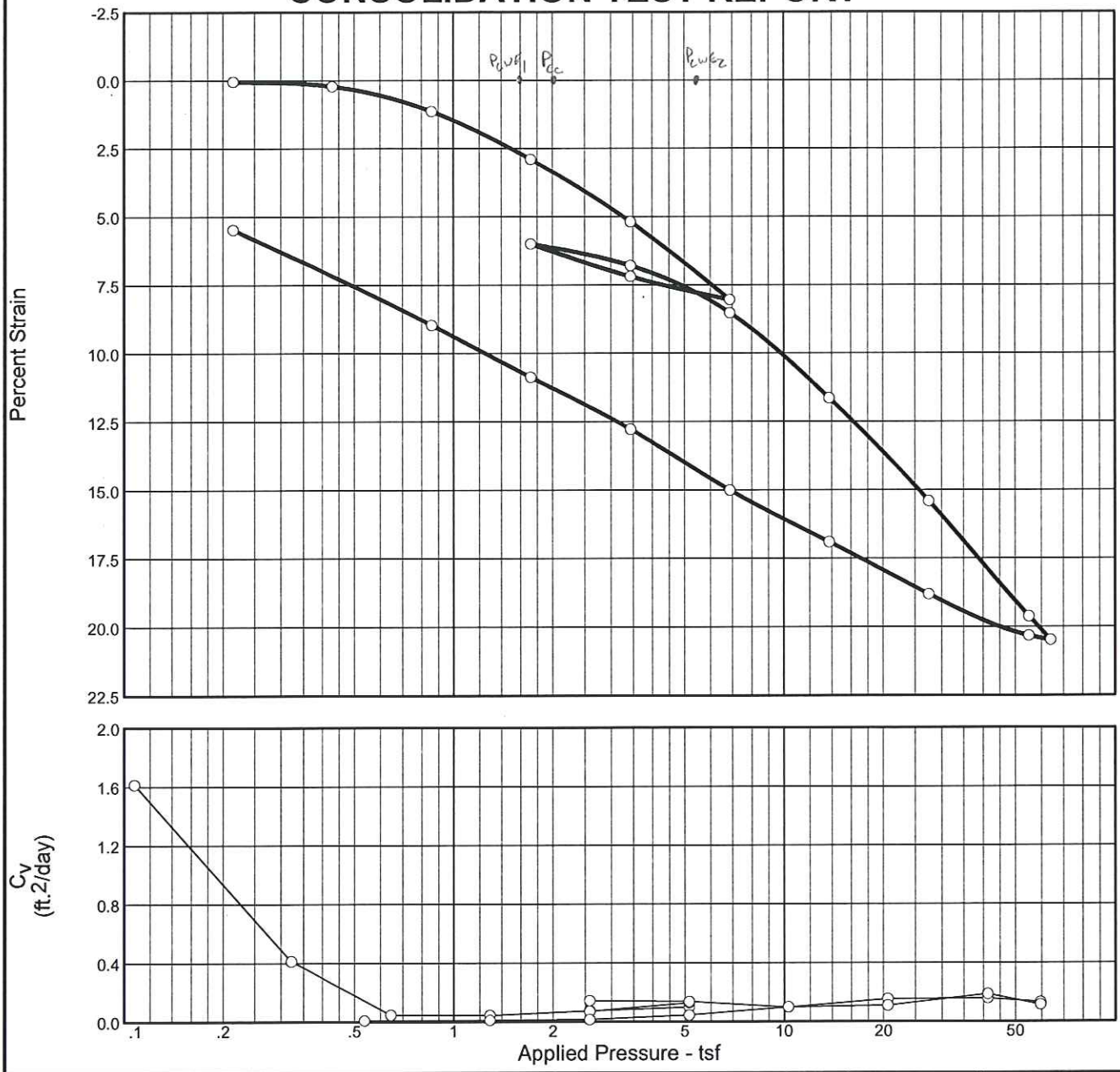
RKK-42

JOT 1-2-09

SJT
1-2-09

RKK-43

CONSOLIDATION TEST REPORT



Natural Sat.	Natural Moist.	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf) 1.24	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 P_{CWE} = 1.6 tsf / ~~5.5 tsf~~	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

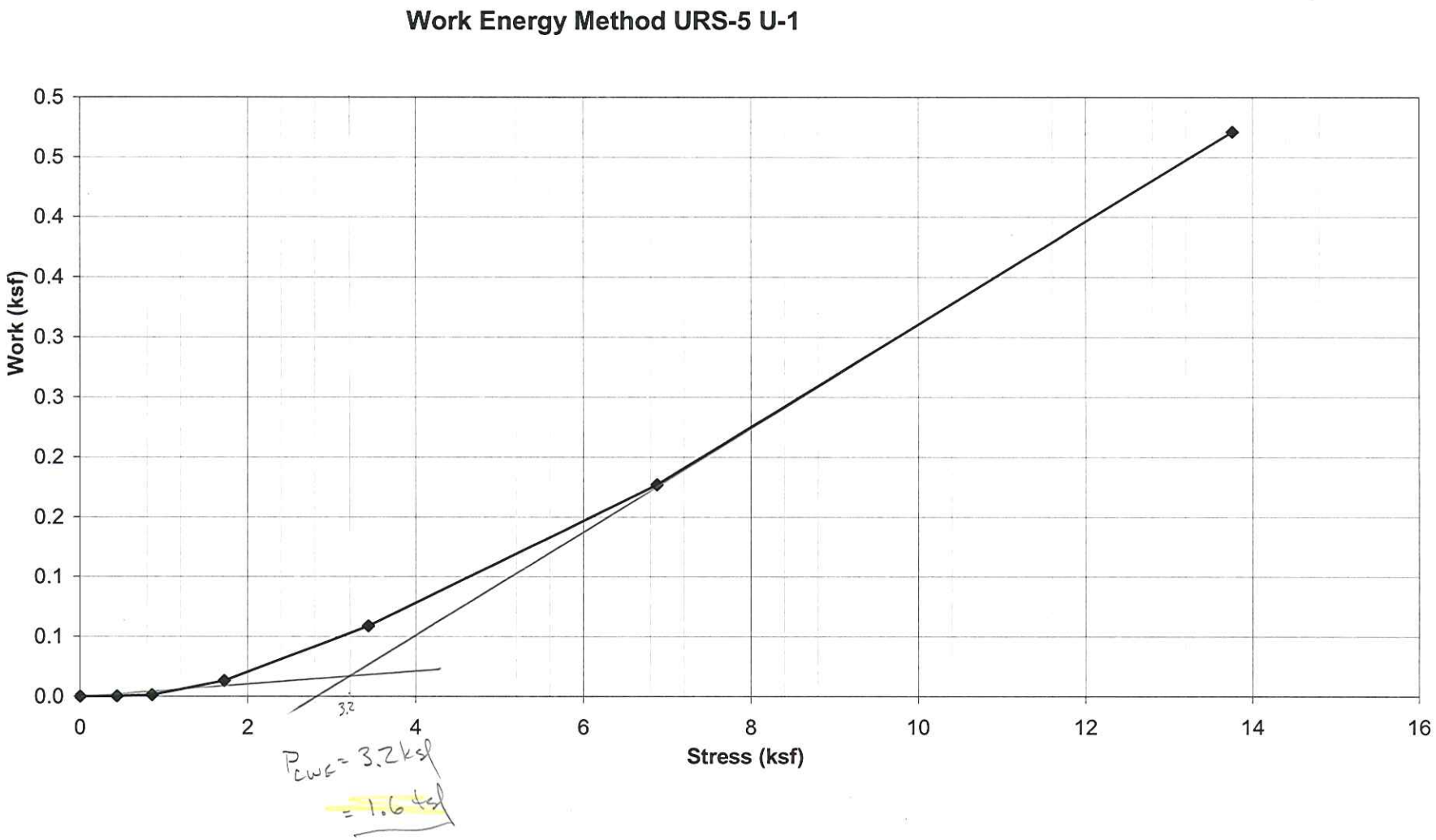
Source: URS # 5 **Sample No.:** U-1 **Elev./Depth:** 35.5

Remarks:

CONSOLIDATION TEST REPORT

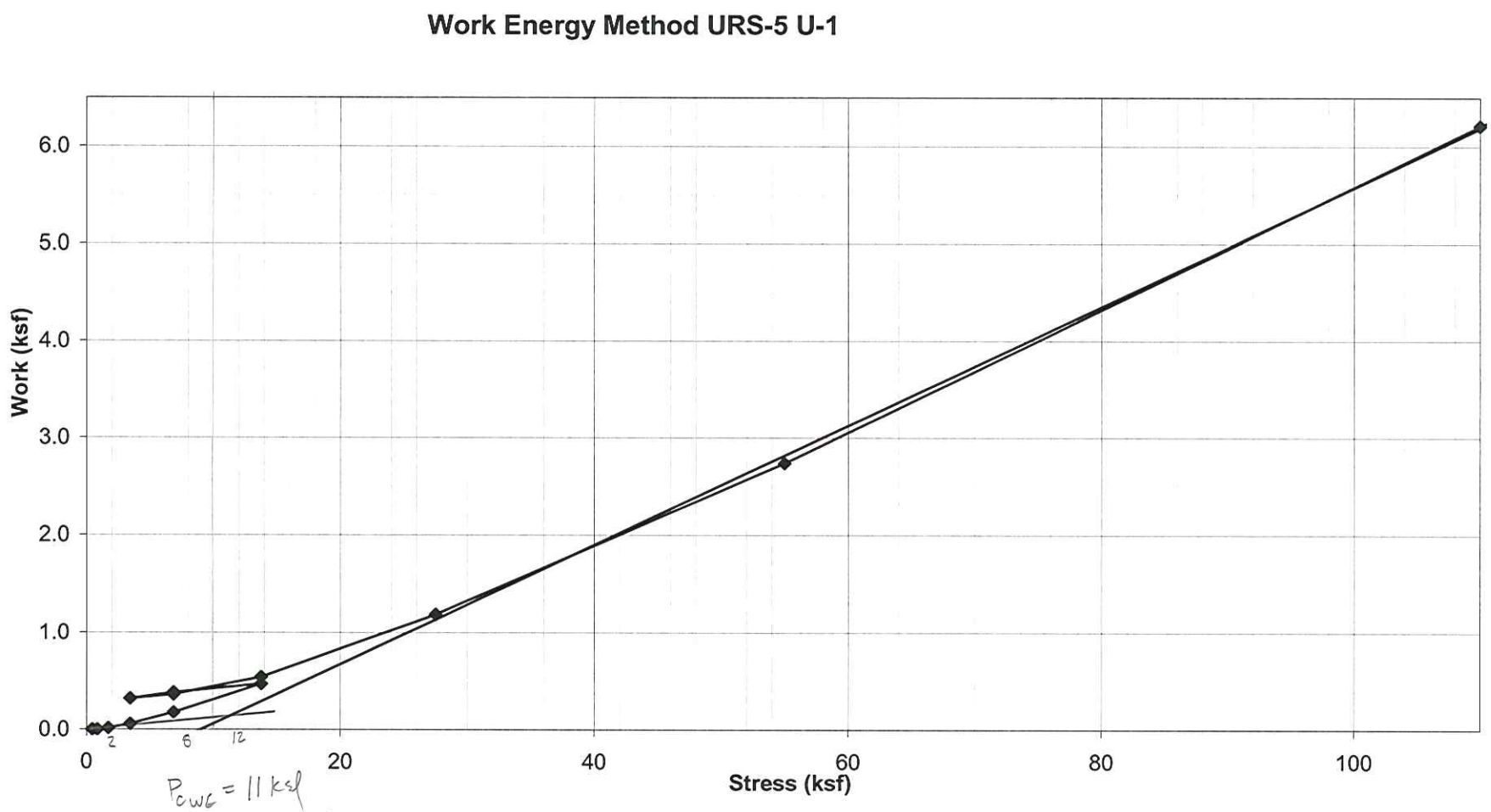
Delaware Department of Transportation
Materials and Research Laboratory

Figure



RKK-44

JCT 1-2-09



$P_{cwG} = 11$ ksf
$= 5.5$ tsf

RKK-45

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.
JJT	9-30-08	All calculations checked and each calculation sheet initialed by checker.
JJT	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 103-059-270 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	~~8~~ 3.09	2.75	~~4.5~~	4.1	~~NV~~ 2.88	~~NV~~ 4.2
IBR-05	T-2	66	38.0	31.5	34.5	119	1.17	~~1.74~~ 4.75	~~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~~ 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

JCPT 9-30-08

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

RKK-48

JPT 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.

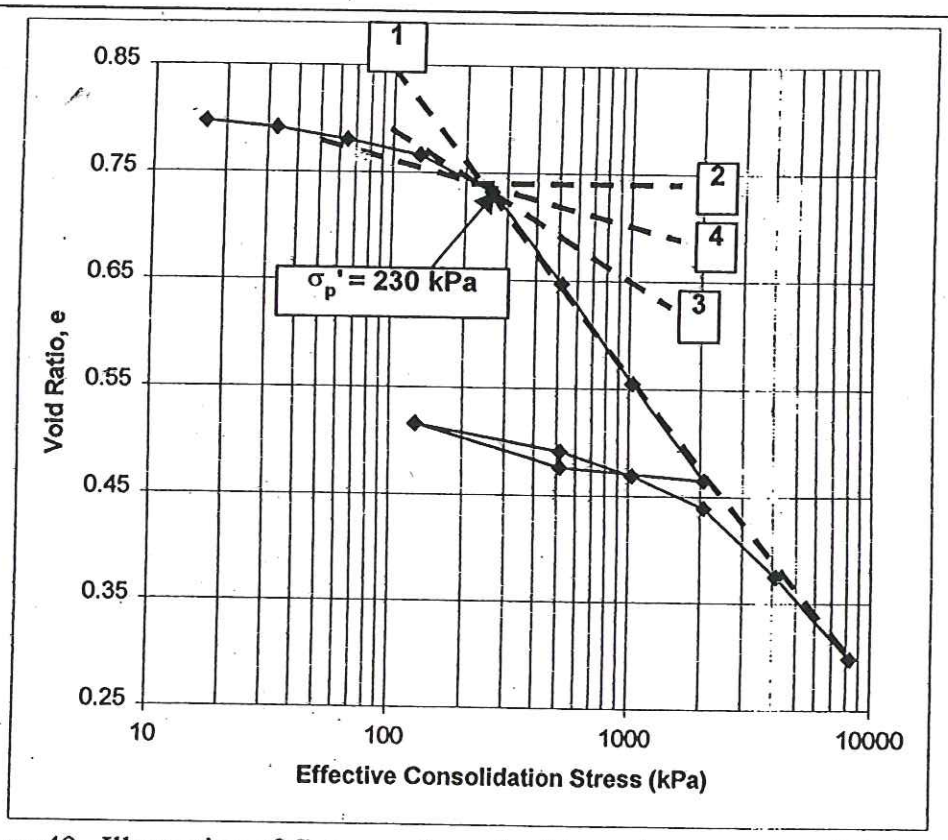
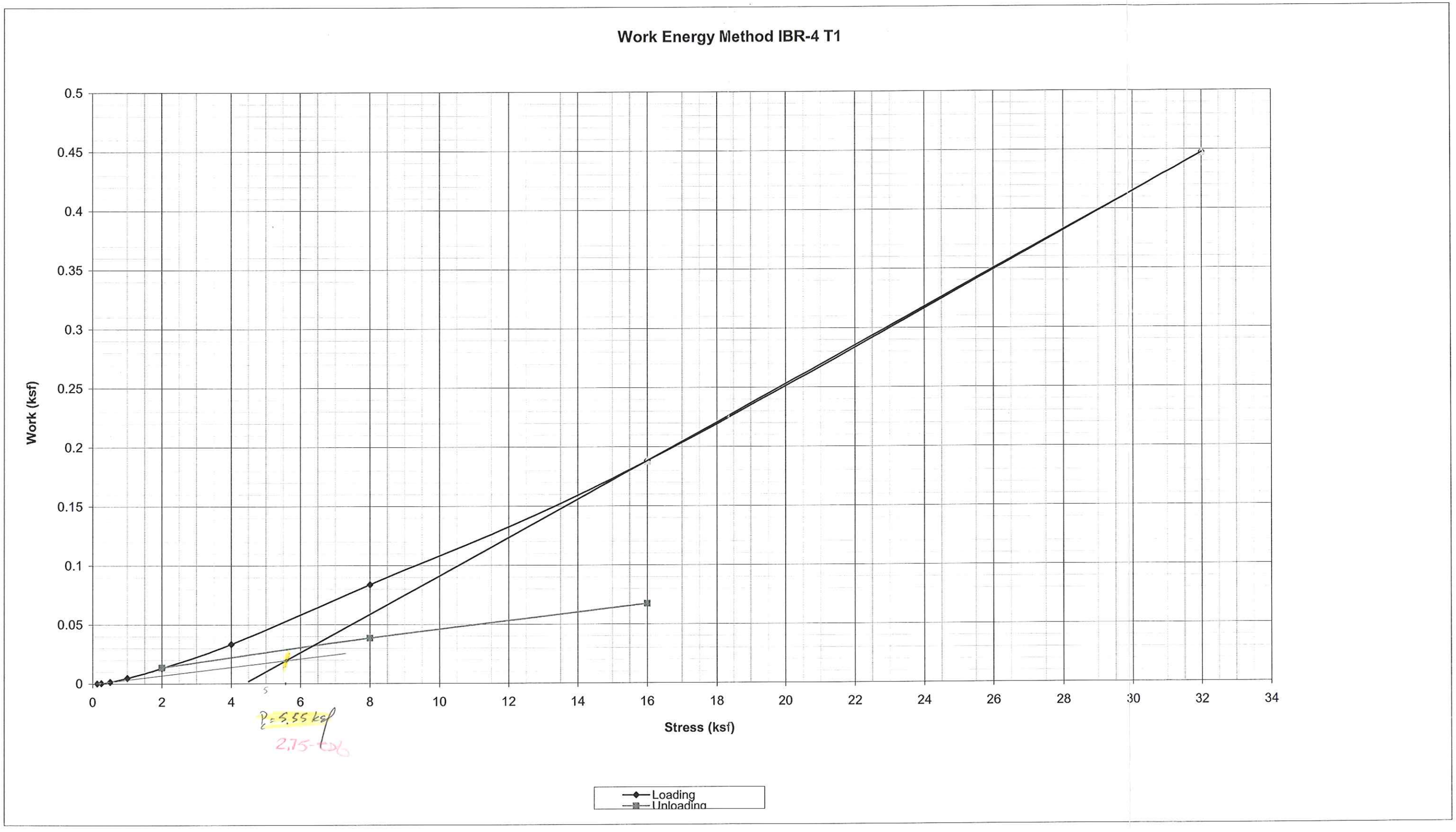


Figure 49. Illustration of Casagrande method to evaluate preconsolidation stress.

JJT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-49

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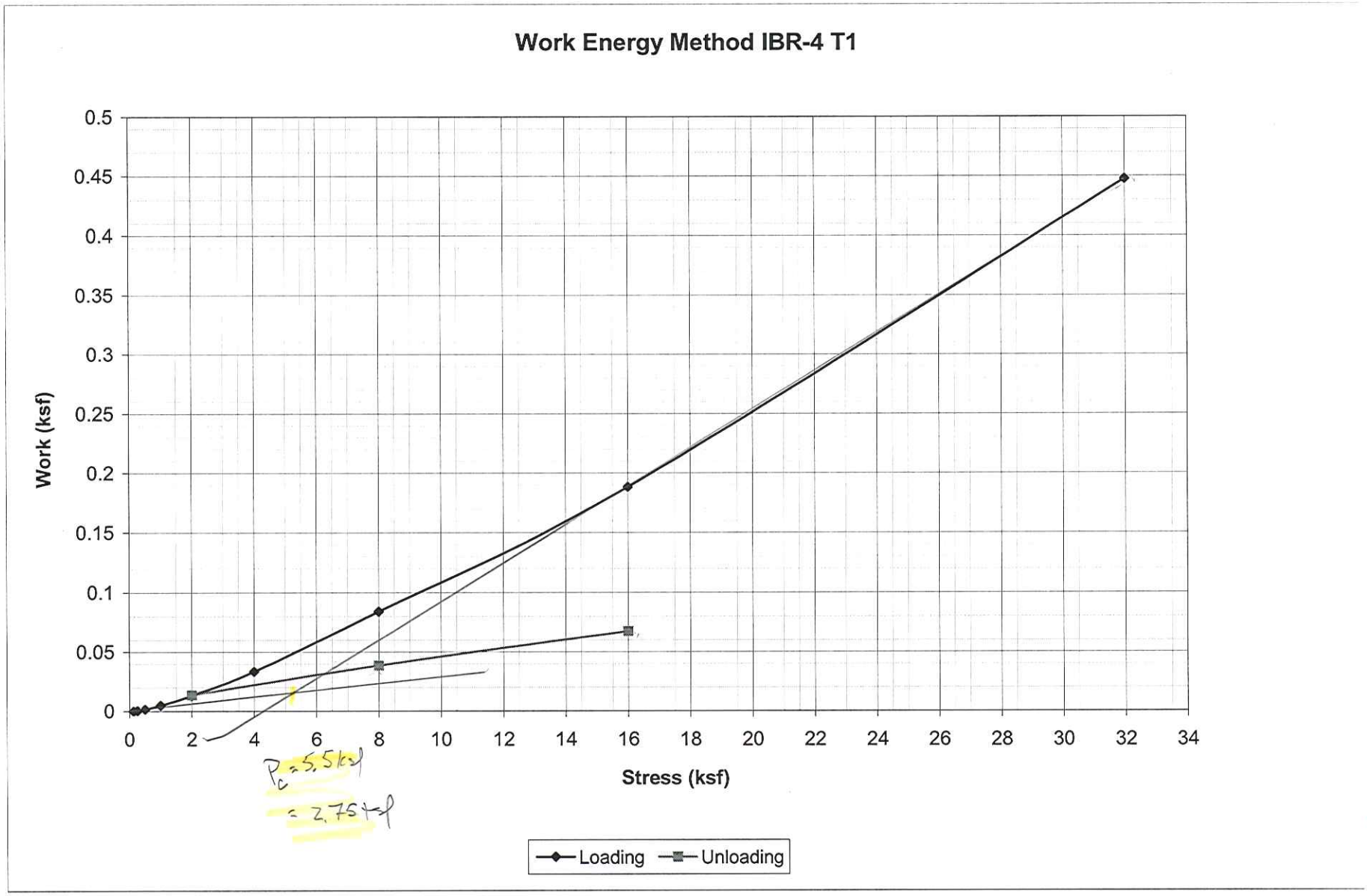
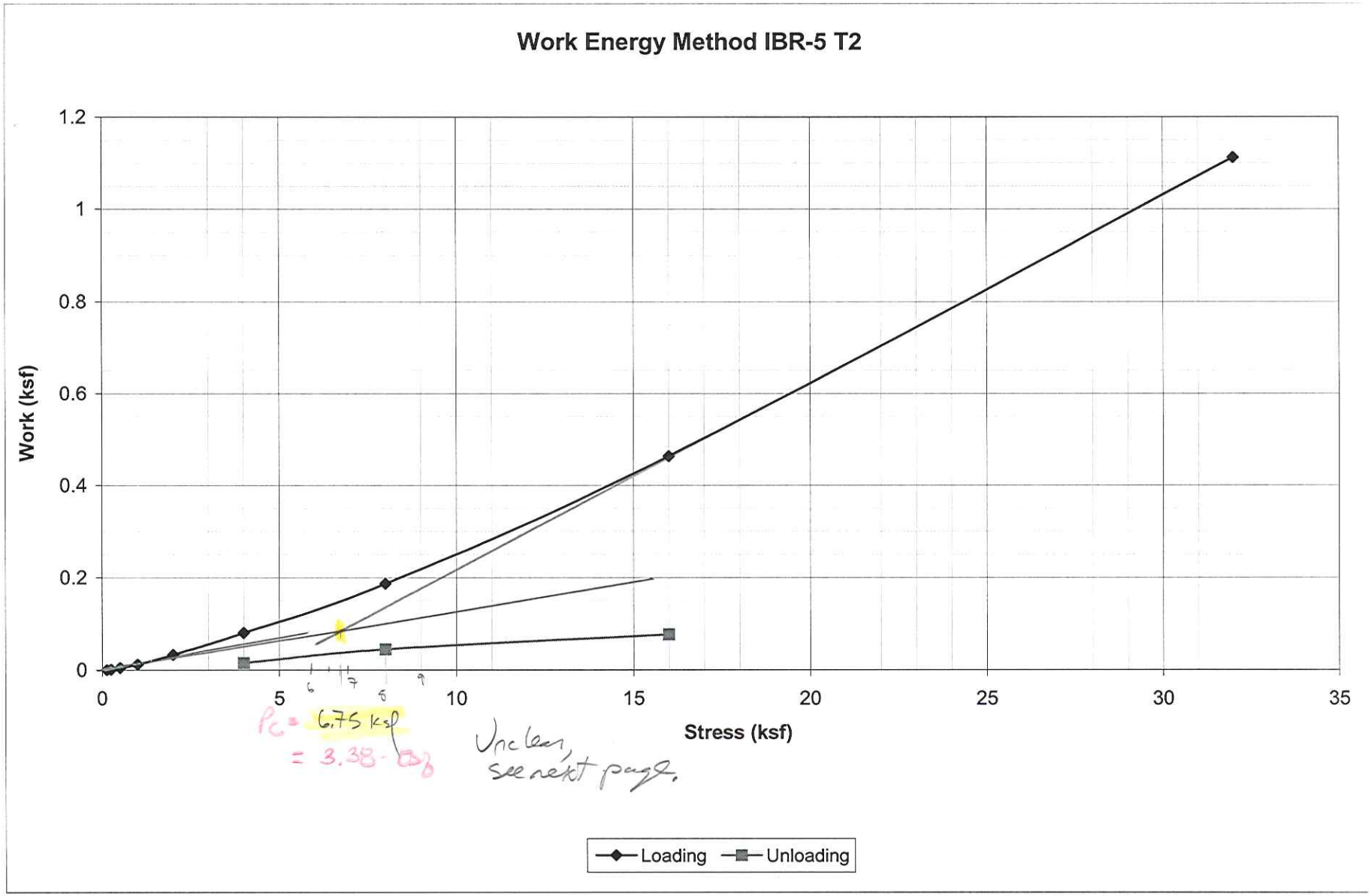
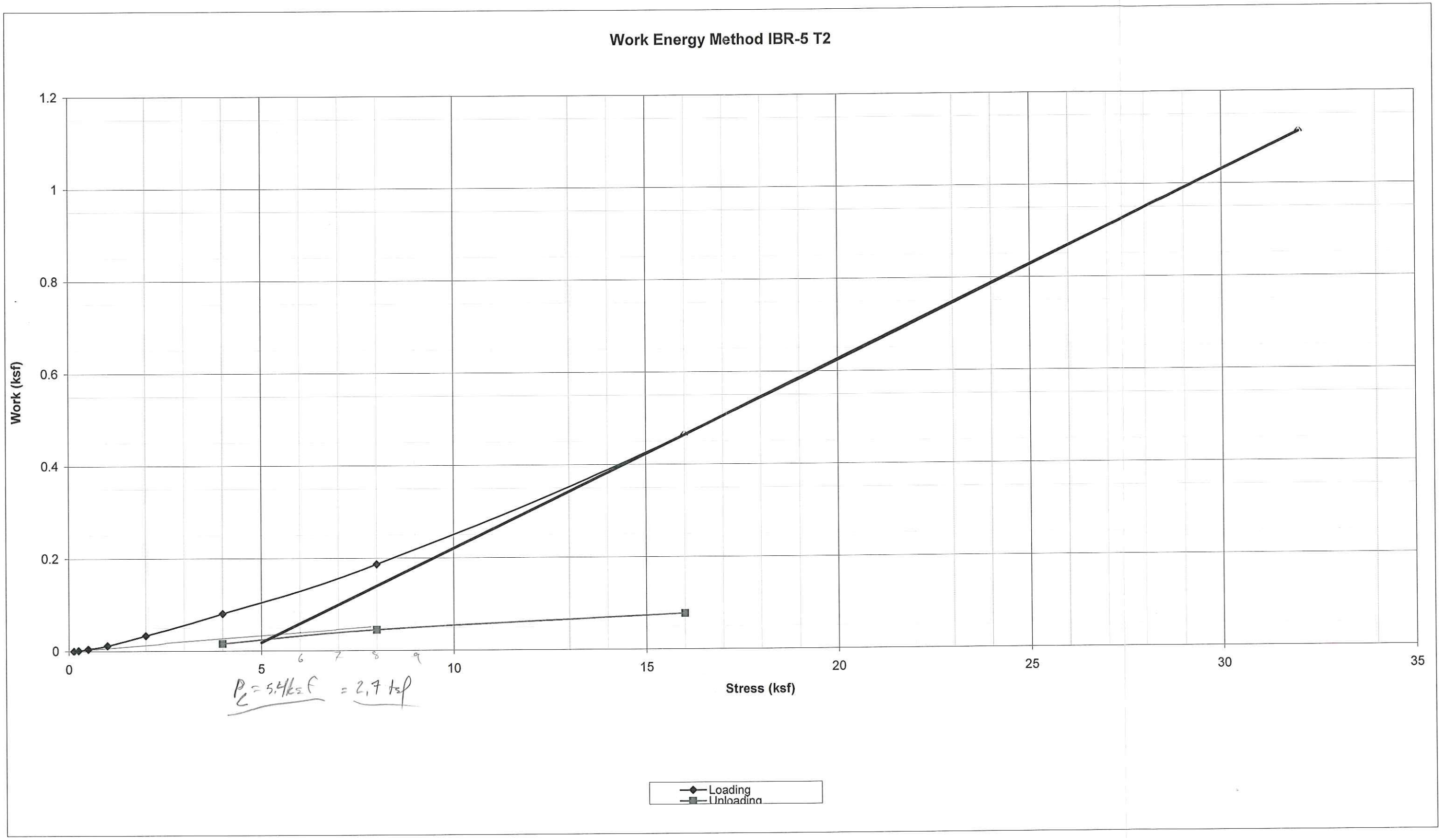

Work Energy Method IBR-4 T1
Work (ksf)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
Stress (ksf)
Pc = 5.5 ksf
= 2.75 ksf
Loading
Unloading

JPT
9-30-08


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)
Loading
Unloading
Pc = 6.75 ksf
= 3.38 - 0.8
Unclear, see next page.

JST 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-52

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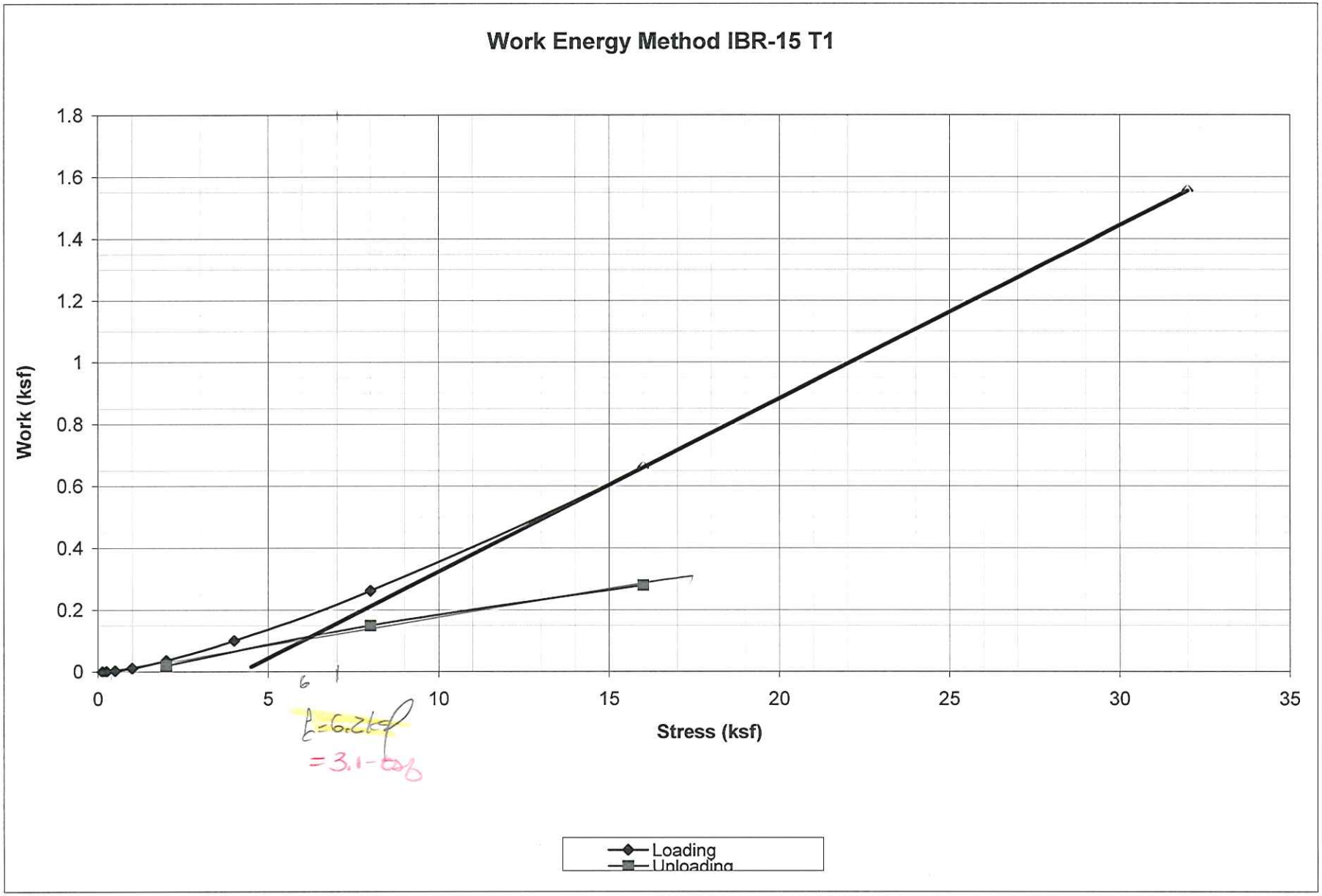
Delaware Turnpike Improvements
SR-1 Interchange



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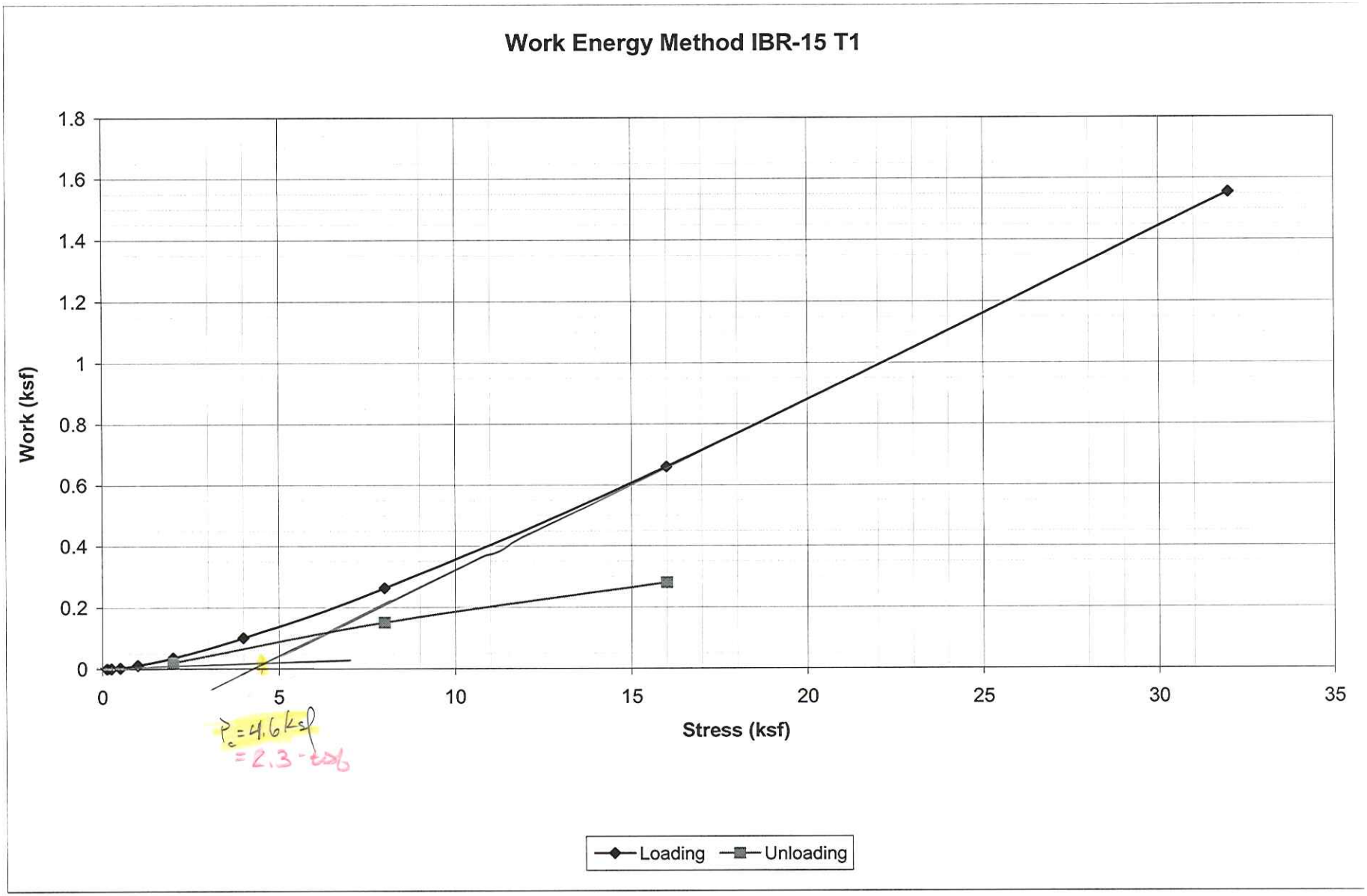
Delaware Turnpike Improvements
SR-1 Interchange



JGT 9-30-08

RKK-54

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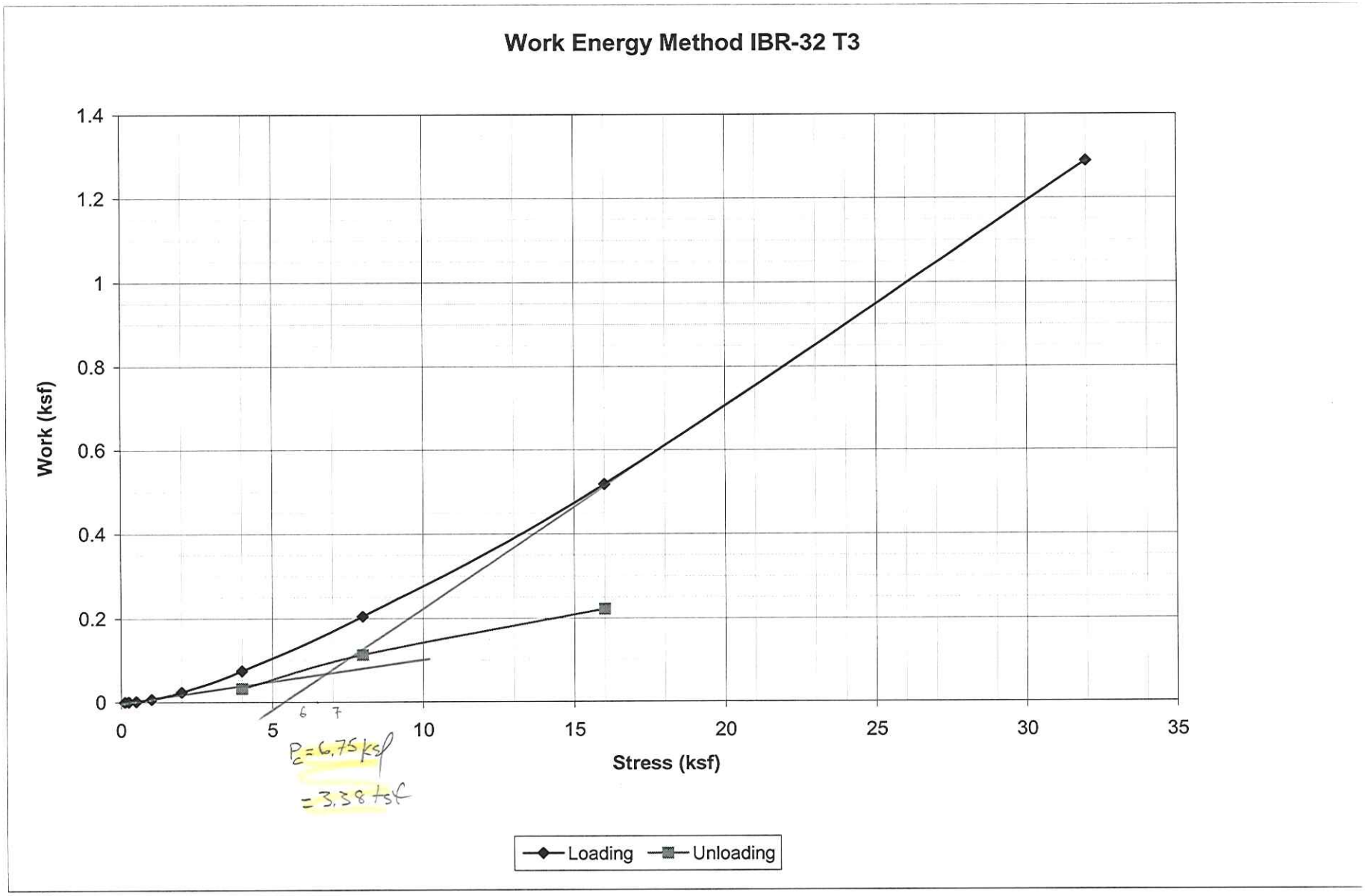
Delaware Turnpike Improvements
SR-1 Interchange



JCP
9-30-08

RKK-55

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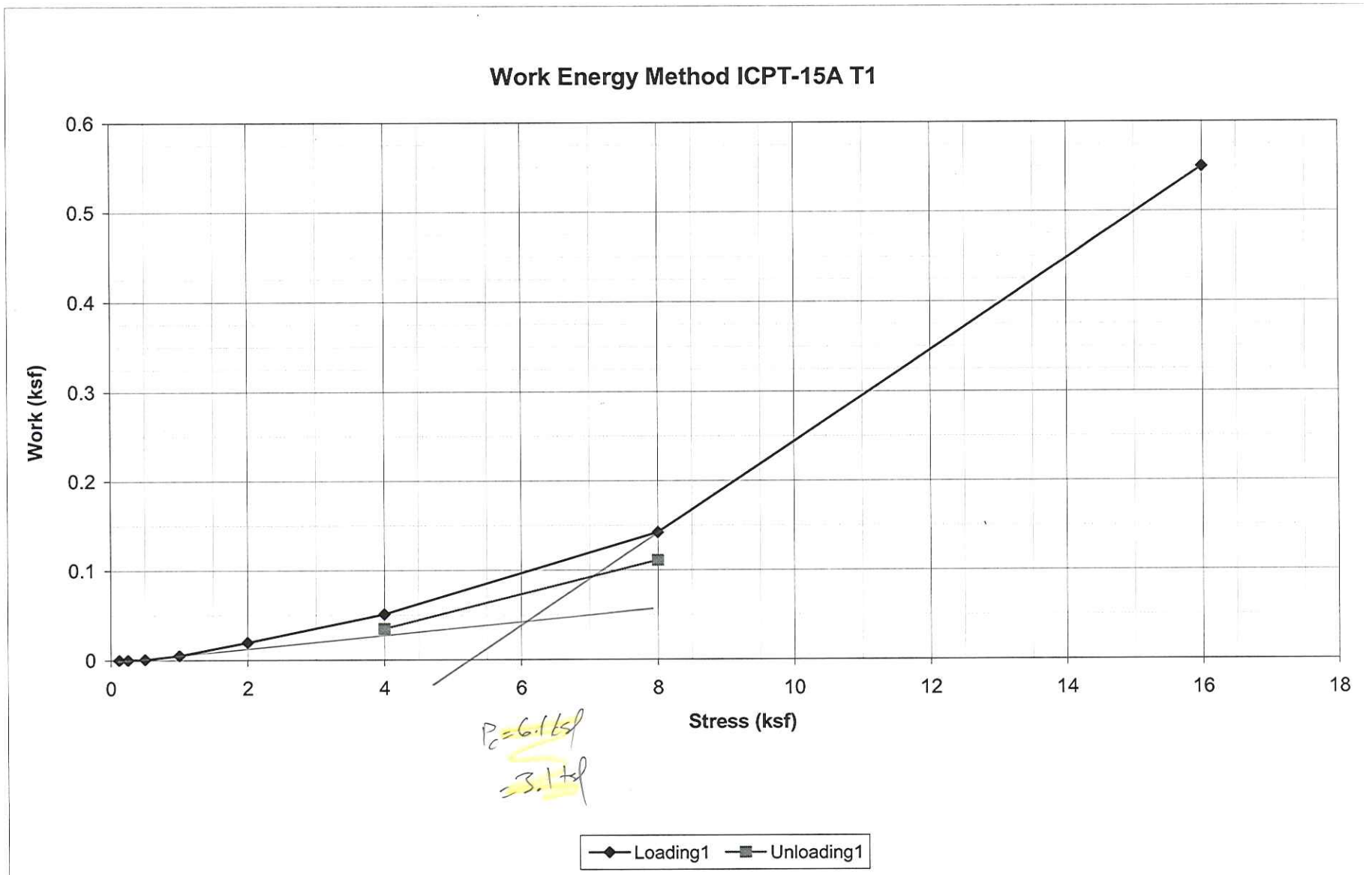
Delaware Turnpike Improvements
SR-1 Interchange



P_c = 6.1 ksf
= 3.1 ksf

JCPT
9-30-08

RKK-56

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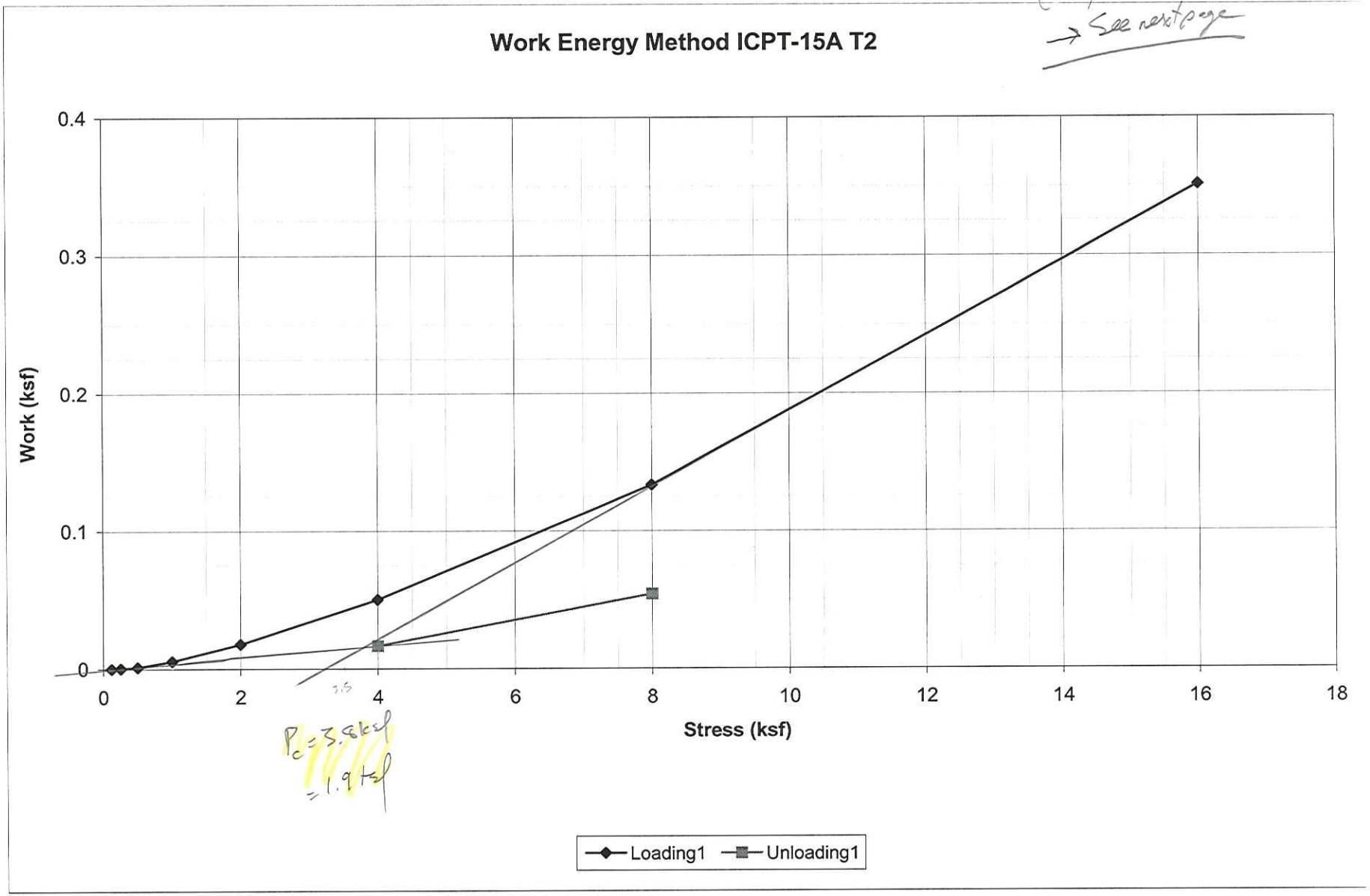
Delaware Turnpike Improvements
SR-1 Interchange

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



JBT 9-30-08

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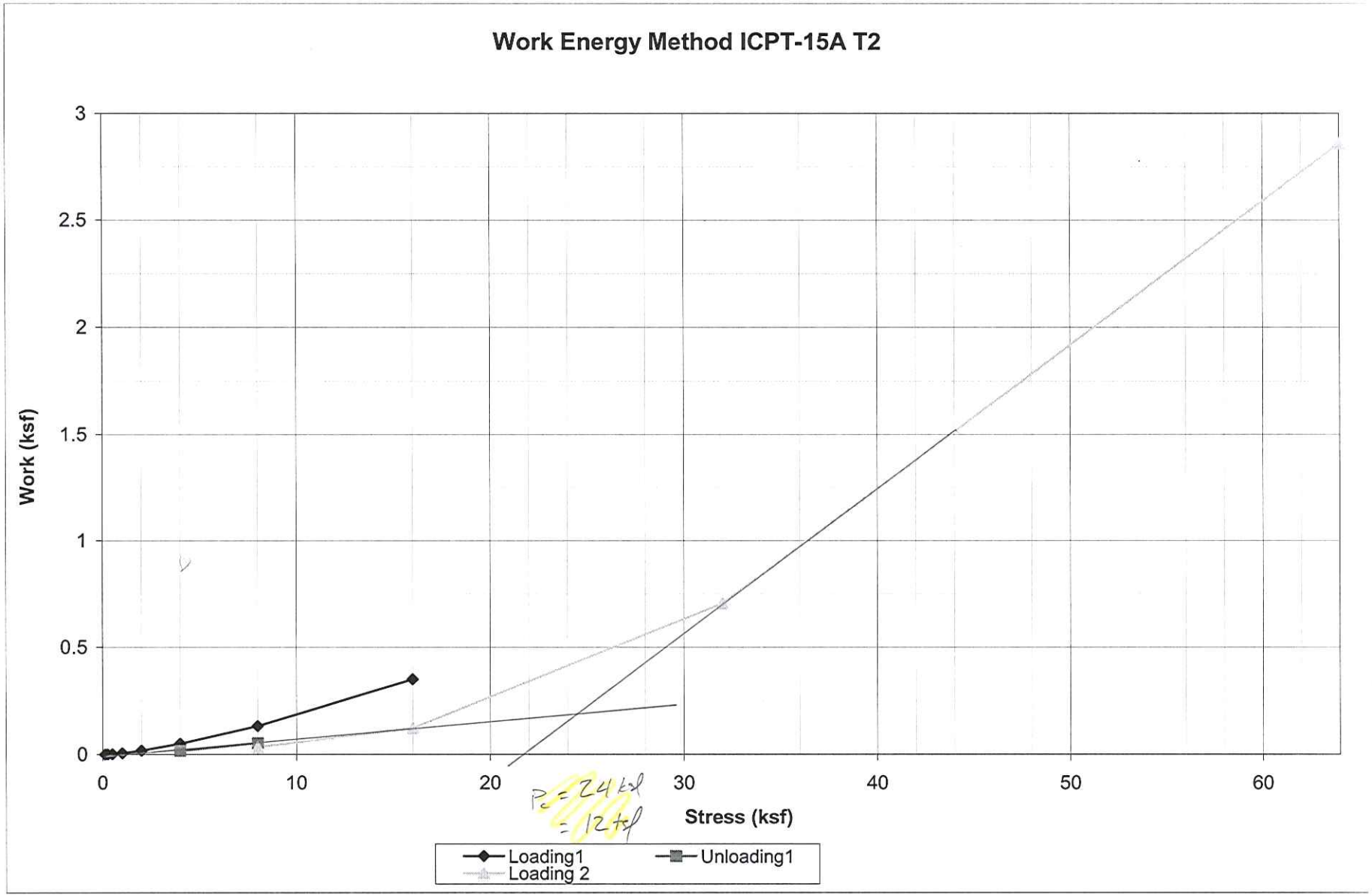
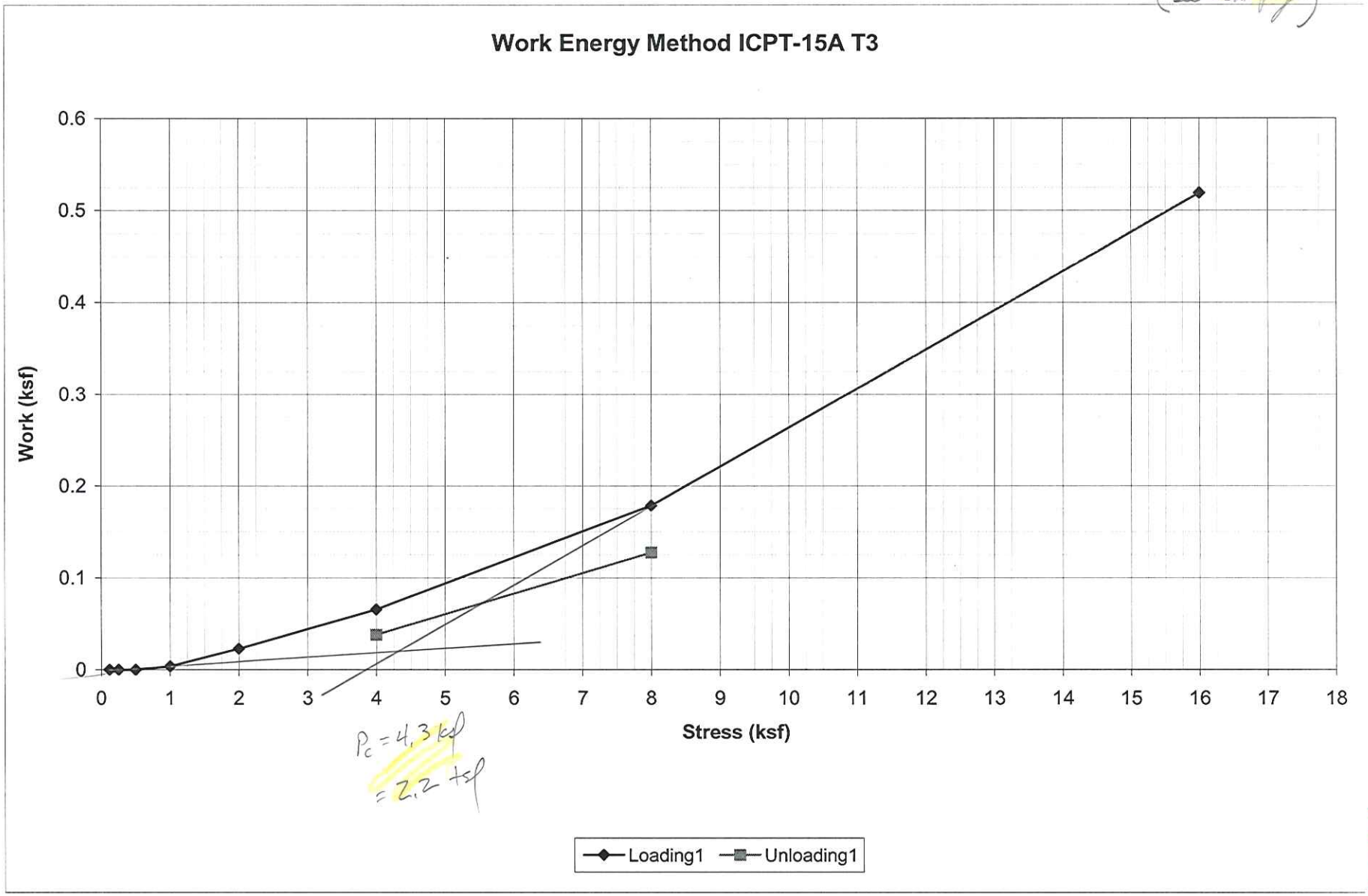

Work Energy Method ICPT-15A T2
Work (ksf)
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
Stress (ksf)
Pc = 24 ksf
= 12 tsf
Loading1
Unloading1
Loading 2

JBP 9-30-08

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

Delaware Turnpike Improvements
SR-1 Interchange



JDT 9.30-08

RKK-59

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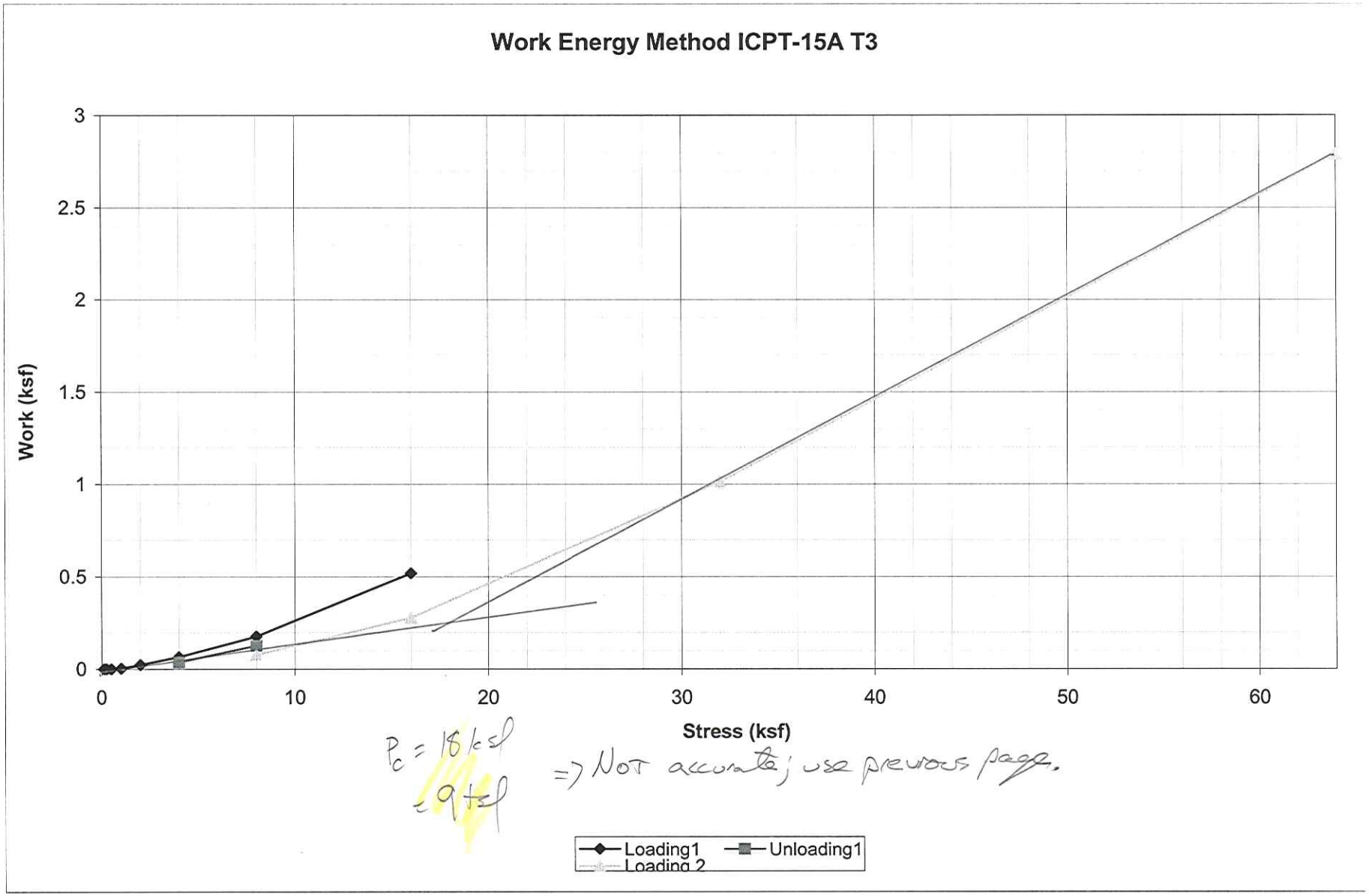


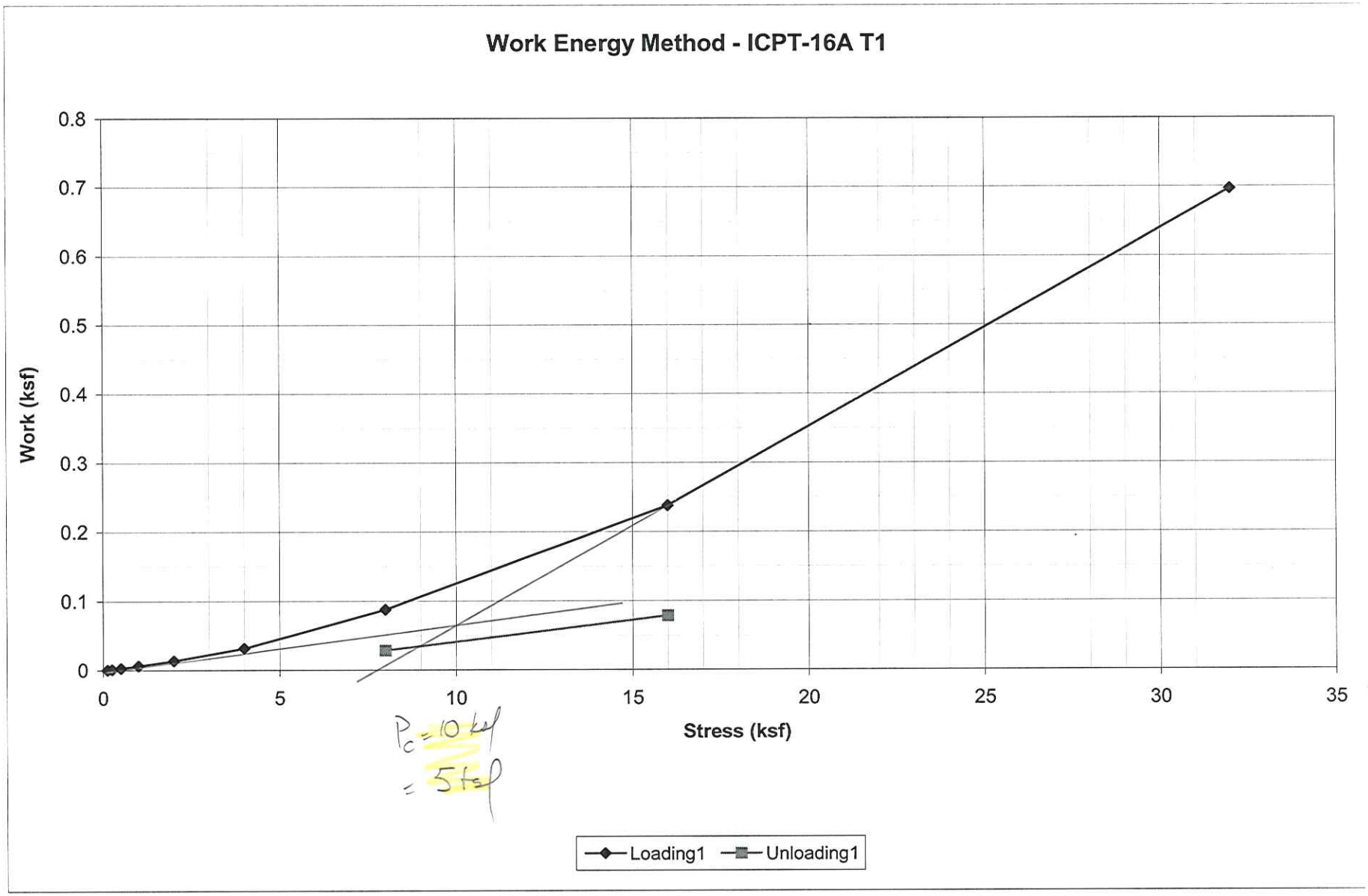
P_c = 18 ksf
= 9 tsf

=> NOT accurate; use previous page.

JPT
9-30-08

RKK-60

Delaware Turnpike Improvements
SR-1 Interchange



JCP
9-30-08

RKK-61

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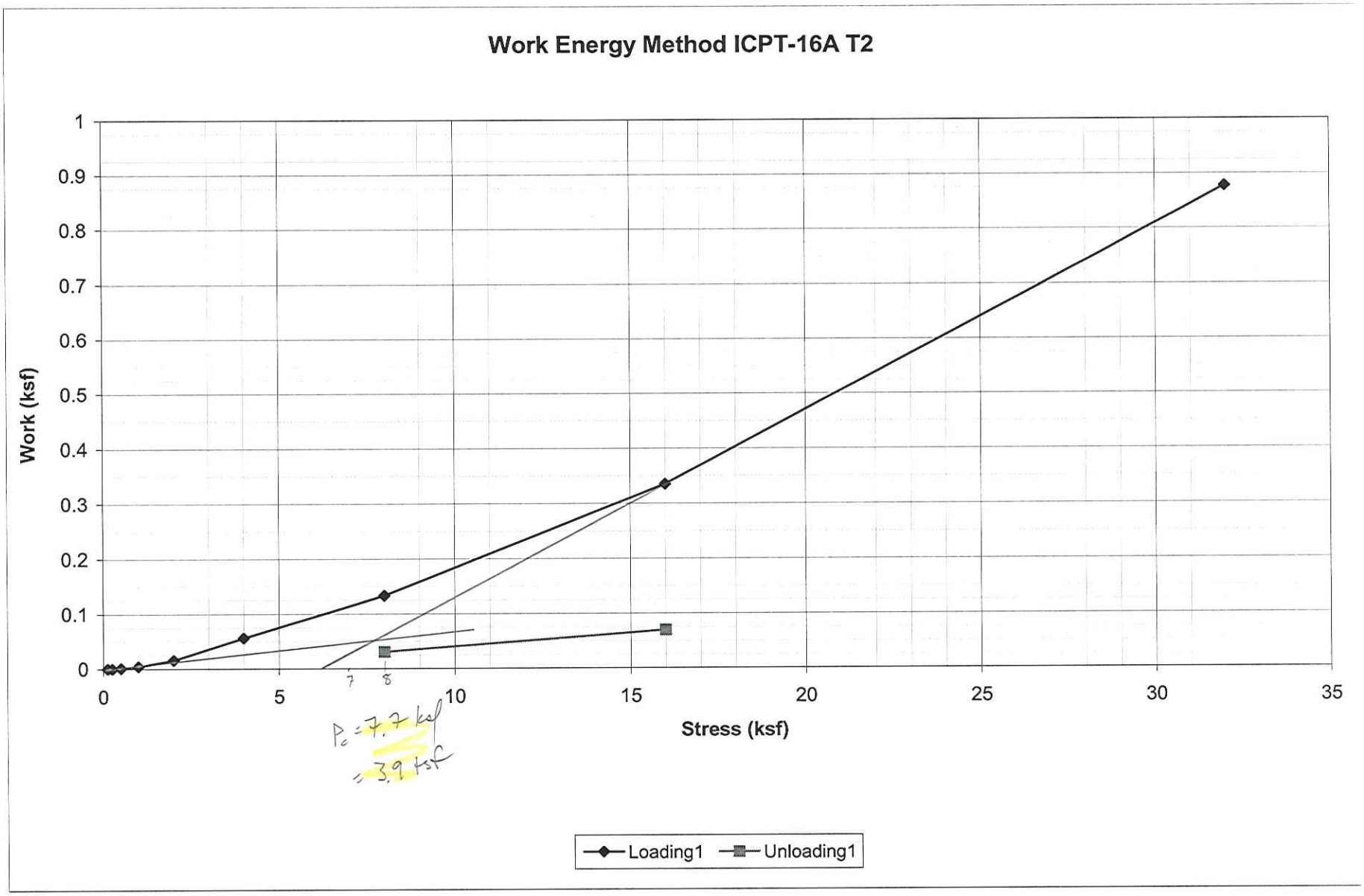
Delaware Turnpike Improvements
SR-1 Interchange



RKK-62

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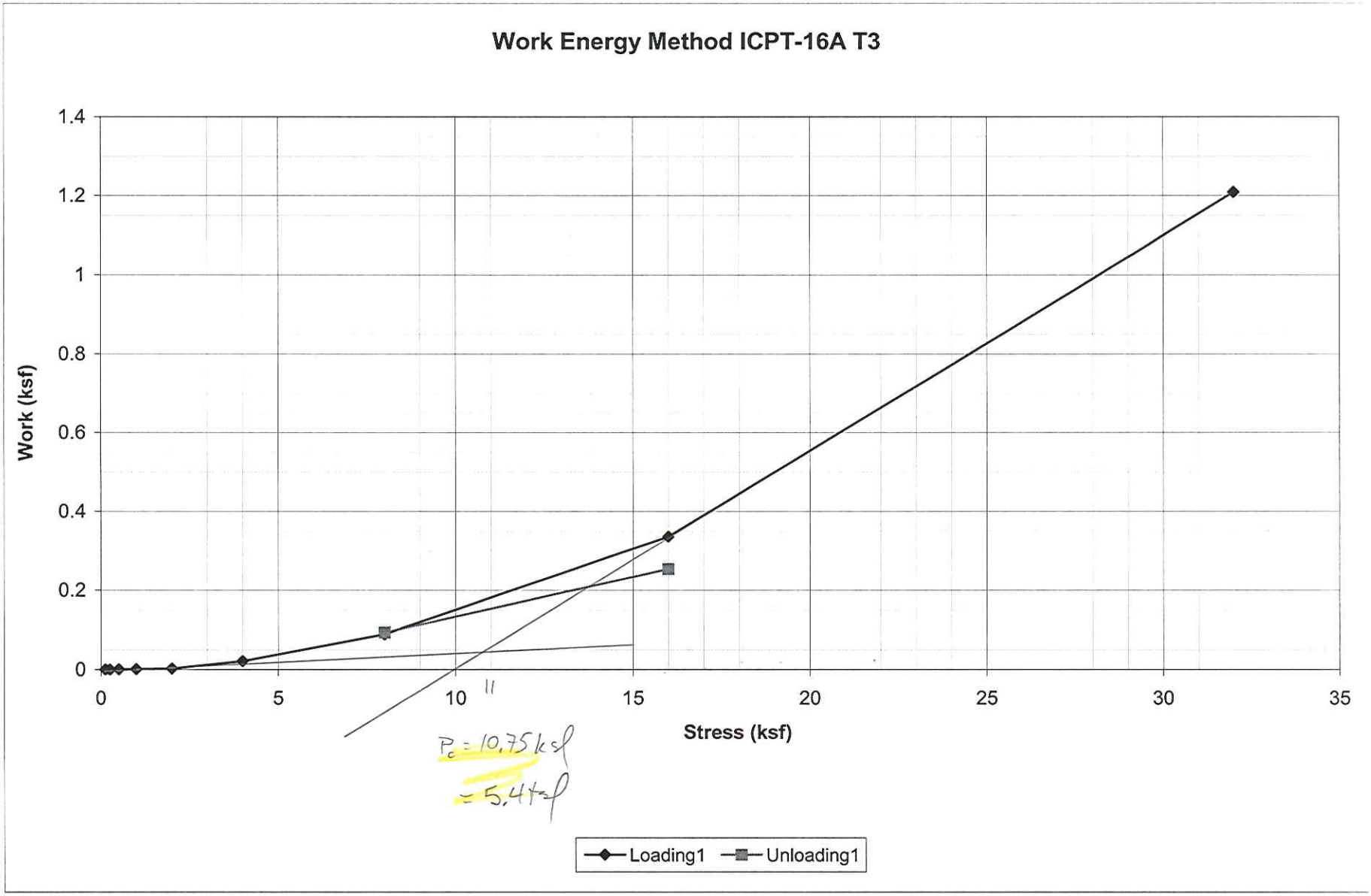
9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-63

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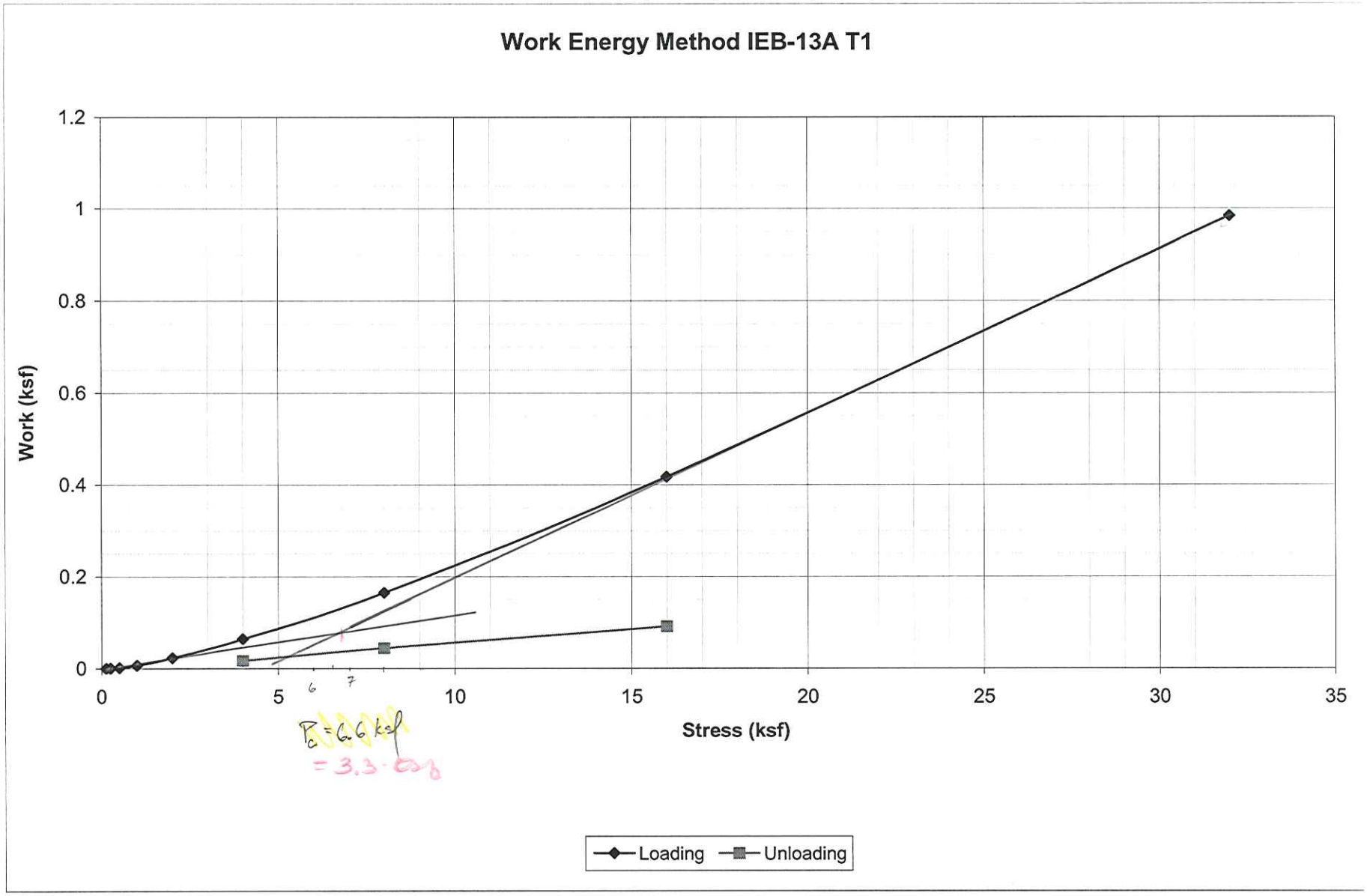
JCT 6-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-64

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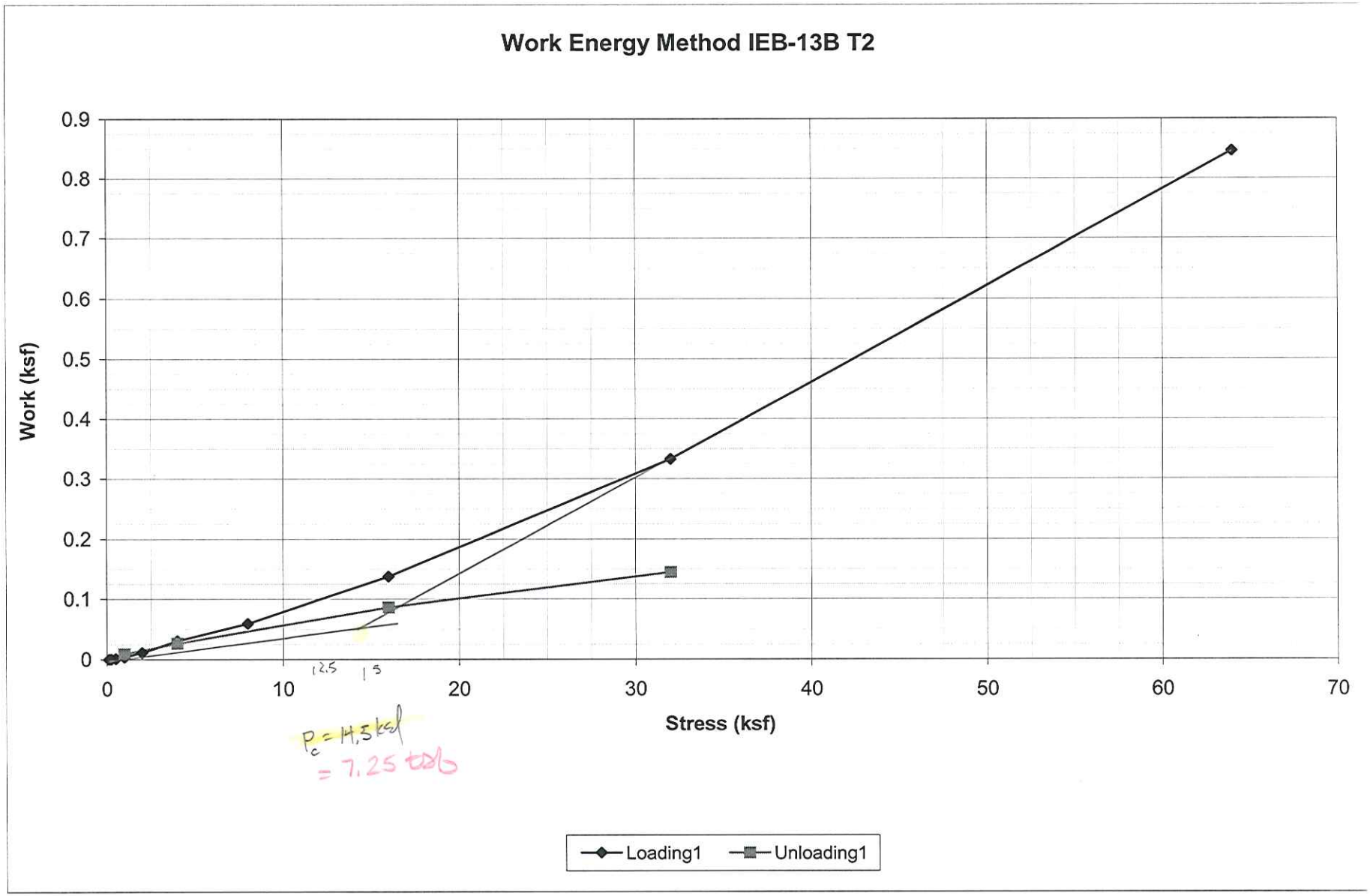
JBT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-65

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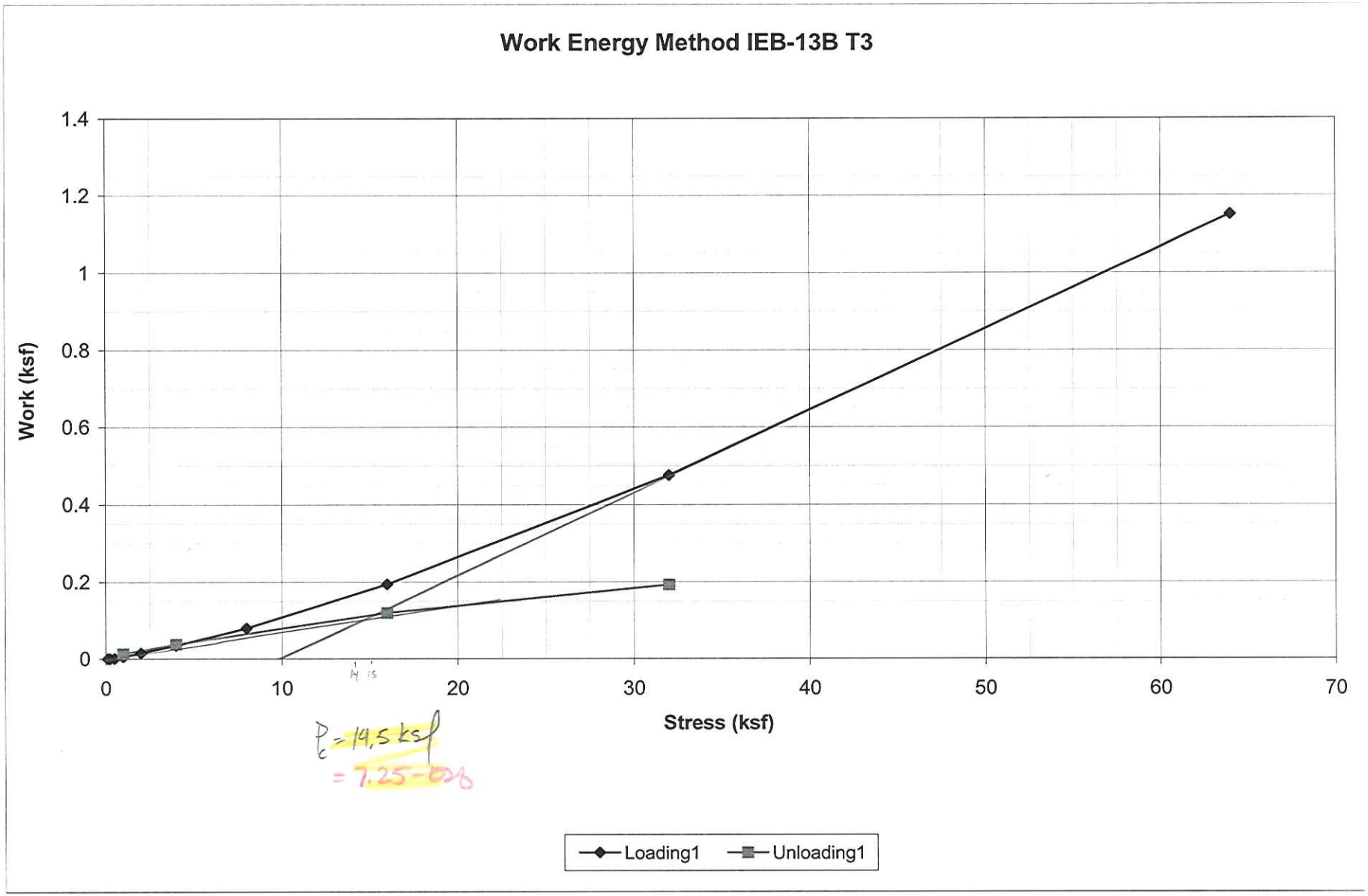
JCPT
9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



P_c = 14.5 ksf
= 7.25 ksf

RKK-66
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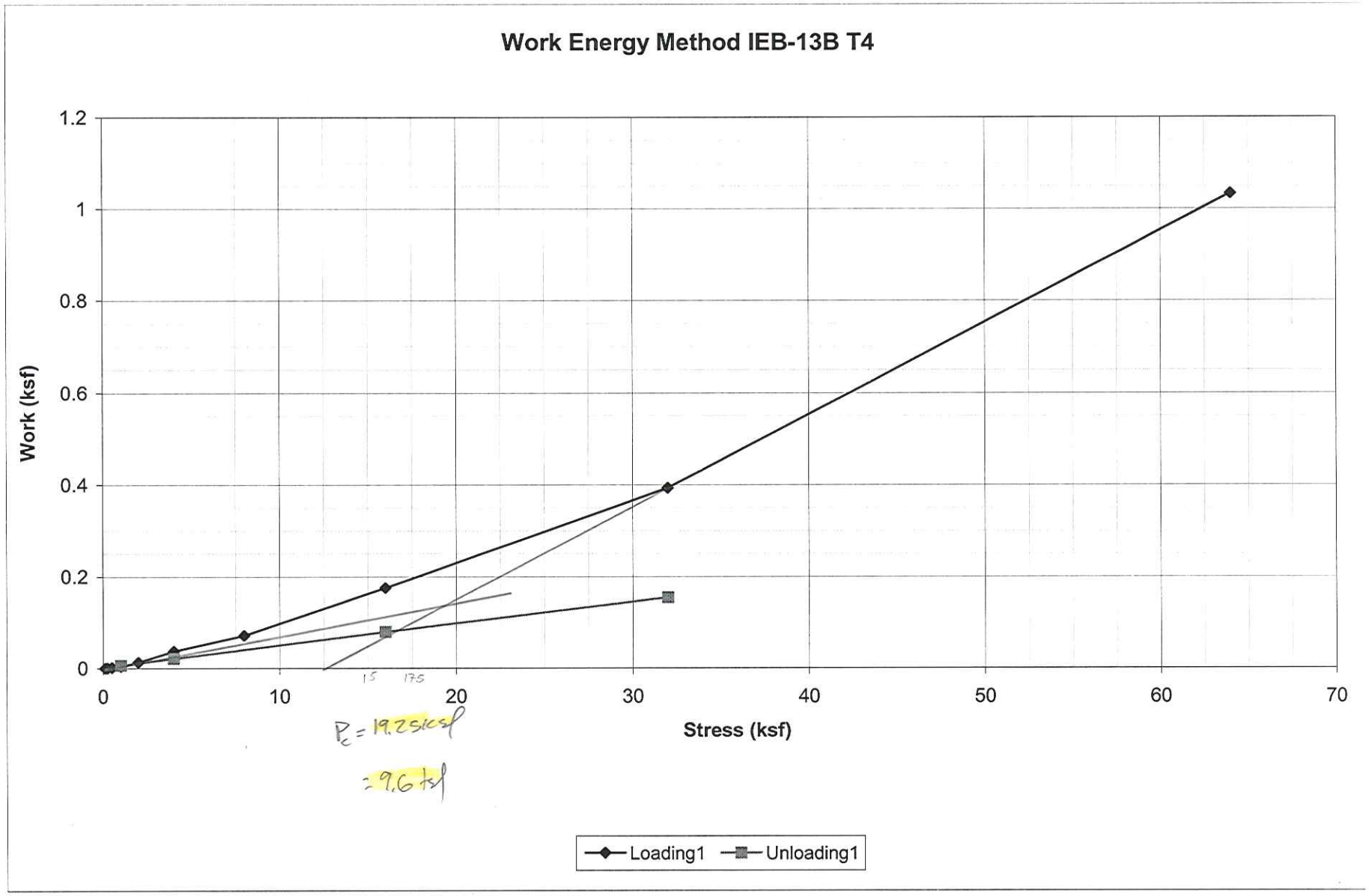
9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



JDT
9-30-08

RKK-67

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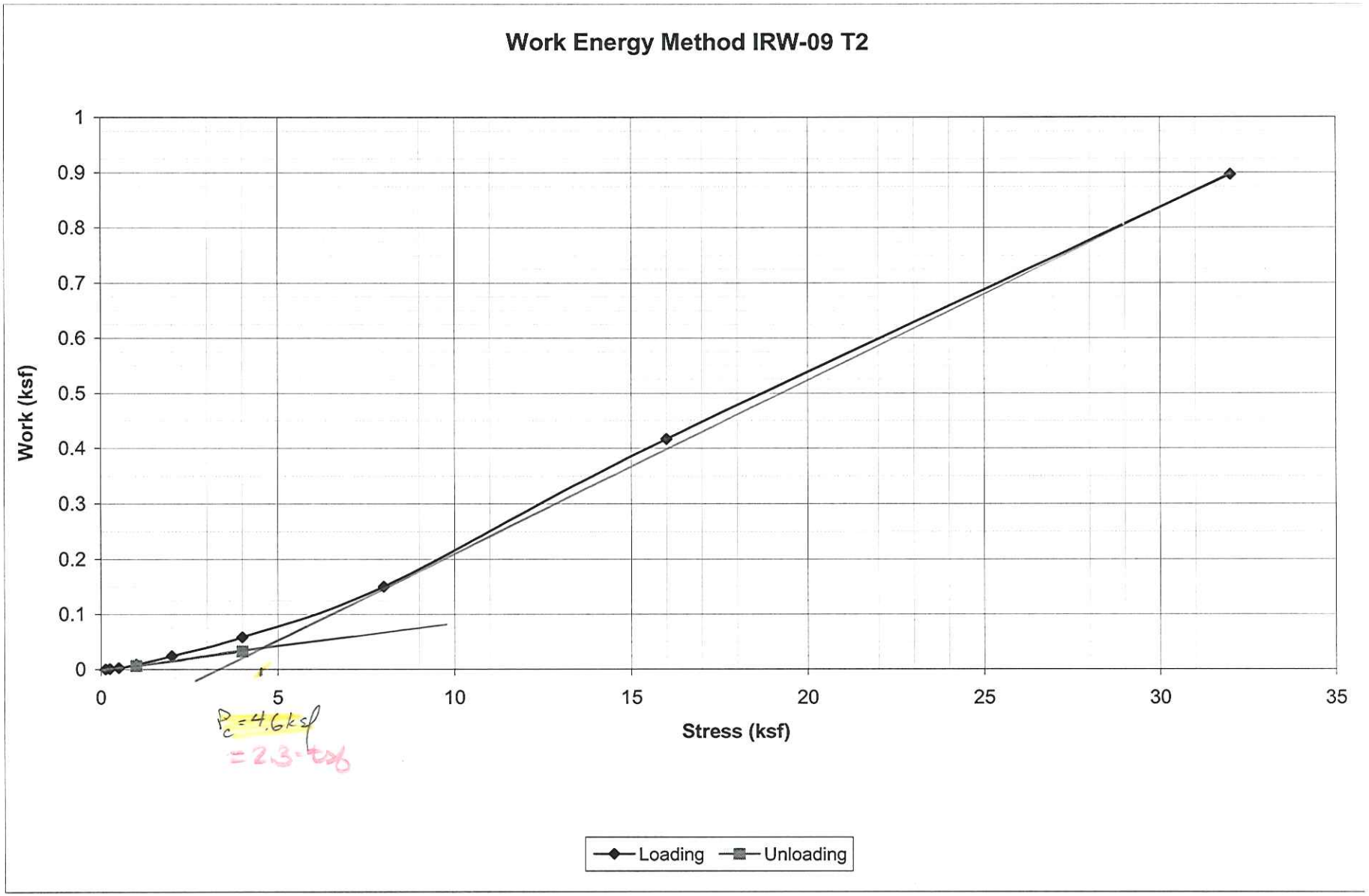
Delaware Turnpike Improvements
SR-1 Interchange



RKK-68

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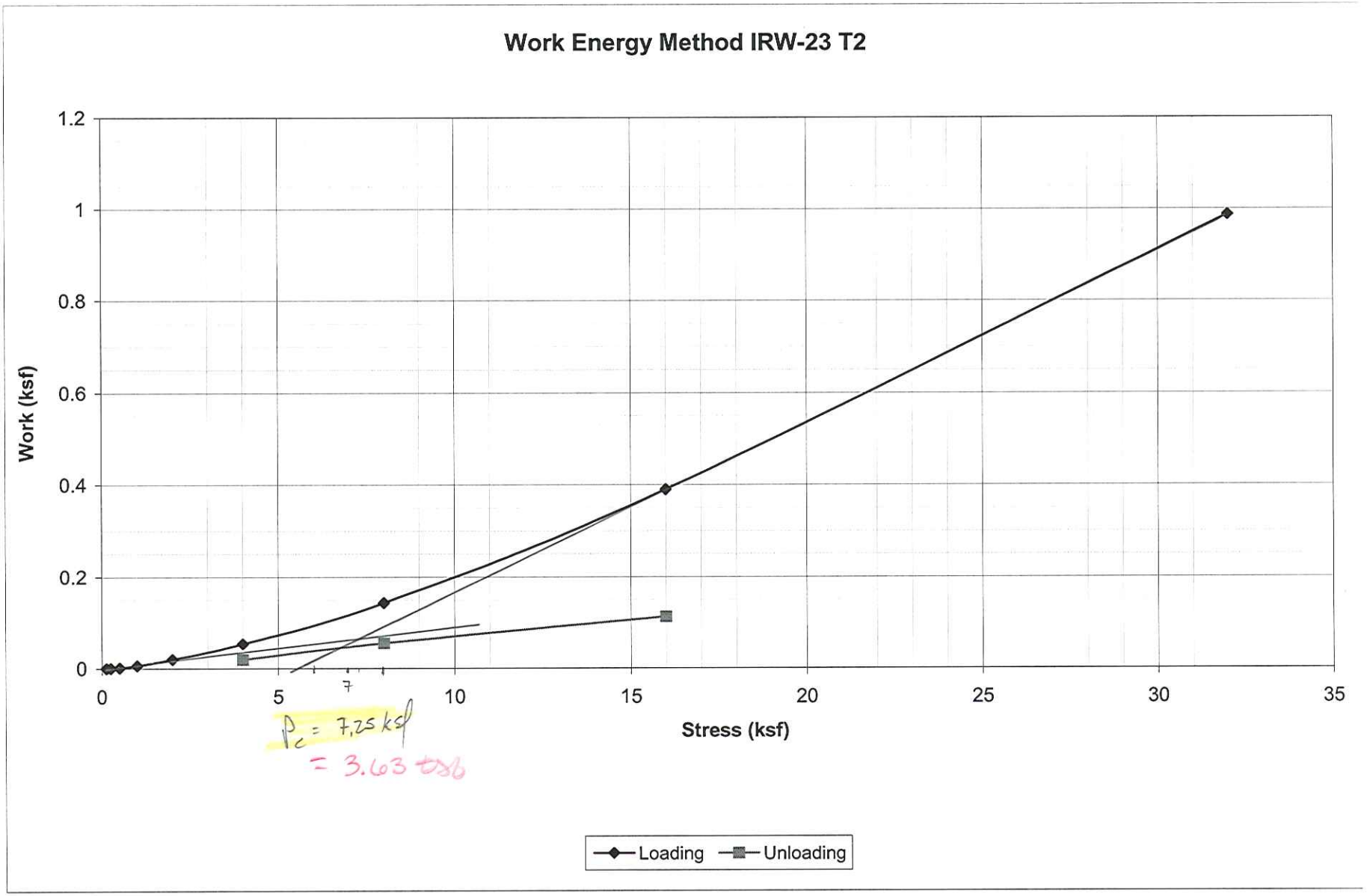
ADT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-69

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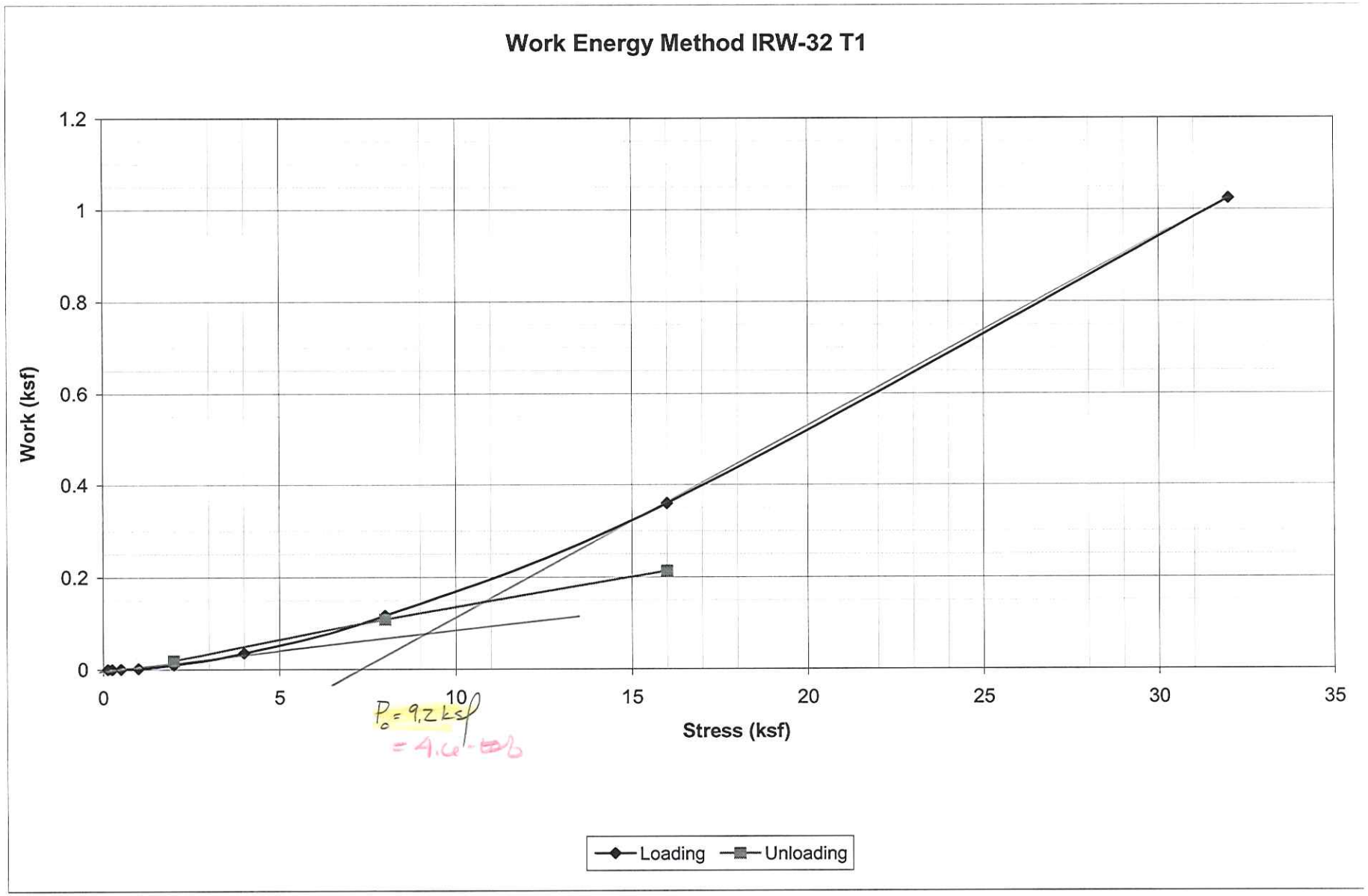
JDT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-70

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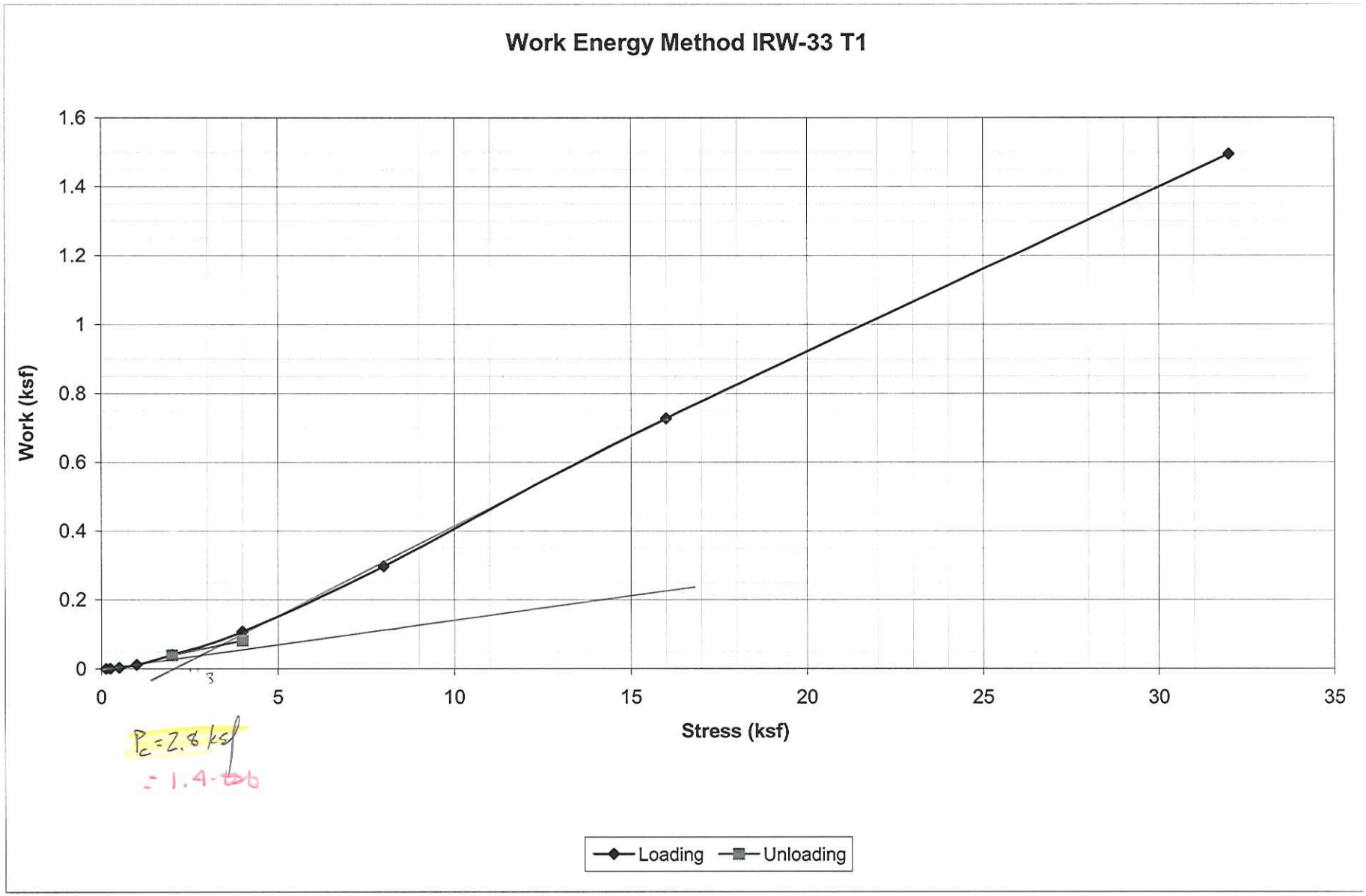
9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-71

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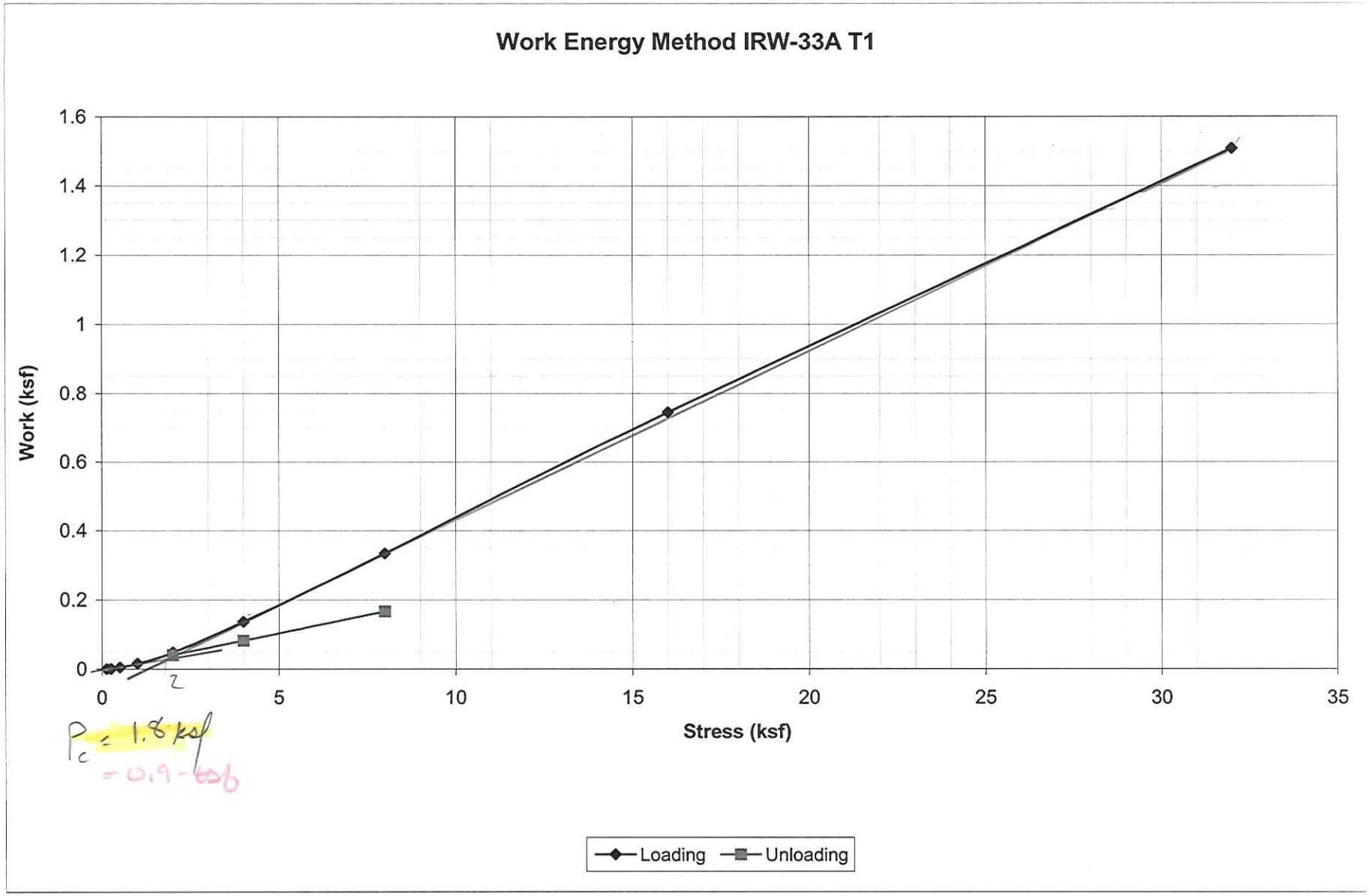
JBT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-72

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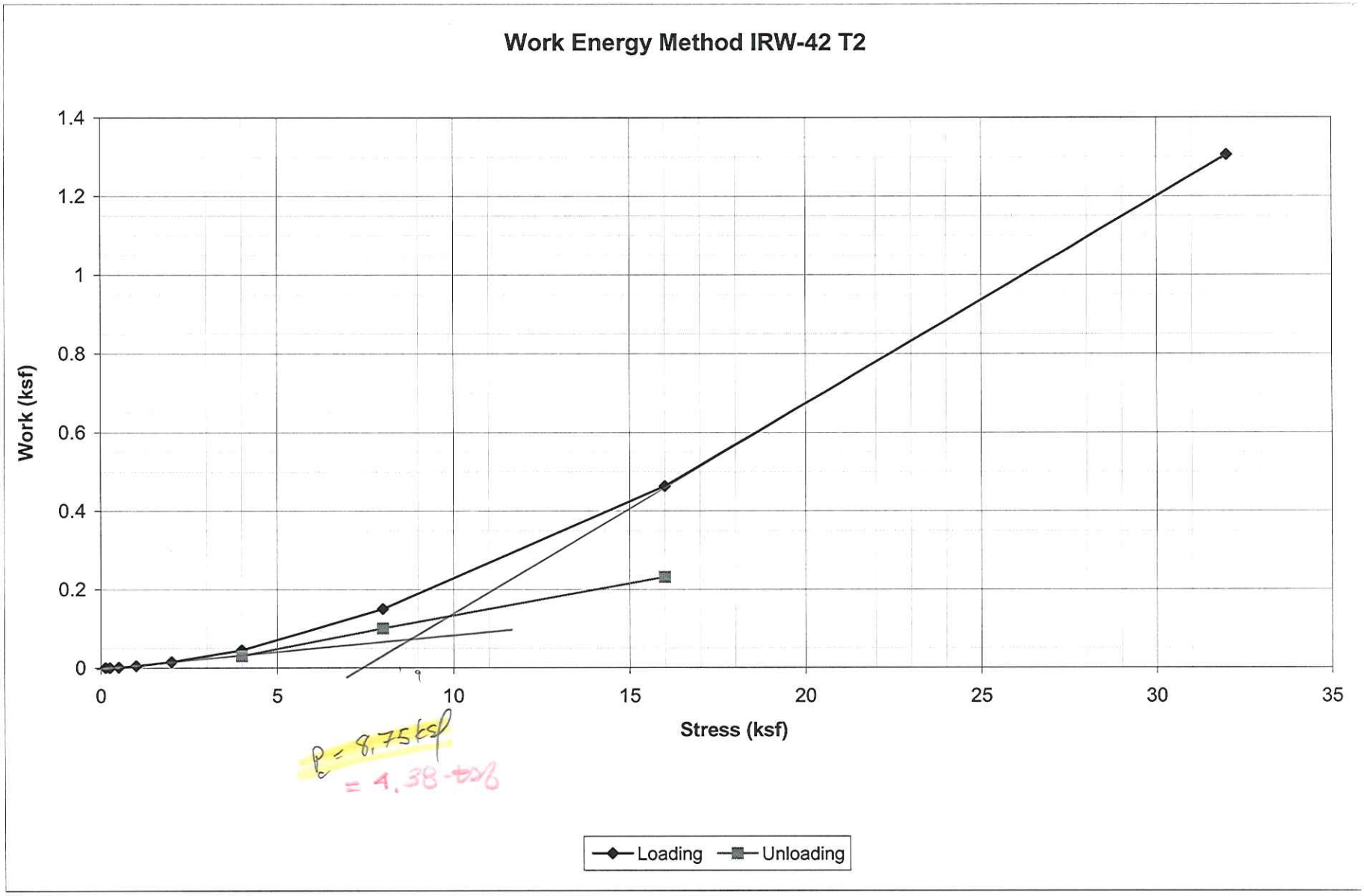
JCDT
2-30-08

Delaware Turnpike Improvements
SR-1 Interchange



JOT 9-30-08

RKK-73

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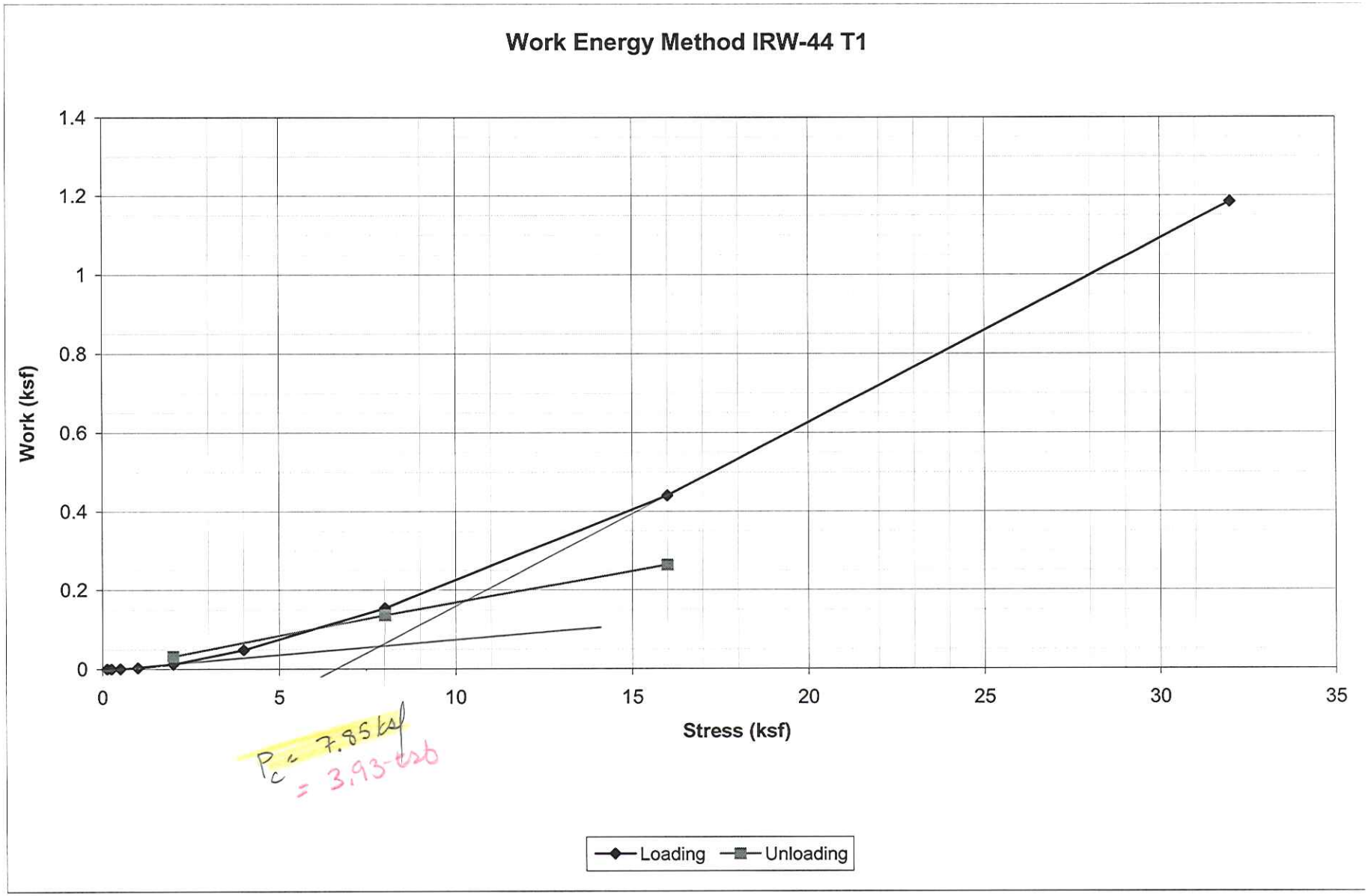
Delaware Turnpike Improvements
SR-1 Interchange



RKK-74

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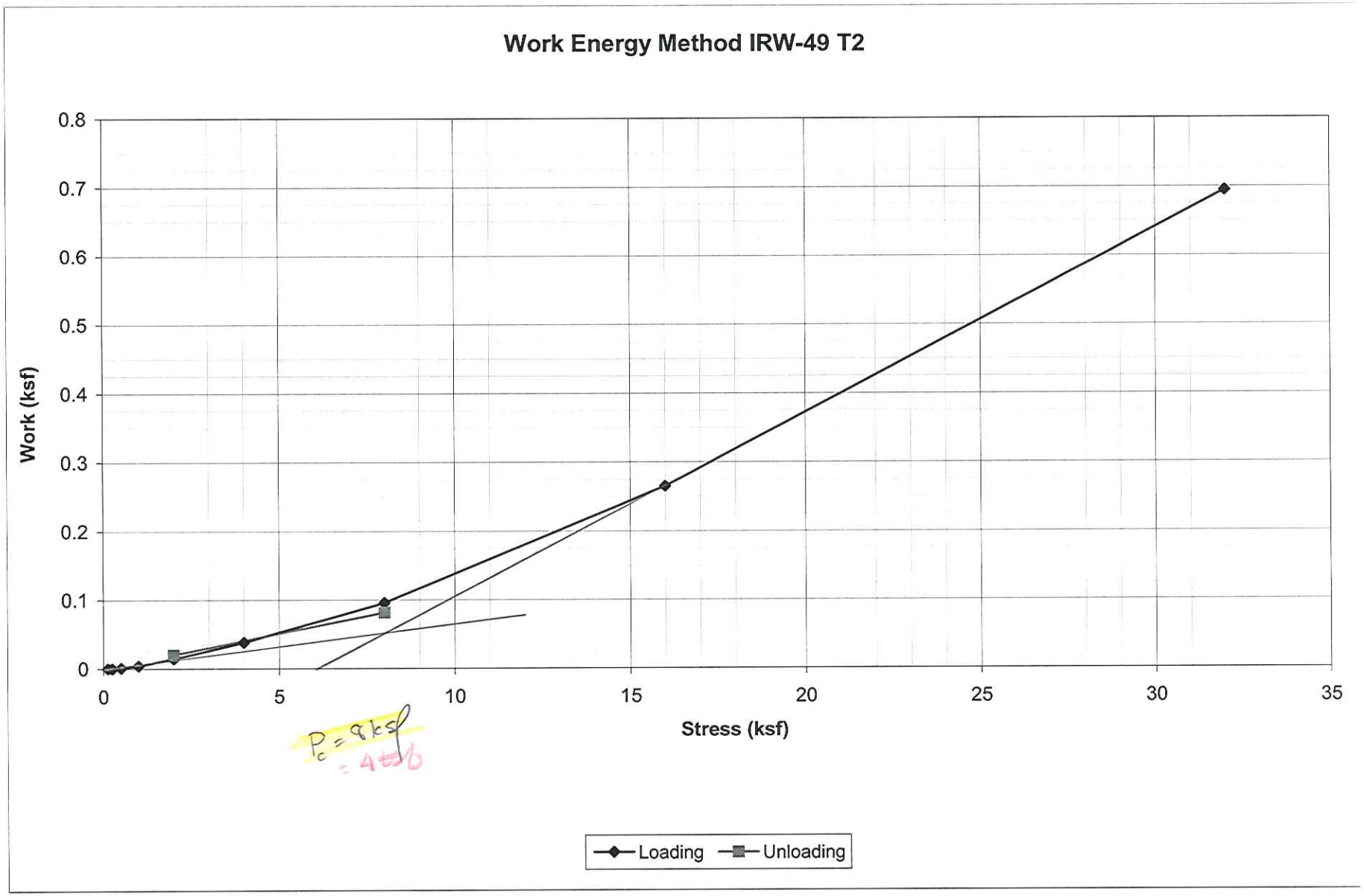
JDT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-75

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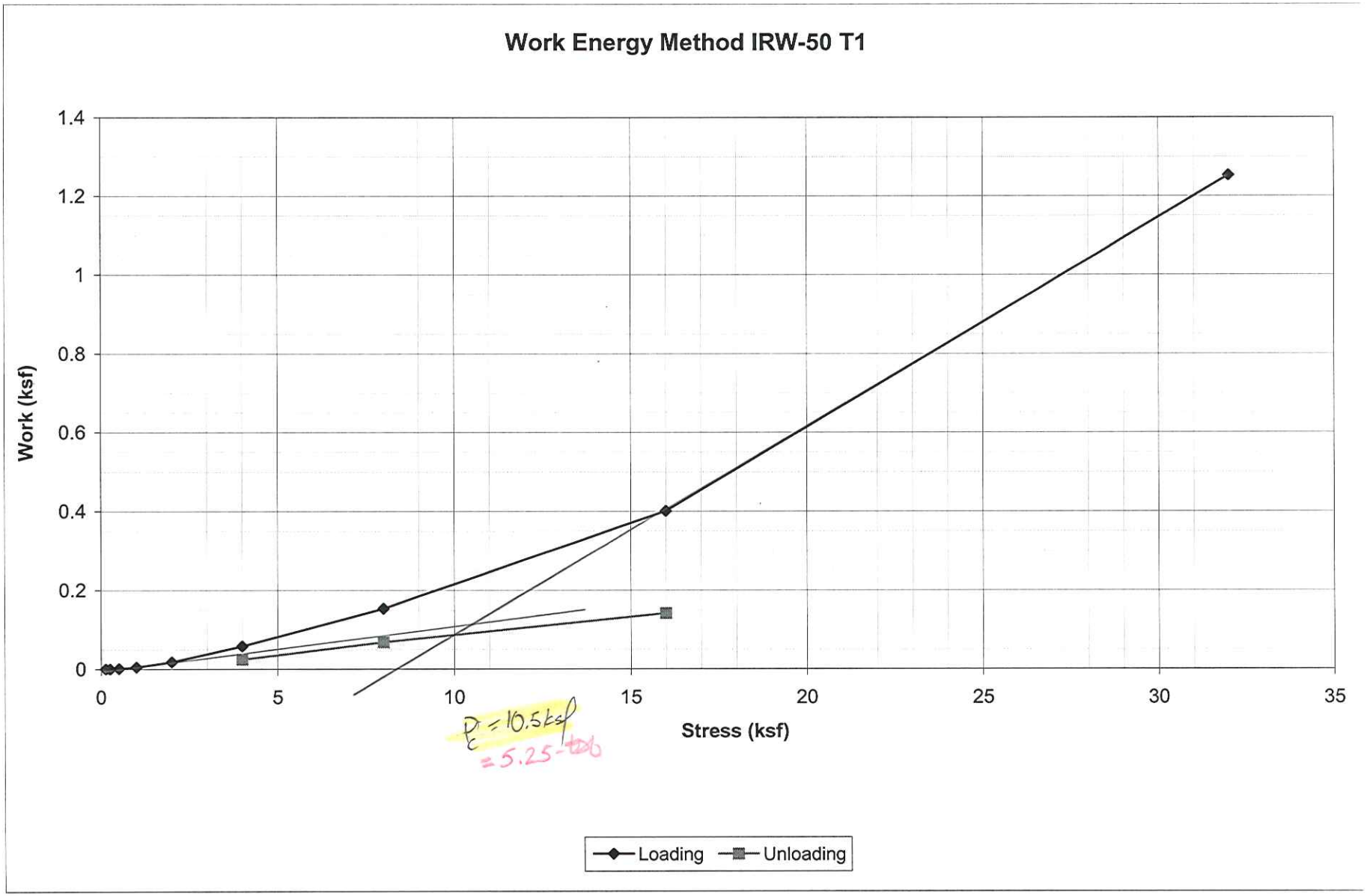
JCT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



JCT 9-30-08

RKK-76
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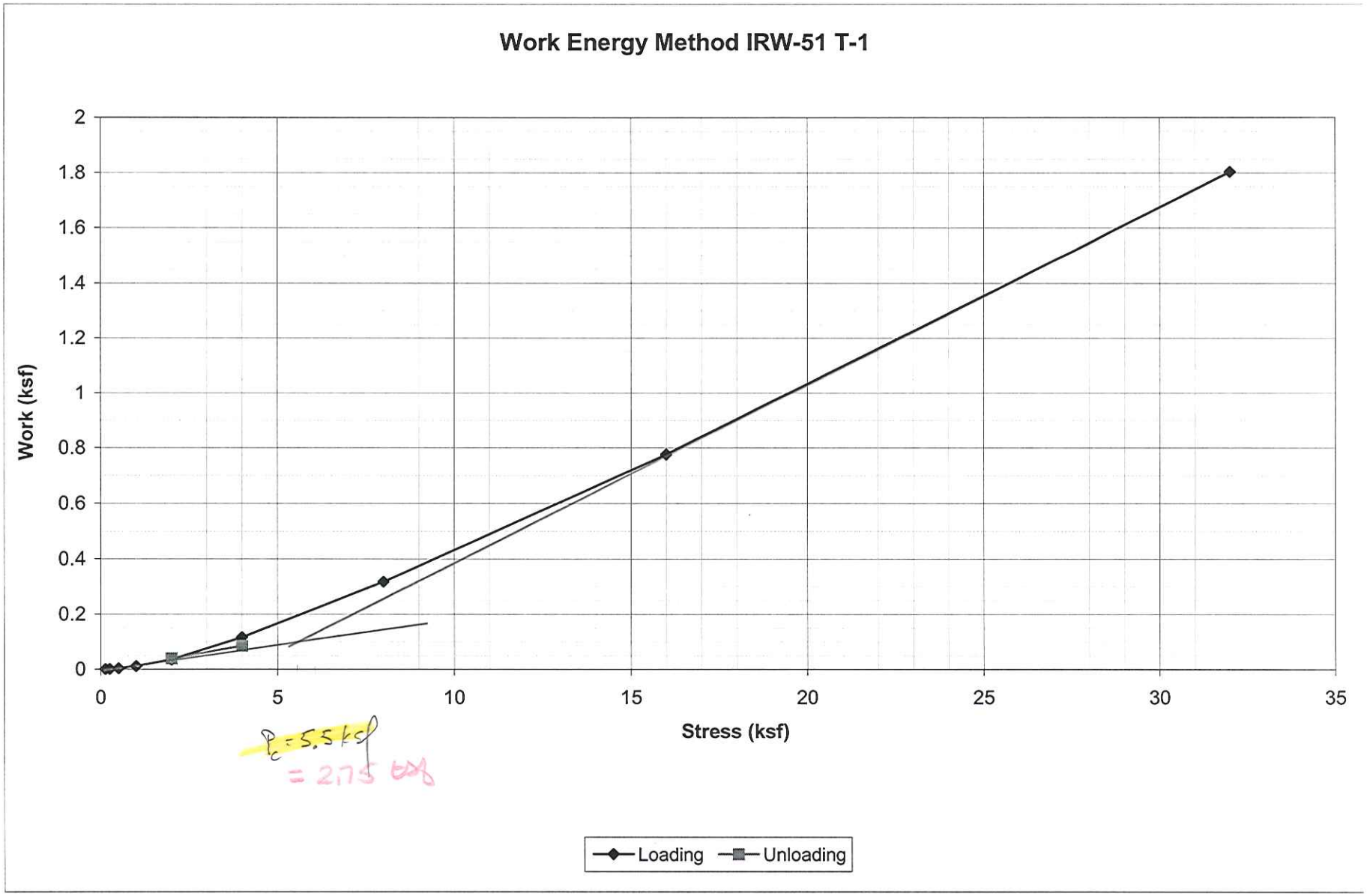
Delaware Turnpike Improvements
SR-1 Interchange



RKK-77
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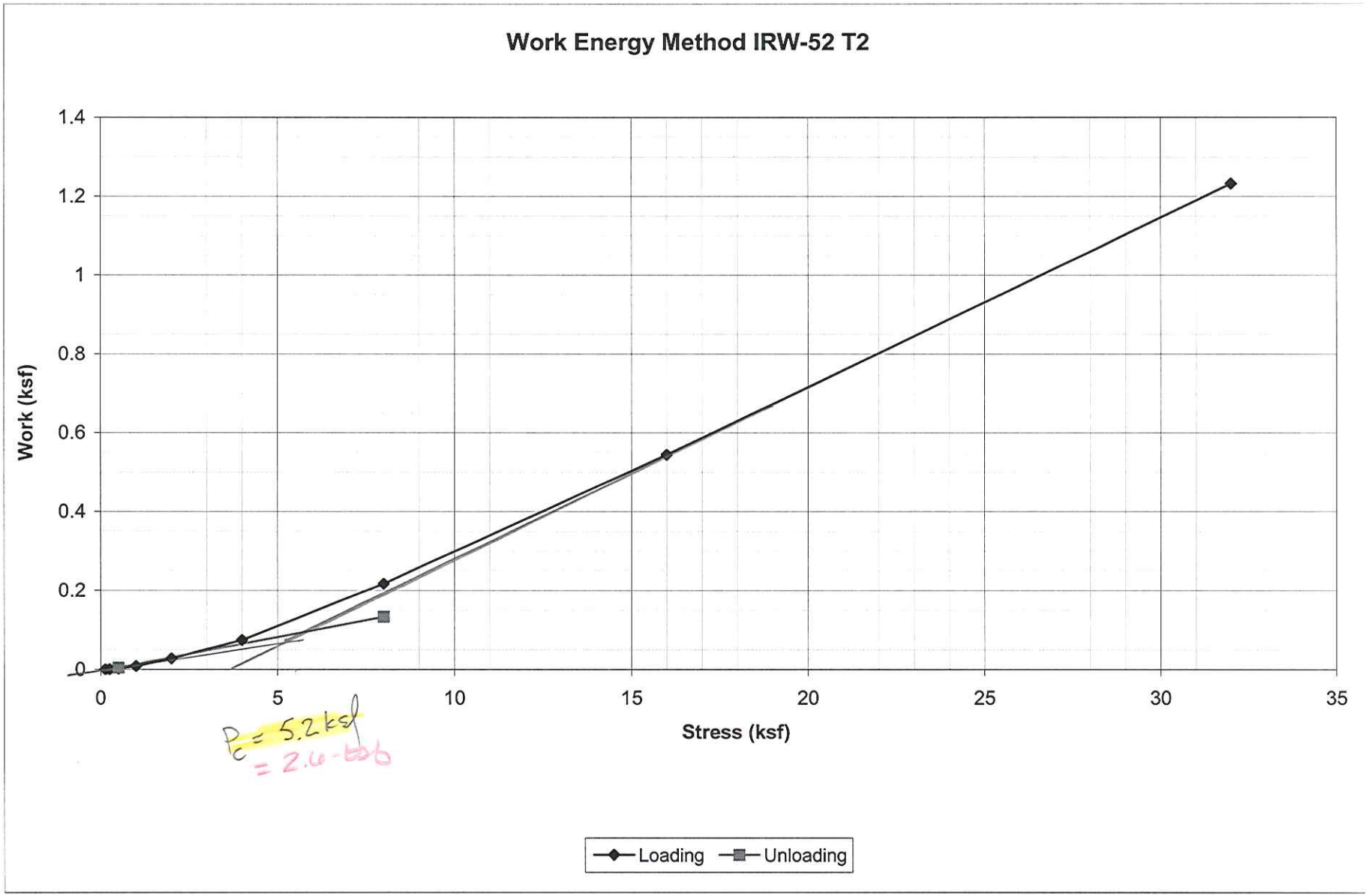
JDT
9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



RKK-78
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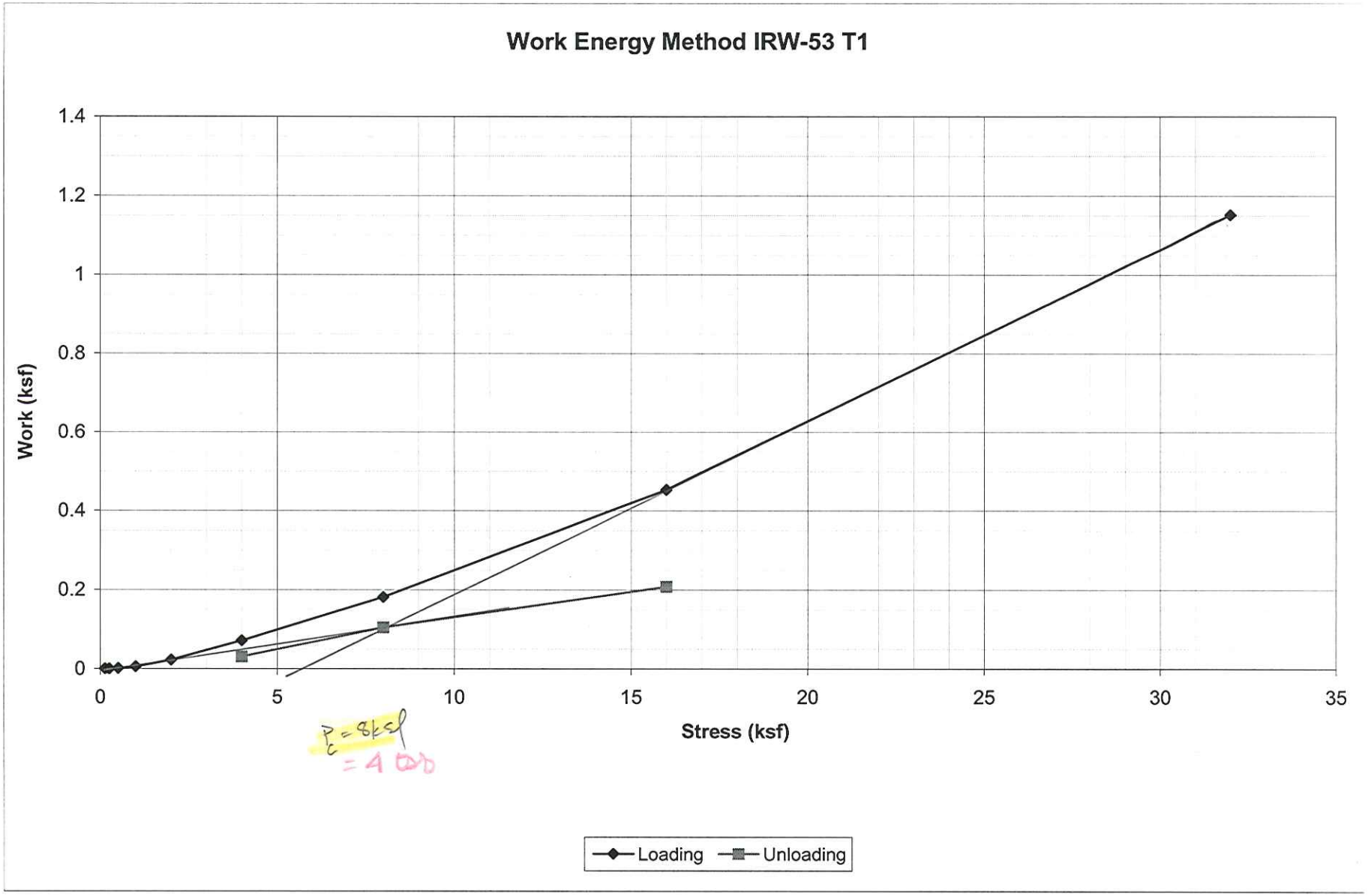
JDT 9-30-08

Delaware Turnpike Improvements
SR-1 Interchange



JDT 9-30-08

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.

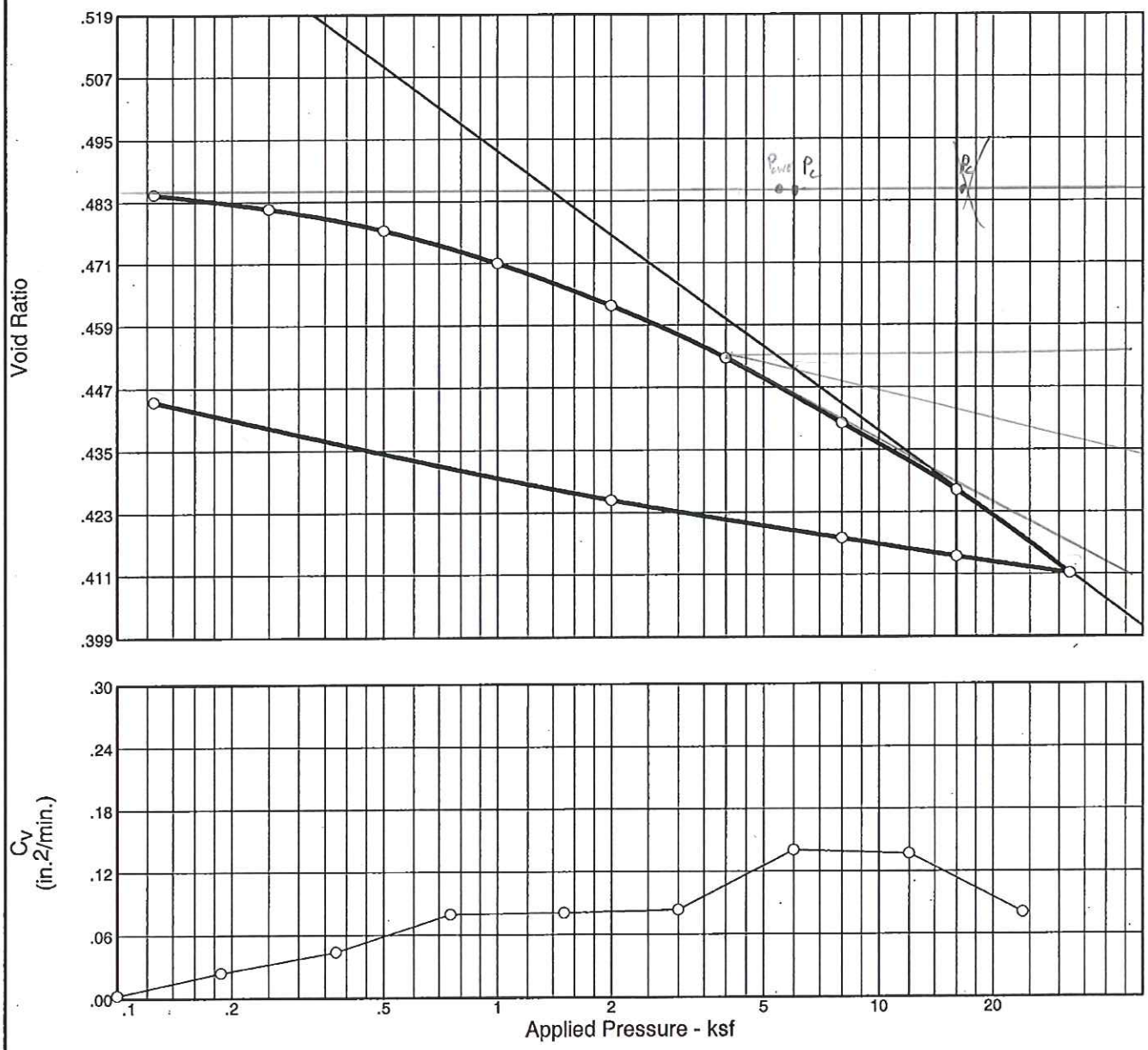
The most realistic P_c is indicated as Final P_c in the Summary Table. The Final OCR was estimated by Final P_c / P_o.

* 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 Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf) P_{cue}	C_c	C_r	Initial Void Ratio
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 P_c 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

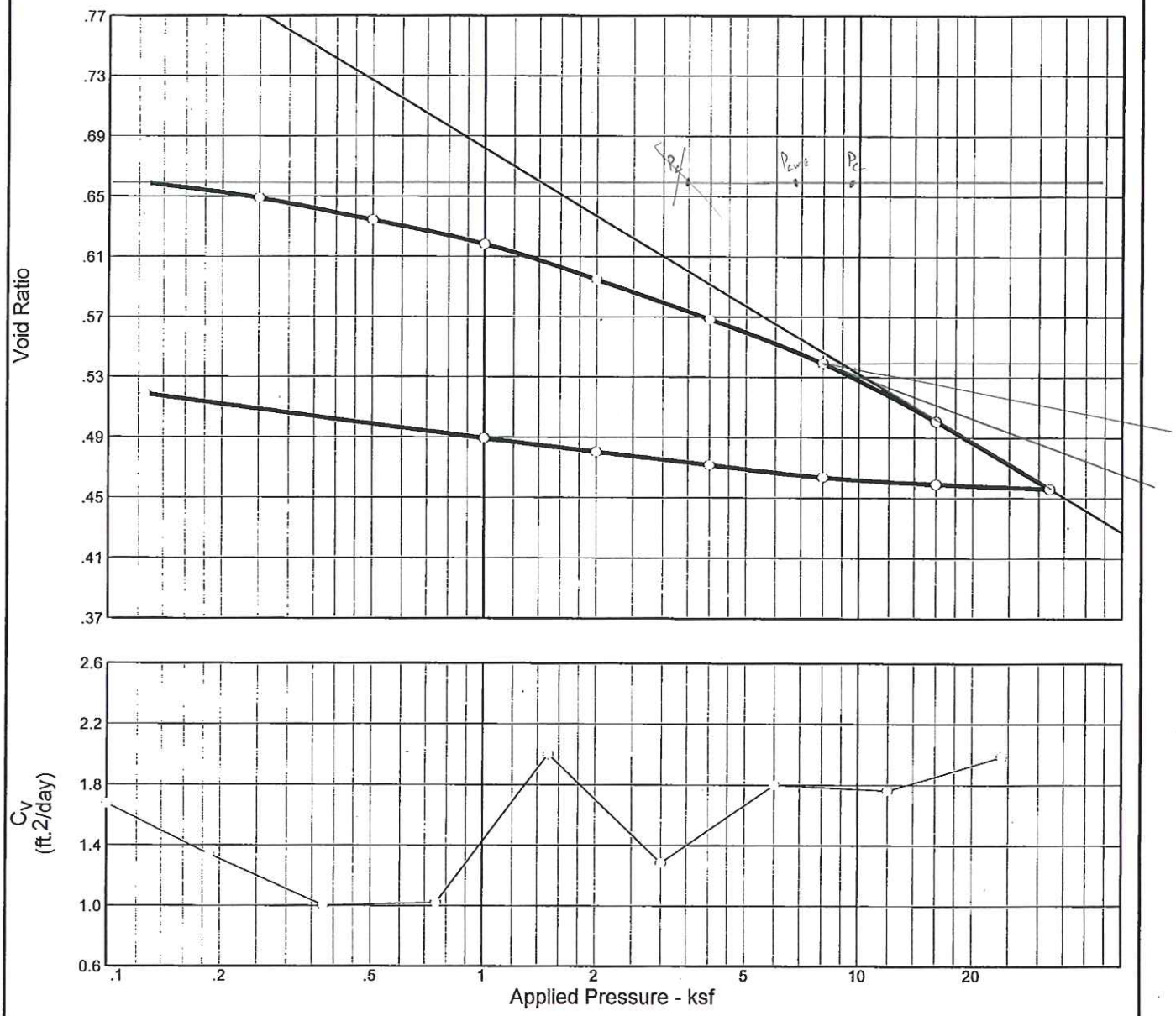
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT
9-30-08

RKK-82

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf) Pcue	C_c	C_r	Initial Void Ratio
70.9 %	17.4 %	101.4	21	3	2.696		~~3.47~~ / ~~6.75~~ 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

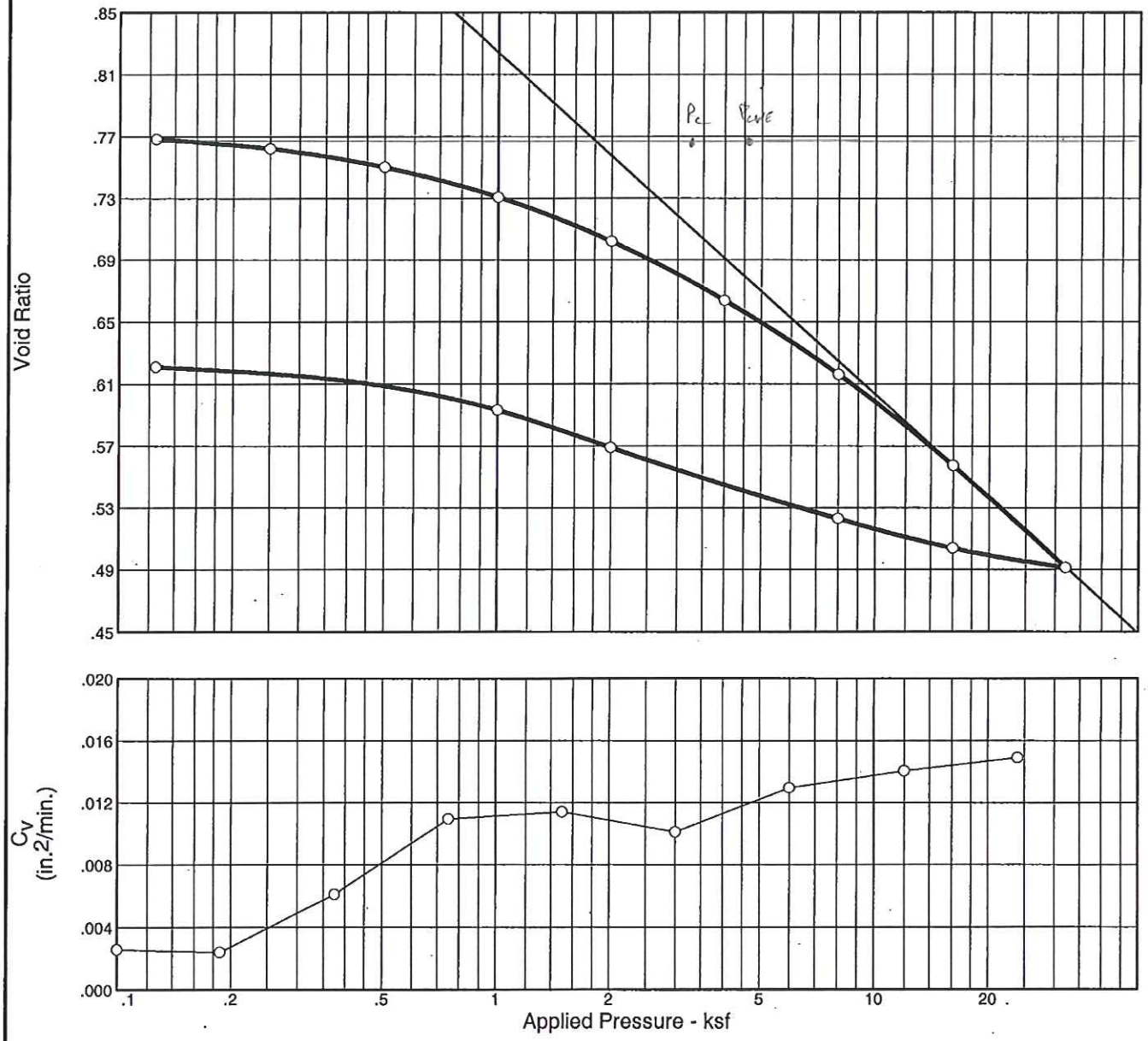
CONSOLIDATION TEST REPORT (ASTM D2435)

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) Pcure	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 Final Pc => 3.93 ksf	USCS	AASHTO
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

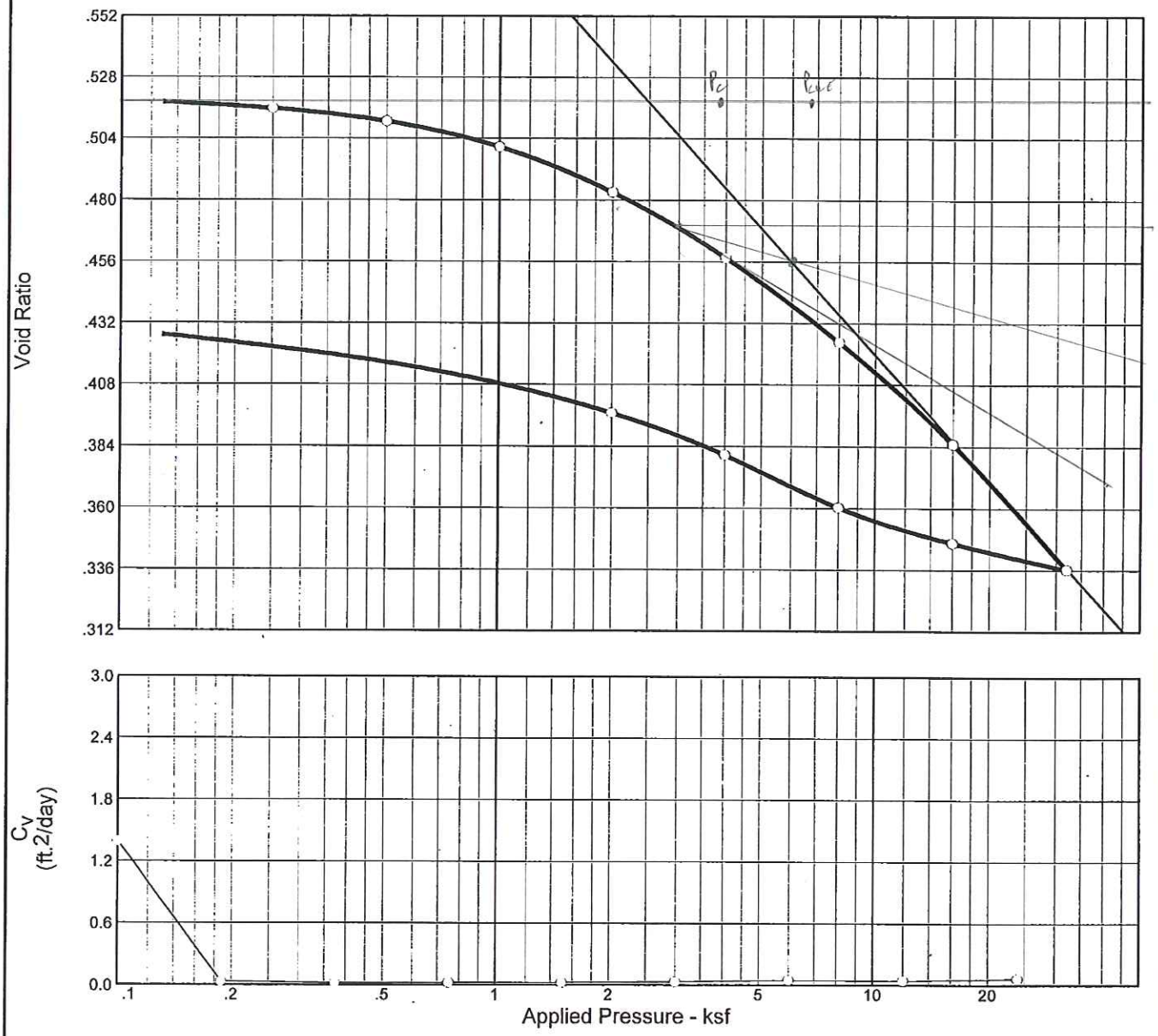
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 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.w.e	C_c	C_r	Initial Void Ratio
88.9 %	16.7 %	113.7	31	13	2.766		~~3.84~~ / ~~6.75~~ 6 ksf	0.16	0.05	0.519

MATERIAL DESCRIPTION	USCS	AASHTO
Mottled Brown & Tan LEAN CLAY. Final Pc => 6.38 ksf	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

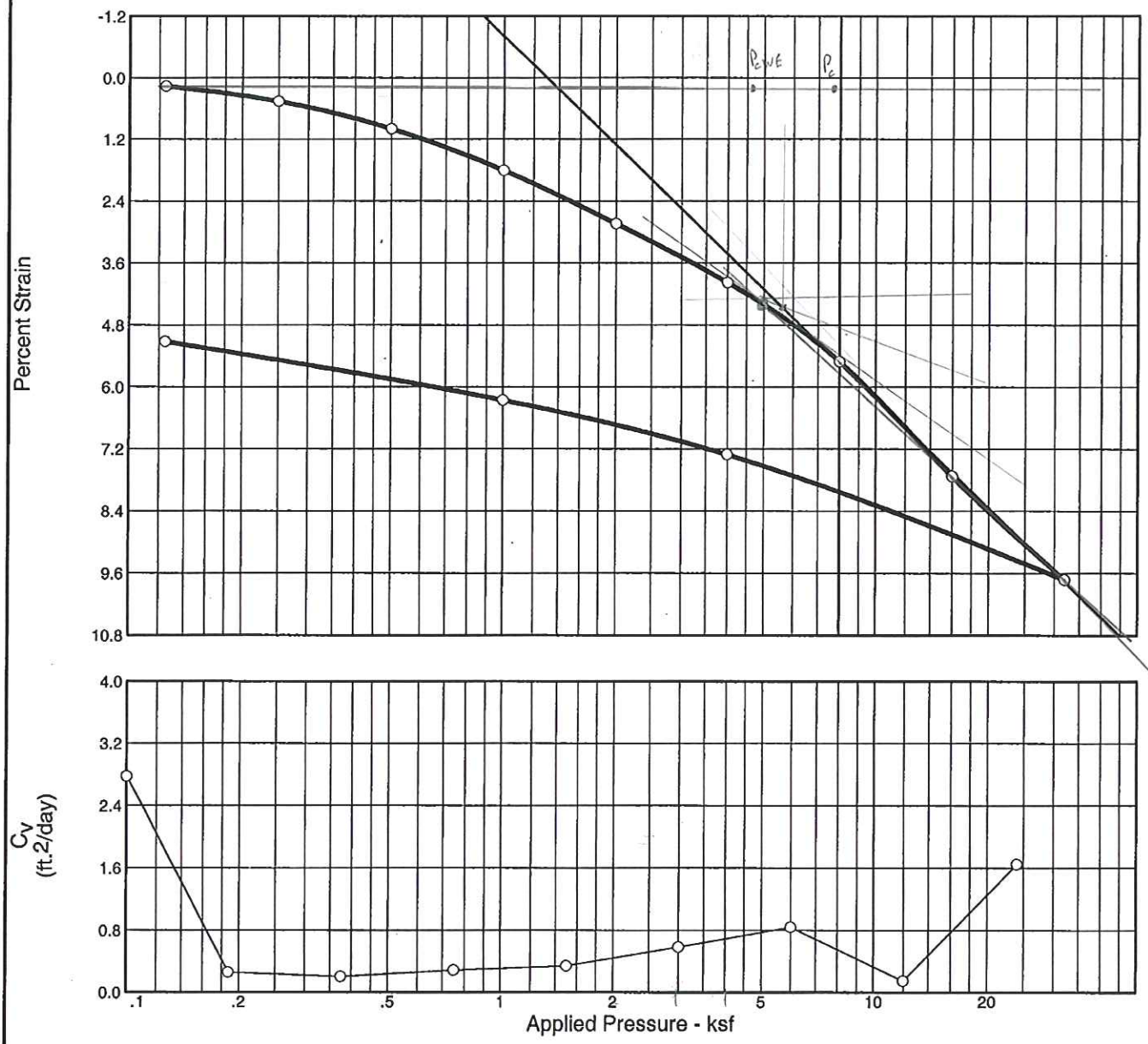
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 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 Fine Pc NV	USCS	AASHTO
Gray SANDY ORGANIC CLAY.	OL	

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

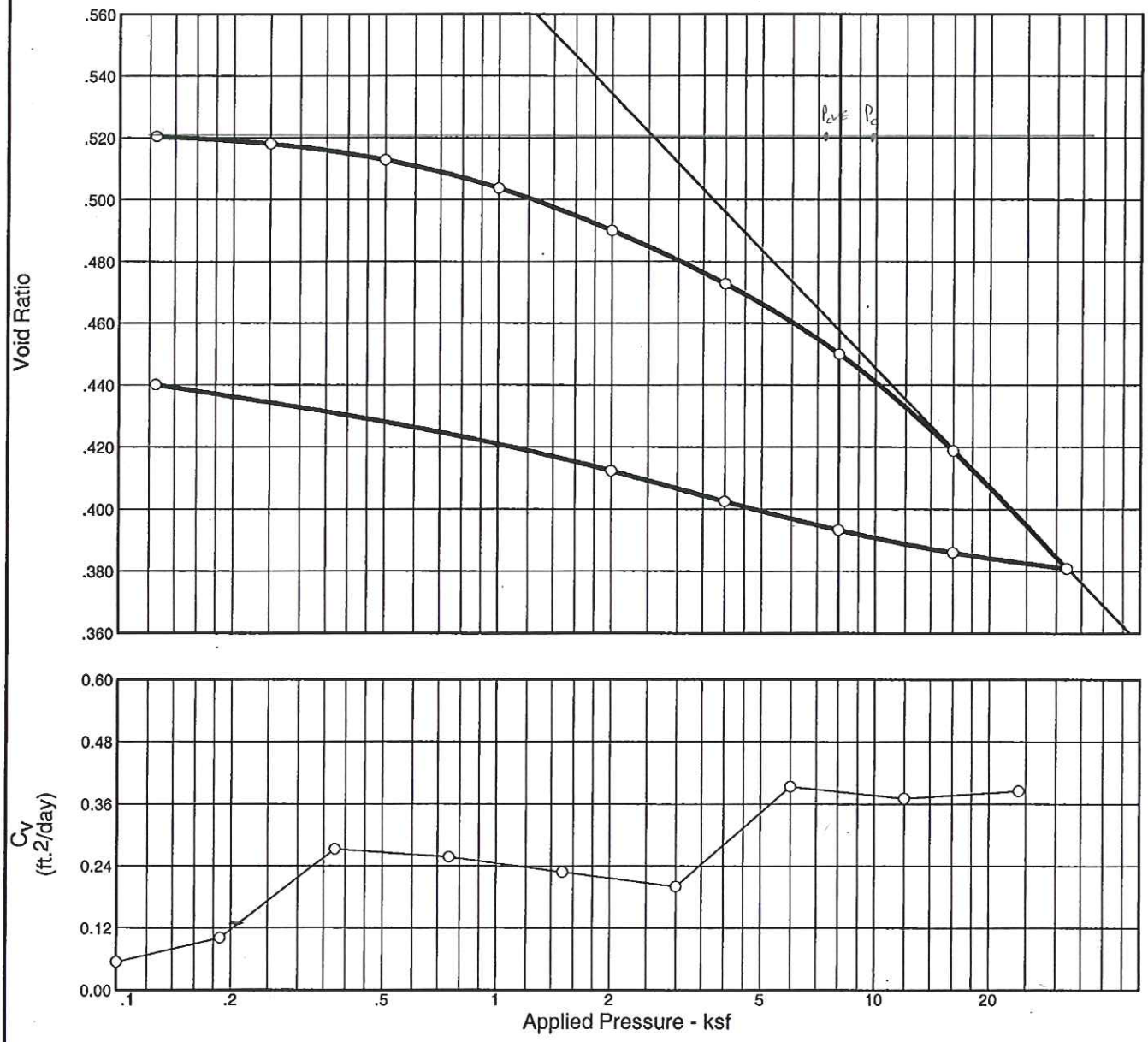
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 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) P_{cve}	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 Final P_c => 8.58 ksf	USCS	AASHTO
Mottled Red & Gray LEAN CLAY.	CL	

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

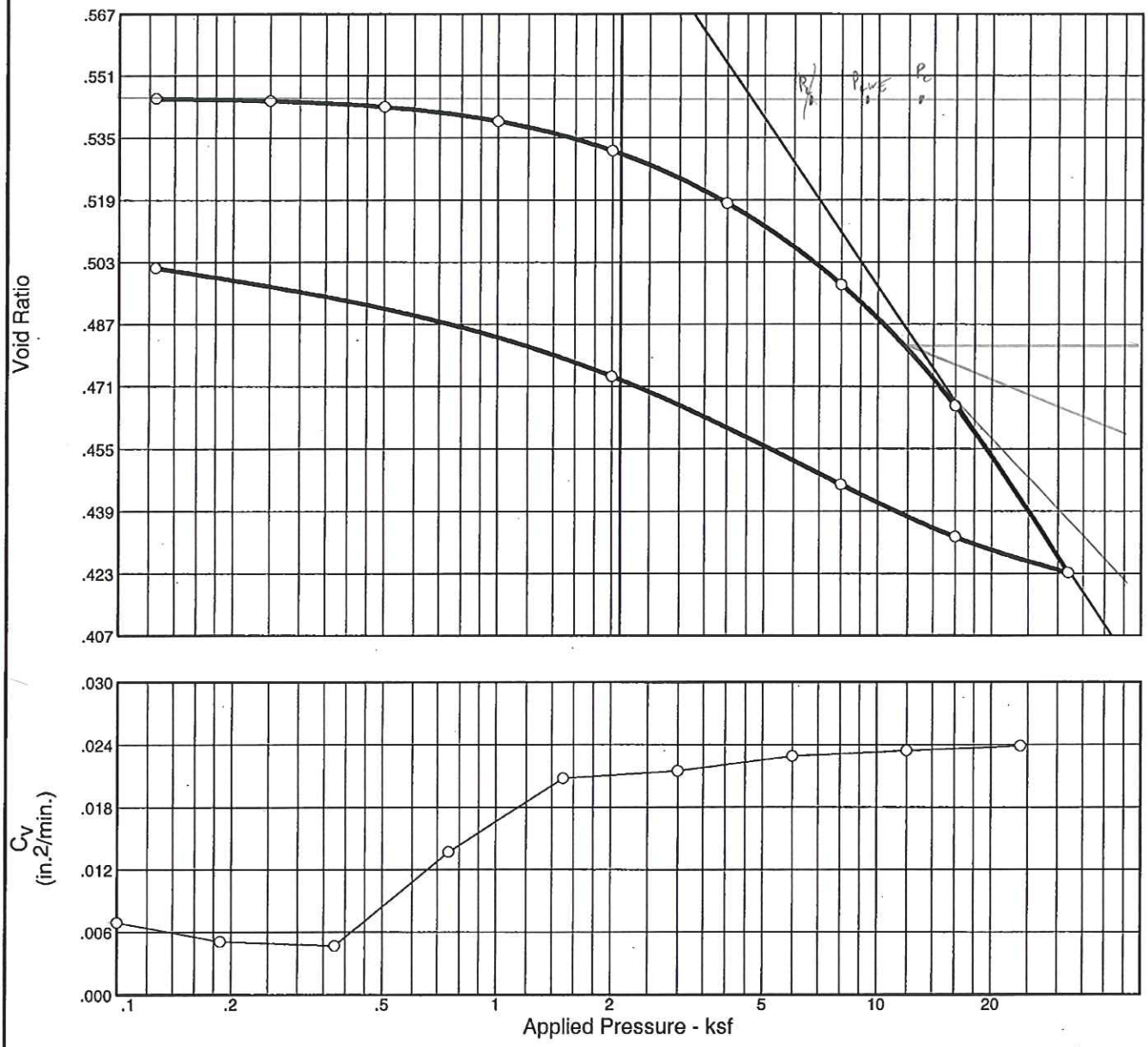
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 9-30-08

RKK-87

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf) Pcure	C_c	C_r	Initial Void Ratio
96.8 %	19.0 %	114.2	39	20	2.78		~~6.68~~ 9.2 ~13	0.14	0.04	0.545

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

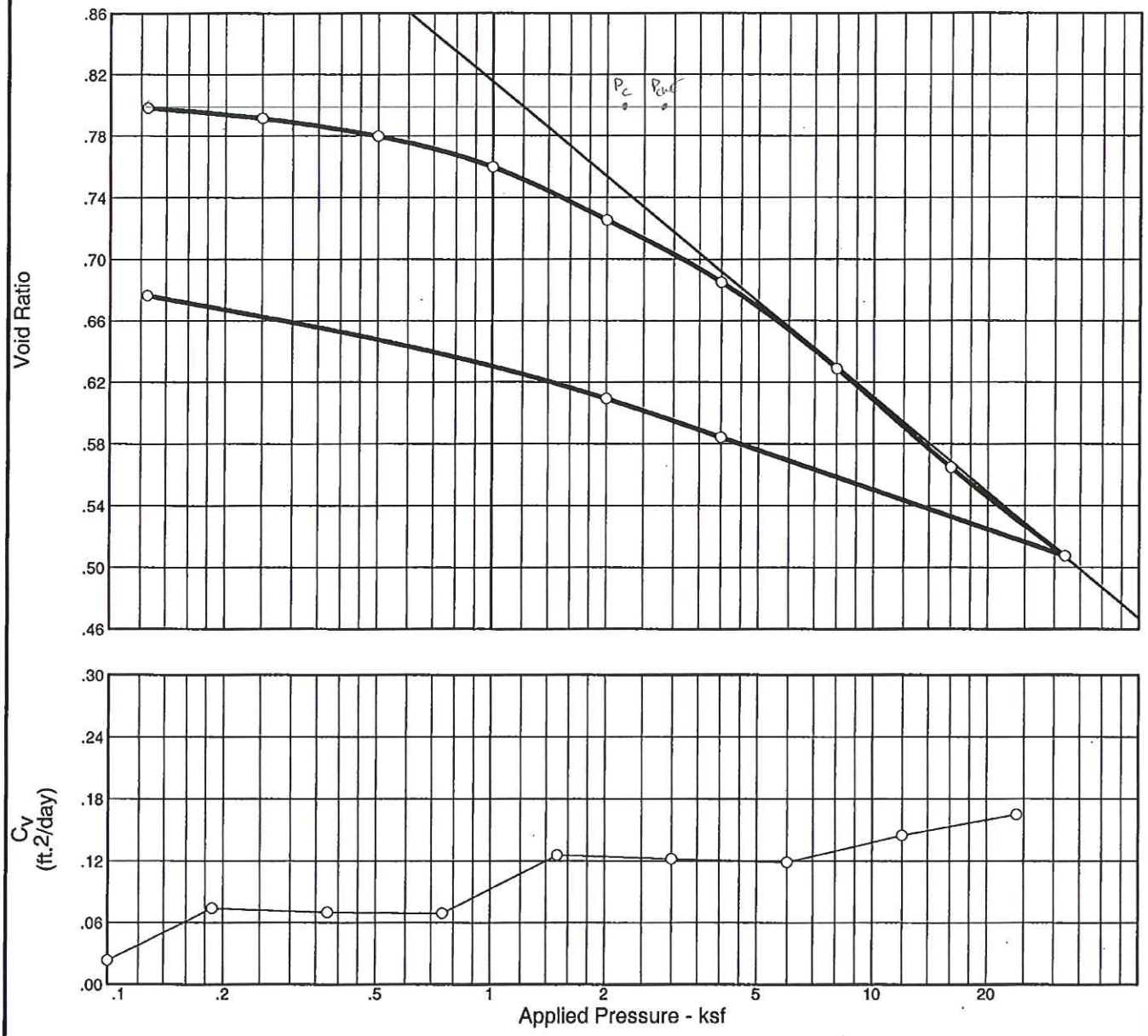
CONSOLIDATION TEST REPORT (ASTM D2435)

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)	P_c (ksf) Pcurve	C_c	C_r	Initial Void Ratio
94.6 %	26.1 %	100.5	47	25	2.90		2.24 / 2.18	0.20	0.07	0.801

MATERIAL DESCRIPTION Final Pc ⇒ 2.52 ksf	USCS	AASHTO
Red LEAN CLAY.	CL	

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

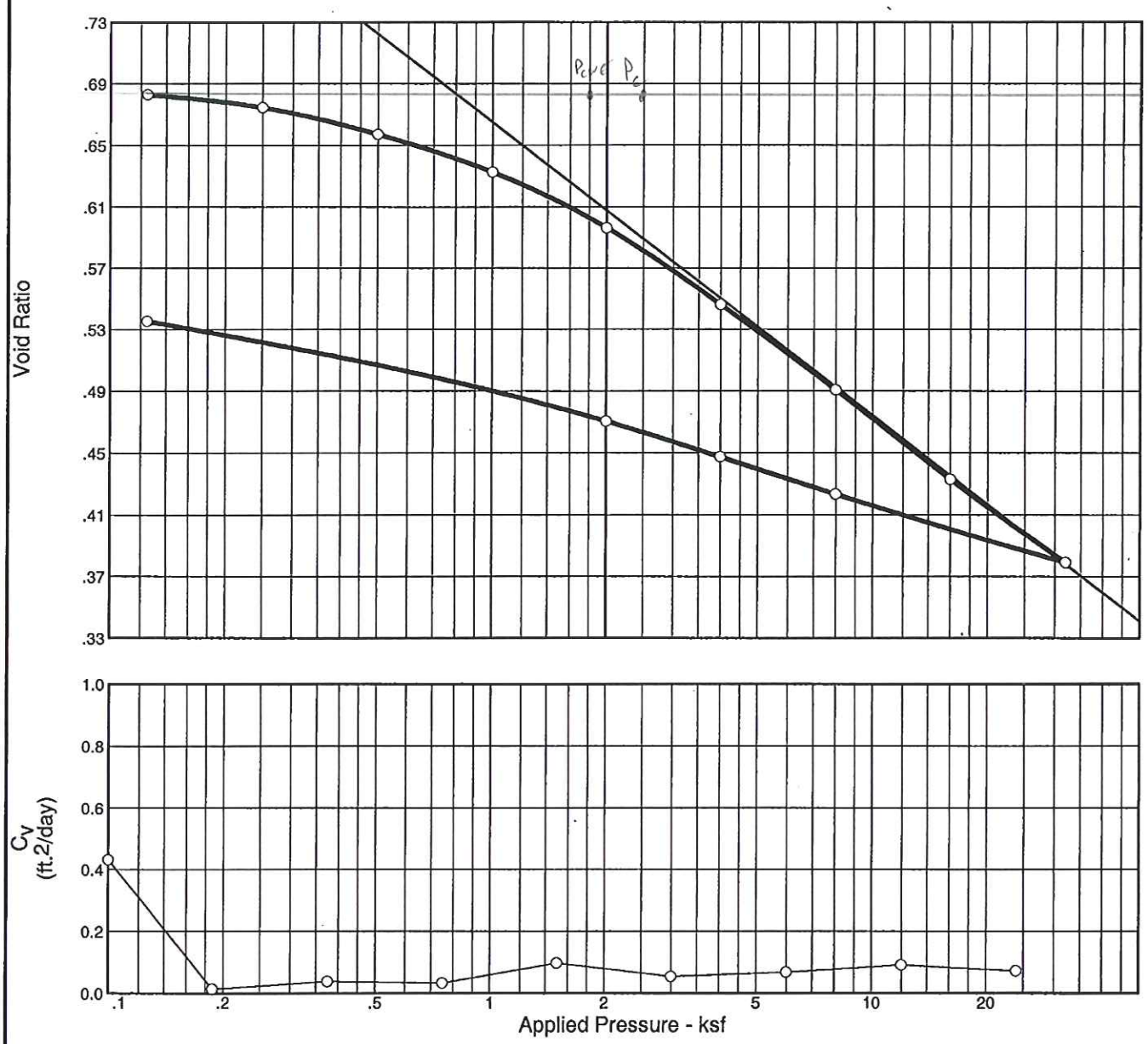
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 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) Pc vs	C_c	C_r	Initial Void Ratio
88.6 %	21.8 %	107.8	42	21	2.787		2.49 / 1.8	0.19	0.07	0.685

MATERIAL DESCRIPTION	USCS	AASHTO
Red LEAN CLAY.	CL	

Final Pc ⇒ 2.15 ksf

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

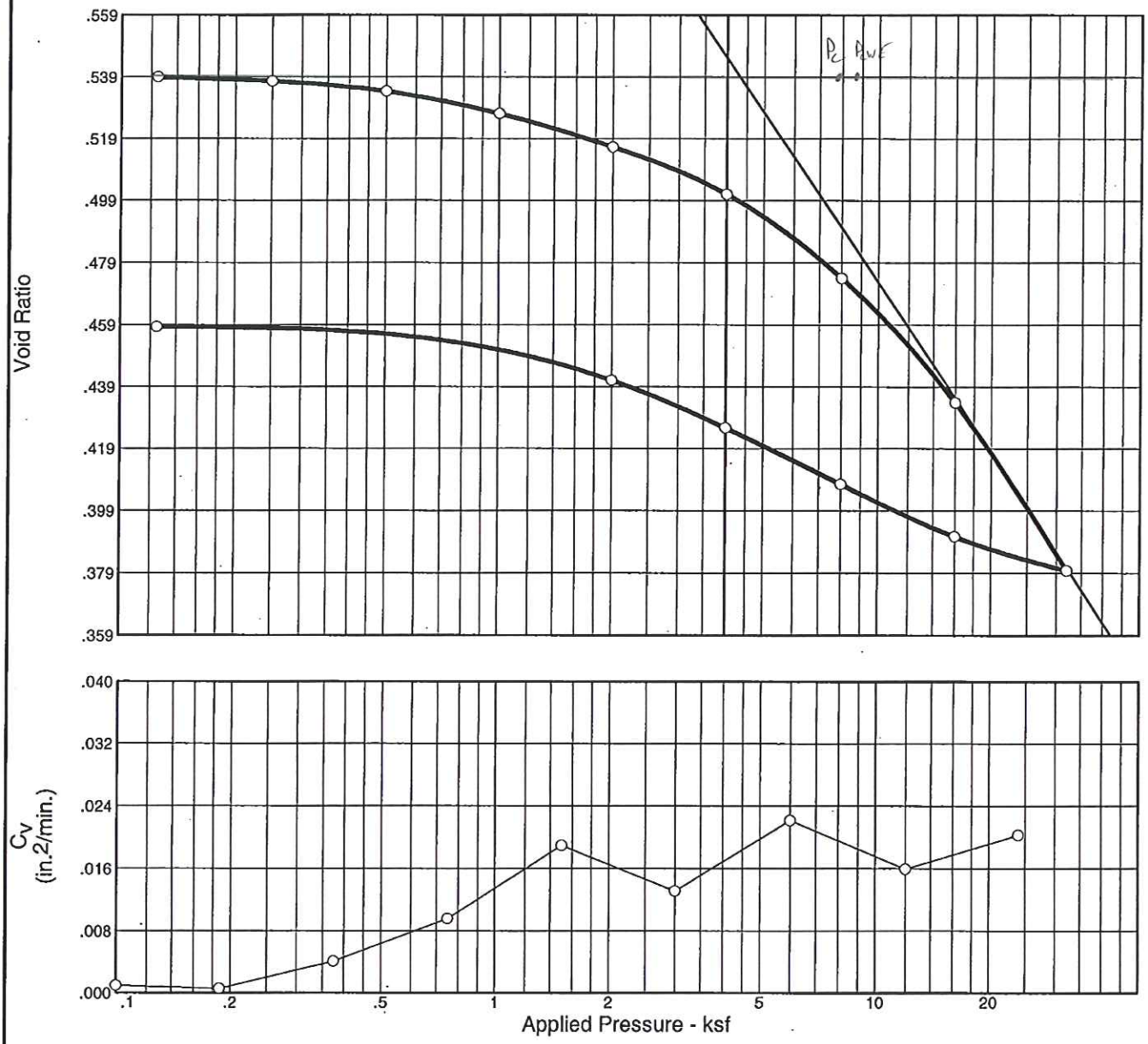
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 9-30-08

RKK-90

CONSOLIDATION TEST REPORT (ASTM D2435)



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

MATERIAL DESCRIPTION	USCS	AASHTO
Final Pc ⇒ 8.34 ksf Mottled Red & Gray Lean CLAY (CL)	CL	

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

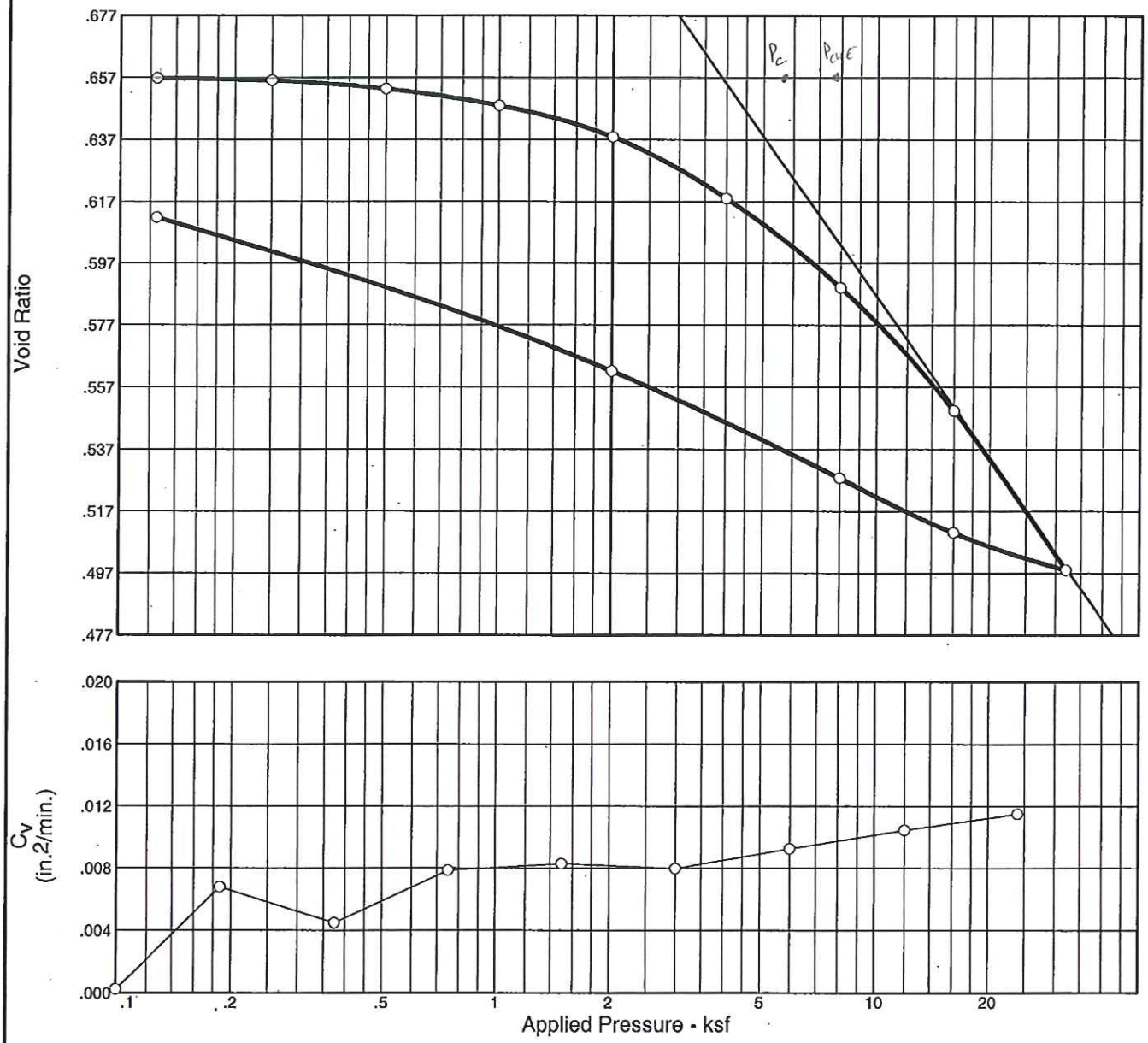
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 9-30-08

RKK-91

CONSOLIDATION TEST REPORT (ASTM D2435)



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (ksf)	P_c (ksf) Pcve	C_c	C_r	Initial Void Ratio
98.5 %	23.5 %	103.6	40	21	2.75		5.81 / 7.85	0.17	0.05	0.657

MATERIAL DESCRIPTION Final Pc => 6.83 ksf	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

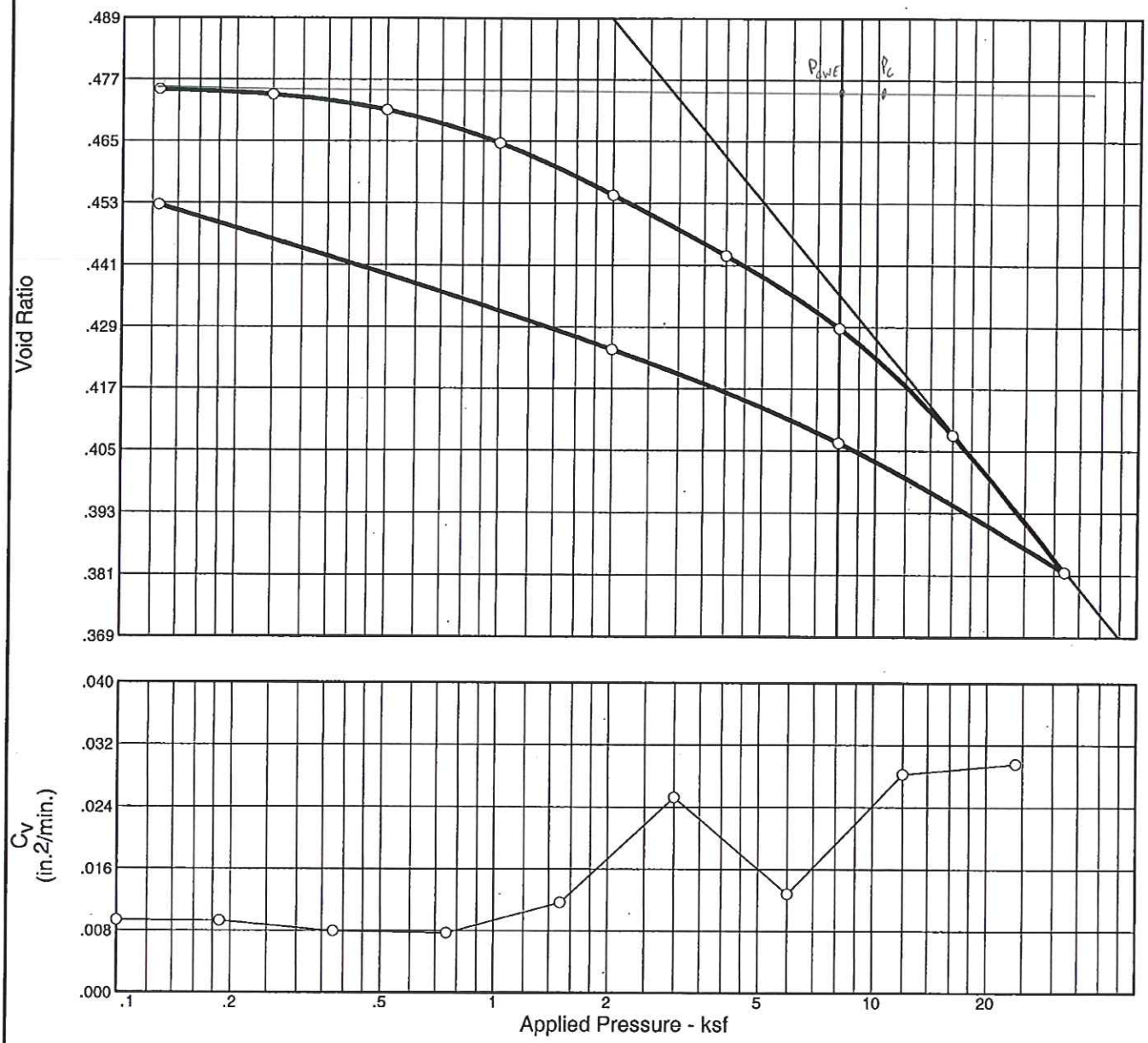
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 9-30-08

RKK-92

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
97.7 %	17.3 %	113.4	60	41	2.68		10.21 / 8 Pcwe	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

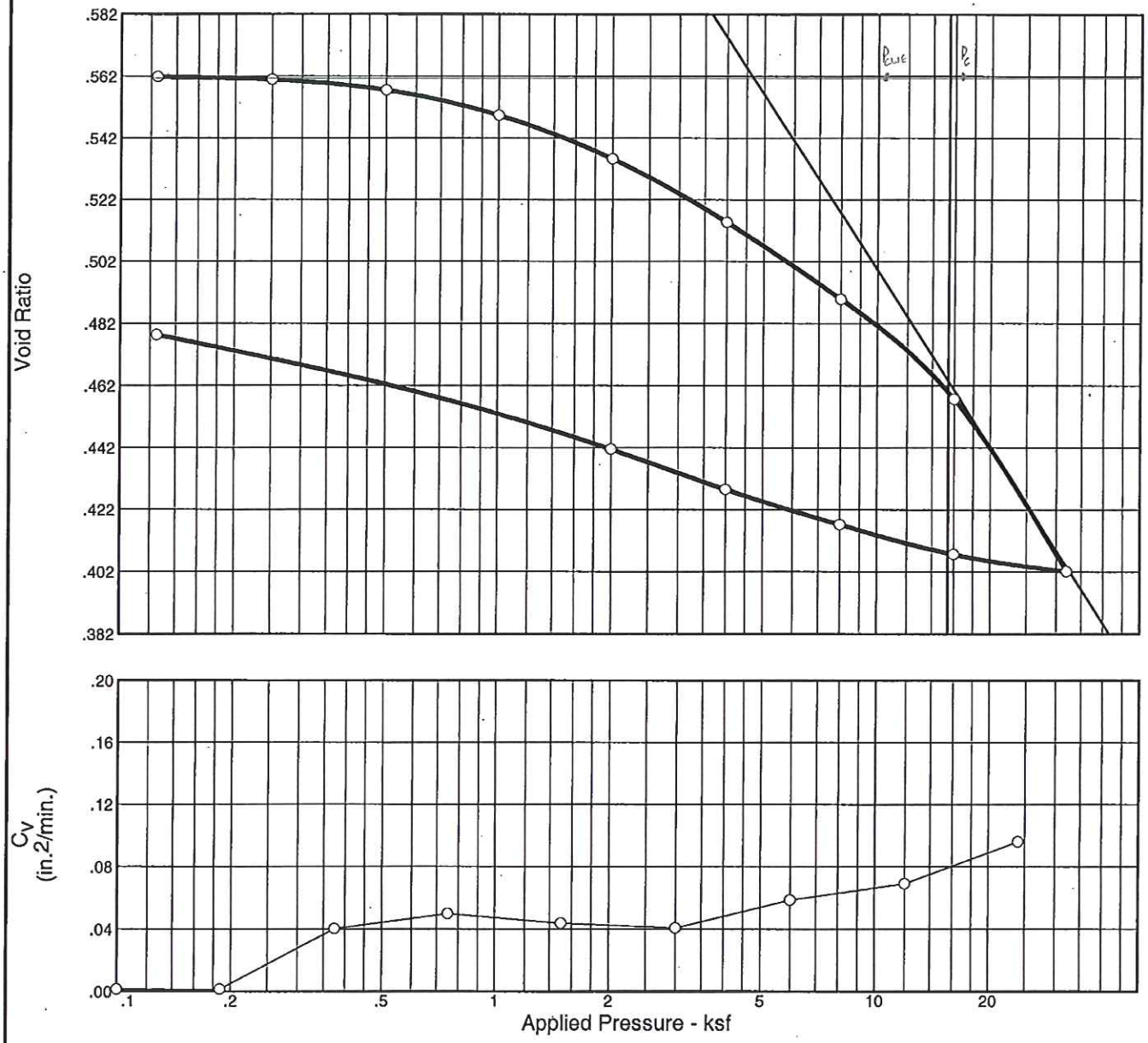
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 9-30-08

RKK-93

CONSOLIDATION TEST REPORT (ASTM D2435)



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

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

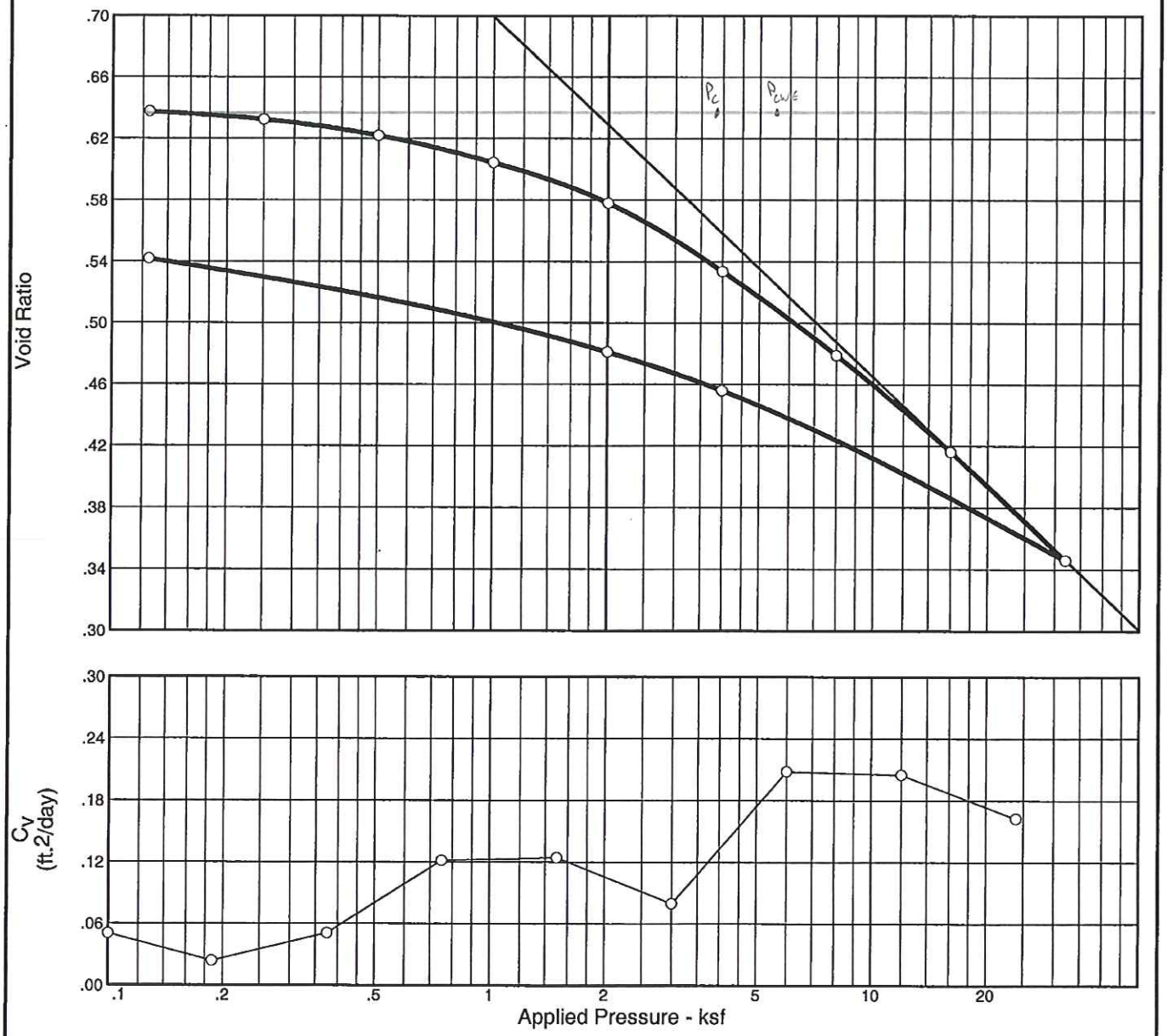
CONSOLIDATION TEST REPORT (ASTM D2435)

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

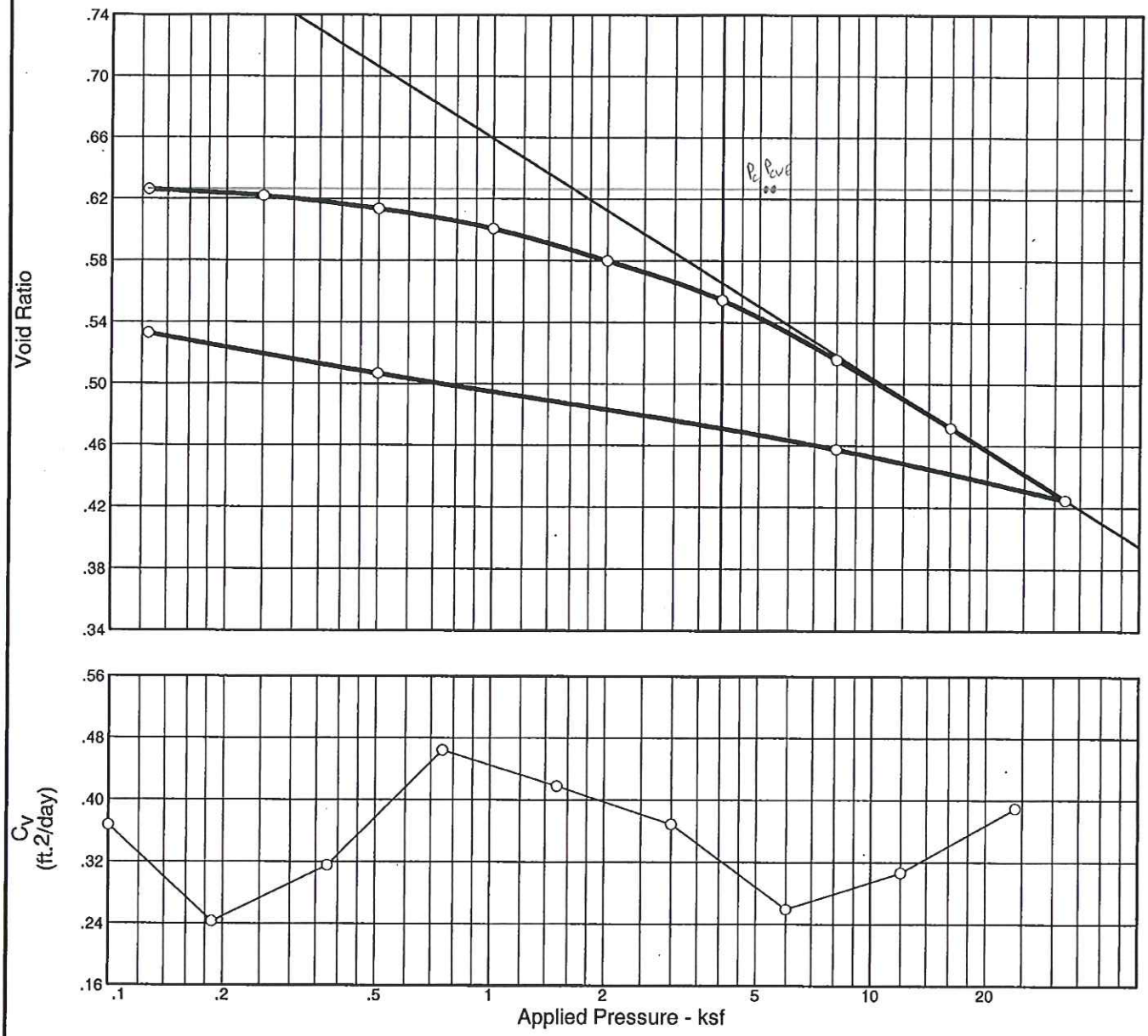
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT 9-30-08

RKK-95

CONSOLIDATION TEST REPORT (ASTM D2435)



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

MATERIAL DESCRIPTION Final Pc ⇒ 5.16 ksf	USCS	AASHTO
Mottled Red & Tan LEAN CLAY.	CL	

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

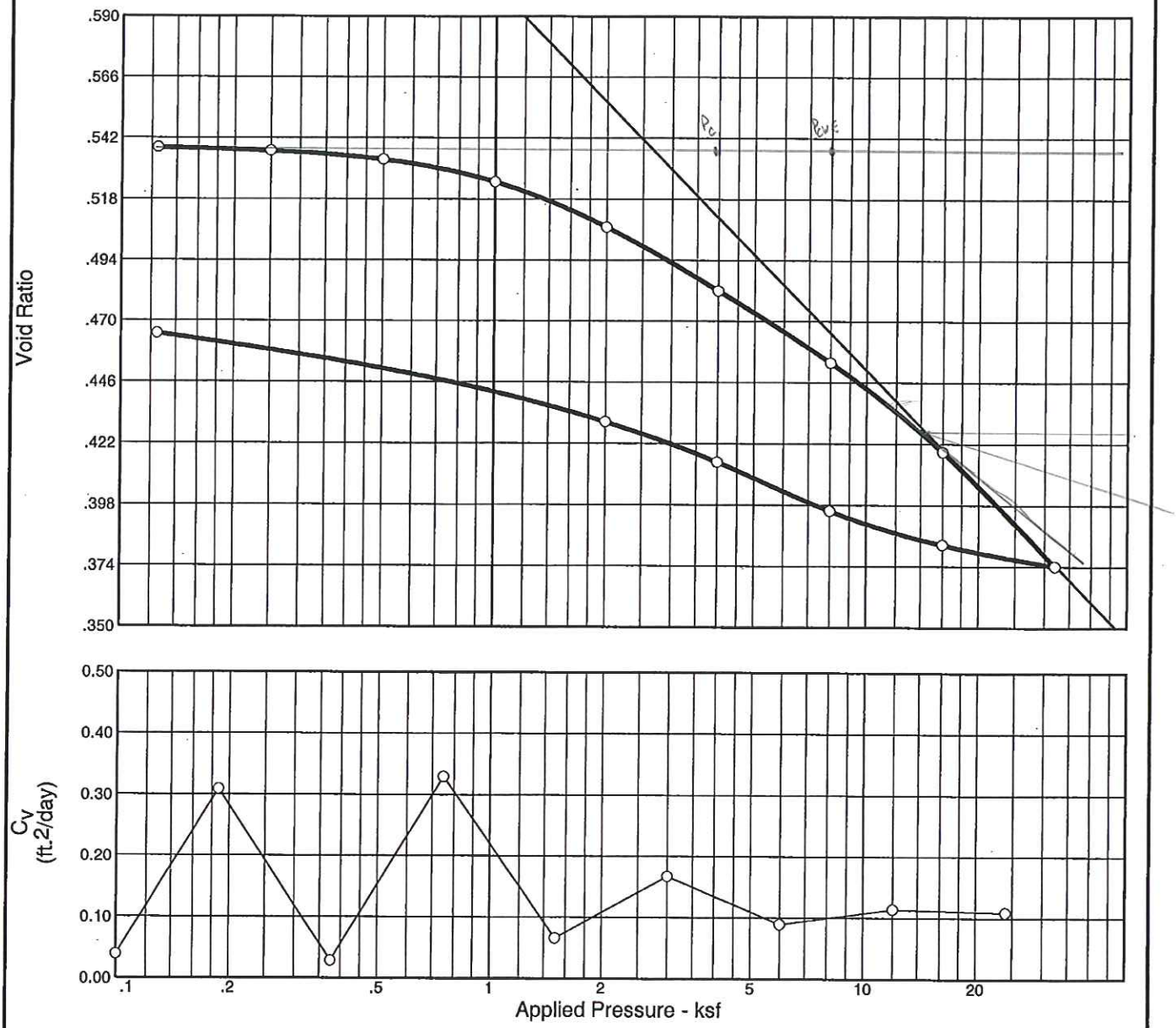
CONSOLIDATION TEST REPORT (ASTM D2435)

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 / 8 Pcc	0.15	0.04	0.539

MATERIAL DESCRIPTION	USCS	AASHTO
Gray LEAN CLAY. Final Pc 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

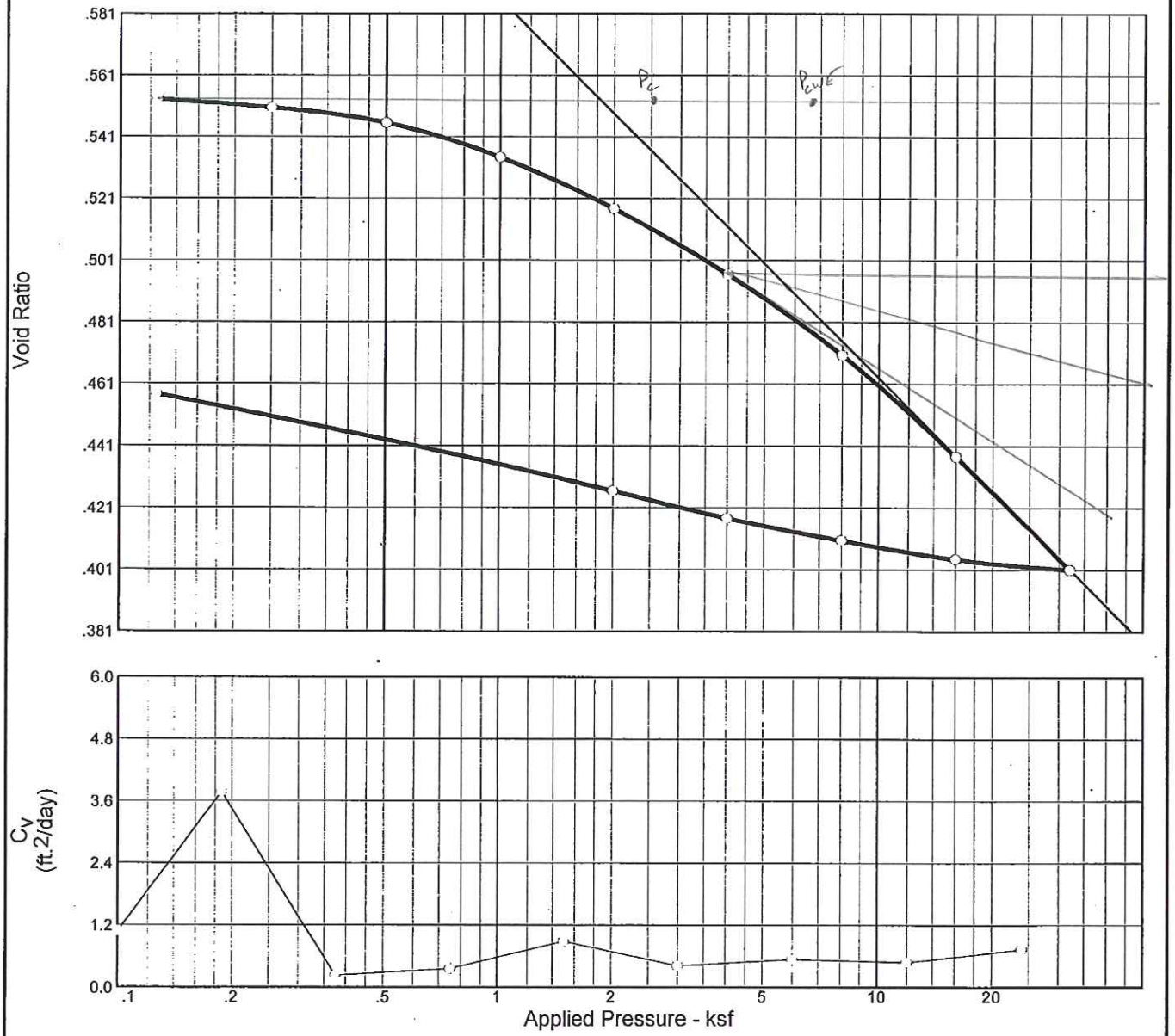
CONSOLIDATION TEST REPORT (ASTM D2435)

The Robert B. Balter Company

JJT
9-30-08

RKK-97

CONSOLIDATION TEST REPORT (ASTM D2435)



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

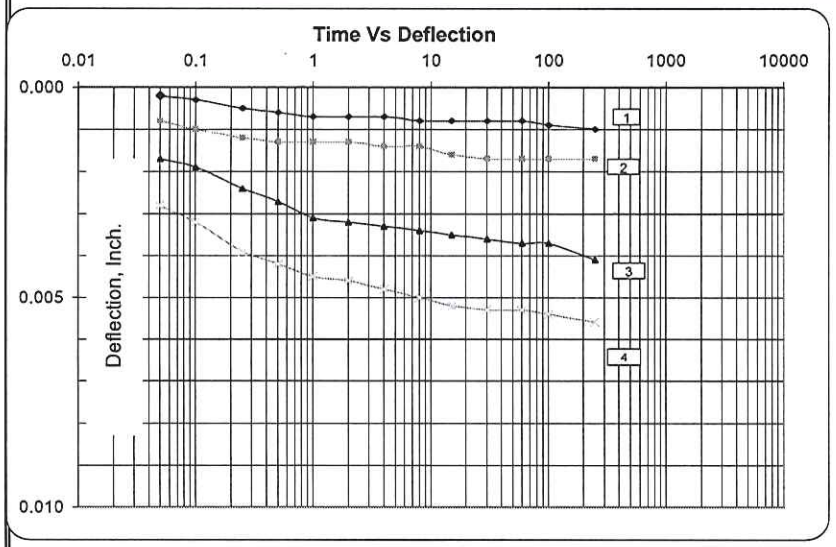
Project: DELAWARE TURNPIKE IMPROVEMENTS -Interchange
RK & K Job No. 103-059

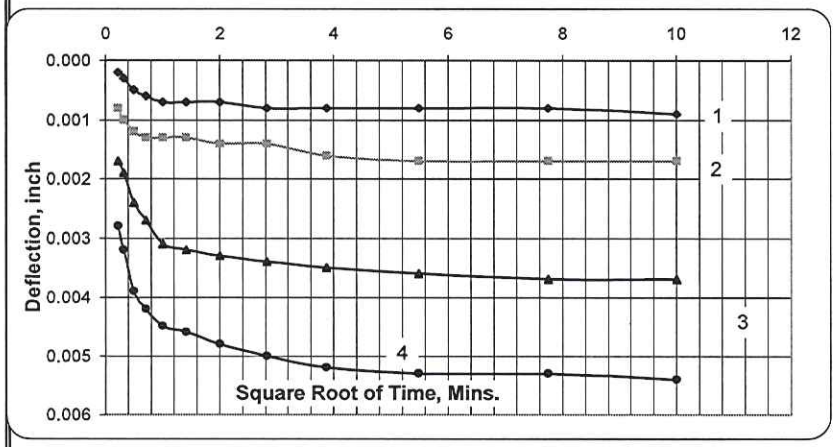
Location: IEB-13A,T-1@ 15.0'-17.0'

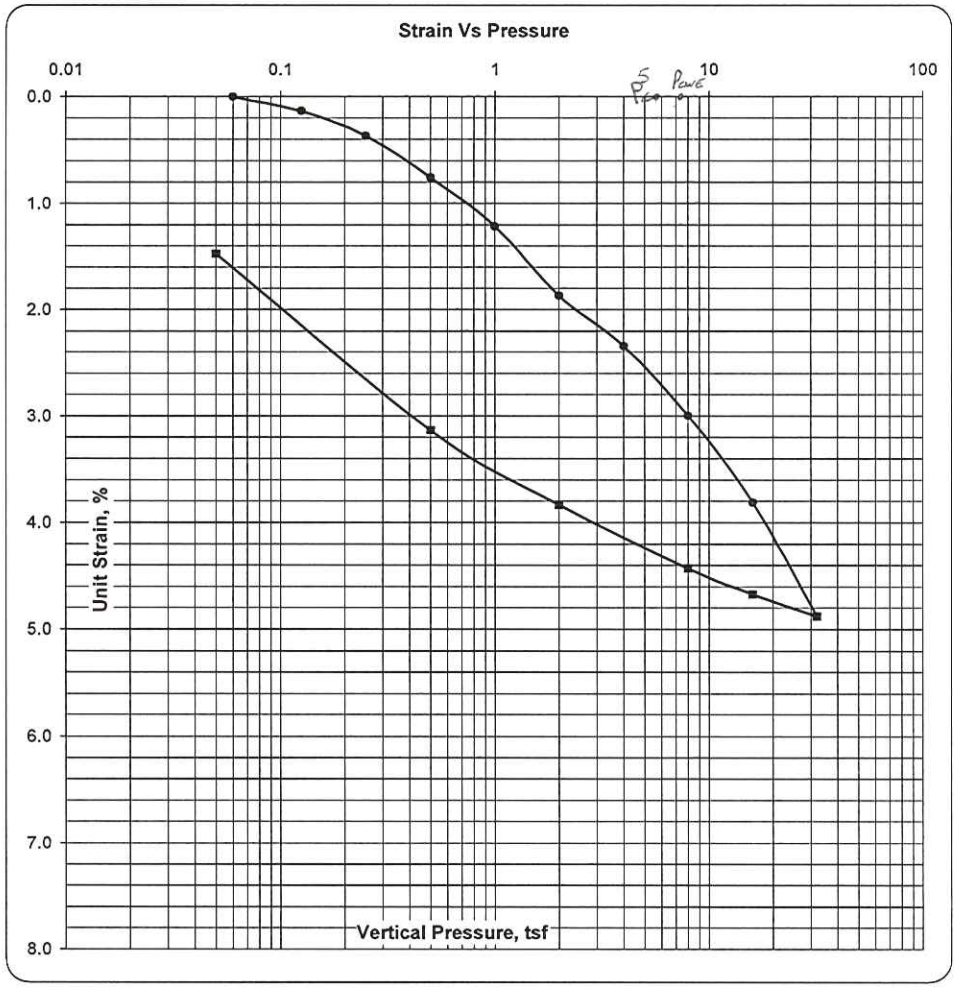
Remarks:
Undisturbed Sample

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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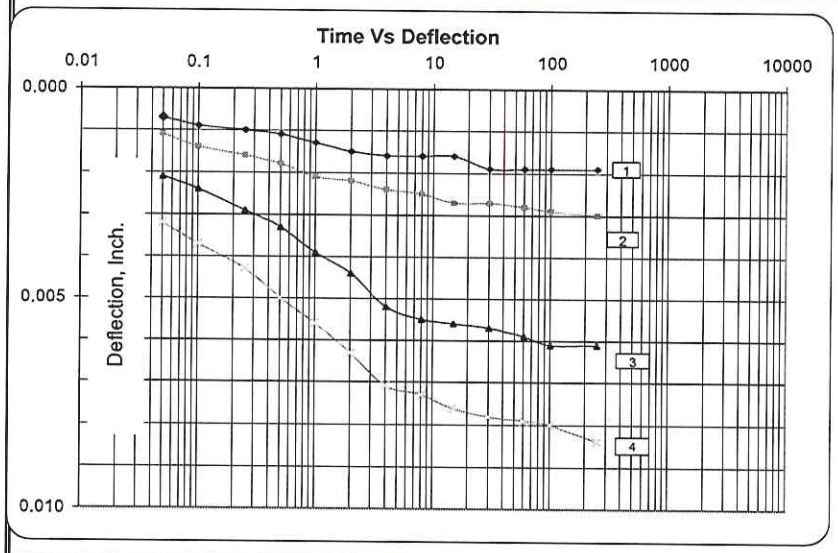
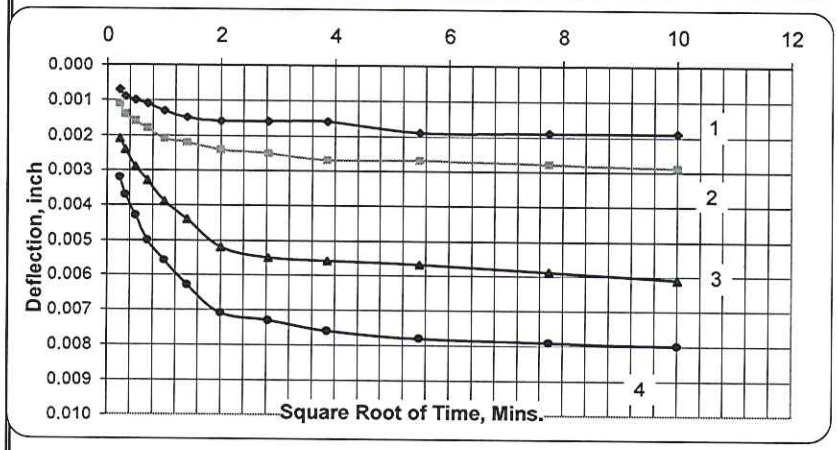
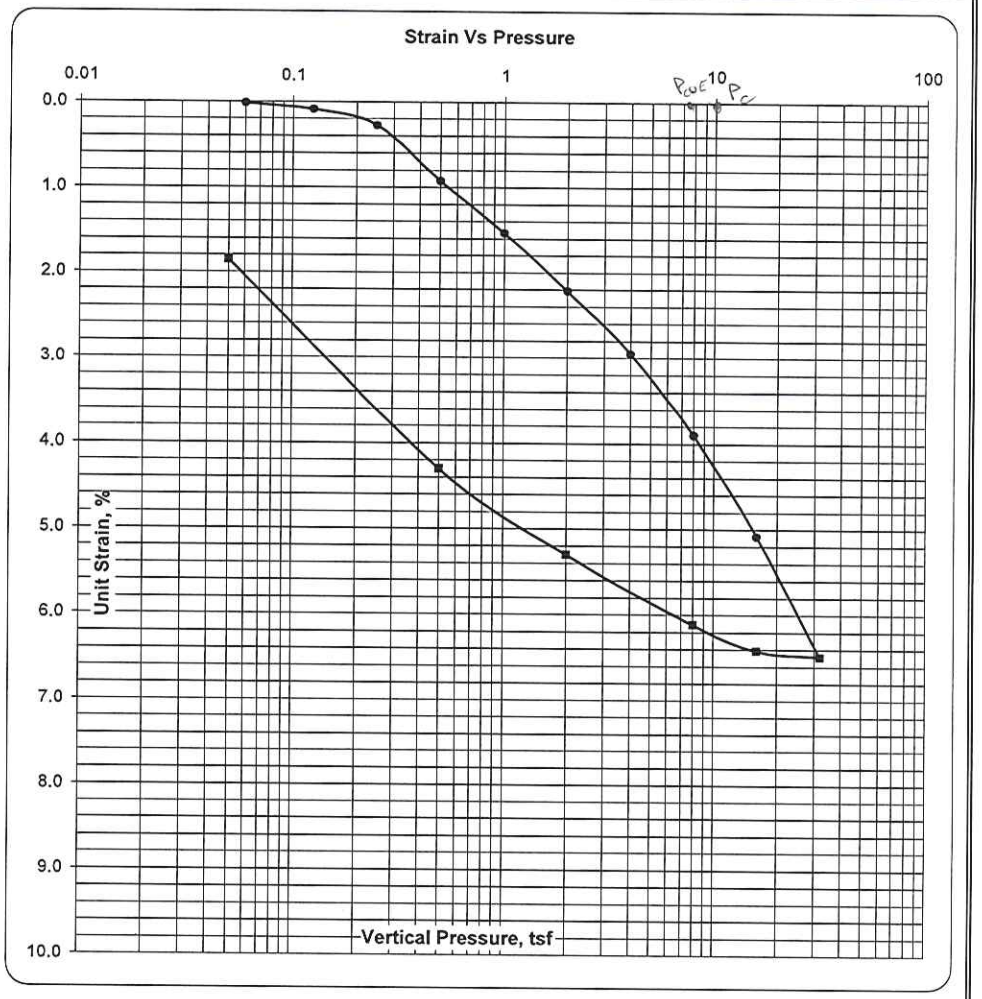
RKK-98

JPT 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)*	10/7.25
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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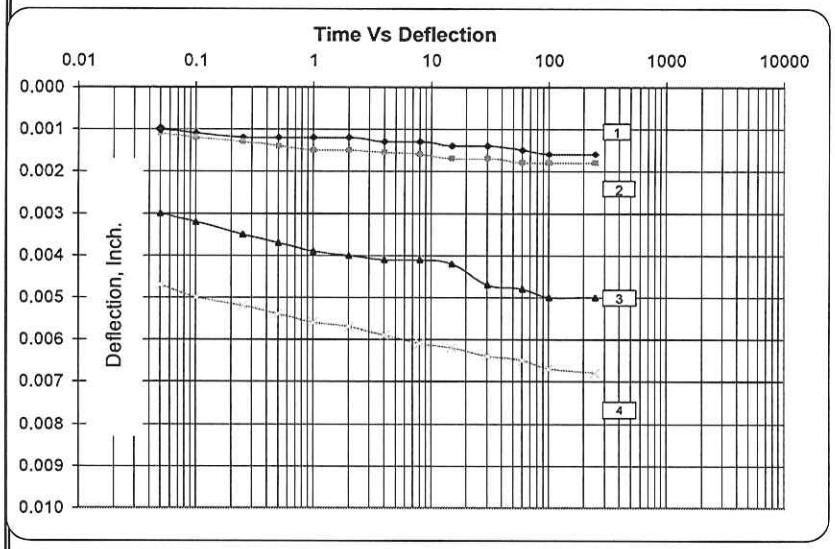
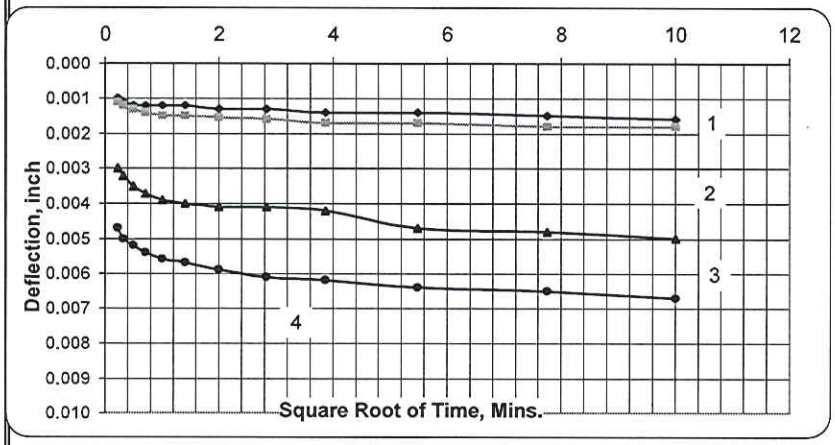
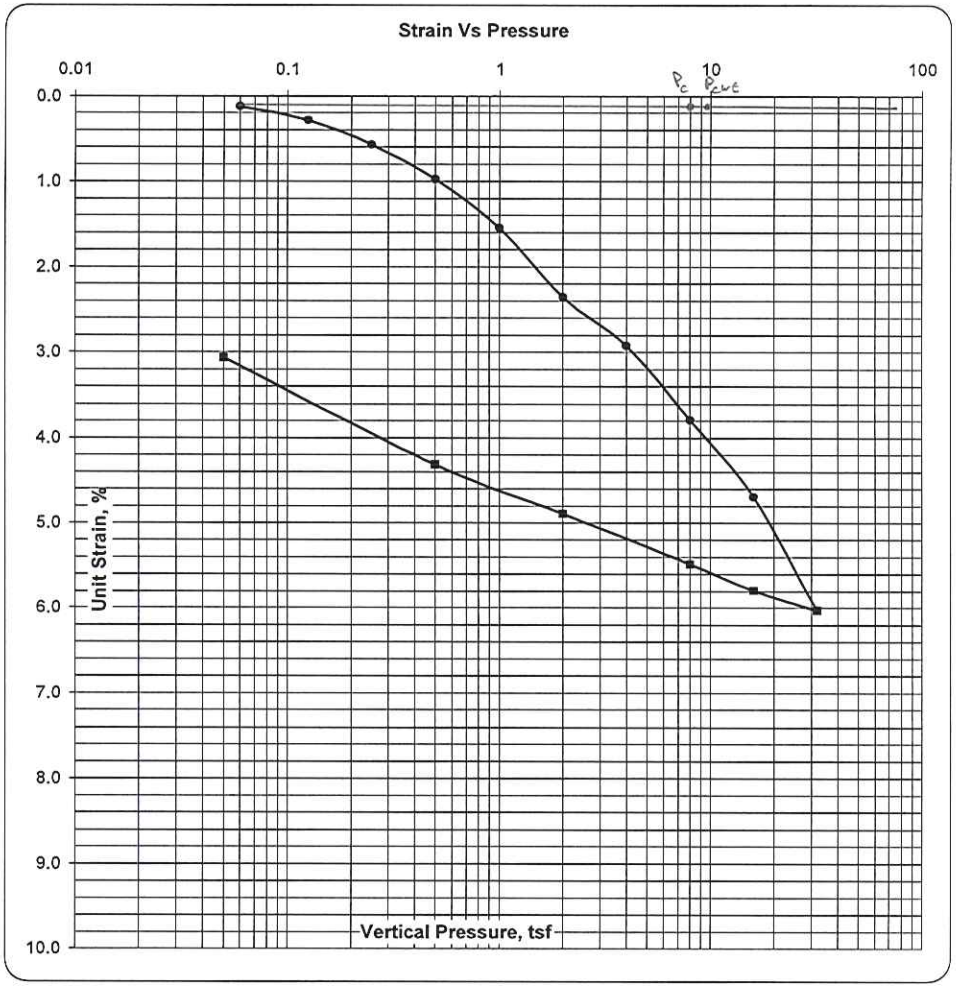
RKK-99

Sept 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	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 / 9.6
Existing Overburden Stress, Po (tsf)*	1
Final P_c = 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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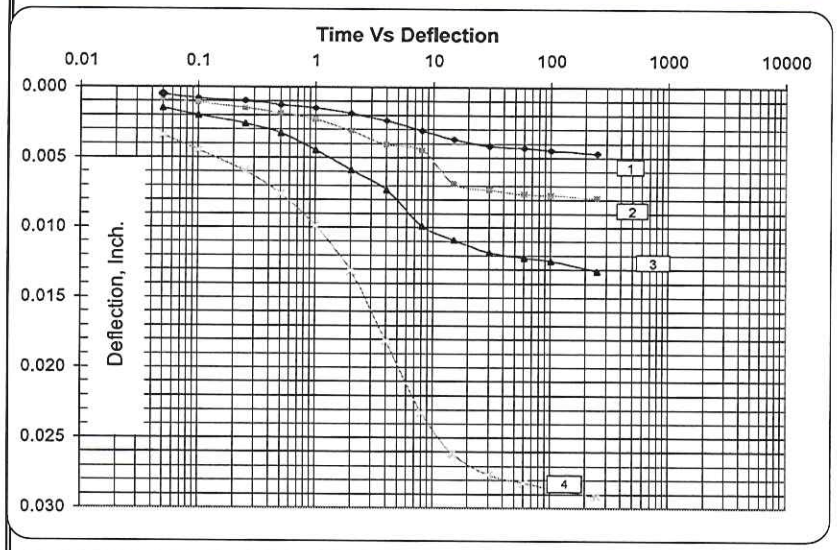

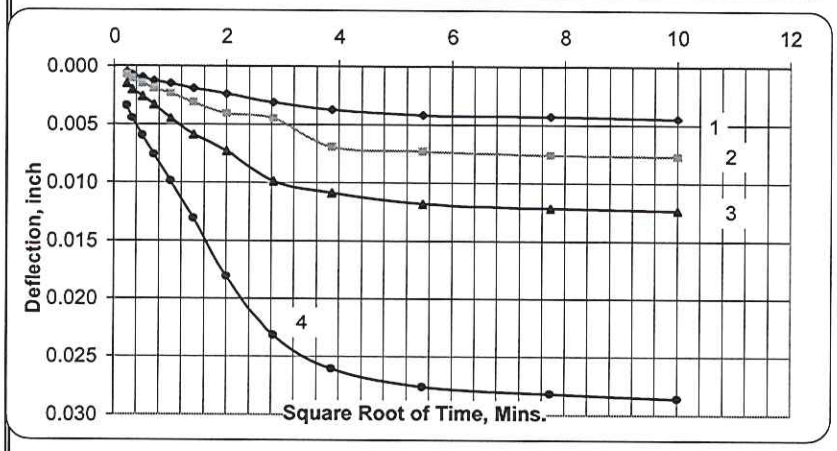

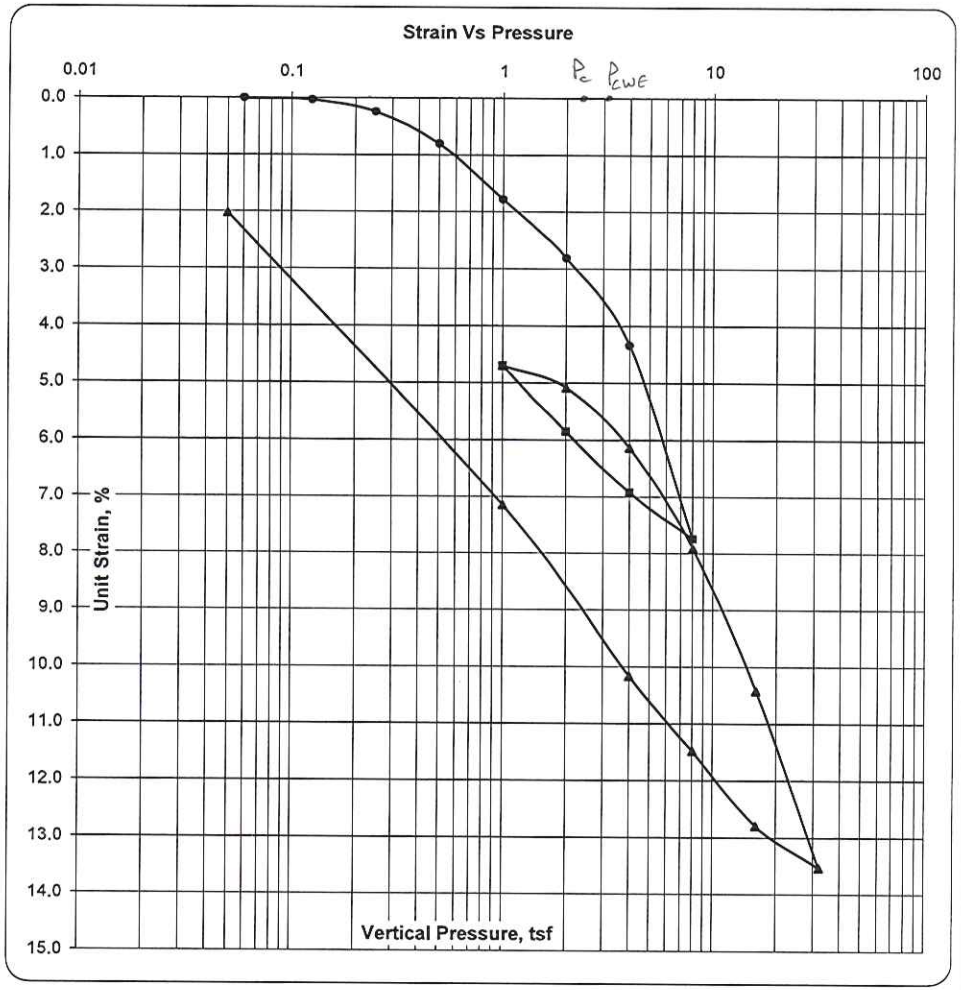

One-Dimensional Consolidation Test (ASTMD-2435)

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 tsf
* Unit Strain Basis	

Project No	19996251
Project Name	RKK I-95 Delaware TP Improve
Boring No.	ICPT-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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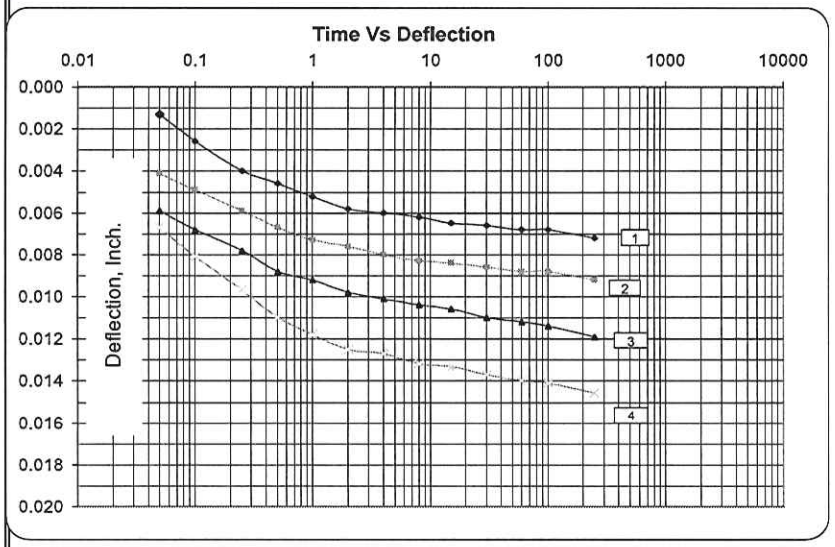

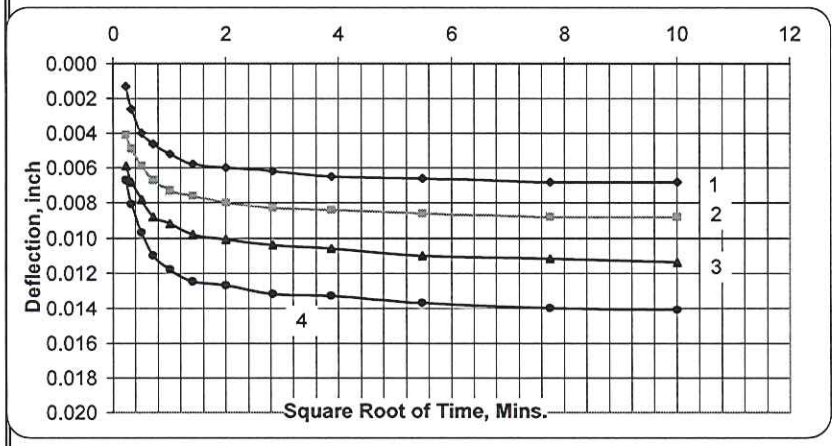

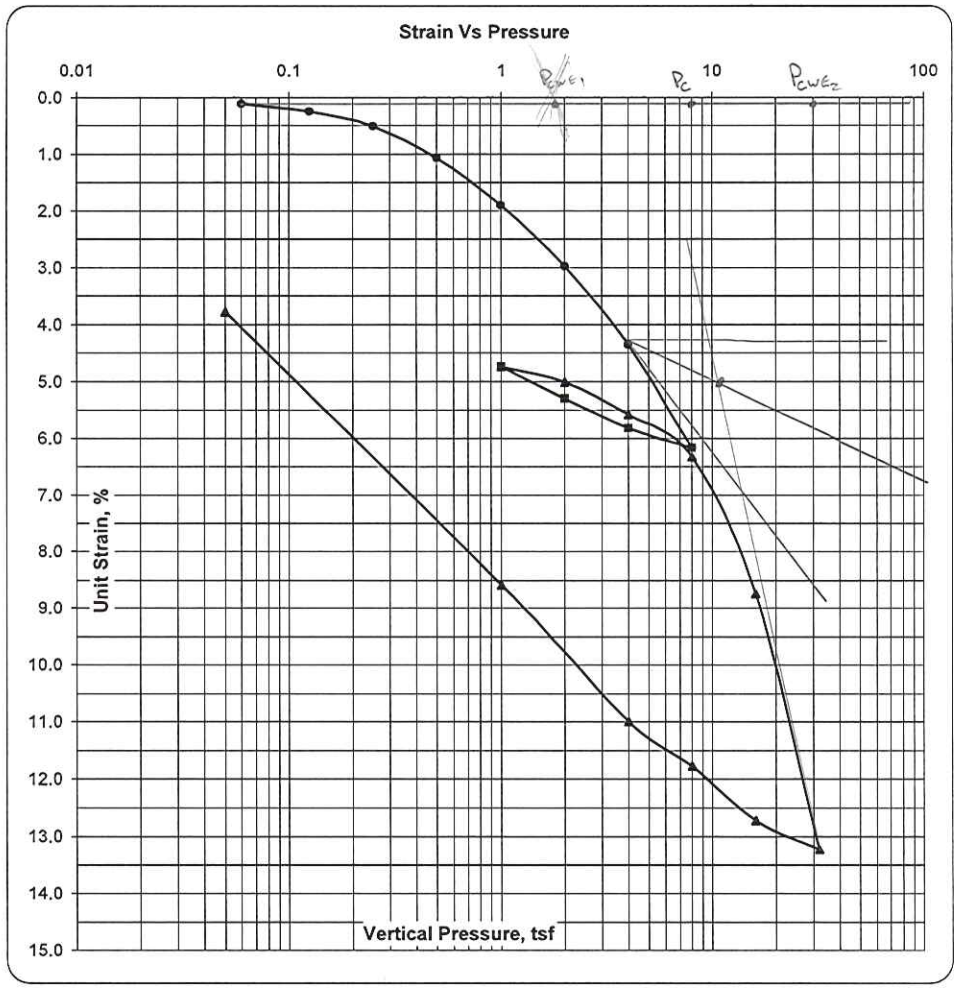

One-Dimensional Consolidation Test (ASTMD-2435)

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')*	11 WE
Preconsolidation Stress, Pc (tsf)*	8 / 19
Existing Overburden Stress, Po (tsf)*	12
Find Pc	
* Unit Strain Basis	

Project No	19996251
Project Name	RKK I-95 Delaware TP Improve
Boring No.	ICPT-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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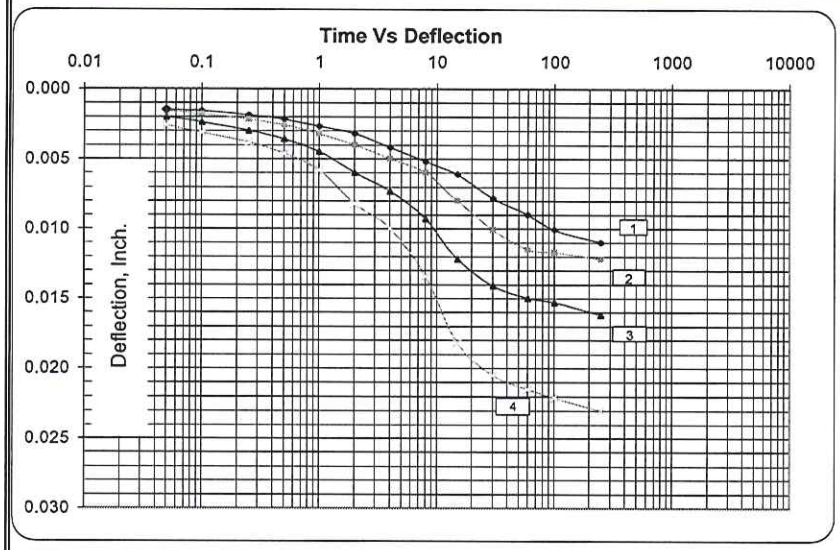
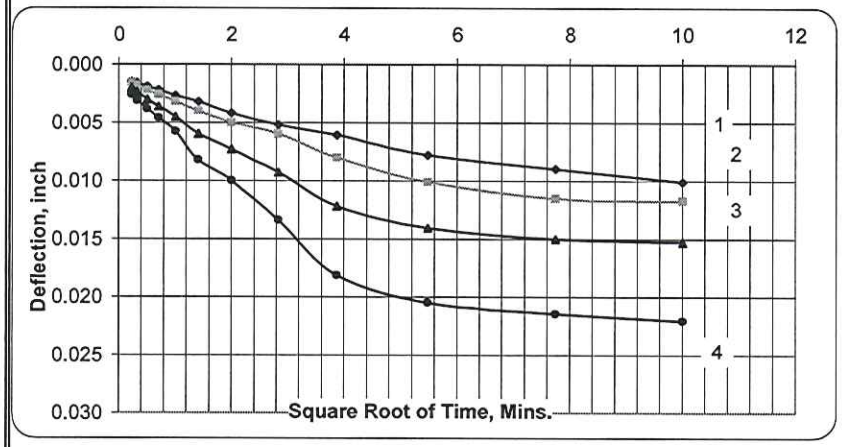
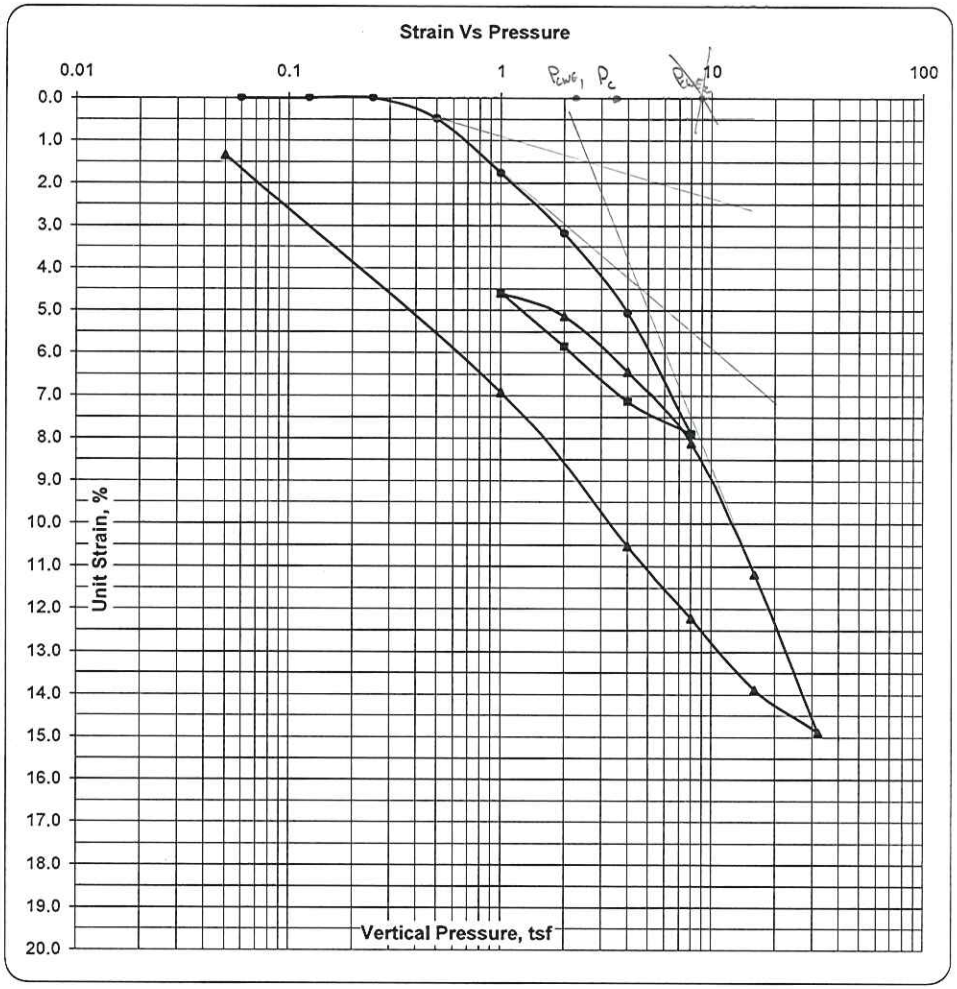
RKK-102

JDP 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)*	1.9
Final P_c = 2.85 t/	
* Unit Strain Basis	

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

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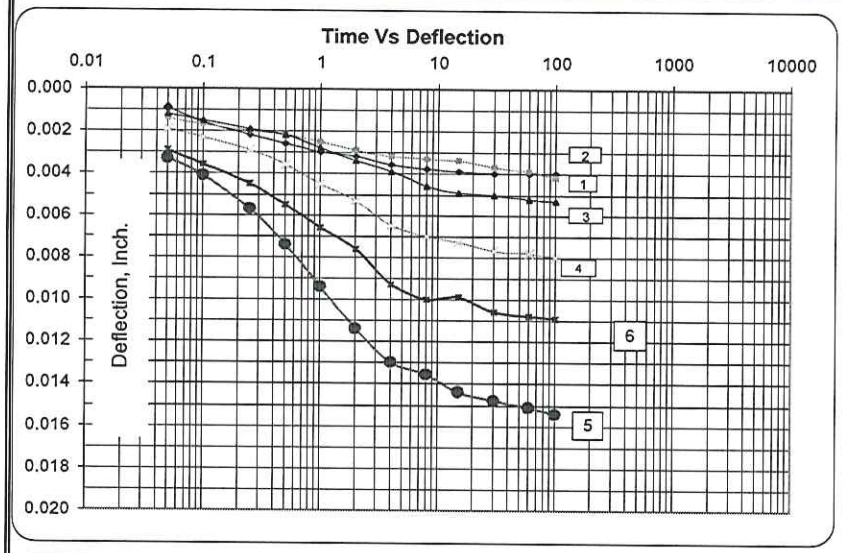
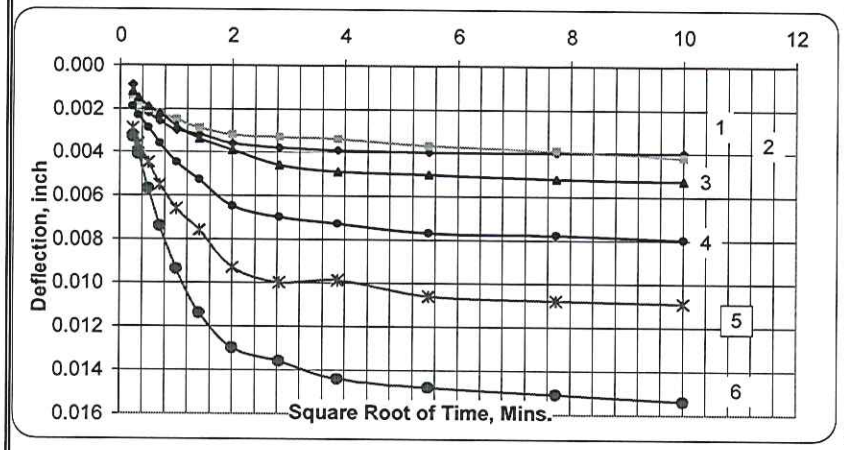
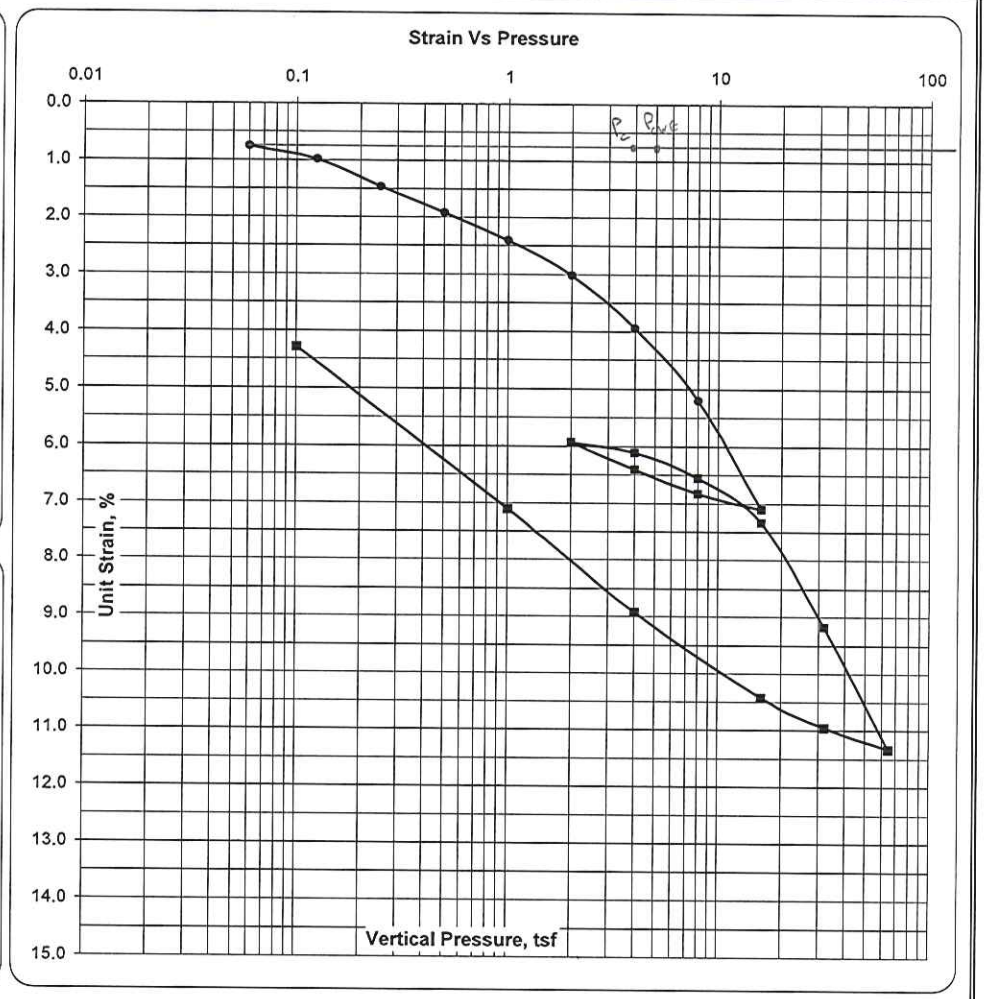
RKK-103

JDT 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	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.)	
Liquid Limit (%)	34	(From Trims.)	
Plastic Limit (%)	19	(From Trims.)	
Plastic Index (%)	15	(From Trims.)	
Specific Gravity(assumed)	2.69	(From Trims.)	
Test Specimen Properties			
Diameter,inch.	2.490		
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 Dry Weight (pcf)	113.9		

Consolidation Properties (Unit Strain Basis)	
Compression Ratio (Cc') *	
Recompression Ratio (Cr')*	
Swelling Ratio (Cs')*	
Preconsolidation Stress, Pc (tsf)*	3.9/5
Existing Overburden Stress, Po (tsf)*	
Final Pc = 4.95 t/	
* Unit Strain Basis	

Project No	19996251
Project Name	RKK
	I-95 Delaware TP Improve
Boring No.	ICPT-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

URS Corporation

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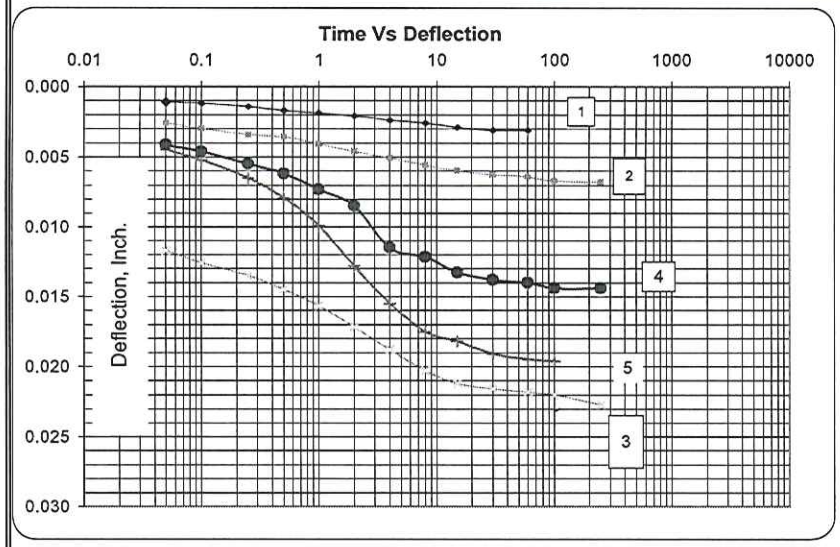
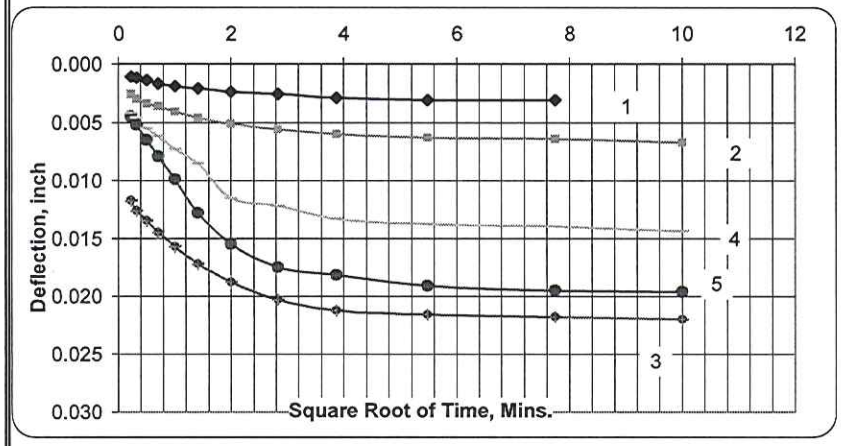
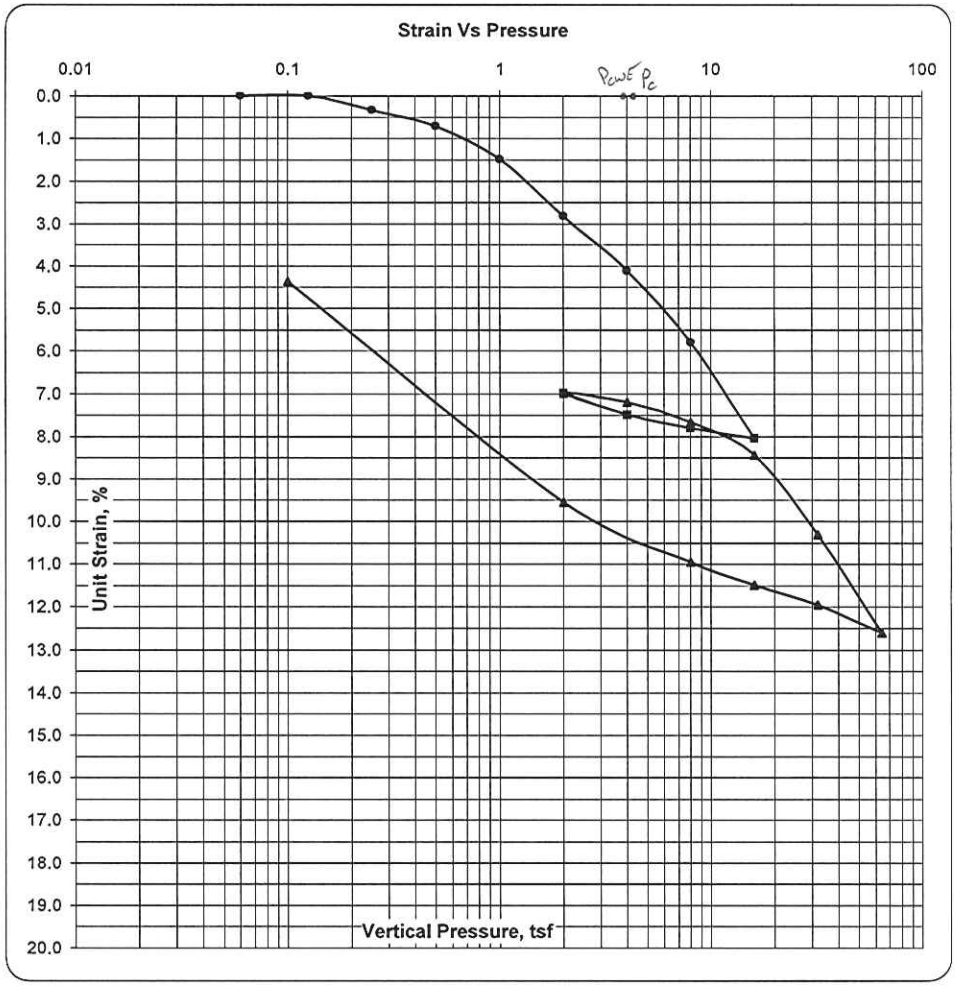
RKK-104

JGT 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

Description of Specimen:	Red-brown-gray mottled silty clay	
Nat.Water Content (%)	13.0	(From Trims.)
Liquid Limit (%)	41	(From Trims.)
Plastic Limit (%)	18	(From Trims.)
Plastic Index (%)	23	(From Trims.)
Specific Gravity(assumed)	2.71	(From Trims.)
Test Specimen Properties		
Diameter,inch.	2.490	
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 Dry Weight (pcf)	129.8	

Consolidation Properties (Unit Strain Basis)	
Compression Ratio (Cc') *	
Recompression Ratio (Cr')*	
Swelling Ratio (Cs')*	
Preconsolidation Stress, Pc (tsf)*	4.2/3.9
Existing Overburden Stress, Po (tsf)*	/
Final Pc = 4.05 tsf	
* Unit Strain Basis	

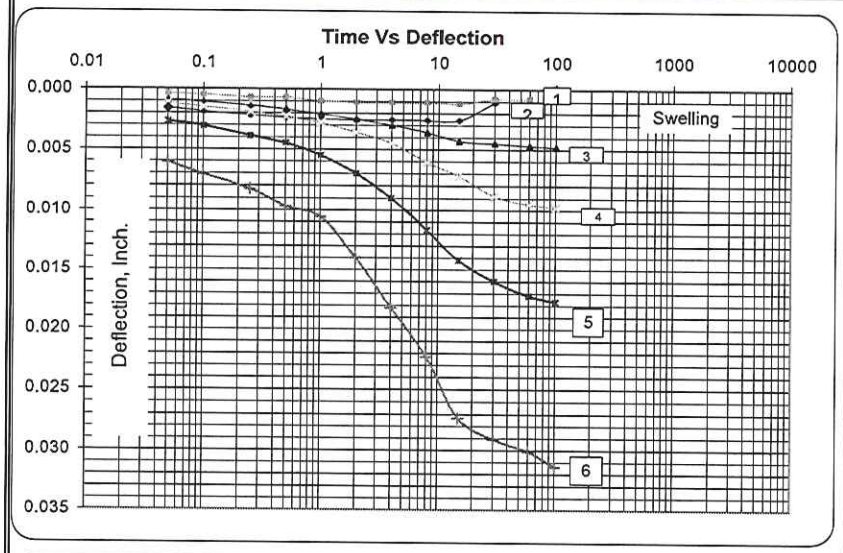
Pc Pcwe

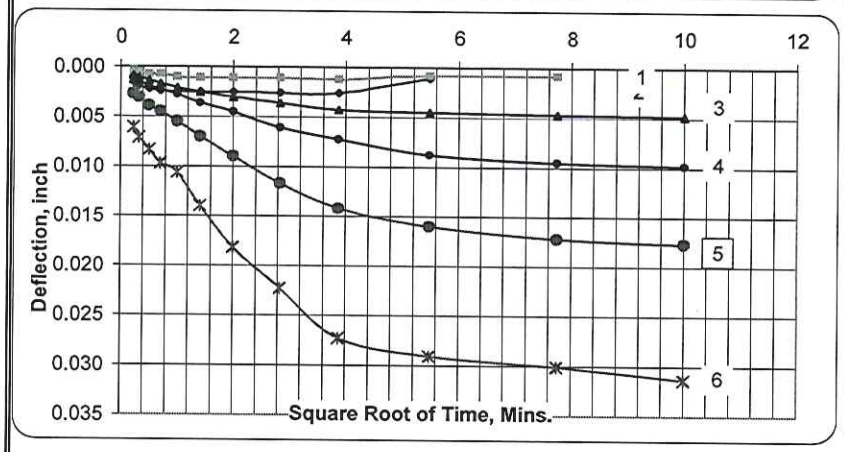
Project No	19996251
Project Name	RKK
	I-95 Delaware TP Improve
Boring No.	ICP1-16a
Sample No.	T-2
Depth, ft.	44.0-46.0
Tested By	rmm
Reviewed By	enm
Date	17-May-05
File No.	19996251C-7

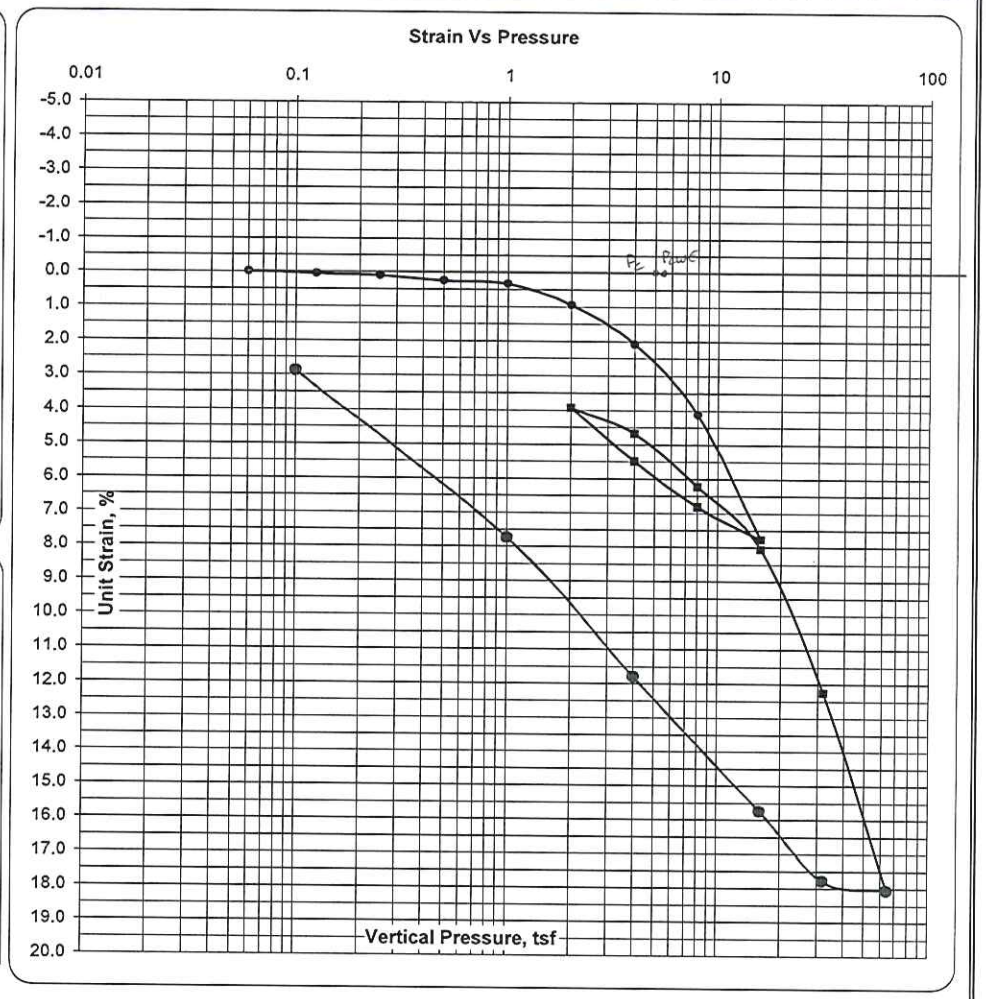
URS Corporation M:\projects\2003\03059_deltrnpk\Geotech\ASSIGN. NO 3 - SR 1 INTERCHANGE\Lab Testing\URS Testing\[19996251c-7.xls]C-1

RKK-105

JOT 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	P_c = 5.2 tsf
* Unit Strain Basis	

Project No	19996251
Project Name	RKK I-95 Delaware TP Improve
Boring No.	ICPT-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

JCPT 9-30-08

CALCULATION CHECKLIST

Project: SR-1/1-95 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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	PAGE
1) PURPOSE	1
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
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8) PLAXIS 2D SETTLEMENT ANALYSIS	16
9) FULL HEIGHT EMBANKMENT SETTLEMENT ANALYSIS	21
10) FENCE	31
11) LOCATION PLAN	32
12) AS BUILT CROSS-SECTION	34
13) SETTLEMENT PLATE READINGS	36

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:

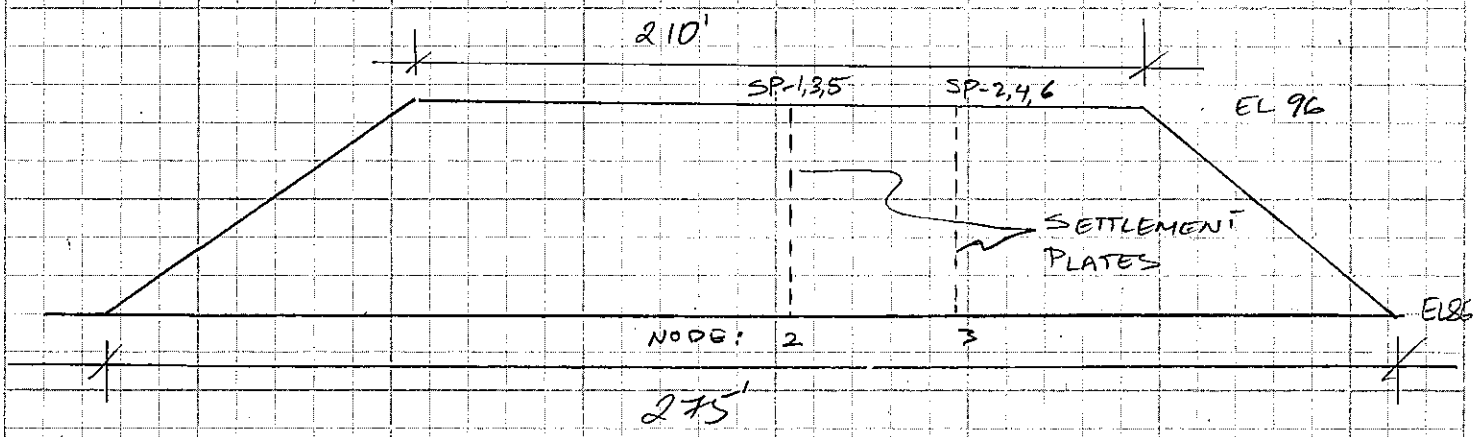
UNIT WEIGHTS → γ	VOID RATIO → e_o
FRICTION ANGLE → ϕ	COMPRESSION INDEX → C_c
UNDRAINED SHEAR STRENGTH → S_u	RECOMPRESSION INDEX → C_r
ELASTIC MODULUS → E_s	POISSON RATIO → μ

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

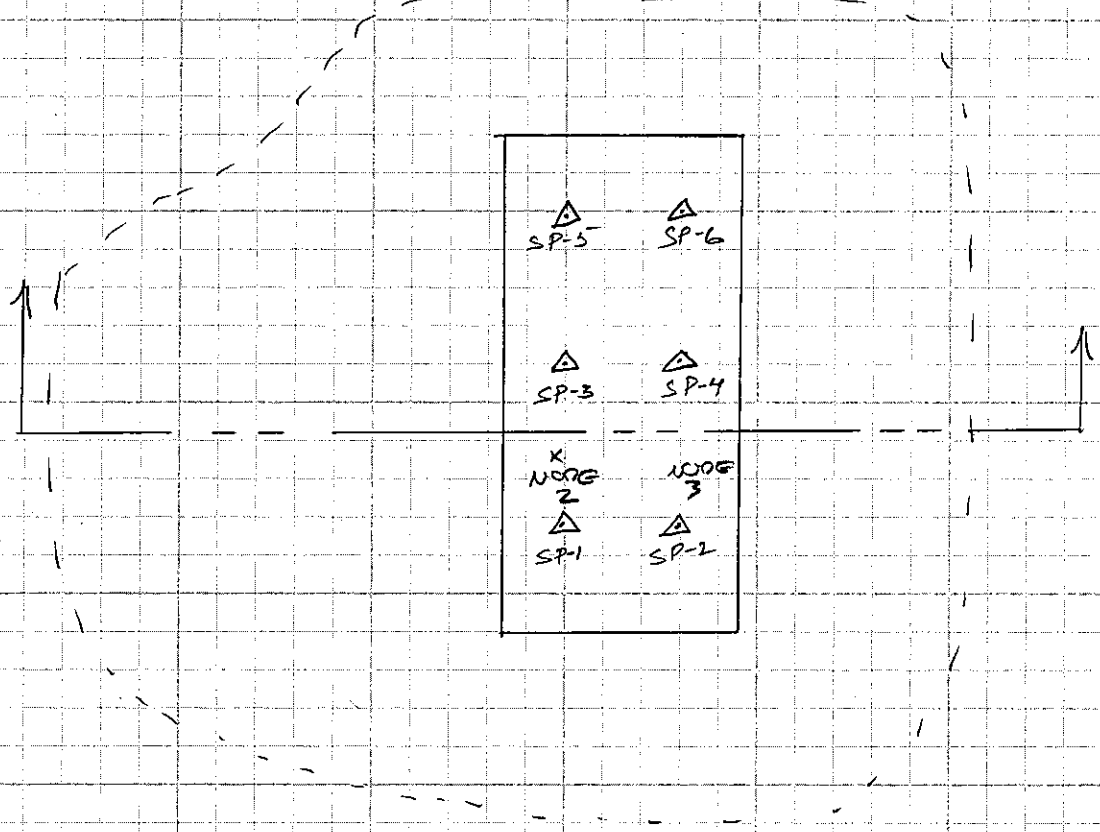
2) ELASTIC SETTLEMENT FOR COARSE GRAINED SOIL & CONSOLIDATION SETTLEMENT FOR FINE GRAINED SOIL.

3) BASED ON LAB TESTING, AVG OCR = 3.5.

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

Subject SR-1/I-95 INTERCHANGE SETTLEMENT PLATES Page 3 of 41
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 1 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

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 C_c 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_s) WAS ADJUSTED MAINTAINING THE SAME RATIO AS CALCULATED USING CPT RESULTS. THE OPTIMIZED ELASTIC MODULUS FOR STRATUM I & STRATUM IIb are

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

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

STRATUM IIa $C_r = 0.015$

STAGE -1 EMBANKMENT HEIGHT RANGES FROM 9 to 12-ft.

FOR ANALYSIS PURPOSE USE 10-ft

SETTLEMENT ANALYSIS

→ ELASTIC SETTLEMENT FOR COARSE GRAINED SOIL

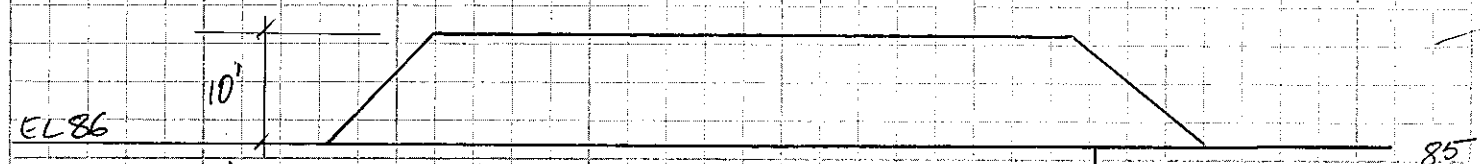
→ CONSOLIDATION SETTLEMENT FOR FINE GRAINED SOIL

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	–	–	–

SOIL PROFILE



EL 86 — 85

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

$\gamma = 125$ pcf

EL 70 — 70

STRATUM 2a(i) — $C_c = 0.092$ — $e_0 = 0.655$

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

EL 60 — 55

STRATUM 2a(ii) — $C_c = 0.092$ — $e_0 = 0.655$

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

EL 50 — 40

STRATUM 2a(iii) — $C_c = 0.105$

$\gamma = 130$ pcf — $C_r = 0.015$

$e_0 = 0.605$

$C_v = 0.75$ ft²/day — 25

EL 20 — 10

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

$\gamma = 130$ pcf — $C_r = 0.015$

$e_0 = 0.605$

EL 0 — -5

STRATUM 2b — $E_s = 1364000$

$\gamma = 125$ pcf

-20

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. $\approx$ 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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8 of 41

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/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 – EMBANKMENT LAYERS – 1 layers

	Wet Unit Weight, γ [lb/ft³]	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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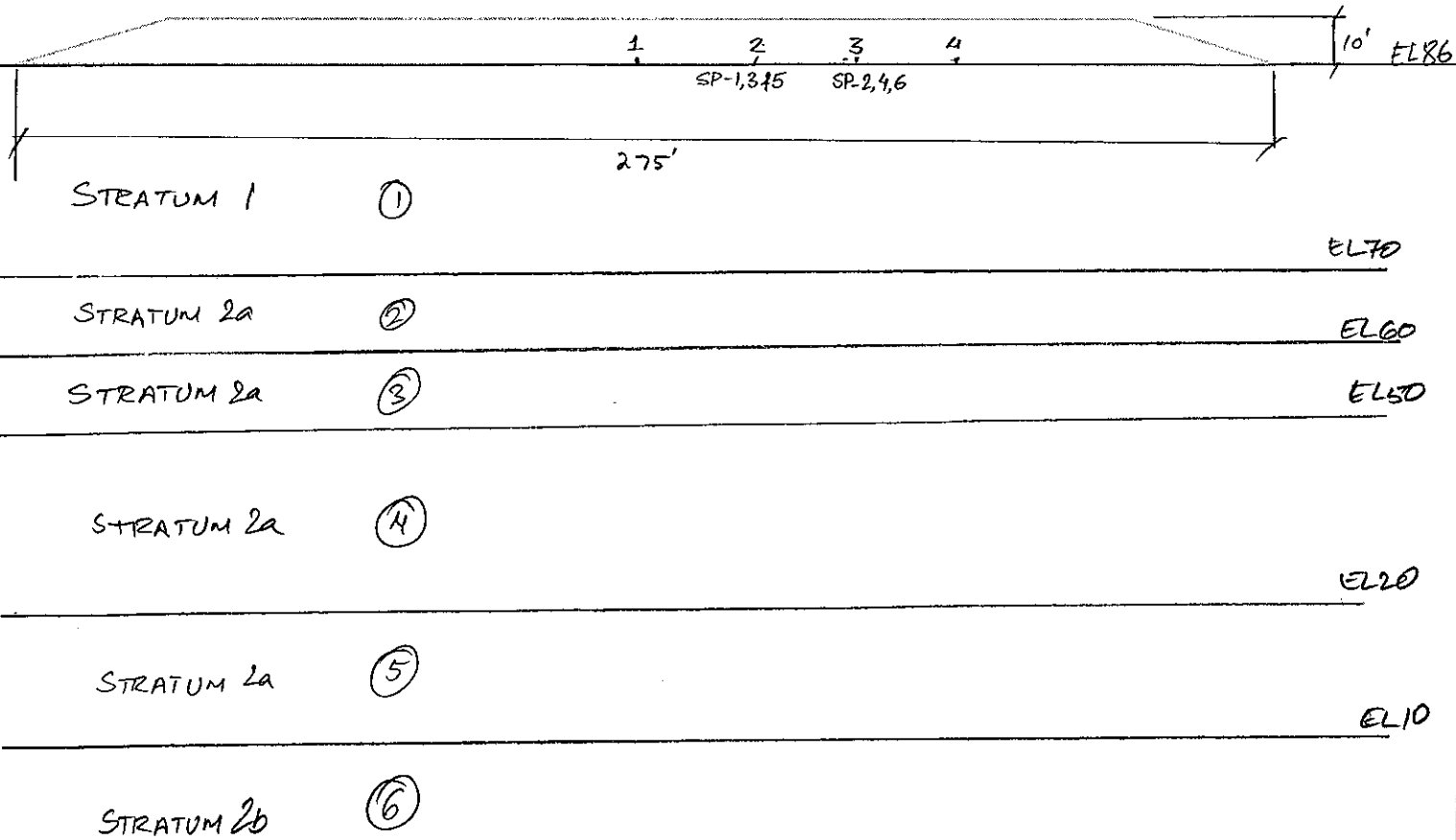
DRAWING OF SPECIFIED GEOMETRY



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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 [ft ²/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/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	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" SP3: 0.38" IS NOT CONSISTENT WITH OTHER 5 SP'S.
2	0.0081 0.0199 0.0280	0.08	0.1080	1.30	
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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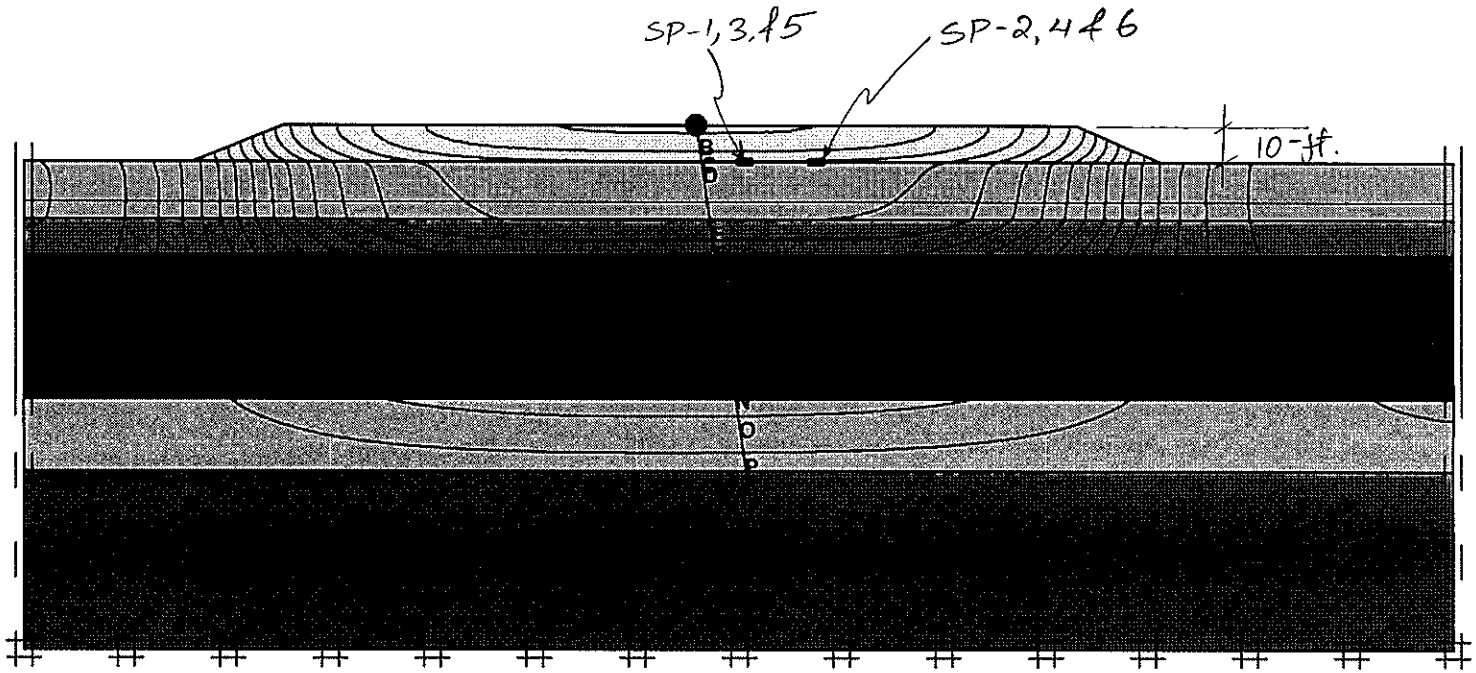
Subject SR-1 / I-95 INTERCHANGE SETTLEMENT PLATES
Page 16 of 45
Cm. No. 103-059
Prepared By BBS Date 1-13-09 Checked By SW Date 1/14/09

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

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RKK-125

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

PLAXIS - Finite Element Code for Soil and Rock Analyses

Project description : SR-1 Interchange

User name : Rummel Klepper & Kahl

Project name : S-1a

Output : Soil and Interfaces Info - Hardening Soil

PLAXIS 8.x

Date : 1/13/2009

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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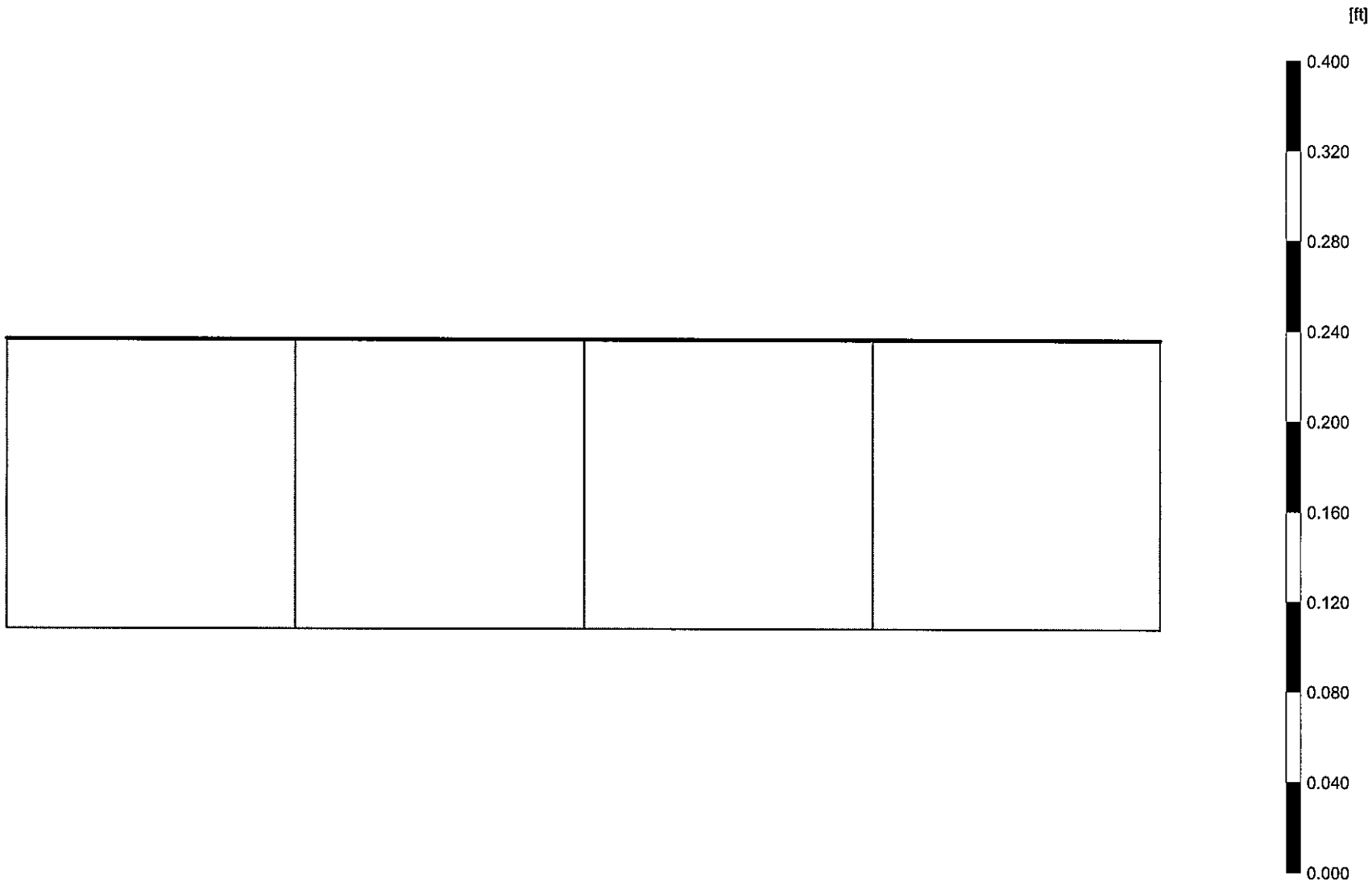
RKK126

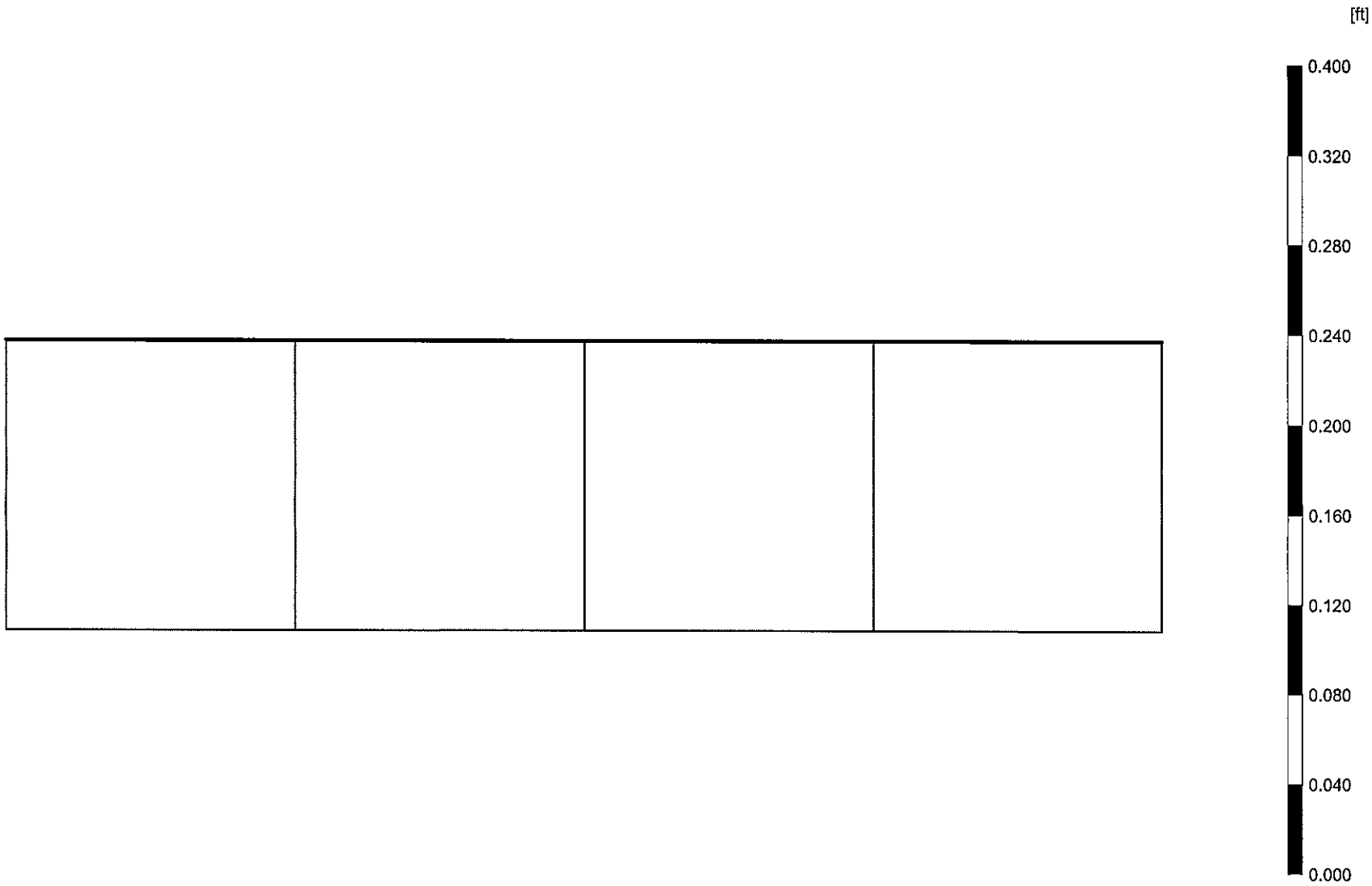


Vertical displacements (Uy)
Extreme Uy -128.33*10^{-3} ft = 1.5 inches
SP - 2, 4 & 6

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-127



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

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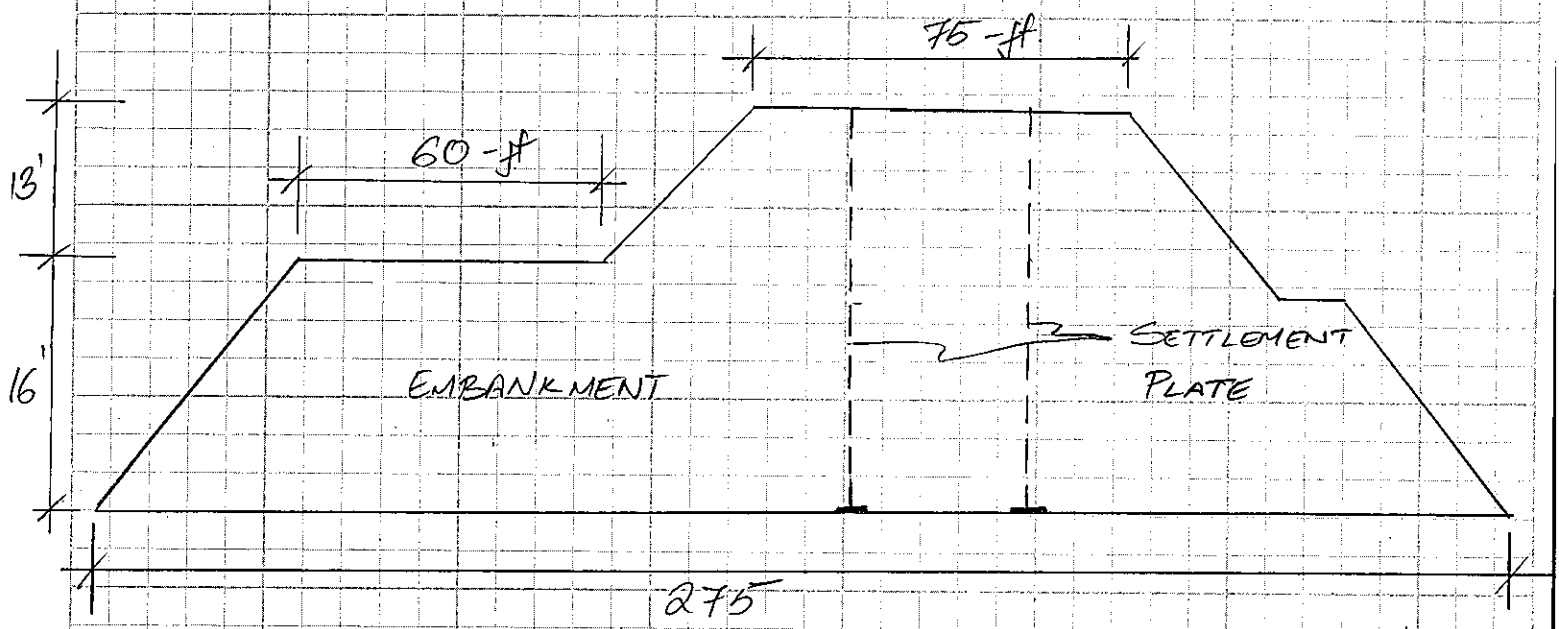
ESTIMATING TOTAL SETTLEMENT FOR FULL HEIGHT EMBANKMENT (29-ft HIGH)



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 CALLULATION
4) MODIFIED ELASTIC MODULUS FROM STAGE 1 SETTLEMENT CALLULATION

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

SP-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:

Description:
Settlement Plate Back Calculation

SOIL PARAMETER DEVELOPED FROM (LAB & OPTIMIZED TO MATCH SETTLEMENT PLATE RESULTS FROM STAGE 1 SETTLEMENT 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/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 – EMBANKMENT LAYERS – 2 layers

	Wet Unit Weight, γ [lb/ft³]	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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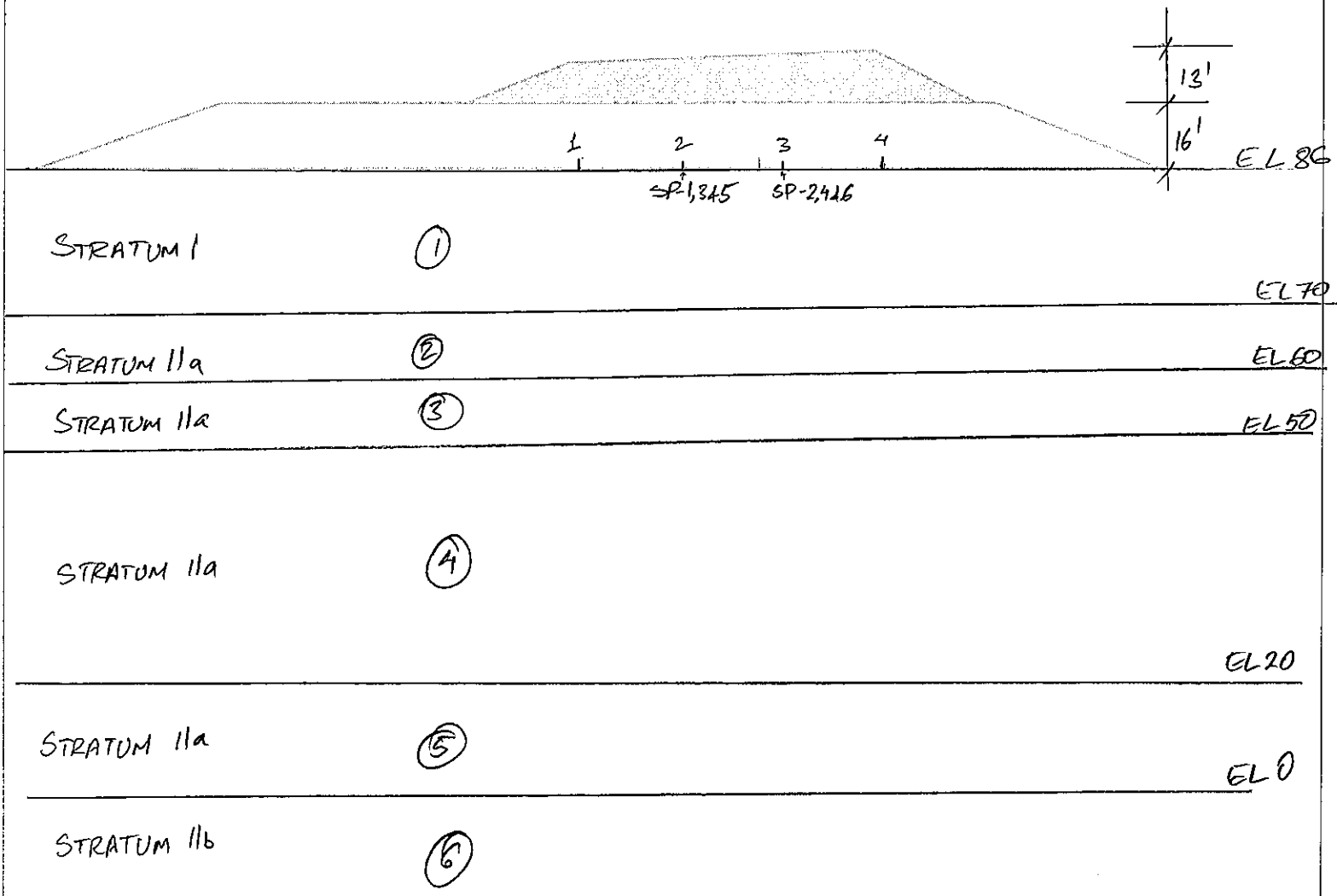
DRAWING OF SPECIFIED GEOMETRY



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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 [ft ²/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/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	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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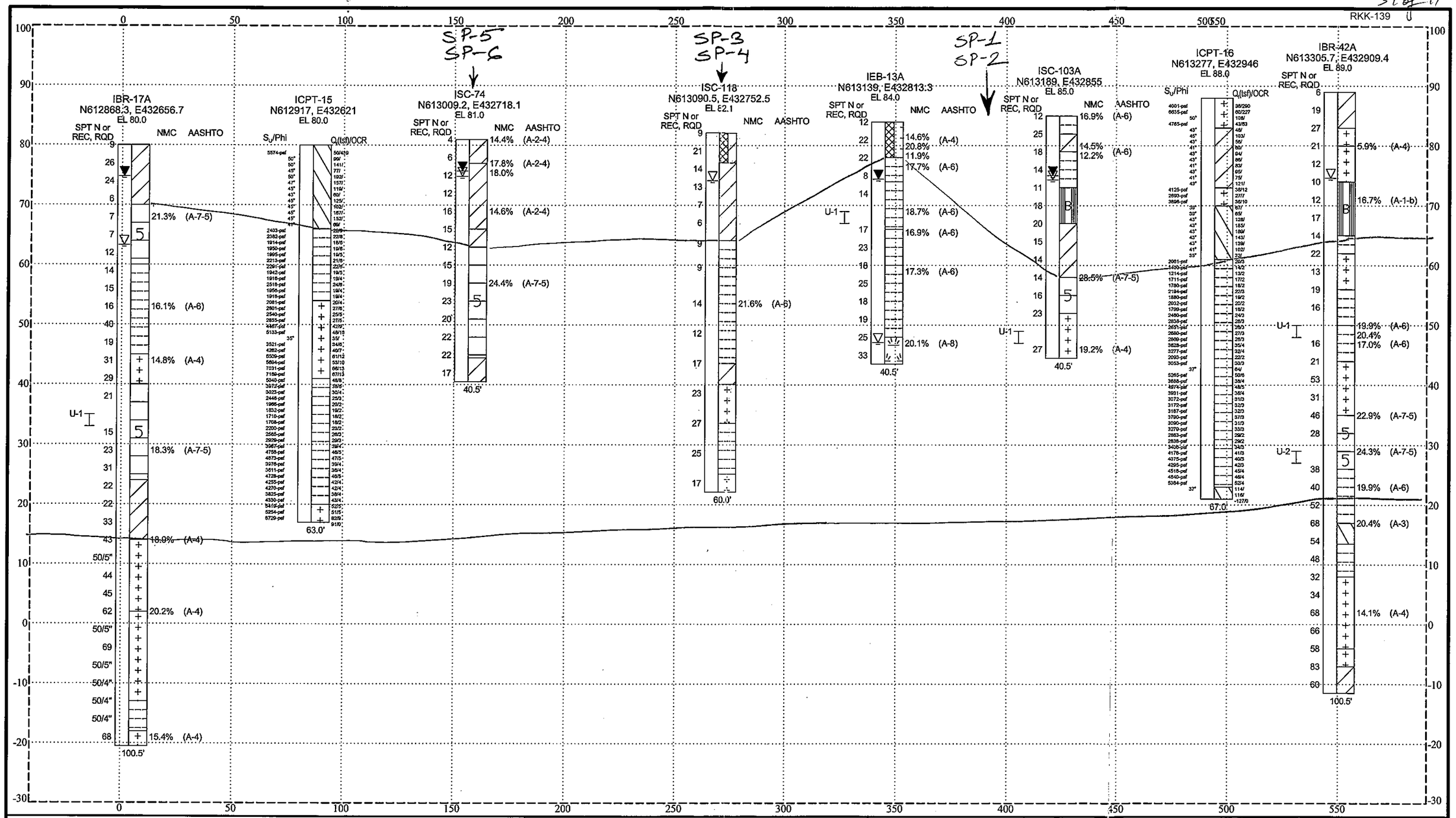
RKK-139



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

Settlement Plate

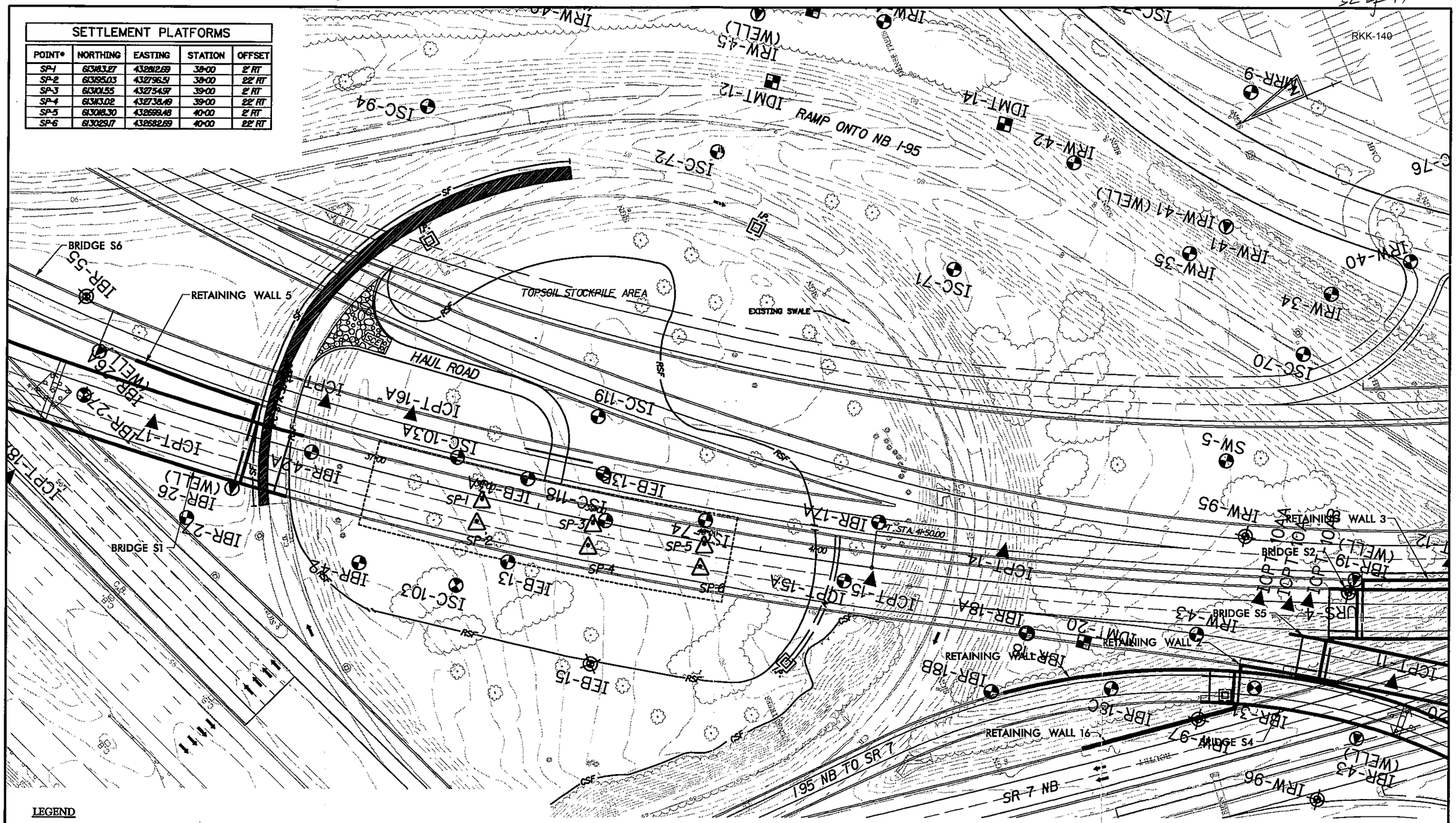
Figure No. A-1

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

RKK-140

SETTLEMENT PLATFORMS				
POINT*	NORTHING	EASTING	STATION	OFFSET
SP-1	613183.27	432812.69	38+00	2' RT
SP-2	613195.03	432796.51	38+00	22' RT
SP-3	613101.55	432754.97	39+00	2' RT
SP-4	613113.02	432738.49	39+00	22' RT
SP-5	613018.30	432699.48	40+00	2' RT
SP-6	613029.77	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	APPROVED BY	SCALE	DATE	COMMISSION. NO.
KDT	EMK	1"=80'-0"	OCTOBER 2008	103-059-27U

10/31/2008
m:\proj-co\2003\03059_aldmph\forms\INTERCHANGE FINAL DESIGN 2008\CADD\cd\landmall.dgn
03059 SR1MALL

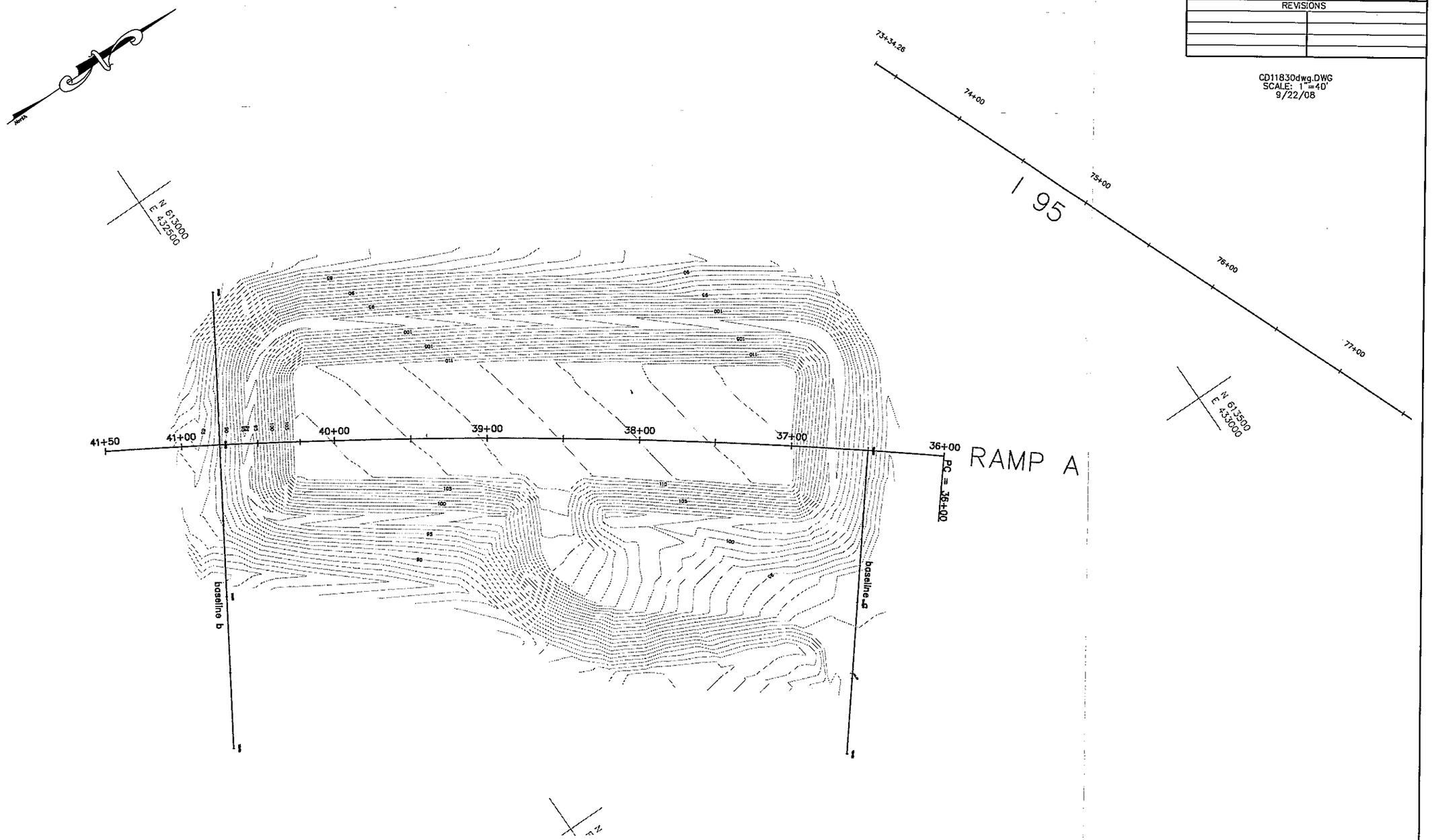
CONTRACT	COUNTY	FEDERAL AID PROJECT NO.	SHEET NO.	TOTAL SHEETS

REVISIONS

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

GRAPHIC SCALE

(IN FEET)
1 inch = 30 ft.



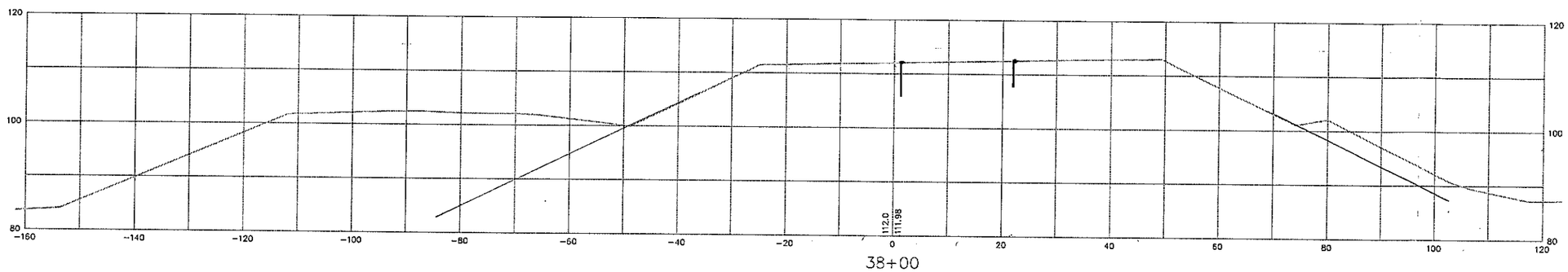
PREL. TRACING_____ DESIGN_____ CHKD._____

GRAPHIC SCALE

(IN FEET)
1 inch = 10 ft.

CONTRACT	COUNTY	FEDERAL AID PROJECT NO	SHEET NO.	TOTAL SHEETS

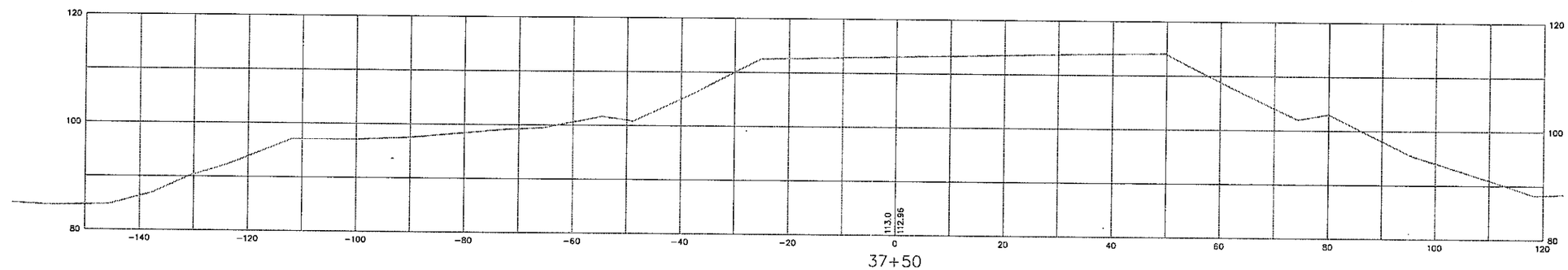
REVISIONS



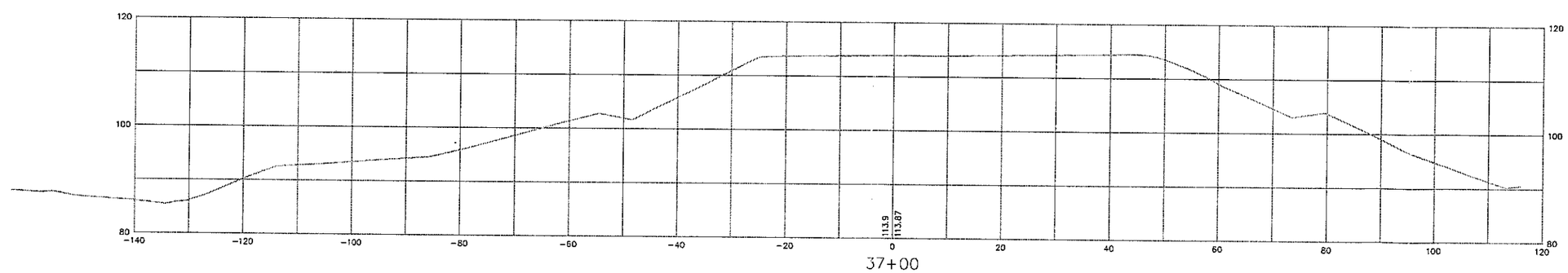
38+00

SP 1 & 2

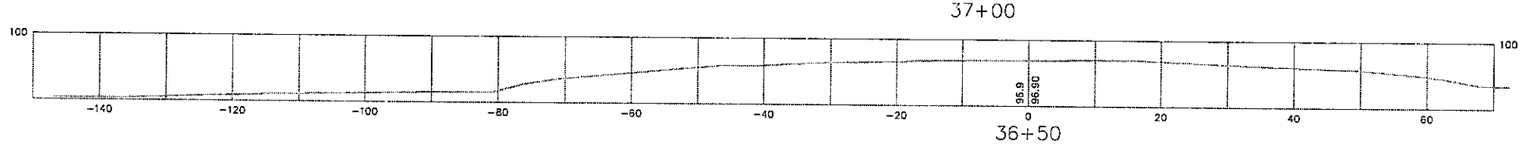
EL 86 GS



37+50



37+00



36+50

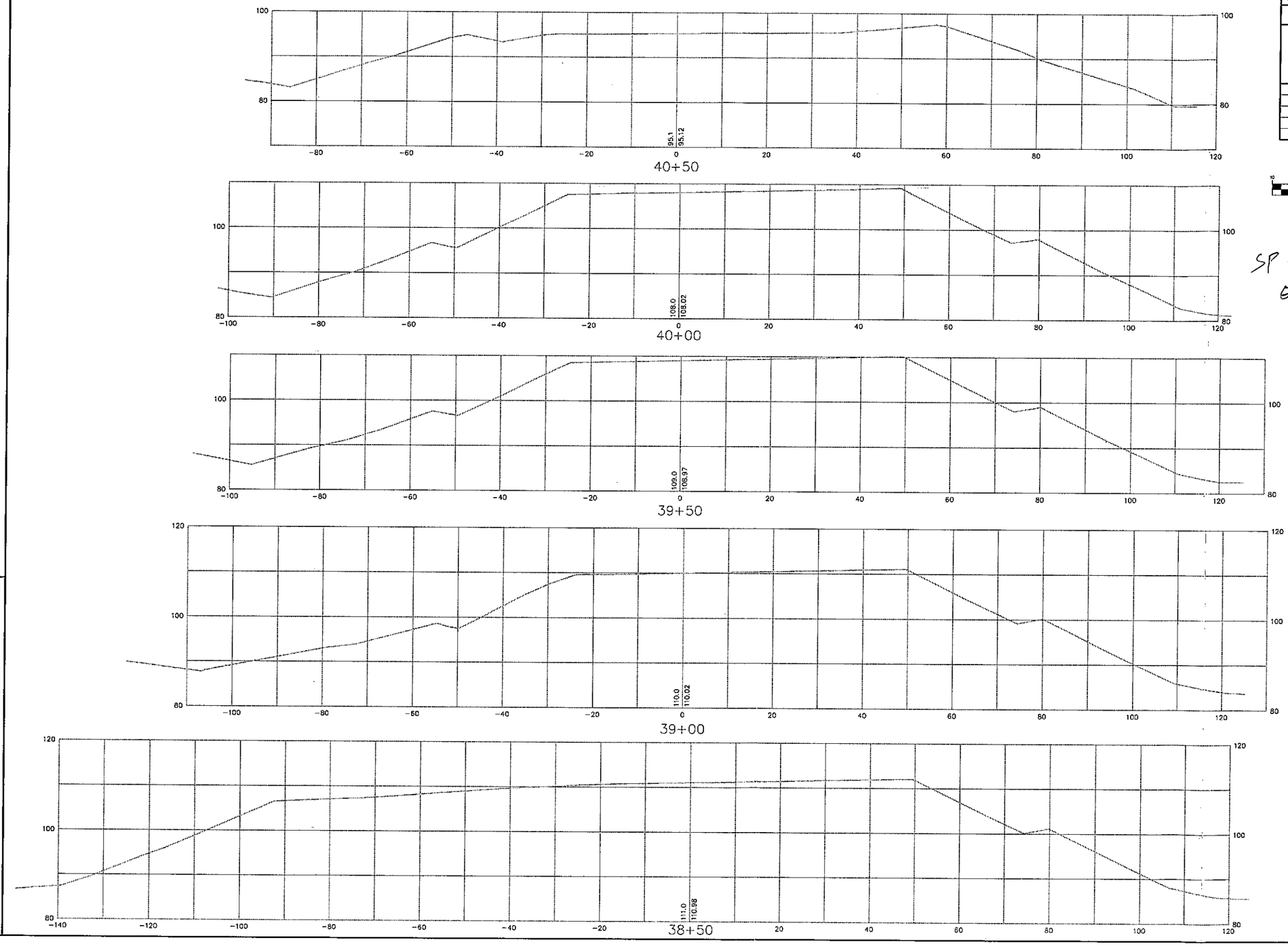
PREL. TRACING _____ DESIGN _____ CHKD. _____

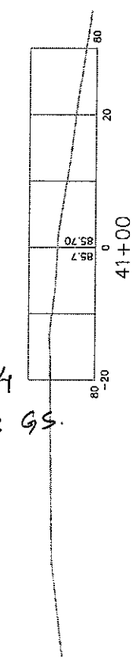
CONTRACT	COUNTY	FEDERAL AID PROJECT NO	SHEET NO	TOTAL SHEETS

REVISIONS

GRAPHIC SCALE

(IN FEET)
1 inch = 10 ft.





SP 5+6
EL+80 GS

SP 3+4
EL 83 GS.

PREL. TRACING ____ DESIGN ____ CHKD. ____

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

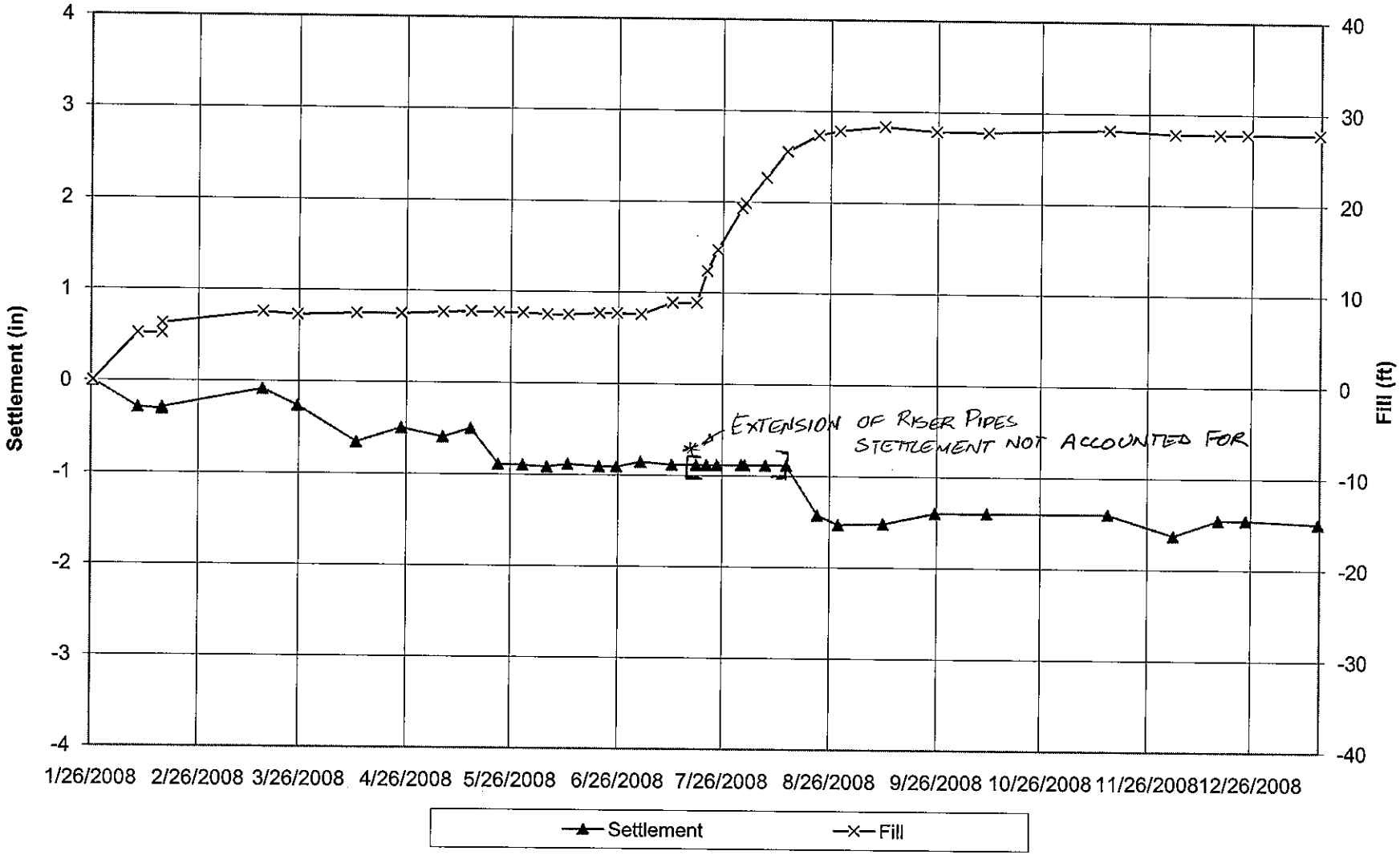


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Figure E-2b: Cumulative Displacement for SP-2

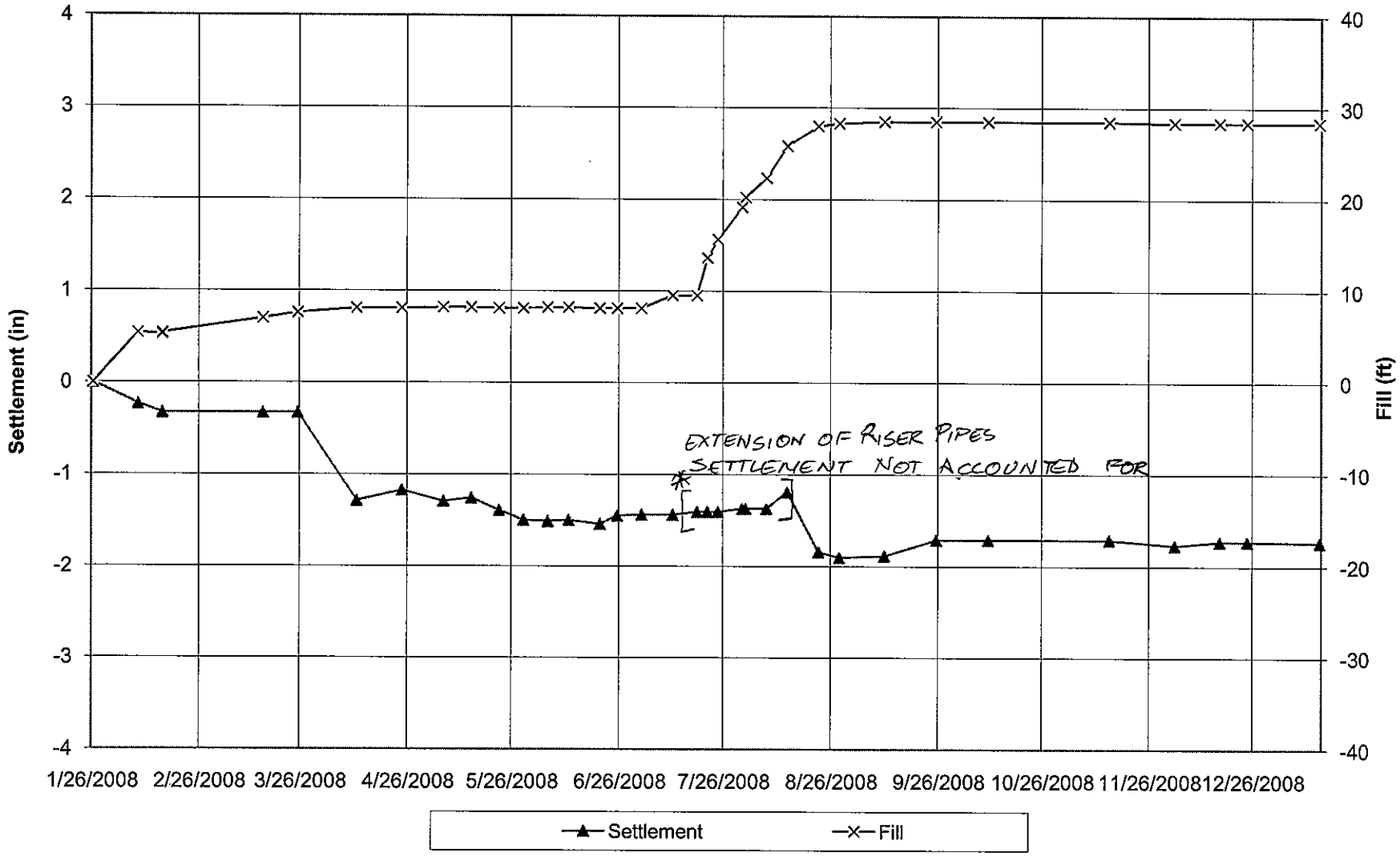


Figure E-2c: Cumulative Displacement for SP-3

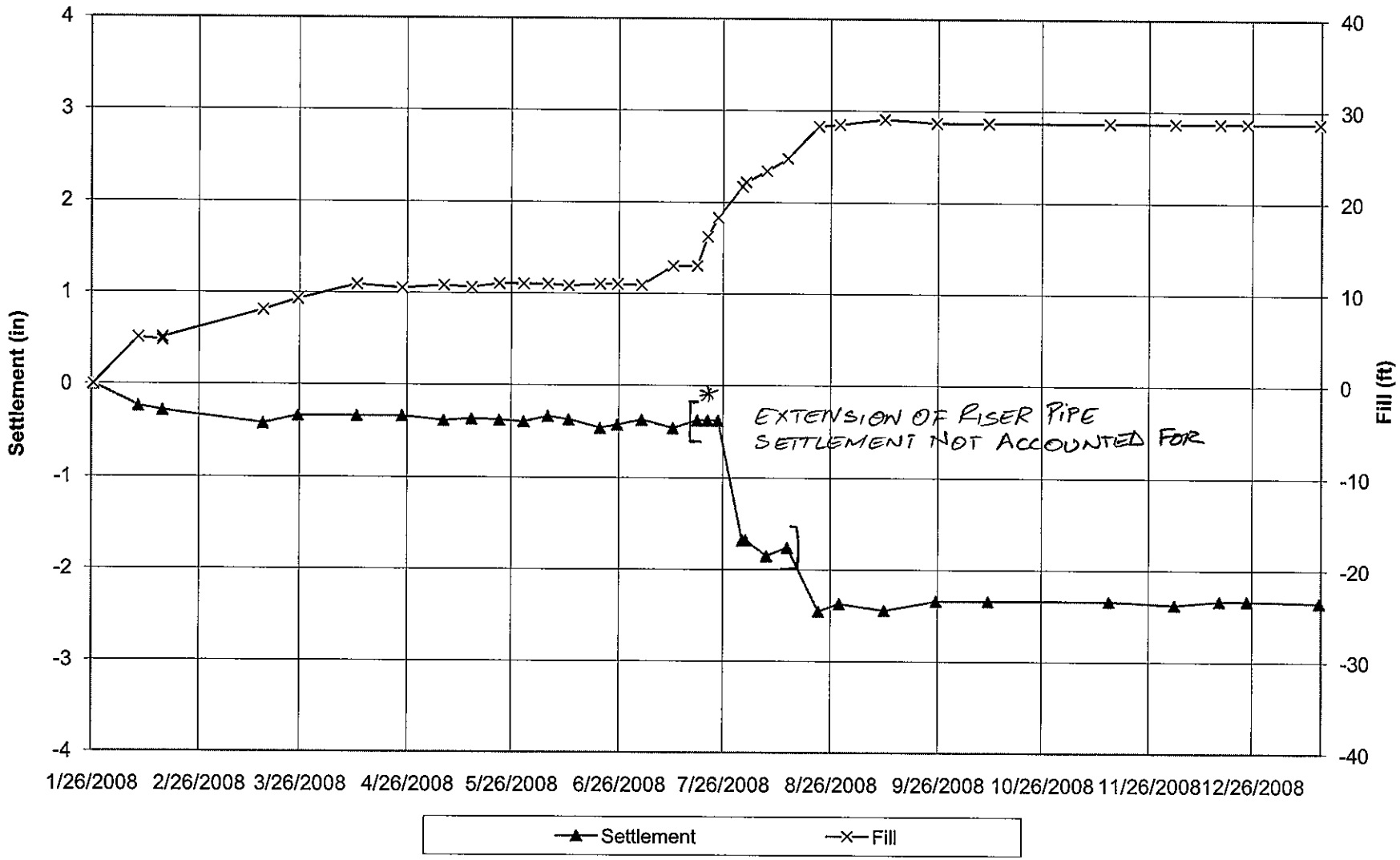
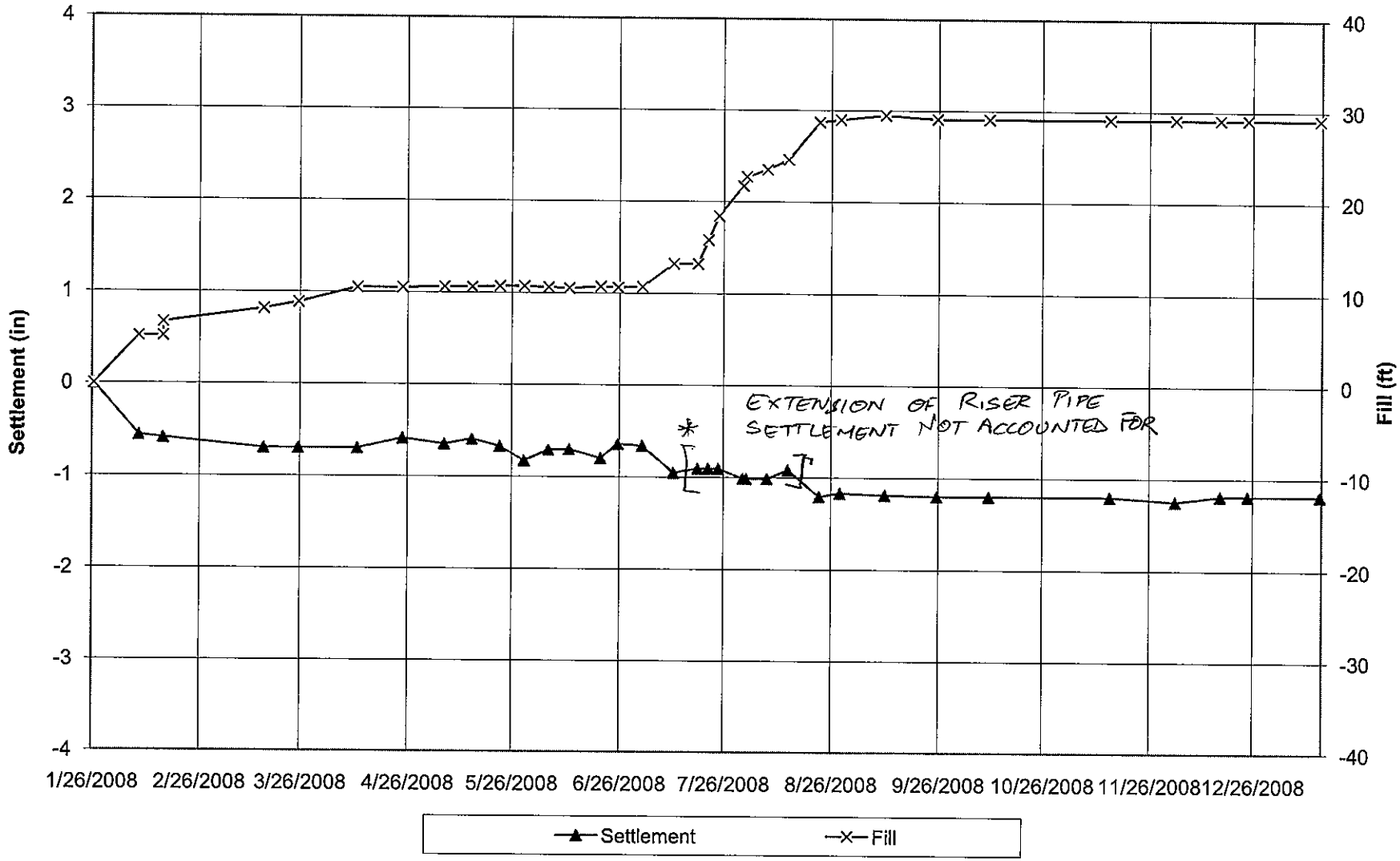


Figure E-2d: Cumulative Displacement for SP-4



RKK-147

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

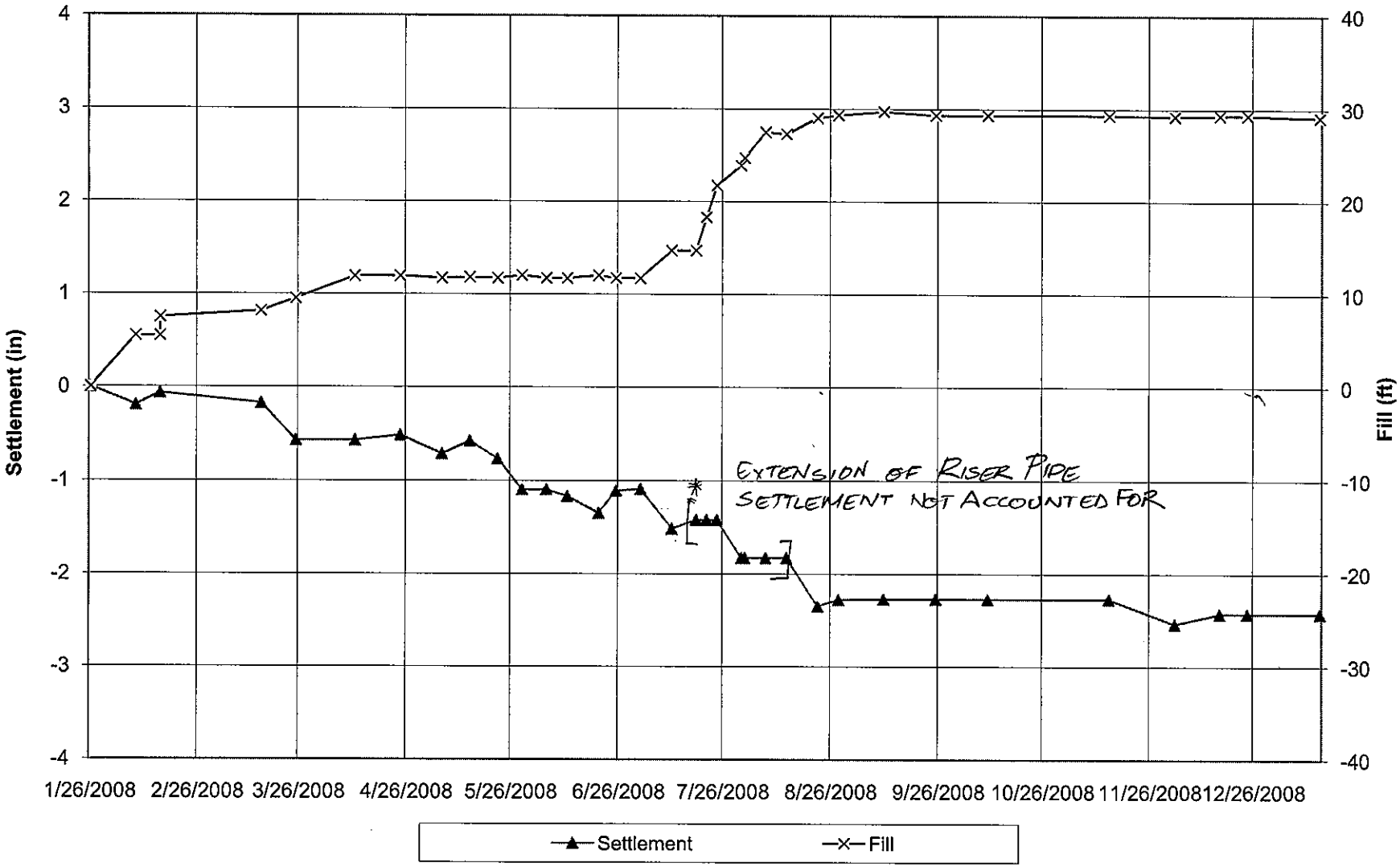
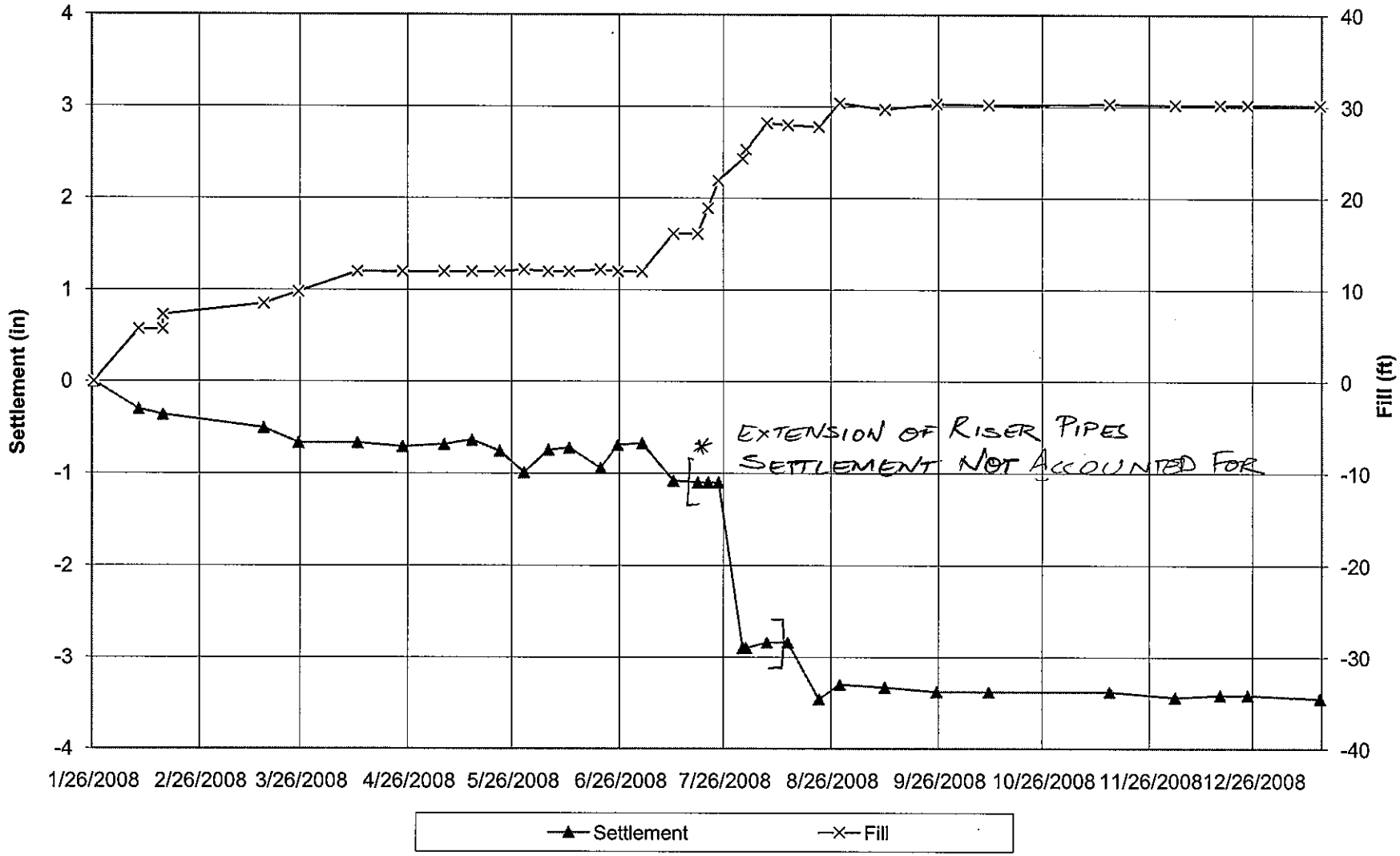


Figure E-2f: Cumulative Displacement for SP-6



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:

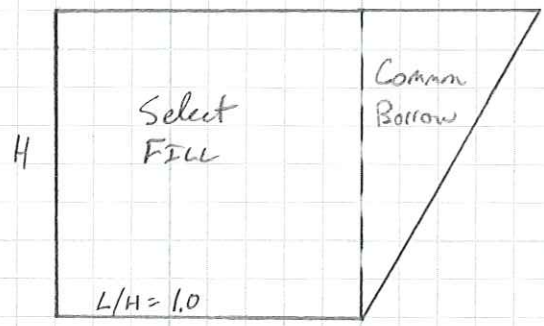
Computer Programs / Files: **MSEW 3.0, Excel**

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.
JPT	1-26-09	All calculations checked and each calculation sheet initialed by checker.
[illegible]	1/28/09	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

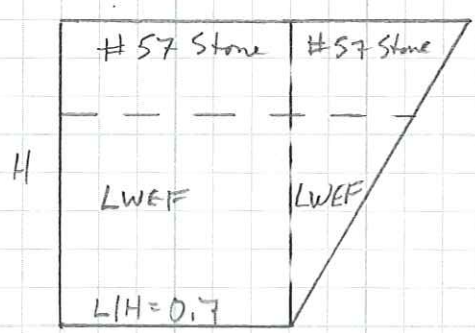
Additional Cost/ft: $230

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

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 JPT Date 1-26-09

Objective: To evaluate Retaining 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

JPT 1-26-09

RKK-153

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

2

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

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 JPT 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 starting, 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
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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)

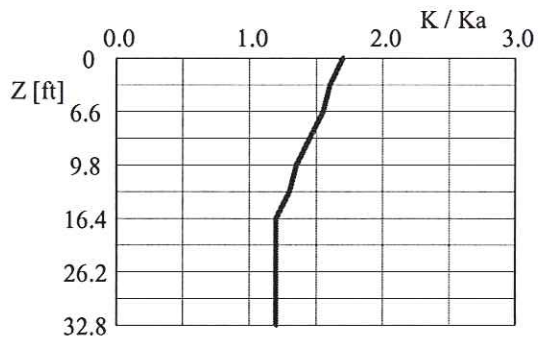
D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in 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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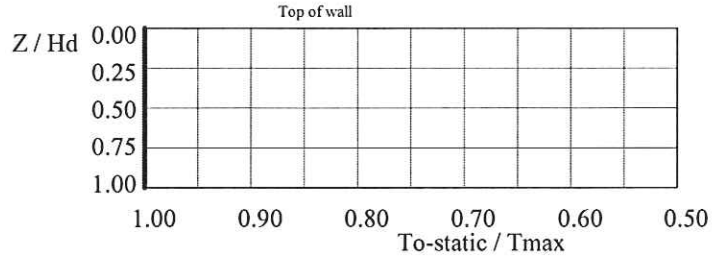
RKK-158
1-26-09

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 $\gamma_f = 150.00$ 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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JPT RKK-159 1-26-09

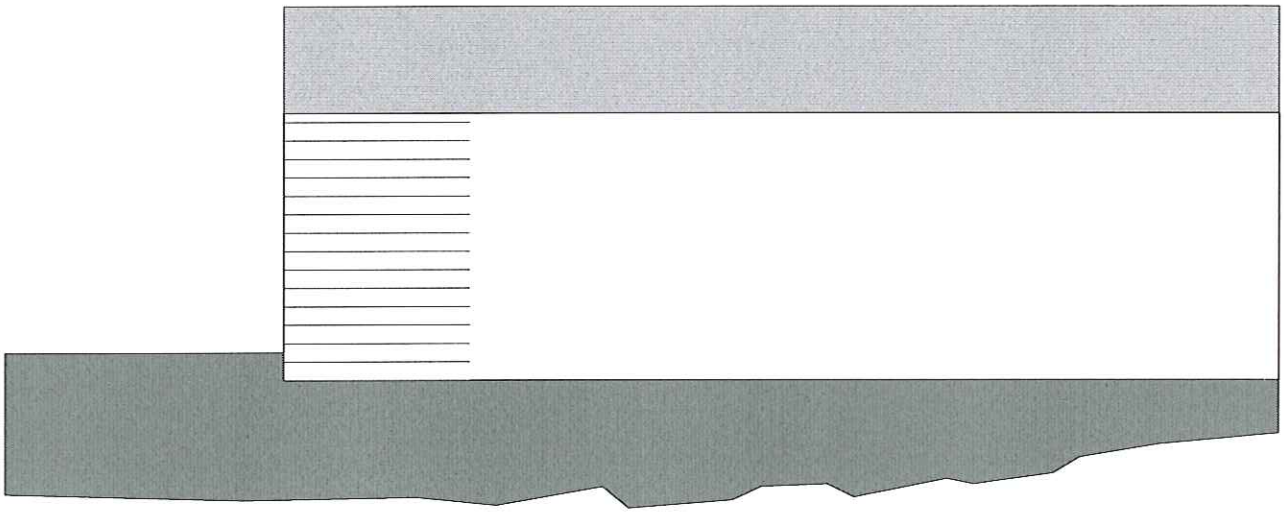
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

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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RKK-160
JPT 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

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

		Static		Combined Static/Seismic
Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:				
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

		Static	Combined Static/Seismic
Resistance factor for shear resistance along common interfaces from Table 10.5.5.2.2-1:			
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 = 1.03, 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

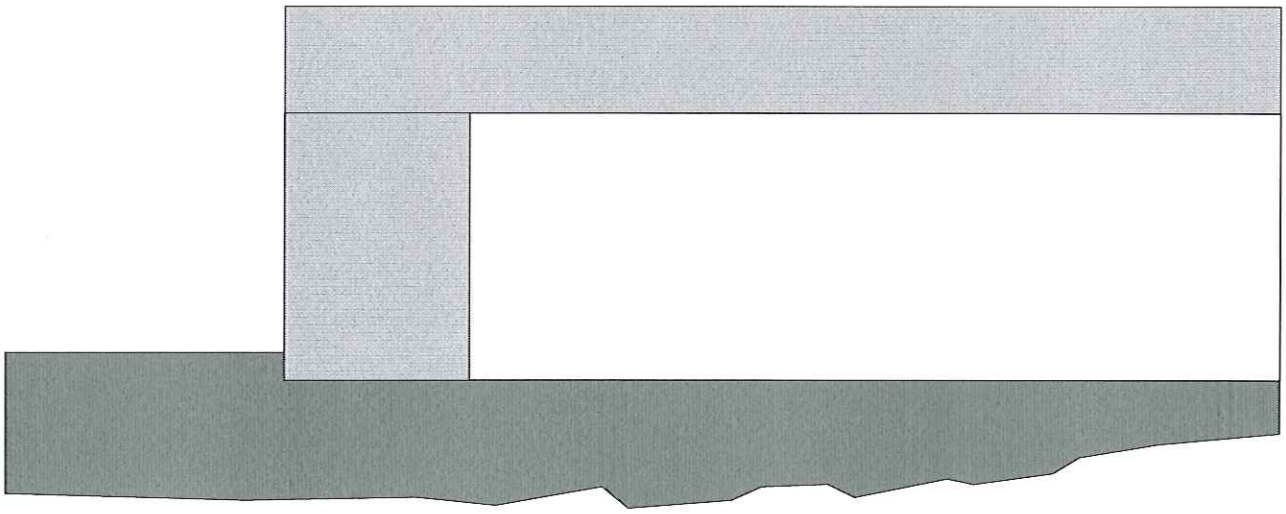
BEARING CAPACITY for GIVEN LAYOUT

	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]

L/H = 0.7

$q_{ult} > \sigma_V$

CDR > 1 ∴ ok



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

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	87,583 cf
					12,733 cy	8,913 cy	3,244 cy

Case 9

Start STA	End STA	L/H=0.7 Volume LWEF (cf)	L/H=0.7 Volume #57 (cf)	Wedge Volume LWEF (cf)	Wedge Volume #57 (cf)
1252+14	1252+68	20427	13618	4459	7927
1252+68	1253+58	28073	21055	5839	12042
1253+58	1254+46	22555	19333	4421	10824
1254+46	1255+35	16746	17474	2980	9474
1255+35	1256+23	11711	15615	1824	8121
1256+23	1257+12	7451	13756	954	6765
1257+12	1258+00	3966	11897	360	5413
1258+00	1258+89	1255	10038	53	4058
1258+89	1259+50	0	5677	0	2066
TOTAL		112,184 cf	128,463	20,889	66,689 cf
		4,155 cy	4,758	774	2,470 cy

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

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.

JCPT 1-26-09
RKK-164

CALCULATION CHECKLIST

Project: SR-1 / I-95 INTERCHANGE Comm. No.: 103-059

Title of Calculation Set: RAMP B BRIDGE (S-6)

Project Manager: EMK

Calculations Prepared By: BBS

Calculation Checked By:

Computer Programs / Files: FOSSA, ALLPILE, GRLWEAP, SLOPEW

Initial	Date	
BBS	1-28-09	Subsurface Characterization approved by Project Manager
BBS	1-28-09	Calculations are neat, legible and understandable.
BBS	1-28-09	Table of Contents is provided.
BBS	1-28-09	Heading on each page filled out
BBS	1-28-09	The first page contains purpose of the calculation.
BBS	1-28-09	Symbols are defined.
BBS	1-28-09	References for data, methods, formulas and computer program names and version numbers are given.
BBS	1-28-09	Assumptions are listed and those that need to be verified later are Flagged.
BBS	1-28-09	Headings on front sheet of each set of computer input and output.
BBS	1-28-09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
EMK	2/2/09	All calculations checked and each calculation sheet initialed by checker.
[illegible]	2/2/09	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.

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Subject SR-1/I-95 INTERCHANGE RAMP B BRIDGE S6 Page ____ of ____
Cm. No. 103-059
Prepared By BBS Date 1-28-09 Checked By ____ Date ____

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SET 3 (FOUNDATION DESIGN FOR ABUTMENTS & PIERS)

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Set 1

Abutment A

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Subject SR-1 INTERCHANGE ABUTMENT A WALLS
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Cm. No. 108-059
Prepared By BBS Date 9-19-08 Checked By CJN Date 9/27/08

PURPOSE: DESIGN OF MSE WING WALLS FOR RAMP B ABUTMENTS.
ABUTMENT A & WING WALLS

REFERENCE: AASHTO LRFD BRIDGE DESIGN SPECIFICATION
CUSTOMARY US UNITS 14th EDITION 2007.

SOFTWARE: MSEW 2.0 SLOPE W
FOSSA 2.0

* BASED ON BACK CALCULATION OF E_s & C_r FROM THE SETTLEMENT PLATES $C_r = 0.015$ & E_s VARIES. THIS DOES NOT AFFECT THE STABILITY.
EMC
1/14/09

SYMBOL:

UNIT WEIGHT → γ
FRICTION ANGLE → ϕ
UNDRAINED SHEAR STRENGTH → S_u
MODULUS OF ELASTICITY OF SOIL → E_s
POISSON'S RATIO → μ

COMPRESSION INDEX C_c
RECOMPRESSION/SWELL INDEX $C_R; C_S$
COEFFICIENT OF CONSOLIDATION C_v

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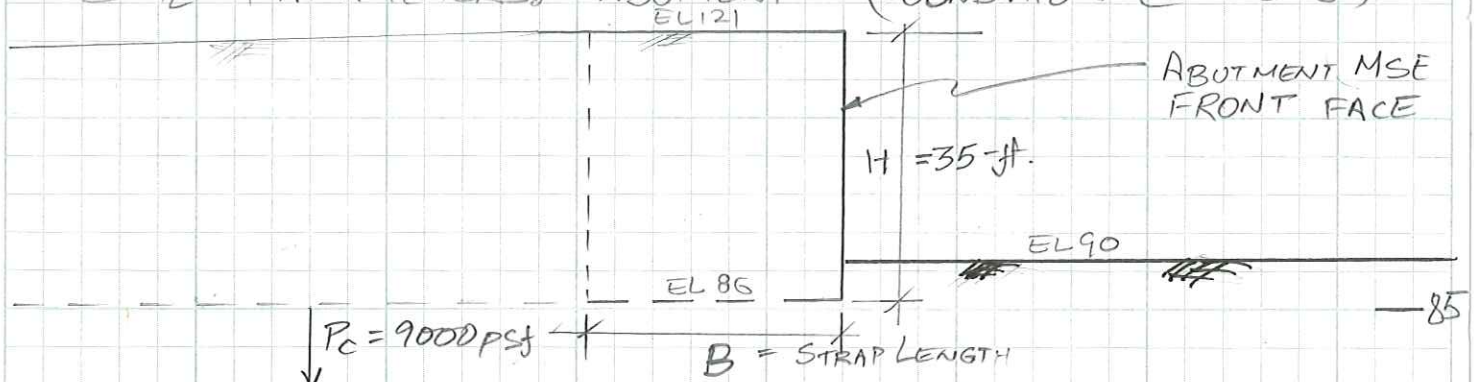
Subject SR-1 INTERCHANGE ABUTMENT A WALLS
Page 2 of 61
Cm. No. 103-059
Prepared By BBS Date 9-19-08 Checked By EMK Date 9/21/08

SOIL PARAMETERS: ABUTMENT A (FOUNDATION @ EL 86)



STRATUM 1a	γ = 125 pcf ϕ = 32° c = 0	E_s = 1500 ksf μ = 0.3	85 75 70
STRATUM 2a	γ = 130 pcf ϕ = 0 S_u = 1500 psf	E_s = 818 ksf μ = 0.4 C_c = 0.092 C_r = 0.015 OCR =	65 55 40
STRATUM 2a	γ = 130 pcf ϕ = 0 S_u = 2500 psf	E_s = 818 ksf μ = 0.4 C_c = 0.092 C_r = 0.0	25 20
STRATUM 2a	γ = 130 pcf ϕ = 0 S_u = 3500 psf	E_s = 818 ksf μ = 0.4 C_c = 0.105 C_r = 0.0	10 0
STRATUM 2a	γ = 130 pcf ϕ = 0 S_u = 5000 psf	E_s = 1364 ksf μ = 0.4 C_c = 0.105 C_r = 0.0	-5 -20

SOIL PROFILE

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Subject SR-1/I-95 INTERCHANGE RAMP B BRIDGE Page 3 of 51
Cm. No. 103-059
Prepared By BBS Date 1-27-09 Checked By DMC Date 2/2/09

SOIL PARAMETERS

→ UNDRAINED SHEAR STRENGTH OF FINE GRAINED 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 LONG TERM PARAMETER

STRATUM 2a $\phi = 24°$ $C = 0$

SPLINE FUNCTION.

SHEAR STRENGTH = $0.7753\,(\text{NORMAL STRESS})^{0.6701}$

→ YOUNGS MODULUS ESTIMATED FROM BACK CALCULATED E_s 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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SOIL PARAMETERS

STRATUM 1 EL 65 & ABOVE (COARSE GRAINED)

$\gamma = 125$ pcf $\phi = 32°$ $E_s = 1500$ ksf $\mu = 0.3$

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

Figure C-1
Summary of Undrained Shear Testing with Stress History
Strata IIa

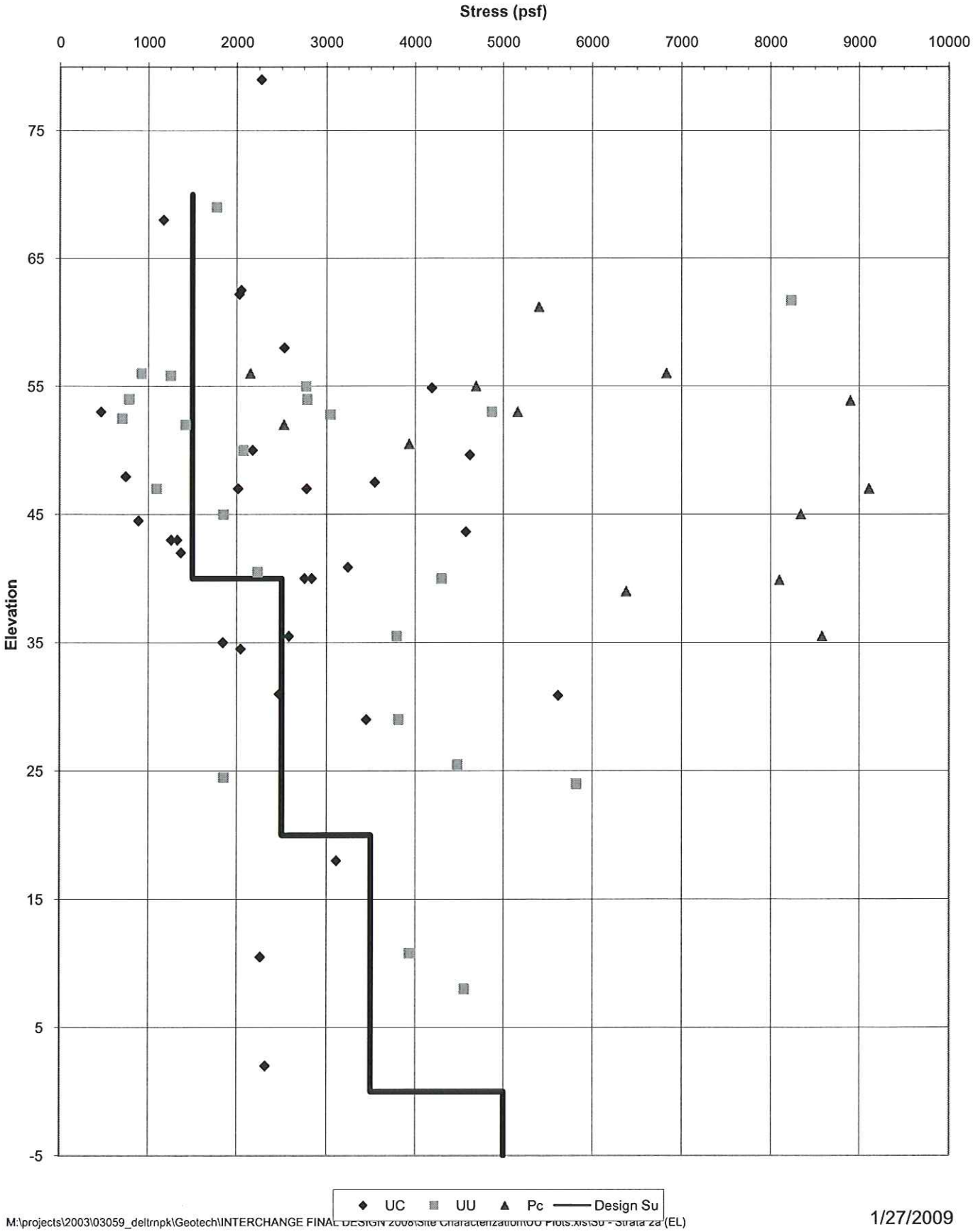
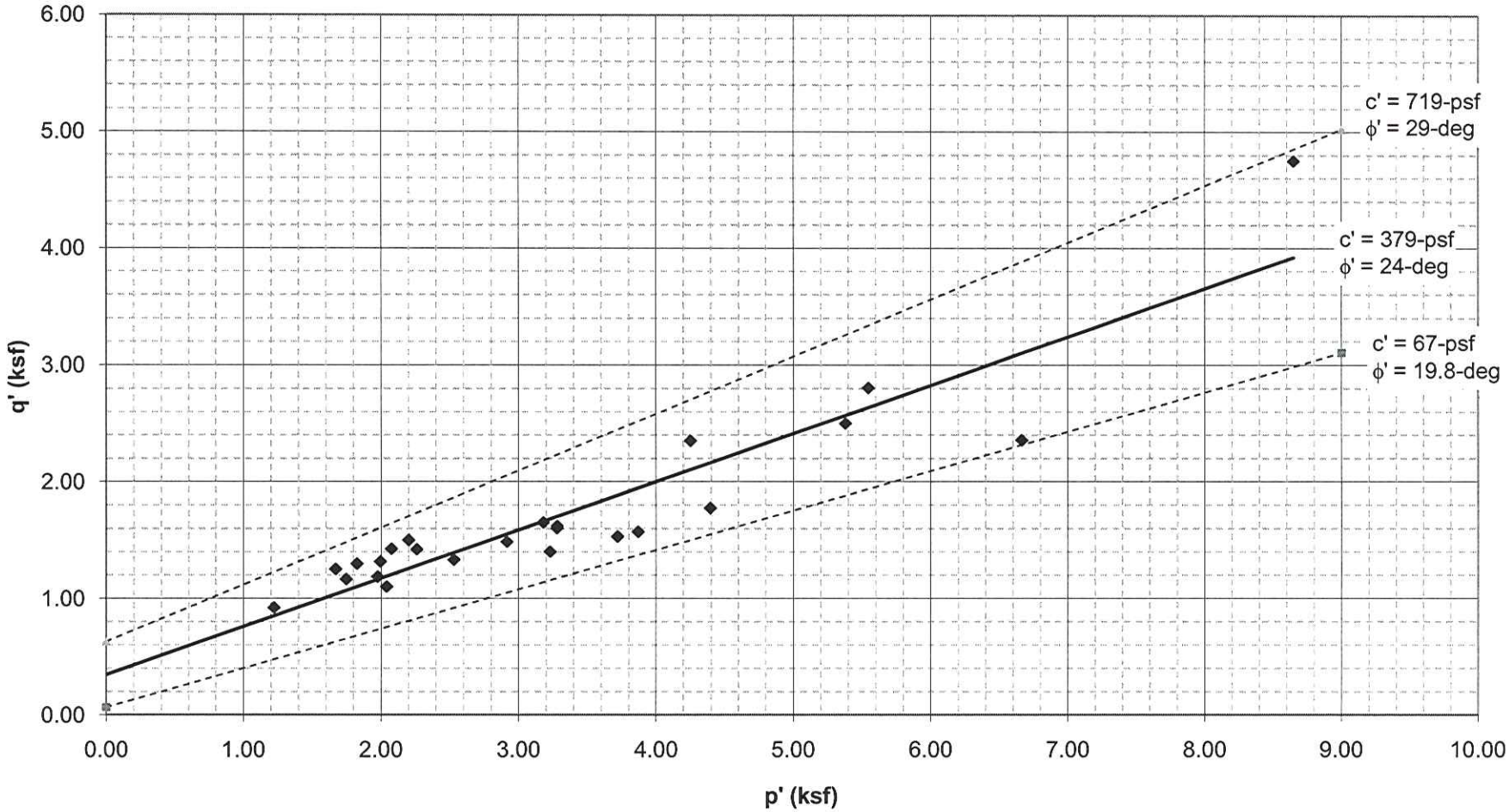


Figure C-2a
Summary of CU with Pore Pressure
Effective Stress - Strata IIa
EL 40 & Above



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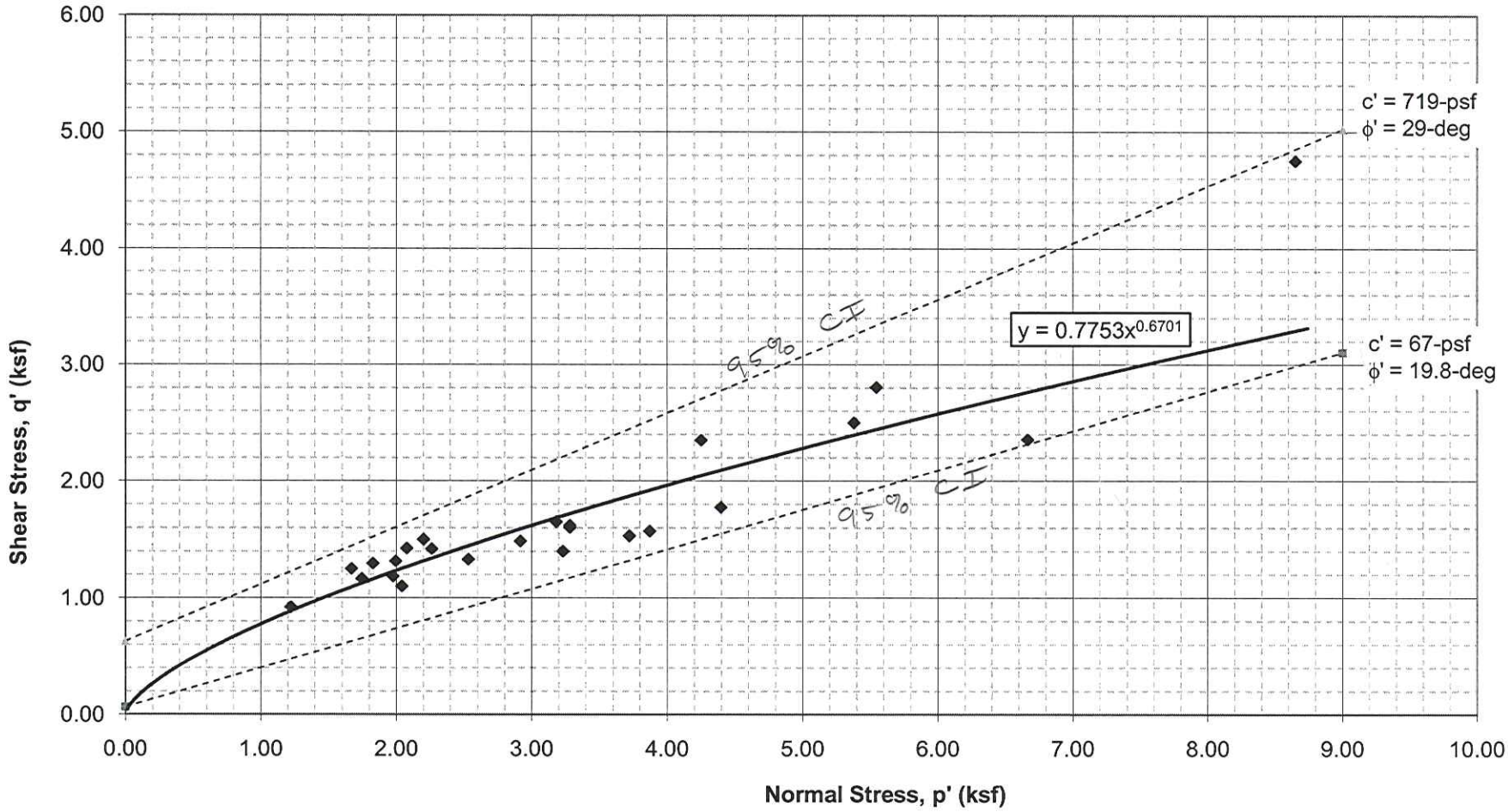
1/27/2009

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

$\tan a = \sin \phi$

$c = \frac{a}{\cos \phi}$



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SOIL PARAMETERS.

REINFORCED SOIL

$\gamma = 125$ pcf $\phi = 34°$

RETAINED SOIL FOR OVERLAPPING REINFORCED ZONE BACK TO BACK WALL WILL BE THE REINFORCED SOIL

$\gamma = 125$ pcf $\phi = 34°$

FOUNDATION SOIL

$\gamma = 125$ pcf $\phi = 32°$ (TOP 20 ft APPROX)

ACTIVE EARTH PRESSURE COEFFICIENT FOR RETAINED 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 BACKFACE

$\alpha = 0°$ HORIZONTAL BACKFILL

$\delta = 0$ FRICTION ANGLE BETWEEN SOIL & WALL
$\delta = \alpha$ FOR MSE WALL 11.10.5.2

$\phi = 34°$ FRICTION ANGLE OF RETAINED SOIL

$$K_a = \frac{\sin^2(124)}{\sin^2 90 \sin 90\left[1+\sqrt{\frac{\sin 34 \sin 34}{\sin 90 \sin 90}}\right]^2} = \frac{0.6873}{2.43}$$

$= 0.2827$

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EARTH PRESSURE FOR EXTERNAL STABILITY

$F_1 = \frac{1}{2} K_a \gamma H^2$

$= \frac{1}{2} \times 0.2827 \times 125 \times 35^2$

$= 21644.22$ lb/ft

$F_2 = K_a q_{sur} H$

$= 0.2827 \times 250 \times 35$

$= 2473.6$ lb/ft

EXTERNAL STABILITY CHECK FOR STRENGTH LIMIT STATE

SETTLEMENT ANALYSIS PERFORMED FOR SERVICE LIMIT STATE

STRENGTH LIMIT STATE (ECCENTRICITY & SLIDING)

ECCENTRICITY

$$e = \frac{1.5 F_1 \cos\alpha \, H/3 + 1.75 F_2 \cos\alpha \, H/2}{V_1}$$

$$= \frac{1.5 \times 21644.2 \times \cos 0 \; 35/3 + 1.75 \times 2413.6 \times \cos 0 \; 35/2}{125 \times 35 \times 25}$$

$$= 4.15 \text{ ft.}$$

THIS ASSUME SOIL IN REINFORCEMENT ZONE

CHECK FOR OVERTURNING:

RESULTANT OF REACTION FORCES SHALL BE WITHIN $\frac{1}{2}$ OF THE CENTER BASE WIDTH

$\frac{1}{2}$ BASE WIDTH $= 0.5 \times 25 = 12.5$ ft

ECCENTRICITY $< \frac{12.5}{2}$

$4.15 < 6.25$ ok

SLIDING CHECK.

FACTORED RESISTANCE AGAINST SLIDING

$R_R = \phi R_n$

$\phi = 1.0$ 11.5.6.1

$R_n = V \tan \delta$

δ = Smaller of ϕ_f or ϕ_R

ϕ_f = FOUNDATION SOIL = 32°

ϕ_R = REINFORCED SOIL = 34°

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$R_n = V_1 \tan 32°$

$= 125 \times 35 \times 25 \times \tan 32$

$= 68345$ lb/ft

HORIZONTAL DRIVING FORCES.

$R_{DR} = 1.5 F_1 + 1.75 F_2$

$= 1.5 \times 21644.2 + 1.75 \times 2473.6$

$= 36795.1$ lb/ft

$R_R = \phi R_n = 1 \times 68345$

$= 68345$ lb/ft $> R_{DR} = 36795.1$ lb/ft OK

THIS ASSUMES SOIL IN THE REINFORCEMENT ZONE

STRENGTH LIMIT STATE (BEARING CAPACITY)

ECCENTRICITY

$$e = \frac{1.5 F_1 \cos\alpha \, H/3 + 1.75 F_2 \cos\alpha \, H/2}{1.35 V_1 + 1.75 q_{sur} B}$$

$$= \frac{1.5 \times 21644.2 \times \cos 0 \times 4/3 + 1.75 \times 2473.6 \times \cos 0 \times 35/2}{1.35 \times 125 \times 35 \times 25 + 1.75 \times 250 \times 25}$$

$$= 2.866 \text{ ft}$$

THIS ASSUME SOIL IN THE REINFORCEMENT ZONE

EQUIVALENT UNIFORM VERTICAL STRESS ON THE BASE

$$\sigma_v = \frac{\Sigma V}{B - 2e}$$

$$= \frac{1.35 V_1 + 1.75 q_{sur} B}{B - 2e}$$

$$= \frac{1.35 \times 125 \times 35 \times 25 + 1.75 \times 250 \times 25}{25 - 2 \times 2.866}$$

$$= \underline{\underline{8231 \text{ psf}}}$$

EFFECTIVE FOOTING WIDTH $= B - 2e = 19.27$ ft

CHECK FOR BEARING CAPACITY

NOMINAL BEARING CAPACITY

$$q_n = c N_c S_c i_c + \gamma D_f N_q S_q d_q i_q C_{wq} + 0.5 \gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$$

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MSE WALL DESIGN FRONT FACE
MINIMUM LENGTH OF REINFORCEMENT = 0.7 H

H = 35-ft (MAX HEIGHT OF WALL)

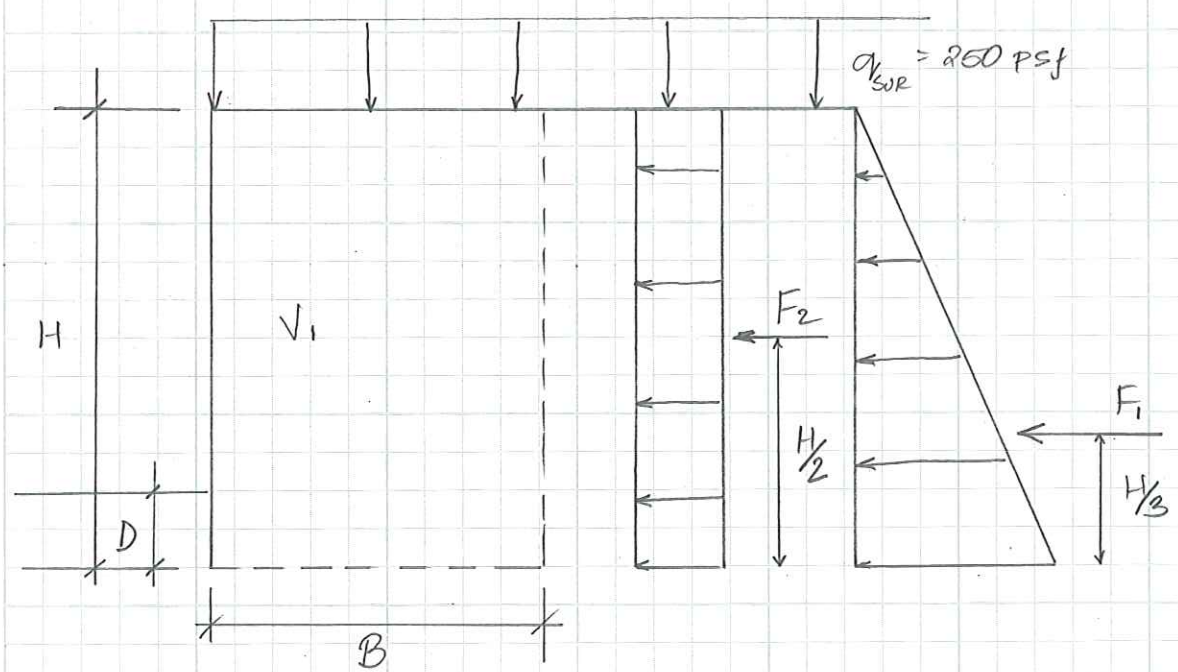
USE B = 24.5-ft ≈ 25 ft

MINIMUM DEPTH OF FRONT FACE EMBEDMENT (D)

PROFILE HORIZONTAL INFRONT OF STRUCTURE

$D = \frac{H}{10}$ FOR ABUTMENTS

$= \frac{35}{10} = 3.5$-ft MINIMUM



$F_1 = \frac{1}{2} K_a \gamma H^2$

$F_2 = K_a q_{SUR} H$

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FOUNDATION SOIL IS COARSE GRAINED

$\phi = 32°$ $c = 0$

$\phi = 32°$ $N_\gamma = 30.2$ 10.6.3.1.2a-1

FOR MSE WALL

N_q IS NEGLECTED

$C_{wt} = 0.5$ FOR WATER TABLE @ FOUNDATION LEVEL

FOR $\phi > 0$

$$S_\gamma = 1 - 0.4\frac{B}{L} = 1 - 0.4\frac{25}{34} = 0.71$$

$$q_n = 0.5 \times 125 \times 19.27 \times 30.2 \times 0.5 \times 0.71$$
$$= 12912.1 \text{ psf}$$

FACTORED RESISTANCE

$$q_R = \phi_b q_n$$

$\phi_b = 0.65$ Table 10.5.6.1

$$q_R = 0.65 \times 12912.1 \text{ psf}$$
$$= 8392.8 \text{ psf} > \sigma_v = 8231 \text{ psf}$$ OK

CHECK FOR 2 LAYERED SYSTEM

$$H_{CRIT} = \frac{3B \ln(q_1/q_2)}{2\left(1+\frac{B}{L}\right)}$$

B = FOOTING WIDTH

L = LENGTH OF FOOTING

q_1 = NOMINAL BEARING RESISTANCE OF FOOTING SUPPORTED ON THE UPPER LAYER

q_2 = NOMINAL BEARING RESISTANCE OF FOOTING SUPPORTED ON THE LOWER LAYER

$q_1 = 12912.1$ psf

$$q_2 = c N_c \cancel{s_c}^{0} i_c + \gamma D_f N_q \cancel{s_q}^{0} d_q i_q C_{wq} + \frac{1}{2} \gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$$

DRAINED CONDITION

$\phi = 24°$ $c = 0$ OVERBURDEN FACTOR IGNORED IN MSE WALL $N_q = 0$

$N_\gamma = 9.4$ (10.6.3.1.2a-1) $S_\gamma = \left(1 - 0.4\frac{B}{L}\right)$

$C_{w\gamma} = 0.5$ (10.6.3.1.2a-2)

$B = 19.27$ ft $L = 33$ ft $H = 21$ ft. (THICKNESS OF UPPER LAYER)

$$q_2 = \frac{1}{2} \times 130 \times 19.27 \times 9.4 \times \left(1 - 0.4 \times \frac{19.27}{33}\right) \times 0.5$$

$= 4511.9$ psf

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$$H_{CRIT} = \frac{3 \times 19.27 \ \ln\left(\frac{12912.1}{4511.9}\right)}{2\left(1 + \frac{19.27}{33}\right)}$$

$$= 19.2 \text{ ft}$$

$$H = 21 \text{ ft} > H_{CRIT} = 19.2 \text{ ft}$$

FOUNDATION SOIL SINGLE LAYER

NOMINAL BEARING RESISTANCE

$$q_n = q_1 = 12912.1 \text{ psf}$$

$$q_R = 0.65 q_n$$

$$= 8392.8 \text{ psf} > \sigma_v = 8231 \quad \text{OK}$$

SERVICE LIMIT STATE (BEARING PRESSURE FOR SETTLEMENT CALCULATION)

ECCENTRICITY

$$e = \frac{F_1 \cos\alpha \, H/3 + F_2 \cos\alpha \, H/2}{V_1 + qB}$$

$$= \frac{21644.22 \times \cos 0 \times 35/3 + 24736 \times \cos 0 \times 35/2}{125 \times 35 \times 25 + 250 \times 25}$$ ← ASSUMES SOIL IN REINFORCEMENT ZONE

$$= \frac{295803.9}{115625}$$

$$= \underline{2.56 \text{ ft}}$$

EQUIVALENT UNIFORM VERTICAL STRESS @ BASE

$$\sigma_v = \frac{V_1 + qB}{B - 2e}$$

$$= \frac{125 \times 35 \times 25 + 250 \times 25}{25 - 2 \times 2.56}$$

$$= \frac{115625}{19.88}$$

$$\boxed{= 5816 \text{ psf.}}$$ FOR SETTLEMENT CALCULATION

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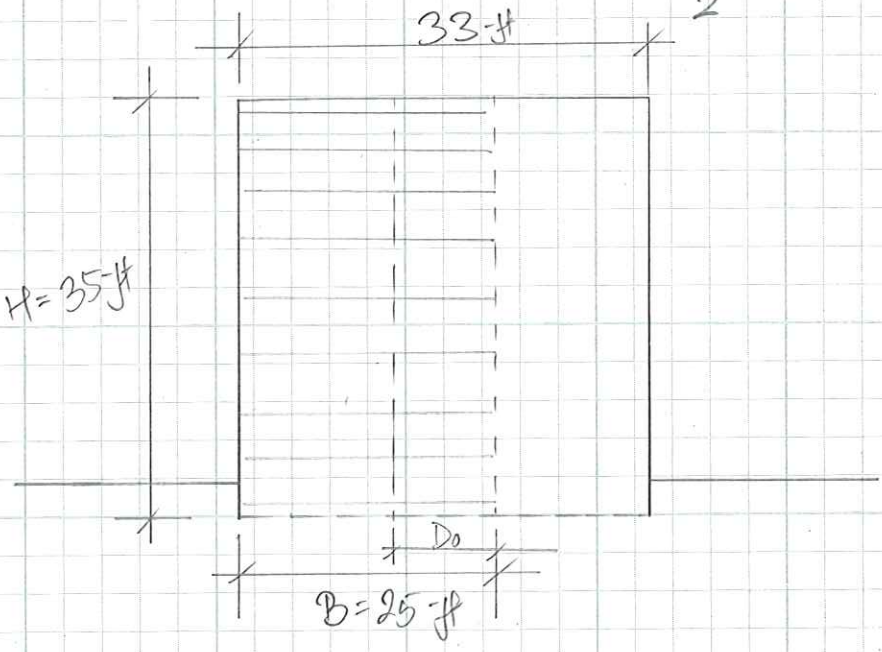
BACK TO BACK WING WALLS

HEIGHT OF WALL = 35-ft.

STRIP LENGTH = 0.7H = 25-ft

DISTANCE BETWEEN WALL = 33-ft.

OVERLAP OF REINFORCEMENT $D_o = 25 - \frac{33}{2} = 8.5$-ft.



IF $D_o > 0.3H$ NO LATERAL PRESSURE

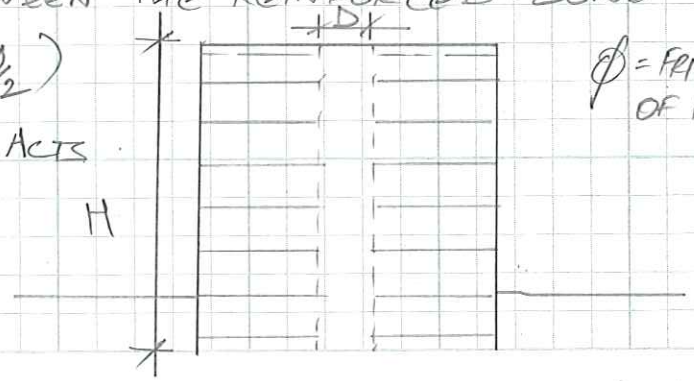
$0.3H = 10.5 > D_o$

D = DISTANCE BETWEEN THE REINFORCED ZONE

IF $D > H \tan(45 - \phi/2)$

TOTAL LATERAL FORCE ACTS

BETWEEN D & D_o
INTERPOLATE



ϕ = FRICTION ANGLE OF RETAINED SOIL

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∴ FOR D = 21-ft. TOTAL LATERAL FORCE ACTS.

∴ LINEAR INTERPOLATION FOR LATERAL FORCE

0 @ D_o = -10.5

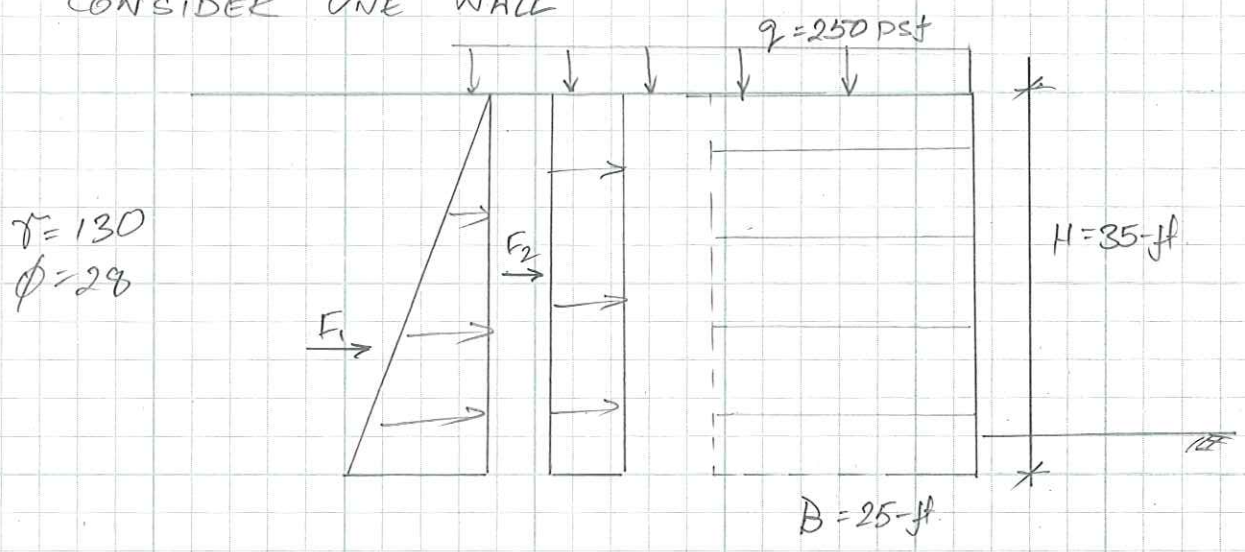
1 @ D = 21-ft

TOTAL = 21+10.5 = 31.5

D_o = -8.5

∴ % of LATERAL FORCE = $\frac{2}{31.5}$ = 6%

CONSIDER ONE WALL



K_a = 0.2827

F_1 = 6% $\frac{1}{2} K_a \gamma H^2$ = 1298.6 lb/ft

F_2 = 6% $q K_a H$ = 148.4 lb/ft

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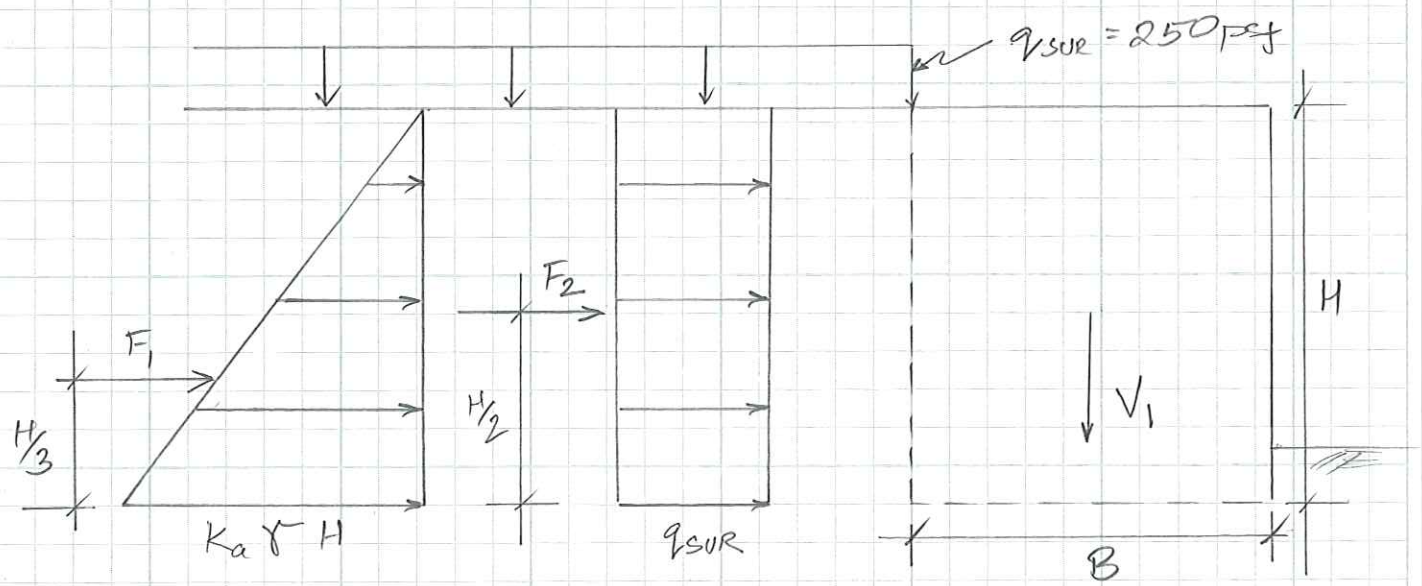
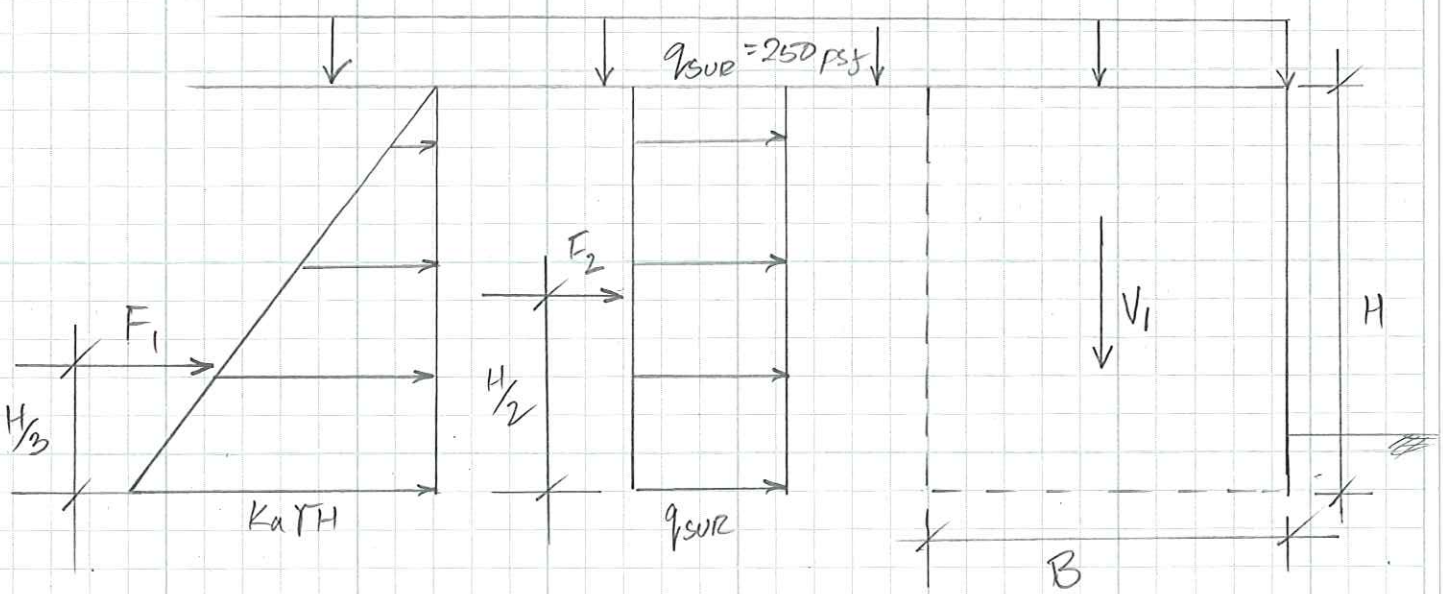
ALLOWABLE STRESS DESIGN



FOR OVERTURNING & SLIDING.



FOR BEARING PRESSURE

ALLOWABLE STRESS DESIGN

SLIDING & OVERTURNING CHECK

ECCENTRICITY:

$$e = \frac{F_1 \cos\alpha \, H/3 + F_2 \cos\alpha \, H/2}{V_1}$$

$$= \frac{1298.6 \times \cos 0 \times 35/3 + 148.4 \times \cos 0 \times 35/2}{125 \times 35 \times 25}$$

$$= \frac{17747.3}{109375}$$

$$= 0.162 \text{ ft}$$

CHECK FOR OVERTURNING

ECCENTRICITY IS WITH IN $\frac{1}{3}$ OF THE CENTER BASE WIDTH

$\frac{1}{2}$ BASE WIDTH $= \frac{1}{2} \times 25 = 12.5$

$$\text{ECCENTRICITY} < \frac{12.5}{3}$$

$0.162 < 4.17$ OK

CHECK FOR SLIDING.

RESISTING FORCE

$$R_R = \Sigma V \tan \delta$$

δ = SMALLER OF ϕ_f OR ϕ_R (FRICTION ANGLE)

ϕ_f = FOUNDATION SOIL = 32°

ϕ_R = REINFORCED SOIL = 34°

$\delta = 32°$

$R_R = 125 \times 35 \times 25 \times \tan 32°$

$= 68{,}345$ lb/ft.

HORIZONTAL DRIVING FORCE

$R_{DR} = F_1 + F_2$

$= 1298.6 + 148.4$

$= 1447.0$ lb/ft.

FACTOR OF SAFETY

$F.S. = \frac{R_R}{R_{DR}} = \frac{68345}{1447} = 47 > 1.5$ OK.

BEARING CAPACITY CHECK

ECCENTRICITY

$$e = \frac{F_1 \cos\alpha \, H/3 + F_2 \cos\alpha \, H/2}{V_1 + q_{sur} B}$$

$$= \frac{1298.6 \times \cos 0 \times 35/3 + 148.4 \times \cos 0 \times 35/2}{125 \times 35 \times 25 + 250 \times 25}$$

$$= \frac{17747.3}{115625}$$

$$= 0.153 \text{ ft}$$

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EQUIVALENT UNIFORM VERTICAL STRESS ON BASE

$$\sigma_v = \frac{\Sigma V}{B-2e}$$

$$= \frac{V_1 + q_{SUR}\, B}{B-2e}$$

$$= \frac{125 \times 35 \times 25 + 250 \times 25}{25 - 2 \times 0.153}$$

$$= \frac{115625}{24.69}$$

$$= 4683 \text{ psf}$$

EQUIVALENT FOOTING $= B - 2e$

$= 24.69$ ft.

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BEARING CAPACITY CHECK

FOR BACK TO BACK WALL WITH OVERLAPPING REINFORCEMENT
USE WIDTH OF FOOTING B = DISTANCE BETWEEN WALLS.

ULTIMATE BEARING RESISTANCE

$$q_{ult} = \cancel{c N_c S_c}^{0} + \gamma D_f N_q \cancel{S_q d_q}^{0} i_q C_{wq} + \frac{1}{2} \gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$$

FOUNDATION SOIL IS GRANULAR $c = 0$

FOR MSE WALL N_q FACTOR IS NEGLECTED

$$q_{ult} = \frac{1}{2} \gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$$

FOR $\phi = 32°$ $N_\gamma = 30.2$

$S_\gamma = 1 - 0.4\, B/L = 1 - 0.4 \frac{33}{50} = 0.736$

$C_{w\gamma} = 0.5$ FOR WATER @ FOOTING ELEVATION

$$q_{ult} = \frac{1}{2} 125 \times 33 \times 30.2 \times 0.736 \times 0.5$$

$$= \underline{\underline{22{,}921.8 \text{ psf}}}$$

FACTOR OF SAFETY

$$F_s = \frac{q_{ult}}{\sigma_v} = \frac{22921.8}{4683} = \underline{\underline{4.9 > 2.5 \text{ OK}}}$$

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CHECK FOR TWO LAYERED SYSTEM

$$H_{CRIT} = \frac{3B \ln(q_1/q_2)}{2(1+\frac{B}{L})}$$

B = FOOTING WIDTH

L = LENGTH OF FOOTING

q_1 = NOMINAL BEARING RESISTANCE OF FOOTING SUPPORTED ON THE UPPER LAYER

q_2 = NOMINAL BEARING RESISTANCE OF FOOTING SUPPORTED ON THE LOWER LAYER

$q_1 = \underline{22921.8 \text{ psf}}$

$$q_2 = cN_c \cancel{s_c} \cancel{i_c}^{0} + \gamma D_f N_q s_q d_q \cancel{i_q}^{0} C_{wq} + \frac{1}{2}\gamma B N_\gamma s_\gamma i_\gamma C_{w\gamma}$$

DRAINED CONDITION

$\phi = 24°$ $c = 0$ $N_q = 0$ FOR MSE WALLS

$N_\gamma = 9.4$ (10.6.3.1.2a-1) $s_\gamma = \left(1 - 0.4 \times \frac{B}{L}\right)$

$C_{w\gamma} = 0.5$ (10.6.3.1.2a-2)

B = 33-ft (BACK TO BACK WALLS)

L = 50-ft. (LENGTH OF WING WALLS)

H = 21-ft (THICKNESS OF UPPER SOIL LAYER)

$$q_2 = \frac{1}{2} \times 130 \times 33 \times 9.4 \times \left(1 - 0.4 \frac{33}{50}\right) \times 0.5$$

$$= \underline{7420 \text{ psf}}.$$

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$$H_{CRIT} = \frac{3 \times 33 \times \ln\left(\frac{22\,921.8}{7420}\right)}{2\left(1 + \frac{33}{50}\right)}$$

$$= 33\text{-ft} > H = 21\text{-ft}$$

CHECK BEARING CAPACITY FOR LAYERED SYSTEM.

q_{ULT} FOR 2 LAYERED SYSTEM

$$q_{ULT} = q_2\, e^{0.67[1+B/L]\,H/B}$$

$$= 7420\, e^{0.67[1+\frac{33}{50}]\frac{21}{33}}$$

$$= 2.029 \times 7420$$

$$q_{ULT} = 15055 \text{ psf}$$ 2 LAYERED SYSTEM

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FACTOR OF SAFETY FOR BEARING

$$F.S. = \frac{q_{ULT}}{\sigma_V}$$

$$= \frac{15055}{4683} = 3.21 > 2.5 \text{ OK.}$$

SETTLEMENT ANALYSIS BEARING STRESS

$$\sigma_V = 4683 \text{ psf}$$

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Prepared By BBS Date 1-27-09 Checked By EWK Date 2/2/09

GLOBAL STABILITY ANALYSIS: ABUTMENT A

SOIL PARAMETERS USED FOR STABILITY ANALYSIS.

EL65-EL90 STRATUM 1 WATER TABLE @ EL 75

$\gamma = 125$ pcf COARSE GRAINED

$\phi = 32°$

EL 40-EL65 STRATUM 2a

$\gamma = 130$ pcf FINE GRAINED

$\phi = 0$ $S_u = 1500$ psf (UNDRAINED CONDITION)

SPLINE FUNCTION (DRAINED CONDITION)

→ SHEAR STRENGTH = $0.7753\,(\text{SHEAR STRESS})^{0.6701}$ —— (1)

EL20-EL40 STRATUM 2a

$\gamma = 130$ pcf FINE GRAINED

$\phi = 0$ $S_u = 2500$ psf (UNDRAINED CONDITION)

SPLINE FUNCTION (DRAINED CONDITION) EQN (1)

EL 0-EL20 STRATUM 2a

$\gamma = 130$ pcf FINE GRAINED

$\phi = 0$ $S_u = 3500$ psf (UNDRAINED CONDITION)

SPLINE FUNCTION (DRAINED CONDITION EQN (1)

REINFORCED SOIL $\gamma = 125$ pcf

$\phi = 34°$

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Subject SR-1 / I-95 INTERCHANGE RAMP B ABUTMENT A
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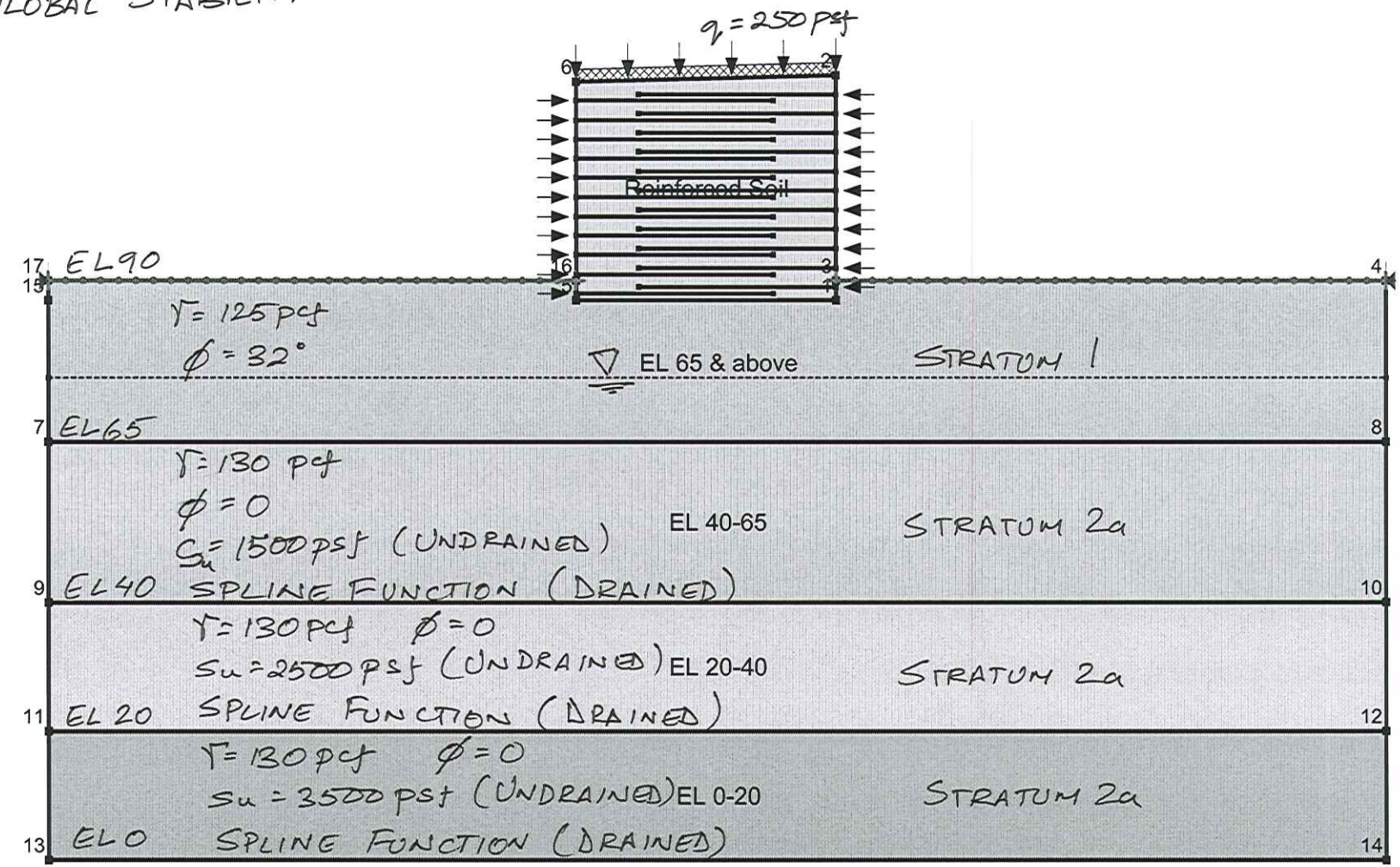
SUMMARY OF GLOBAL STABILITY ANALYSIS RESULTS.

ANALYSIS	FACTOR OF SAFETY	RESISTANCE FACTOR
DRAINED	2.711	0.368 < 0.65 OK
UNDRAINED	2.549	0.392 < 0.65 OK.

GLOBAL STABILITY ANALYSIS



S6: ABUTMENT A

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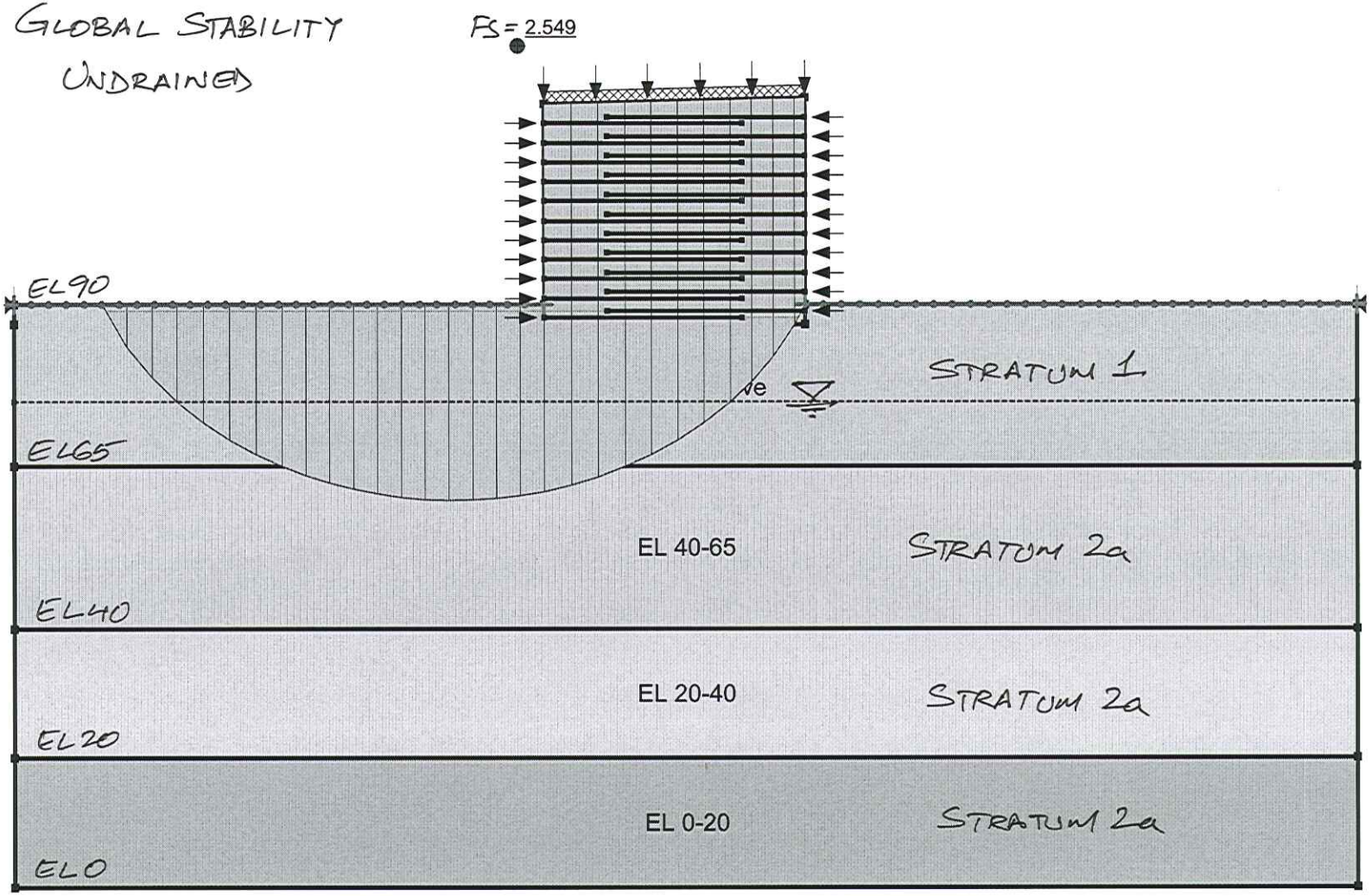
BRS
12/12/01

GLOBAL STABILITY
UNDRAINED



S6 : ABUTMENT A

SLOPE/W Analysis

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File Information

Revision Number: 59
Date: 1/27/2009
Time: 9:06:56 AM
File Name: Abut A (UnDrained).gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Ramp B\Global Stability\
Last Solved Date: 1/27/2009
Last Solved Time: 9:07:49 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: Abutment A
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 °

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: (0, 103) ft
Left-Zone Right Coordinate: (66.9, 103) 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, 103) 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

Coordinates

	X (ft)	Y (ft)
	67	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: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 3

Type: Fabric
Outside Point: (100, 126) ft
Inside Point: (75, 126) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 4

Type: Fabric
Outside Point: (100, 123) ft
Inside Point: (75, 123) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 5

Type: Fabric
Outside Point: (100, 120) ft
Inside Point: (75, 120) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 6

Type: Fabric
Outside Point: (100, 117) ft
Inside Point: (75, 117) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 7

Type: Fabric
Outside Point: (100, 114) ft
Inside Point: (75, 114) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 8

Type: Fabric
Outside Point: (100, 111) ft
Inside Point: (75, 111) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °

Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 9

Type: Fabric
Outside Point: (100, 108) ft
Inside Point: (75, 108) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 10

Type: Fabric
Outside Point: (100, 105) ft
Inside Point: (75, 105) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 11

Type: Fabric
Outside Point: (100, 102) ft
Inside Point: (75, 102) ft
Slip Surface Intersection: (11.636, 102) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 12

Type: Fabric
Outside Point: (67, 101) ft
Inside Point: (92, 101) ft
Slip Surface Intersection: (99.129, 101) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 13

Type: Fabric
Outside Point: (67, 104) ft
Inside Point: (92, 104) ft
Slip Surface Intersection: (0, 0) ft

Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 14

Type: Fabric
Outside Point: (67, 107) ft
Inside Point: (92, 107) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 15

Type: Fabric
Outside Point: (67, 110) ft
Inside Point: (92, 110) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 16

Type: Fabric
Outside Point: (67, 113) ft
Inside Point: (92, 113) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 17

Type: Fabric
Outside Point: (67, 116) ft
Inside Point: (92, 116) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 18

Type: Fabric
Outside Point: (67, 119) ft
Inside Point: (92, 119) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 19

Type: Fabric
Outside Point: (67, 122) ft
Inside Point: (92, 122) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 20

Type: Fabric
Outside Point: (67, 125) ft
Inside Point: (92, 125) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 21

Type: Fabric
Outside Point: (67, 128) ft
Inside Point: (92, 128) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 22

Type: Fabric
Outside Point: (67, 131) ft
Inside Point: (92, 131) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °

Applied Load Option: Variable
F of S Dependent: Yes

Regions

	Material	Points	Area (ft²)
Region 1	EL 0-20	13,14,12,11	3400
Region 2	EL 20-40	11,9,10,12	3400
Region 3	EL 40-65	9,10,8,7	4250
Region 4	Reinforced Soil	6,16,5,1,3,2	1138.5
Region 5	EL 65 & above	15,7,8,4,3,1,5,16,17	4151

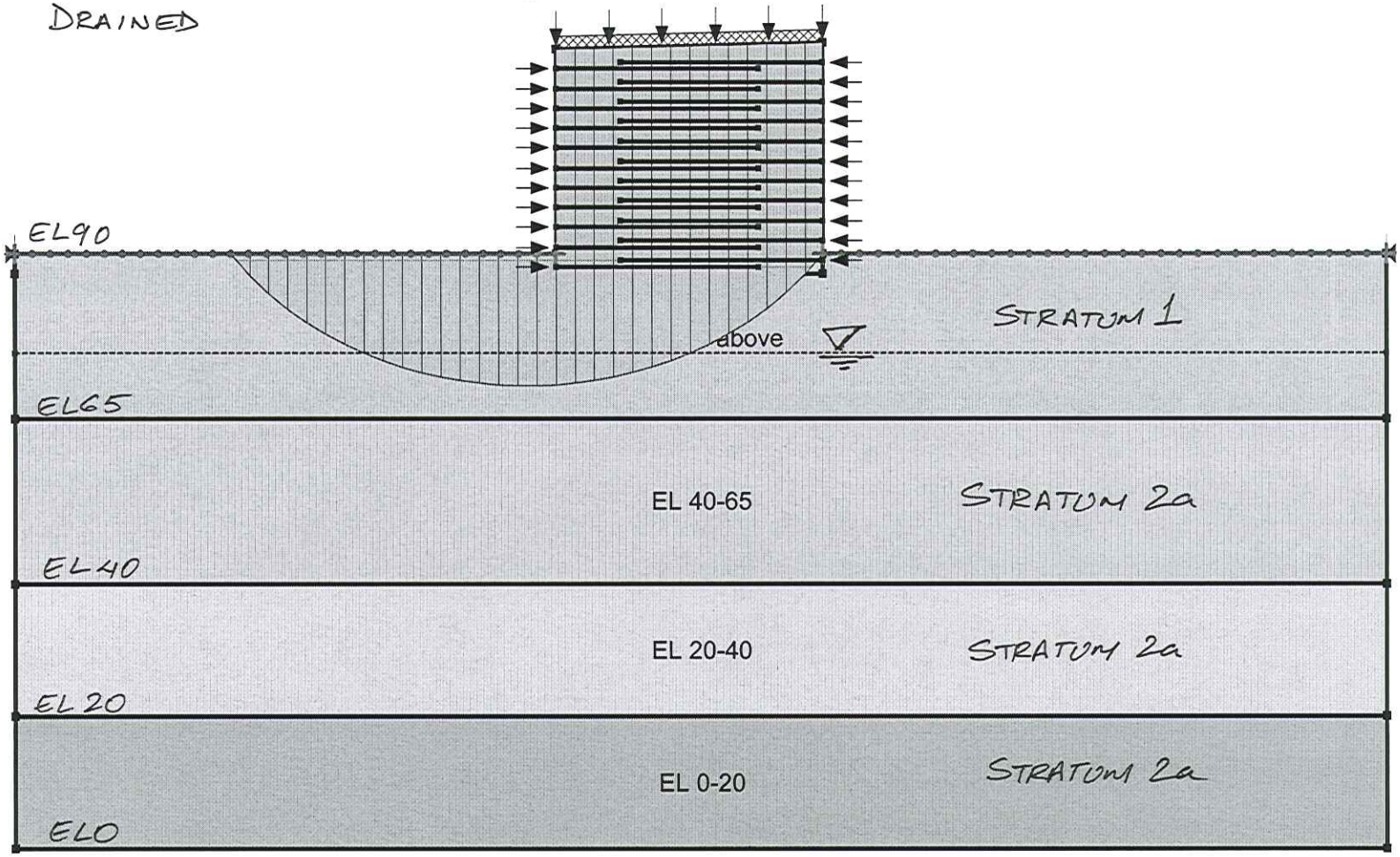
Points

	X (ft)	Y (ft)
Point 1	100	100
Point 2	100	135
Point 3	100	103
Point 4	170	103
Point 5	67	100
Point 6	67	134
Point 7	0	78
Point 8	170	78
Point 9	0	53
Point 10	170	53
Point 11	0	33
Point 12	170	33
Point 13	0	13
Point 14	170	13
Point 15	0	100
Point 16	67	103
Point 17	0	103

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	3270	2.549	(55.575, 120.561)	47.77	(100, 135)	(11.15, 103)

GLOBAL STABILITY ANALYSIS FS = 2.711
DRAINED



S6 : ABUTMENT A

RKK S6-46

4/24/07
BBS
EMS
2/2/09

SLOPE/W Analysis

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File Information

Revision Number: 54
Date: 1/27/2009
Time: 9:00:01 AM
File Name: Abut A (Drained) alt.gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Ramp B\Global Stability\
Last Solved Date: 1/27/2009
Last Solved Time: 9:01:14 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: Abutment A
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 °

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: (0, 103) ft
Left-Zone Right Coordinate: (66.9, 103) 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, 103) 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

Coordinates

	X (ft)	Y (ft)
	67	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: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 3

Type: Fabric
Outside Point: (100, 126) ft

Inside Point: (75, 126) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 4

Type: Fabric
Outside Point: (100, 123) ft
Inside Point: (75, 123) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 5

Type: Fabric
Outside Point: (100, 120) ft
Inside Point: (75, 120) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 6

Type: Fabric
Outside Point: (100, 117) ft
Inside Point: (75, 117) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 7

Type: Fabric
Outside Point: (100, 114) ft
Inside Point: (75, 114) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 8

Type: Fabric
Outside Point: (100, 111) ft
Inside Point: (75, 111) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 9

Type: Fabric
Outside Point: (100, 108) ft
Inside Point: (75, 108) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 10

Type: Fabric
Outside Point: (100, 105) ft
Inside Point: (75, 105) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 11

Type: Fabric
Outside Point: (100, 102) ft
Inside Point: (75, 102) ft
Slip Surface Intersection: (27.473, 102) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 12

Type: Fabric
Outside Point: (67, 101) ft
Inside Point: (92, 101) ft
Slip Surface Intersection: (98.587, 101) ft
Total Length: 25 ft
Reinforcement Direction: 180 °

Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 13

Type: Fabric
Outside Point: (67, 104) ft
Inside Point: (92, 104) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 14

Type: Fabric
Outside Point: (67, 107) ft
Inside Point: (92, 107) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 15

Type: Fabric
Outside Point: (67, 110) ft
Inside Point: (92, 110) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 16

Type: Fabric
Outside Point: (67, 113) ft
Inside Point: (92, 113) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 17

Type: Fabric
Outside Point: (67, 116) ft
Inside Point: (92, 116) ft
Slip Surface Intersection: (0, 0) ft

Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 18

Type: Fabric
Outside Point: (67, 119) ft
Inside Point: (92, 119) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 19

Type: Fabric
Outside Point: (67, 122) ft
Inside Point: (92, 122) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 20

Type: Fabric
Outside Point: (67, 125) ft
Inside Point: (92, 125) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 21

Type: Fabric
Outside Point: (67, 128) ft
Inside Point: (92, 128) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 22

Type: Fabric

Outside Point: (67, 131) ft
Inside Point: (92, 131) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

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	13,14,12,11	3400
Region 2	EL 20-40	11,9,10,12	3400
Region 3	EL 40-65	9,10,8,7	4250
Region 4	Reinforced Soil	6,16,5,1,3,2	1138.5
Region 5	EL 65 & above	15,7,8,4,3,1,5,16,17	4151

Points

	X (ft)	Y (ft)
Point 1	100	100
Point 2	100	135
Point 3	100	103
Point 4	170	103
Point 5	67	100
Point 6	67	134
Point 7	0	78
Point 8	170	78
Point 9	0	53
Point 10	170	53
Point 11	0	33
Point 12	170	33
Point 13	0	13
Point 14	170	13
Point 15	0	100
Point 16	67	103
Point 17	0	103

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	7824	2.711	(63.38, 126.617)	43.575	(100, 135)	(26.76, 103)

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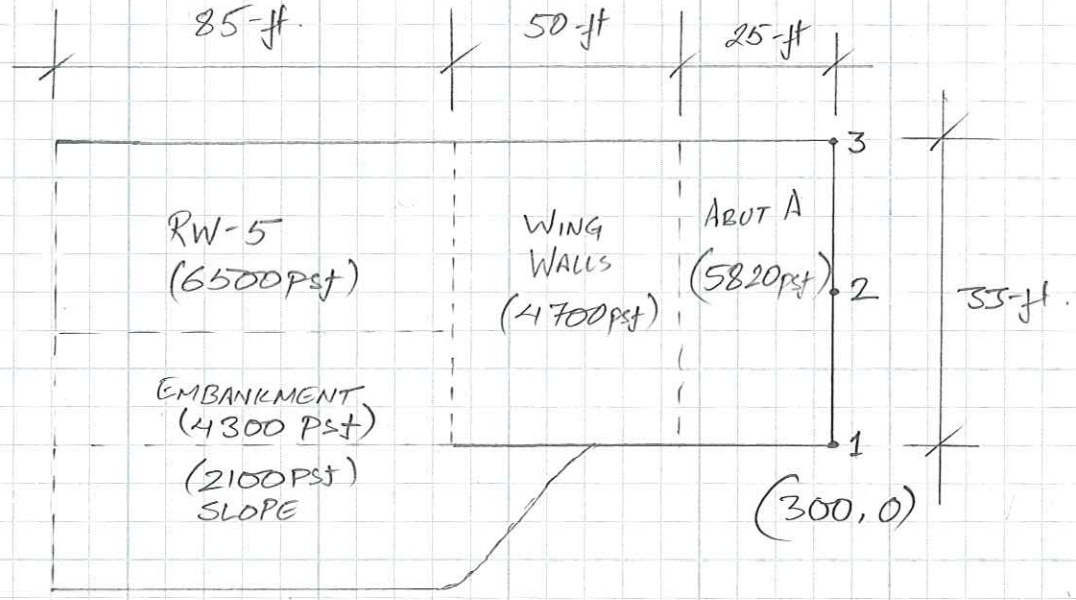
Subject SR-1/I-95 INTERCHANGE ABUT A SETTLEMENT
Page 52 of 61
Cm. No. 103-059
Prepared By BBS Date 1-27-09 Checked By EMK Date 2/2/09

SETTLEMENT ANALYSIS FOR ABUTMENT A RAMP B BRIDGE

PLAN VIEW



ABUTMENT A PLAN

SOIL PROFILE & SOIL PARAMETERS SEE pg 2

ELASTIC SETTLEMENT FOR COARSE GRAINED SOIL LAYER
CONSOLIDATION SETTLEMENT FOR FINE GRAINED SOIL LAYER
EXTENDED WING WALL PAST 30-ft TO ACCOUNT FOR PARTIAL HEIGHT BACK TO BACK WALL

SETTLEMENT ESTIMATED FOR POINTS 1, 2 & 3 ON FACE OF ABUTMENT

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Subject SR-1/I-95 INTERCHANGE ABUTMENT A SETTLEMENT
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Cm. No. 103-059
Prepared By BBS Date 1-27-09 Checked By EM Date 2/2/09

SUMMARY OF SETTLEMENT

POINTS	ELASTIC (ft)	ELASTIC (in)	CONSOLIDATION (ft)	CONSOLIDATION (in)	TOTAL (ft)	TOTAL in
1	0.0147	0.176	0.07	0.84	0.0847	1.01
2	0.0298	0.358	0.09	1.08	0.1198	1.44
3	0.0149	0.179	0.07	0.84	0.0849	1.02

DIFFERENTIAL SETTLEMENT BETWEEN POINTS 1 & 2

$\Delta = 1.44 - 1.01$

$= 0.43$ in

DISTANCE BETWEEN 1 & 2

$D = 33/2 = 16.5$ ft.

DIFFENTIAL SETTLEMENT

$$\text{RATIO} = \frac{\Delta}{12} \times \frac{1}{D}$$

$$= \frac{0.43}{12} \times \frac{1}{16.5} = \frac{1}{460} < \frac{1}{100} \quad \text{OK.}$$

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BBS 1-27-09

EMM
2/2/09

SR-1 Interchange Ramp B Settlement

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PROJECT IDENTIFICATION

Title: SR-1 Interchange Ramp B Settlement
Project Number: 103-059 -
Client: DelDot
Designer: BBS
Station Number:

Description:
ABUTMENT A Settlement Analysis

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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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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 – 5 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

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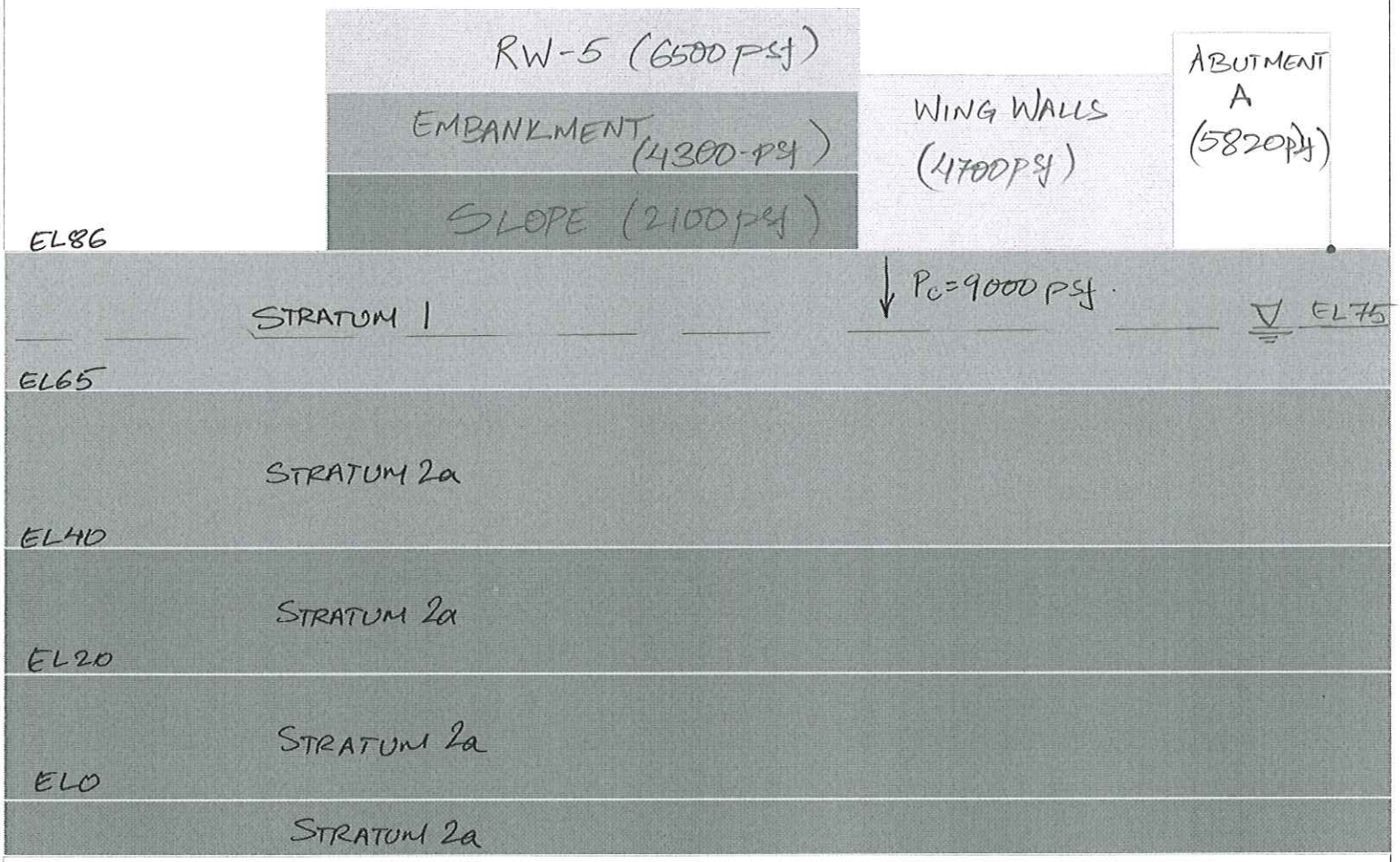
DRAWING OF SPECIFIED GEOMETRY



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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 [ft ²/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

CALCULATION OF $(\sigma_p' - \sigma_o')$ $\sigma_p' = 9000$ psf

WT @ EL 75

EL 40 - EL65 STRATUM 2a

TOP = 9000 - 125 x 12 - (125 - 62.4) 10 = 6874 ≈ 6850 psf

BOTTOM = 6874 - (130 - 62.4) x 25 = 5184 ≈ 5150 psf

EL 20 - EL40 STRATUM 2a

TOP = 5150 psf

BOTTOM = 5184 - (130 - 62.4) x 20 = 3832 ≈ 3800 psf

EL 0 - EL20 STRATUM 2a

TOP = 3800 psf

BOTTOM = 3832 - (130 - 62.4) x 20 = 2480 ≈ 2450 psf

EL 0 & BELOW STRATUM 2a

TOP = 2450 psf

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	300.00	0.00	1	1500000	0.3000	0.0147	187.00	186.91	~~0.09~~ 0.0147
			2	818000	0.4000	~~0.0268~~			
			3	818000	0.4000	~~0.0177~~			
			4	818000	0.4000	~~0.0150~~			
			5	1364000	0.4000	~~0.0147~~			
			6	1364000	0.3000	~~0.0020~~			
2	300.00	16.50	1	1500000	0.3000	0.0298	187.00	186.87	~~0.13~~ 0.0298
			2	818000	0.4000	~~0.0403~~			
			3	818000	0.4000	~~0.0214~~			
			4	818000	0.4000	~~0.0167~~			
			5	1364000	0.4000	~~0.0155~~			
			6	1364000	0.3000	~~0.0021~~			
3	300.00	33.00	1	1500000	0.3000	0.0149	187.00	186.91	~~0.09~~ 0.0149
			2	818000	0.4000	~~0.0268~~			
			3	818000	0.4000	0.0177			
			4	818000	0.4000	~~0.0149~~			
			5	1364000	0.4000	~~0.0145~~			
			6	1364000	0.3000	~~0.0020~~			

*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	300.00	0.00	187.00	0.07	186.93
2	300.00	16.50	187.00	0.09	186.91
3	300.00	33.00	187.00	0.07	186.93

*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	200.00	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	

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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	25.00	33.00	287.50	16.50	5820.00
2	50.00	33.00	250.00	16.50	4700.00
3	85.00	25.00	182.50	20.50	6500.00
4	85.00	8.00	182.50	4.00	4300.00
5	85.00	35.00	182.50	-17.50	2100.00

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Set 2

Abutment B

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Subject SR2/I-95 INTERCHANGE ABUTMENT B WALLS Page 1 of 76
Cm. No. 103-059
Prepared By BBS Date 1-27-09 Checked By BN Date 2/2/09

PURPOSE: DESIGN OF MSE WING WALLS FOR RAMP B ABUTMENTS
ABUTMENT B & WING WALLS

REFERENCE: AASHTO LRFD BRIDGE SPECIFICATION
CUSTOMARY US UNITS 14th EDITION 2007.

SOFTWARE: MSEW 2.0 SLOPE W
FOSSA 2.0

SYMBOL:

UNIT WEIGHT → γ
FRICTION ANGLE → ϕ
UNDRAINED SHEAR STRENGTH → S_u
MODULUS OF ELASTICITY OF SOIL → E_s
POISSON'S RATIO → μ

COMPRESSION INDEX → C_c
RECOMPRESSION INDEX → C_r
COEFFICIENT OF CONSOLIDATION → C_v

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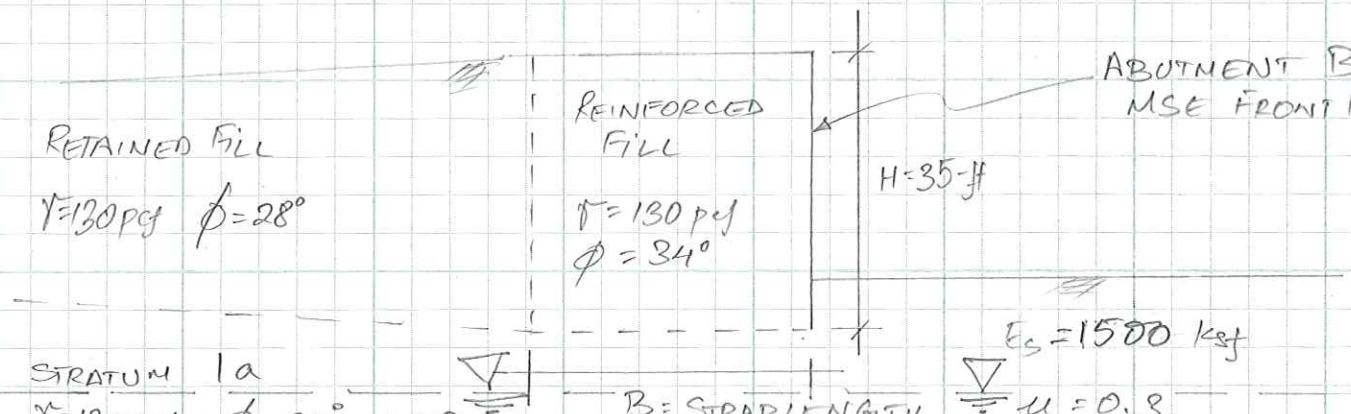
Subject SR-1 INTERCHANGE ABUTMENT B WALLS. Page 2 of 76
Cm. No. 103-059
Prepared By BBS Date 9-25-08 Checked By [illegible] Date 9/30/08

SOIL PARAMETERS ABUTMENT B FOUNDATION @ EL 79.0



85

E_s = 1500 ksf

STRATUM 1a
γ=125 pcf φ=32° c=0
μ = 0.3

75

70

STRATUM 2a
γ=130 pcf S_u = 1700 psf (UC LAB RESULT IBR-61)
C_c = 0.24 OCR = E_s = 818 ksf
C_r = 0.015 μ = 0.4
e_o = 0.75

60

55

40

STRATUM 2a (i)
γ = 130 pcf
φ = 0 c = 2500 psf
E_s = 818 ksf
μ = 0.4
e_o = 0.84
C_c = 0.22 C_r = 0.015

25

20

STRATUM 2a (ii)
γ = 130 pcf
φ = 0 c = 3500 psf
E_s = 818 ksf
μ = 0.4
e_o = 0.84
C_c = 0.22 C_r = 0.015

10

0

STRATUM 2a (iii)
γ = 130 pcf
φ = 0° c = 5000 psf
E_s = 1364 ksf
μ = 0.4
e_o = 0.84
C_c = 0.22 C_r = 0.015

-5

SOIL PARAMETERS

→ UNDRAINED SHEAR STRENGTH OF FINE GRAINED 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 LONG TERM PARAMETER

STRATUM 2a $\phi = 24°$ $C = 0$

SPLINE FUNCTION

SHEAR STRENGTH = $0.7753\,(\text{SHEAR STRESS})^{0.6701}$

→ YOUNGS MODULUS ESTIMATED FROM BACK CALCULATED E_s 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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RAMP B BRIDGE ABUT B Cm. No. 103-059
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SOIL PARAMETERS.

STRATUM 1. EL 70 & ABOVE

$\gamma = 125$ pcf $\phi = 32°$ $E_s = 1500$ ksf (BACK CALCULATED)

STRATUM 2a

$\gamma = 130$ pcf $\phi = 0$ $\mu = 0.4$

EL 40 & ABOVE

$S_u = 1700$ psf (LAB RESULT) $C_c = 0.24$ $e_o = 0.748$ (LAB RESULT IBR-61)

$E_s = 818$ ksf (BACK CALC) $C_r = 0.015$ OCR = 3.3

EL 20 TO EL 40

$S_u = 2500$ psf $C_c = 0.22$ $e_o = 0.839$

$E_s = 818$ ksf $C_r = 0.015$ OCR = 3.3

EL 0 TO EL 20

$S_u = 3500$ psf $C_c = 0.22$ $e_o = 0.839$

$E_s = 818$ ksf $C_r = 0.015$ OCR = 2.1

EL 0 & BELOW

$S_u = 5000$ psf $C_c = 0.22$ $e_o = 0.839$

$E_s = 1364$ ksf $C_r = 0.015$ OCR = 2.1

Figure C-1
Summary of Undrained Shear Testing with Stress History
Strata IIa

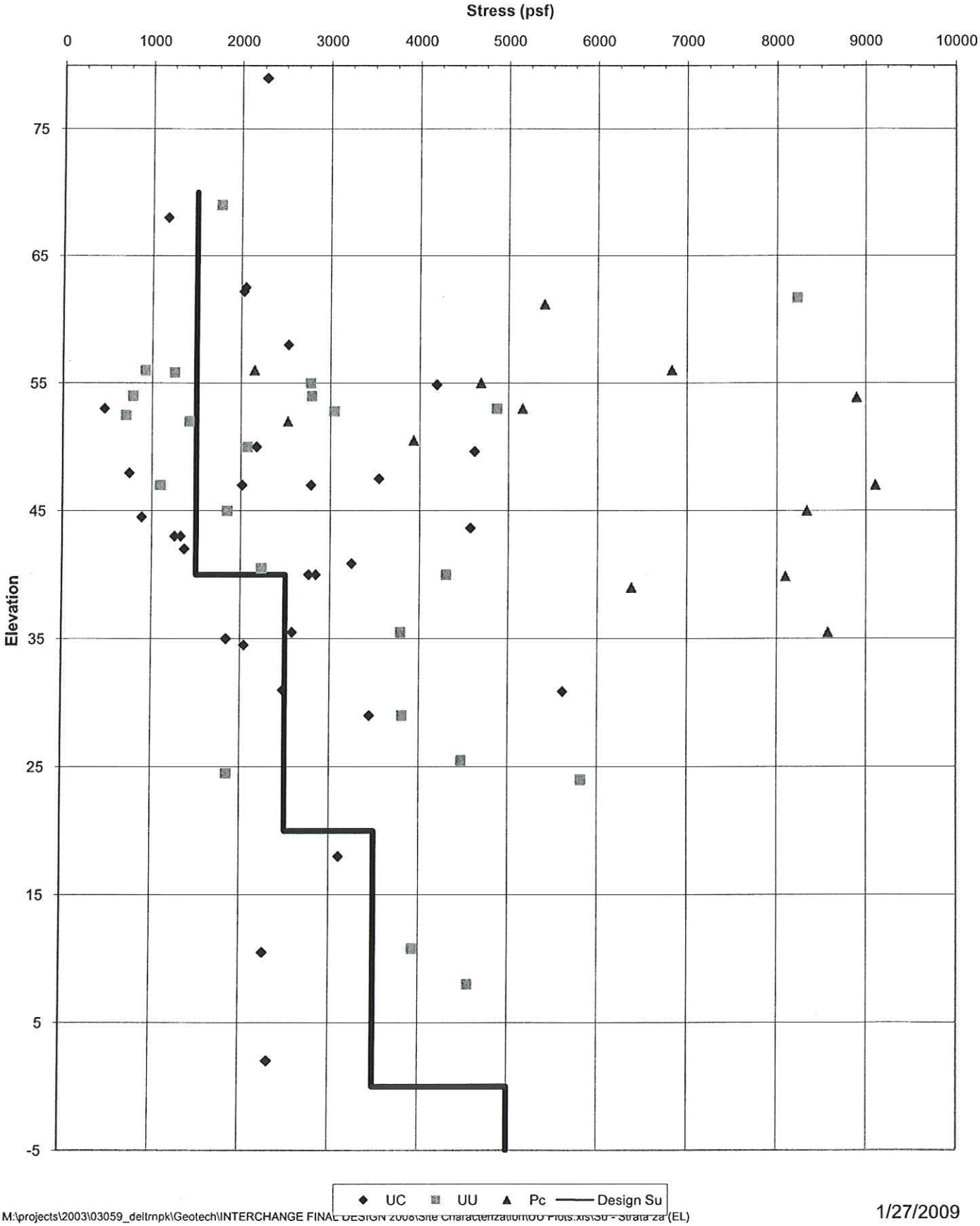

Figure C-2a
Summary of CU with Pore Pressure
Effective Stress - Strata IIa
EL 40 & Above

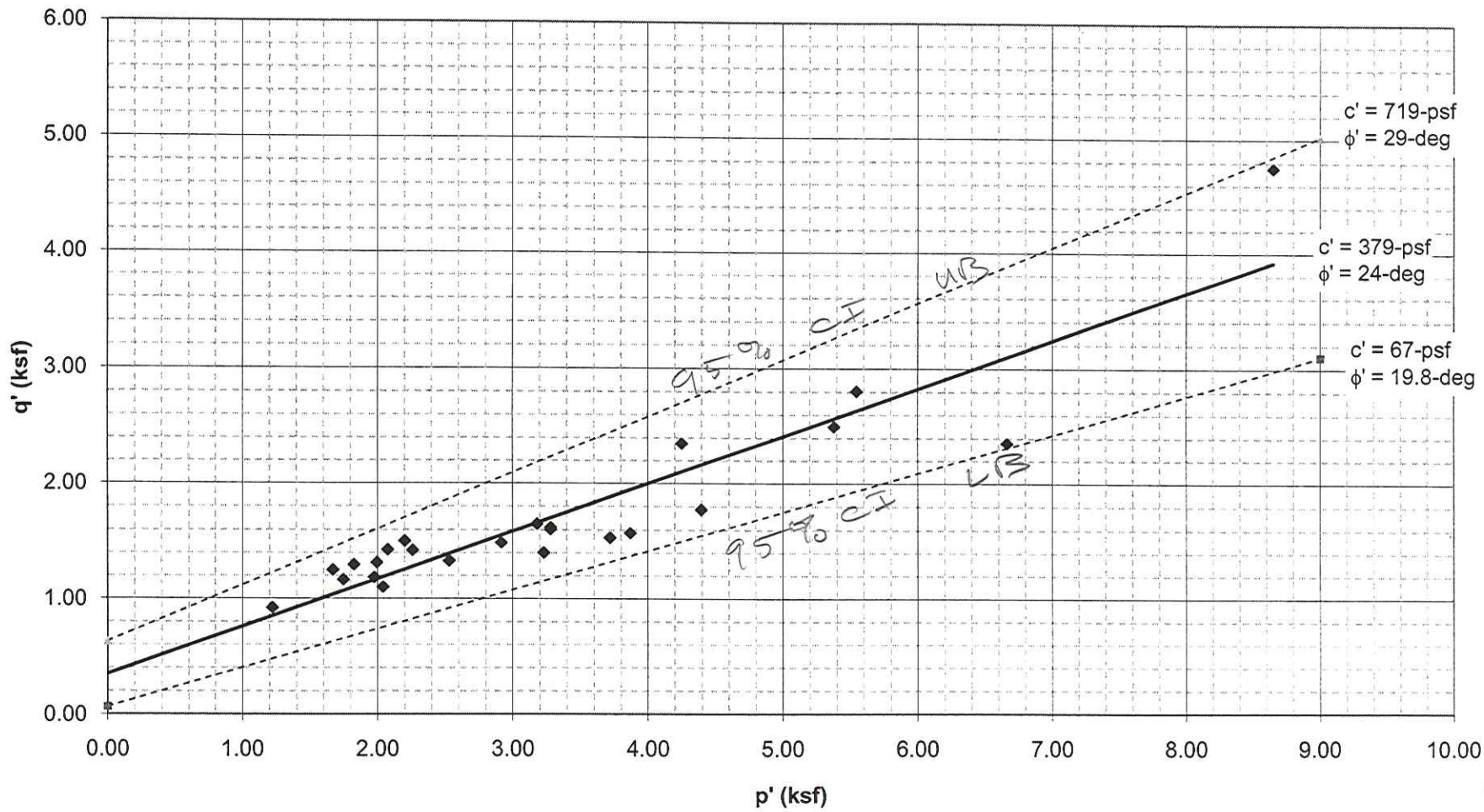

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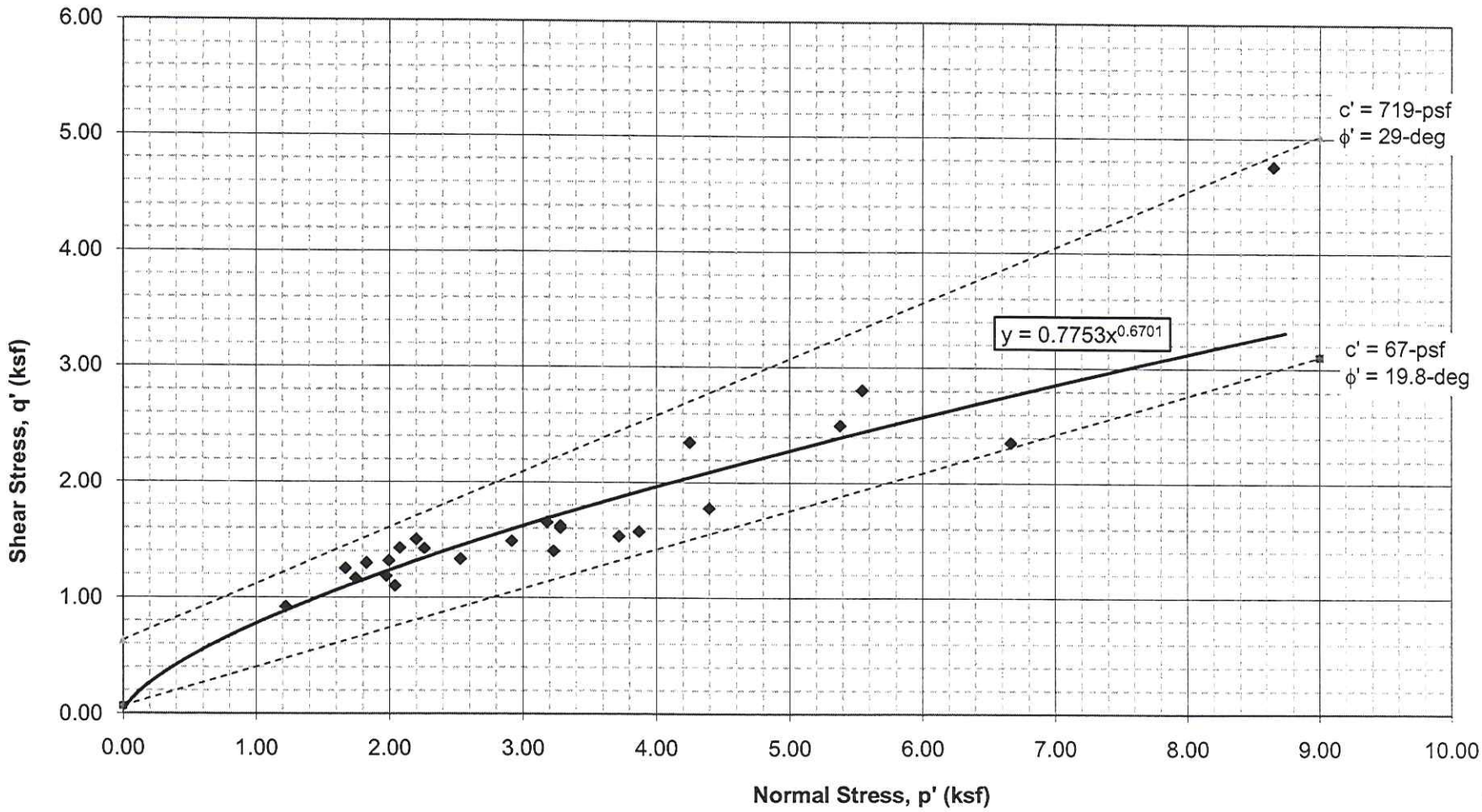
Figure C-2a
Summary of CU with Pore Pressure
Effective Stress - Strata IIa
EL 40 & Above



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SOIL PARAMETERS.

REINFORCED SOIL

$\gamma = 125$ pcf $\phi = 34°$

RETAINED SOIL FOR OVERLAPPING REINFORCED ZONE BACK TO BACK WALL WILL BE THE REINFORCED SOIL

$\gamma = 125$ pcf $\phi = 34°$

FOUNDATION SOIL

$\gamma = 125$ pcf $\phi = 32°$ (TOP ~~20~~ 9 ft APPROX)

ACTIVE EARTH PRESSURE COEFFICIENT FOR RETAINED SO

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 BACKFACE

$\alpha = 0°$ HORIZONTAL BACKFILL

$\delta = 0$ FRICTION ANGLE BETWEEN SOIL & WALL
$\delta = \alpha$ FOR MSE WALL 11.10.5.2

$\phi = 34°$ FRICTION ANGLE OF RETAINED SOIL

$$K_a = \frac{\sin^2(124)}{\sin^2 90 \sin 90\left[1+\sqrt{\frac{\sin 34 \sin 34}{\sin 90 \sin 90}}\right]^2} = \frac{0.6873}{2.43}$$

$= 0.2827$

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MINIMUM LENGTH OF REINFORCEMENT = 0.7H

H = 35-ft (MAX HEIGHT OF WALL)

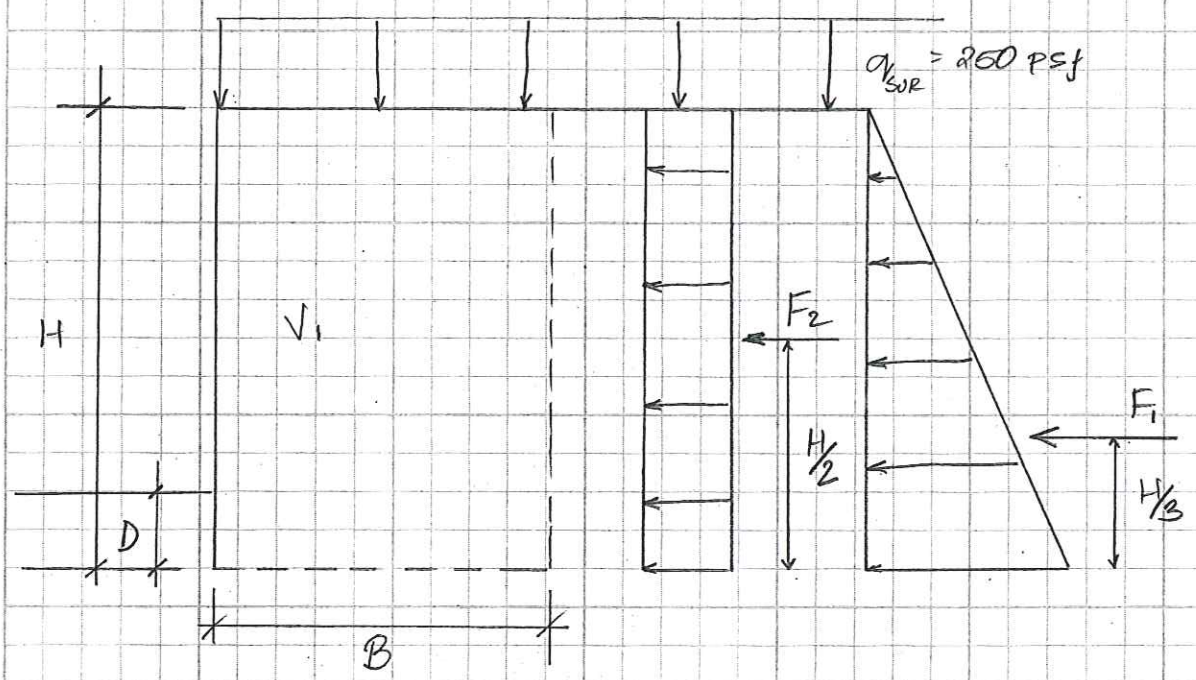
USE B = 24.5-ft ≈ 25 ft

MINIMUM DEPTH OF FRONT FACE EMBEDMENT (D)

PROFILE HORIZONTAL INFRONT OF STRUCTURE

$D = \frac{H}{10}$ FOR ABUTMENTS

$= \frac{35}{10} = 3.5$-ft MINIMUM



$F_1 = \frac{1}{2} K_a \gamma H^2$

$F_2 = K_a q_{SUR} H$

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EARTH PRESSURE FOR EXTERNAL STABILITY

$F_1 = \frac{1}{2} K_a \gamma H^2$

$= \frac{1}{2} \times 0.2827 \times 125 \times 35^2$

$= 21644.22$ lb/ft

$F_2 = K_a q_{sur} H$

$= 0.2827 \times 250 \times 35$

$= 2473.6$ lb/ft

EXTERNAL STABILITY CHECK FOR STRENGTH LIMIT STA

SETTLEMENT ANALYSIS PERFORMED FOR SERVICE LIMIT STA

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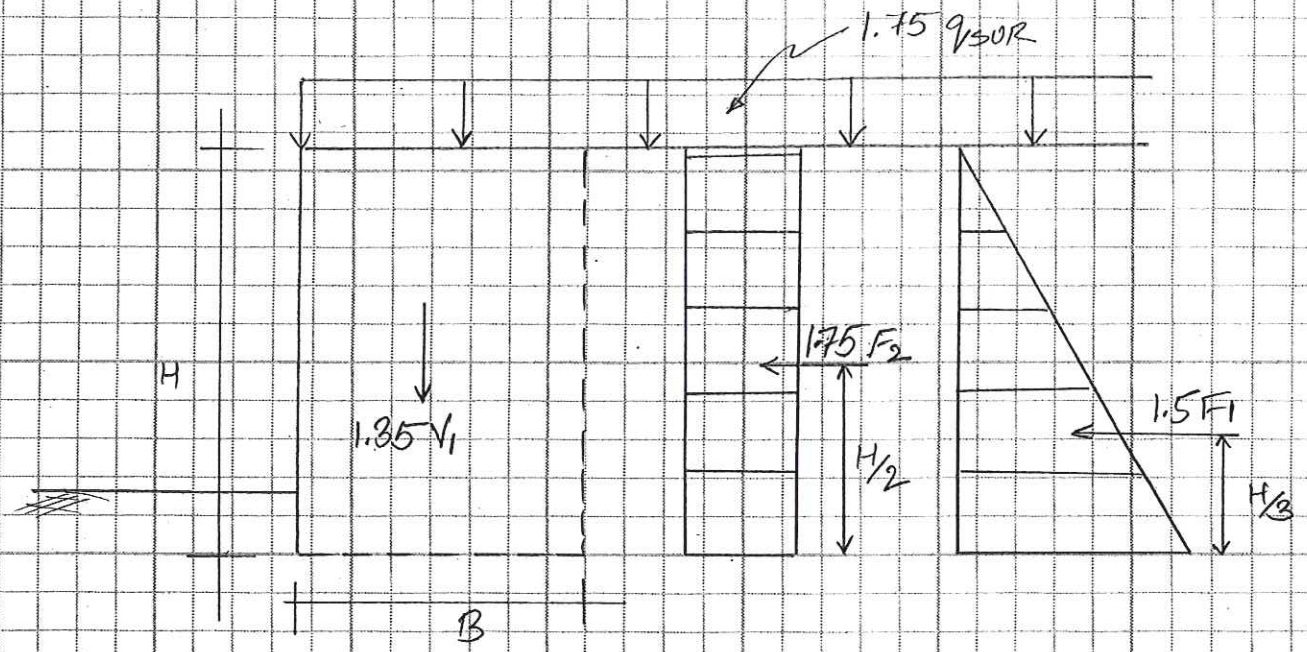
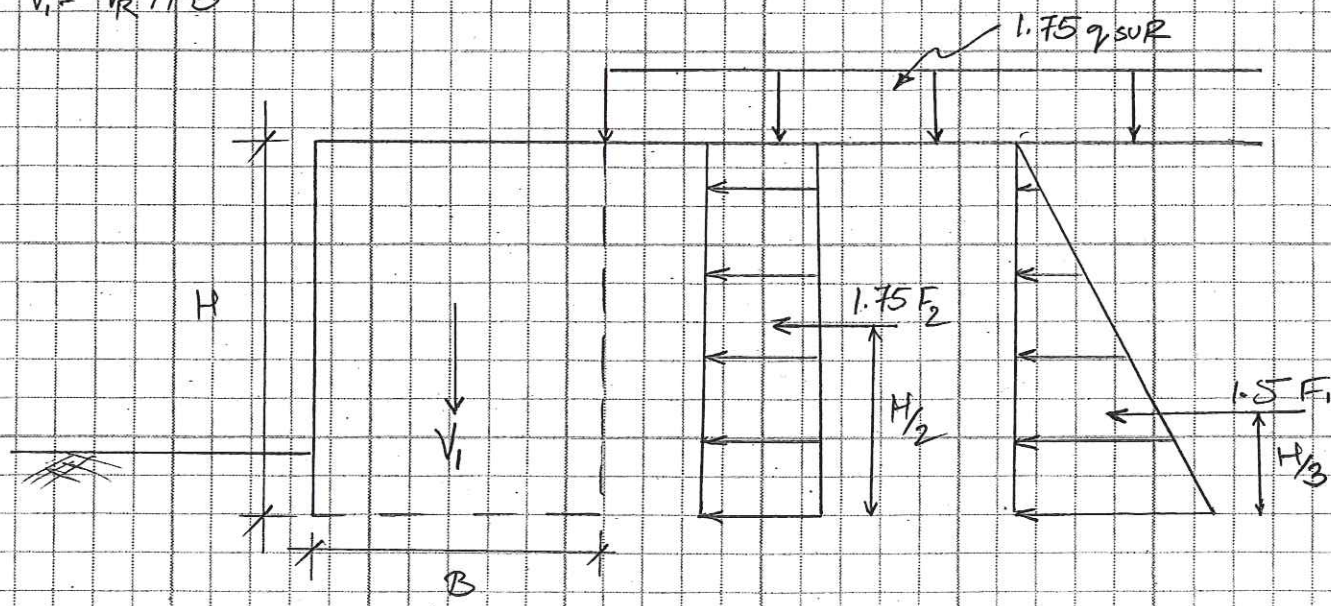


FOR BEARING PRESSURE CALCULATION

$F_1 = \frac{1}{2} K_a \gamma H^2$

$F_2 = K_a q_{SUR} H$

$V_1 = \gamma_R H B$



FOR ECCENTRICITY & SLIDING CALCULATION

STRENGTH LIMIT STATE

STRENGTH LIMIT STATE (ECCENTRICITY & SLIDING)

ECCENTRICITY

$$e = \frac{1.5 F_1 \cos\alpha \, H/3 + 1.75 F_2 \cos\alpha \, H/2}{V_1}$$

$$= \frac{1.5 \times 2164.2 \times \cos 0 \; 35/3 + 1.75 \times 2473.6 \times \cos 0 \; 35/2}{125 \times 35 \times 25}$$

$$= 4.15 \text{ ft.}$$

CHECK FOR OVERTURNING:

RESULTANT OF REACTION FORCES SHALL BE WITHIN ½ OF THE CENTER BASE WIDTH

$\frac{1}{2}$ BASE WIDTH $= 0.5 \times 25 = 12.5$ ft

ECCENTRICITY $< \frac{12.5}{2}$

$4.15 < 6.25$ ok

SLIDING CHECK.

FACTORED RESISTANCE AGAINST SLIDING

$R_R = \phi R_n$

$\phi = 1.0$ 11.5.6.1

$R_n = V \tan \delta$

δ = Smaller of ϕ_f or ϕ_R

ϕ_f = FOUNDATION SOIL = 32°

ϕ_R = REINFORCED SOIL = 34°

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$R_n = V_1 \tan 32°$

$= 125 \times 35 \times 25 \times \tan 32$

$= 68345$ lb/ft

HORIZONTAL DRIVING FORCES.

$R_{DR} = 1.5 F_1 + 1.75 F_2$

$= 1.5 \times 21644.2 + 1.75 \times 2473.6$

$= 36795.1$ lb/ft

$R_R = \phi R_n = 1 \times 68345$

$= 68345$ lb/ft $> R_{DR} = 36795.1$ lb/ft OK

STRENGTH LIMIT STATE (BEARING CAPACITY)

ECCENTRICITY

$$e = \frac{1.5 F_1 \cos\alpha \, H/3 + 1.75 F_2 \cos\alpha \, H/2}{1.35 V_1 + 1.75 q_{sur} B}$$

$$= \frac{1.5 \times 21644.2 \times \cos 0 \times 4/3 + 1.75 \times 2473.6 \times \cos 0 \times 35/2}{1.35 \times 125 \times 35 \times 25 + 1.75 \times 250 \times 25}$$

$$= 2.866 \text{ ft}$$

ASSUMES SOIL IN REINFORCEMENT ZONE

EQUIVALENT UNIFORM VERTICAL STRESS ON THE BASE

$$\sigma_v = \frac{\Sigma V}{B - 2e}$$

$$= \frac{1.35 V_1 + 1.75 q_{sur} B}{B - 2e}$$

$$= \frac{1.35 \times 125 \times 35 \times 25 + 1.75 \times 250 \times 25}{25 - 2 \times 2.866}$$

$$= \underline{\underline{8231 \text{ psf}}}$$

EFFECTIVE FOOTING WIDTH $= B - 2e = 19.27$ ft

CHECK FOR BEARING CAPACITY

NOMINAL BEARING CAPACITY

$$q_n = c N_c S_c i_c + \gamma D_f N_q S_q d_q i_q C_{wq} + 0.5 \gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$$

THICKNESS OF TOP GRANULAR LAYER $H = 9\text{-ft}$

CHECK FOR LAYERED SYSTEM

CRITICAL HEIGHT

$$H_{CRIT} = \frac{3B \ln\left(q_1/q_2\right)}{2\left(1+\frac{B}{L}\right)}$$

where,

q_1 = NOMINAL BEARING RESISTANCE OF FOOTING SUPPORTED IN THE UPPER LAYER OF A TWO LAYERED SYSTEM

q_2 = NOMINAL BEARING RESISTANCE OF FOOTING SUPPORTED IN THE LOWER LAYER OF A TWO LAYERED SYSTEM

B = FOOTING WIDTH

L = LENGTH OF FOOTING

$B = 19.27$ $\quad L = 38\text{-ft}$

$$q_n = cN_c \cancel{s_c}^{0} i_c + \gamma_D D_f \cancel{N_q}^{0} s_q d_q i_q C_{wq} + \frac{1}{2}\gamma B N_\gamma s_\gamma i_\gamma C_{w\gamma}$$

FOR LONGTERM DRAINED CONDITION

$C = 0$ $\quad N_q$ TERM $= 0$ FOR MSE WALLS $\quad$ NO INCLINATION

$$q_n = \frac{1}{2}\gamma B N_\gamma s_\gamma C_{w\gamma}$$

UPPER LAYER

$\phi = 32°$ $N_\gamma = 30.2$ Table 10.6.3.1.2a-1

$\gamma = 125$ pcf $S_\gamma = 1 - 0.4\left(\frac{B}{L}\right)$ Table 10.6.3.1.2a-3

$C_{w\gamma}$ = LINEAR INTERPOLATION Table 10.6.3.1.2a-2

FOR DEPTH OF WT $0 \rightarrow 0.5$ $1.5B = 37.5 \rightarrow 1.0$

FOR DEPTH OF 4-ft $\rightarrow 0.553$

$$q_{1n} = \frac{1}{2} \times 125 \times 19.27 \times 30.2 \times \left(1 - 0.4 \times \frac{19.27}{38}\right) \times 0.553$$

$$= 16033.86 \text{ psf}$$

LOWER LAYER

q_{2n} $\phi = 24°$ $N_\gamma = 9.4$ $\gamma = 130$ pcf

$C_{w\gamma} = 0.553$

$$q_{2n} = \frac{1}{2} \times 130 \times 19.27 \times 9.4 \times \left(1 - 0.4 \times \frac{19.27}{38}\right) \times 0.553$$

$$= 5190.3 \text{ psf}$$

$$H_{CRIT} = \frac{3 \times 19.27 \ln\left(\frac{16033.86}{5190.3}\right)}{2\left(1 + \frac{19.27}{38}\right)}$$

$$= 21.6 \text{ ft} > H = 9 \text{ ft}$$

FOUNDATION SOIL IS TWO LAYERED SYSTEM.

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Prepared By BBS Date 12/18/08 Checked By EM Date 2/2/09

CHECK FOR BEARING CAPACITY FOR LAYERED SYSTEM

COARSE GRAINED SOIL FOUNDATION LEVEL DEPTH = 9-ft

BEARING CAPACITY

$$q_n = q_2 e^{0.67[1+B/L]H/B}$$ C 10.6.3.1.2f-1

q_2 = BEARING RESISTANCE OF FICTICIOUS FOOTING OF THE SAME SIZE & SHAPE AS THE ACTUAL FOOTING SUPPORTED ON THE LOWER WEAKER SOIL

B = FOOTING WIDTH

H = THICKNESS OF TOP LAYER BELOW FOUNDATION ELEVATION

L = LENGTH OF FOOTING

$$q_2 = CN_c S_c i_c + \gamma_D D_f \cancel{N_q S_q d_q i_q} C_{wq} + \frac{1}{2}\gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$$

$N_q = 0$ FOR MSE WALL

DRAINED CONDITION

$\phi = 24°$ $C = 0$

$N_c = 19.3$ $N_\gamma = 9.4$ (10.6.3.1 2a-1)

$C_{w\gamma} = 0.5$ (10.6.3.1.2a-2)

$B = 19.27$ ft $L = 38$ ft $H = 9$ ft $S_\gamma = 1 - 0.4\frac{B}{L}$

$$q_2 = \frac{1}{2} \times 130 \times 19.27 \times 9.4 \times \left(1 - 0.4 \times \frac{19.27}{38}\right) \times 0.553$$

$$= \underline{\underline{5190.3 \text{ psf}}}$$

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$$q_n = q_2 \, e^{0.67[1+B/2]\,4/B}$$

$$= 5190.3 \; e^{0.67\left[1+\frac{19.27}{38}\right]\frac{9}{19.27}}$$

$$= 5190.3 \times 1.602$$

$$= \underline{\underline{8314.9 \text{ psf}}}$$

FACTORED BEARING RESISTANCE

$$q_R = \phi_b \, q_n \qquad \phi_b = 0.65$$

$$= 0.65 \times 8314.9$$

$$= 5404.6 \text{ psf} < \sigma_v = 8231 \text{ psf}$$ APPLIED BEARING STRESS

NOT OK

REDESIGN WITH STRAP LENGTH = 1.0H

$B = 35$ ft.

WALL DESIGN FOR $H = 35$ ft

$B = 35$ ft

EARTH PRESSURE FOR EXTERNAL STABILITY

$F_1 = 21644.22$ lb/ft

$F_2 = 2473.6$ lb/ft

EXTERNAL STABILITY CHECK FOR STRENGTH LIMIT STATE

$V_1 = 125 \times 35 \times 35$

$= 153{,}125$ lb/ft

BEARING CAPACITY CHECKS.

ECCENTRICITY

$$e = \frac{1.5 F_1 \cos\alpha \, H/3 + 1.75 F_2 \cos\alpha \, H/2}{1.35 V_1 + 1.75 q_{sur} B}$$

$$= \frac{1.5 \times 21644.2 \times \cos 0 \times 35/3 + 1.75 \times 2473.6 \times \cos 0 \; 35/2}{1.35 \times 153125 + 1.75 \times 250 \times 35}$$

$$= \frac{454527.5}{222031.25}$$

$$= \underline{2.047 \text{ ft}}$$

$B' = B - 2e$

$= 35 - 2 \times 2.047$

$= \underline{30.906}$

EQUIVALENT UNIFORM VERTICAL STRESS ON THE BASE

$$\sigma_v = \frac{\Sigma V}{B-2e}$$

$$= \frac{1.35 V_1 + 1.75 q_{SUR} B}{B-2e}$$

$$= \frac{1.35 \times 153125 + 1.75 \times 250 \times 35}{35 - 2 \times 2.047}$$

$$= 7184.1 \text{ psf} \quad \checkmark$$

BEARING CAPACITY FOR LAYERED SYSTEM

NOMINAL BEARING CAPACITY

$$q_n = q_2 \, e^{0.67 [1 + B/L] H/B}$$ C 10.6.3.1.2j-1

$$q_2 = c N_c S_c i_c + \frac{1}{2} \gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$$

DRAINED CONDITION

$\phi = 24°$ $c = 0$

$N_c = 19.3$ $N_\gamma = 9.4$ (10.6.3 1.2a-1)

$C_{w\gamma} = 0.5$ (10.6.3.1.2a-2)

$B' = 30.906$ $L = 38'$ $H = 9$-ft. $S_\gamma = \left(1 - 0.4 \frac{B}{L}\right)$

$$q_2 = \frac{1}{2} \times 130 \times 30.906 \times 9.4 \times \left(1 - 0.4 \times \frac{30.96}{38}\right) \times 0.553$$

$$= 7045.4 \text{ psf}$$

$q_n = q_2 e^{0.67[1+B/L]\,H/B}$

$= 7045.4\, e^{0.67[1+\frac{30.96}{38}]\frac{9}{30.96}}$

$= 7045.4 \times 1.424$

$= 10032$ psf

$q_R = \phi_b q_n$

$= 0.65 \times 10032$

$= 6521.$ psf $< \sigma_v = 7184$ psf NOT OK

CDR = 0.91 $\frac{L}{H} = 1.0$ SELECT FILL

USE LIGHT WT FILL

USE 14-ft of LIGHT WT FILL B = 35-ft

$\gamma_c = 40$ pcf (LIGHT WT FILL) 21-ft of SELECT FILL

EARTH PRESSURE FOR EXTERNAL STABILITY.

$F_1 = 21644.22$ lb/ft.

$F_2 = 2478.6$ lb/ft.

EXTERNAL STABILITY CHECK FOR STRENGTH LIMIT STATE

$V_1 = 125 \times 21 \times 35 + 40 \times 14 \times 35$

$= 111{,}475$ ✓

BEARING CAPACITY CHECKS

ECCENTRICITY

$$e = \frac{1.5 F_1 \cos\alpha \, H/3 + 1.75 F_2 \cos\alpha \, H/2}{1.35 V_1 + 1.75 q_{SUR} B}$$

$$= \frac{1.5 \times 21644.22 \times \cos 0 \times 35/3 + 1.75 \times 2473.6 \times \cos 0 \times 35/2}{1.35 \times 111{,}475 + 1.75 \times 250 \times 35}$$

$$= \frac{454527.5}{165803.75}$$

$$= 2.74$$

$$B' = B - 2e$$
$$= 35 - 2 \times 2.74$$
$$= 29.52$$ ← USE THIS FOR BEARING CAPACITY CHECK

EQUIVALENT UNIFORM VERTICAL STRESS ON THE BASE

$$\sigma_v = \frac{\Sigma V}{B - 2e}$$

$$= \frac{1.35 V_1 + 1.75 \times q_{SUR} \times B}{B - 2e}$$

$$= \frac{1.35 \times 111475 + 1.75 \times 250 \times 35}{35 - 2 \times 2.74}$$

$$= \frac{165803.75}{29.52}$$

$$= 5616.7 \text{ psf}$$

BEARING CAPACITY FOR LAYERED SYSTEM.

NOMINAL BEARING CAPACITY

$q_n = q_2 \, e^{0.67[1+B/L]H/B}$ C. 10.6.3.1.2f-1

$q_2 = c N_c S_c d_c + \gamma_D D_f N_q S_q d_q i_q C_{wq} + \frac{1}{2} \gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$

$N_q = 0$ FOR MSE WALL

DRAINED CONDITION

$\phi = 24°$ $c = 0$

$N_c = 19.3$ $N_\gamma = 9.4$ (10.6.3.1.2a-1)

$C_{w\gamma} = 0.5$ (10.6.3.1.2a-2)

$B' = 29.52$ ft $L = 38$ ft $H = 9$ ft $S_\gamma = 1 - 0.4 \frac{B'}{L}$

$q_2 = \frac{1}{2} \times 130 \times 29.52 \times 9.4 \left(1 - 0.4 \times \frac{29.52}{38}\right) \times 0.5$

$= \underline{6216.02}$

$q_n = q_2 \, e^{0.67[1+B/L]H/B}$

$= 6216.02 \times e^{0.67[1+\frac{29.52}{38}]\frac{9}{29.52}}$

$= 6216.02 \times 1.44$

$= \underline{\underline{8936 \text{ psf}}}$

FACTORED BEARING RESISTANCE

$q_R = \phi_b q_n$ $\phi_b = 0.65$

$= 0.65 \times 8936$

$= 5808$ psf $> \sigma_v = 5616.7$ psf OK

USING 14' LWF / 21' SELECT FILL
$B = L = 35'$

UNDRAINED CONDITION

$c = 1700$ psf $\phi = 0$

$N_c = 5.14$ (10.6.3.1.2a-1)

$B = 29.52$ $L = 38$-ft $H = 9$-ft

$S_c = 1 + \frac{B}{5L} = 1 + \frac{29.52}{5 \times 38} = 1.155$

$q_2 = c \cdot N_c S_c i_c$

$= 1700 \times 5.14 \times 1.155$

$= 10{,}092.39$

$q_n = q_2 \, e^{0.67[1 + B/L] H/B}$

$= 10{,}092.39 \times e^{0.67[1 + \frac{29.52}{38}] 9/29.52}$

$= 10{,}092.39 \times 1.44$

$= 14533$ psf

FACTORED BEARING RESISTANCE

$q_R = \phi_b q_n \qquad \phi_b = 0.65$

$= 0.65 \times 14533$

$= \underline{9446}$ psf $> \sigma_v = \underline{5616.7}$ psf OK

STRENGTH LIMIT STATE CHECK FOR ECCENTRICITY & SLIDING.

ECCENTRICITY

$e = 1.5\, F_1 \cos\alpha \; H/3 + 1.75\, F_2 \cos\alpha \; H/2 \qquad \alpha$ = BACKSLOPE ON TOP OF WALL

V_1

$= 1.5 \times 21644.2 \times \cos 0 \times 35/3 + 1.75 \times 2473.6 \times \cos 0 \times 35/2$

$111,475$

$= \dfrac{454527.5}{111,475} = \underline{4.08 \text{ ft}}$

CHECK FOR OVERTURNING

RESULTANT OF REACTION FORCES SHALL BE WITHIN ½ OF THE CENTER BASE WIDTH

½ BASE WIDTH = 0.5 × 35 = 17.5 ft.

ECCENTRICITY $< \dfrac{17.5}{2}$

$4.08 < \underline{8.75}$ OK

CHECK FOR SLIDING

$R_R = \phi R_n$

$\phi = 1.0$ 11.5.6.1

$R_n = V_1 \tan \delta$

δ = Smaller of ϕ_f or ϕ_R

ϕ_f = FOUNDATION SOIL = 32°

ϕ_R = REINFORCED SOIL = 34°

USE OF LWEF THE FRICTION ANGLE CHANGES TO 'FRICTION BETWEEN SAND & CONCRETE

$\delta = 19°$ Table 3.11.5.3-1

$R_n = 111475 \times \tan 19°$

$= 38,383.9$ lb/ft

HORIZONTAL DRIVING FORCES

$R_{DR} = 1.5 F_1 + 1.75 F_2$

$= 1.5 \times 21644.2 + 1.75 \times 2473.6$

$= \underline{36795.1}$ lb/ft

$R_R = \phi R_n = 1 \times 38383.9$

$= 38383.9$ lb/ft $> R_{DR} = \underline{36795}$ ok

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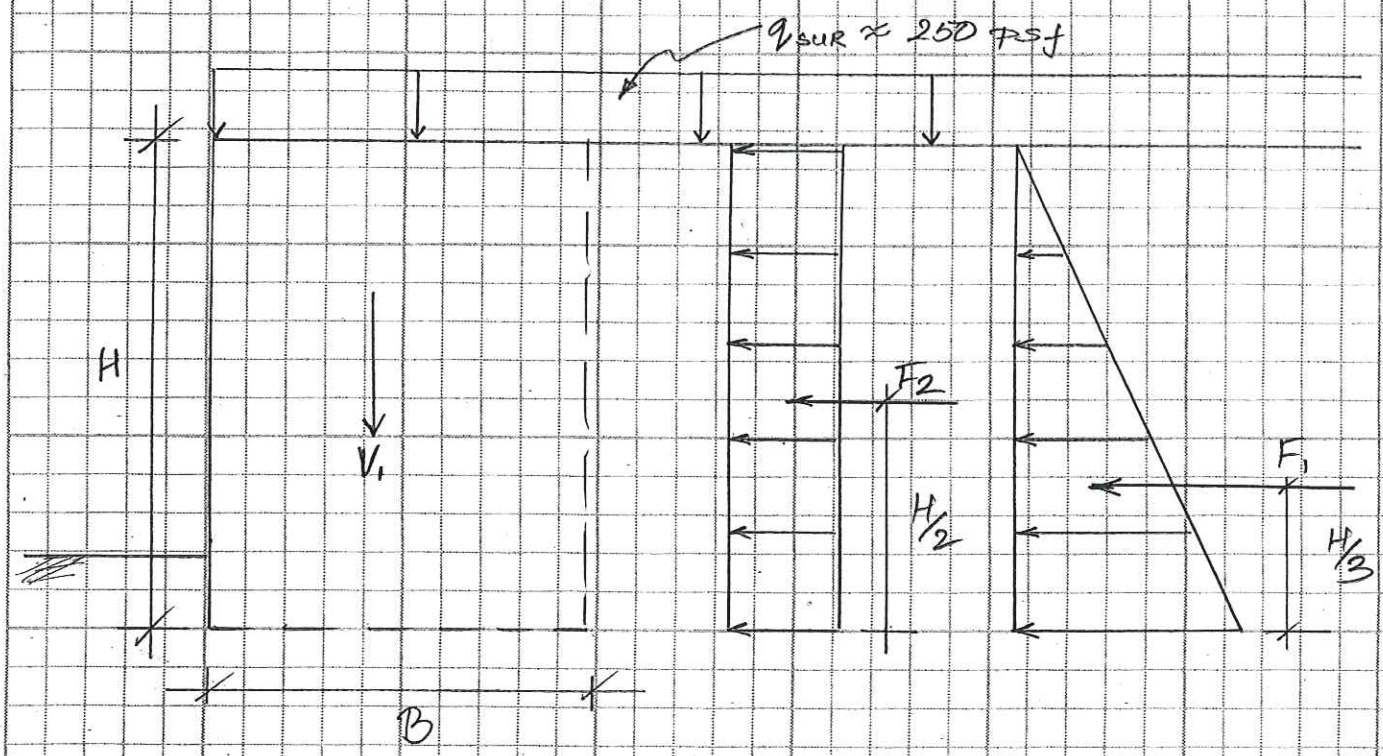
Prepared By BBS Date 10-6-08 Checked By [illegible] Date 1/14/09



$F_1 = \frac{1}{2} K_a \gamma H^2$ 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

SERVICE LIMIT STATE (BEARING PRESSURE FOR SETTLEMENT CALCULATION)

ECCENTRICITY

$$e = \frac{F_1 \cos\alpha \, H/3 + F_2 \cos\alpha \, H/2}{V_1 + q_{sur} B}$$

$$= \frac{21644.22 \times \cos 0 \times 35/3 + 2473.6 \times \cos 0 \times 35/2}{111475 + 250 \times 35}$$

$$= \frac{295803.9}{120225}$$

$$= 2.46 \text{ ft}$$

EQUIVALENT UNIFORM VERTICAL STRESS @ BASE

$$\sigma_v = \frac{V_1 + q_{sur} B}{B - 2e}$$

$$= \frac{111475 + 250 \times 35}{35 - 2 \times 2.46}$$

$$= \frac{120225}{30.08}$$

$$= 3996.84 \text{ psf}$$

SAY 4000 psf
USE THIS FOR SETTLEMENT CALCULATION

$$B' = B - 2e = 35 - 2 \times 2.46$$

$$= 30.08 \text{ ft}$$

BACK TO BACK WALL

SOIL PARAMETERS:

REINFORCED SOIL

$\gamma = 125$ pcf $\phi = 34°$

RETAINED SOIL FOR OVERLAPPING REINFORCED ZONE
BACK TO BACK WALL WILL BE THE REINFORCED SOIL

$\gamma = 125$ pcf $\phi = 34°$

FOUNDATION SOIL

$\gamma = 125$ pcf $\phi = 32°$ (APPROXIMATELY TOP 9-ft)

ACTIVE EARTH PRESSURE COEFFICIENT

COULUMB'S

$K_a = 0.2827$ FROM Pg

33 N
38 F
39 J
40 R
41 B
42 C
43 S

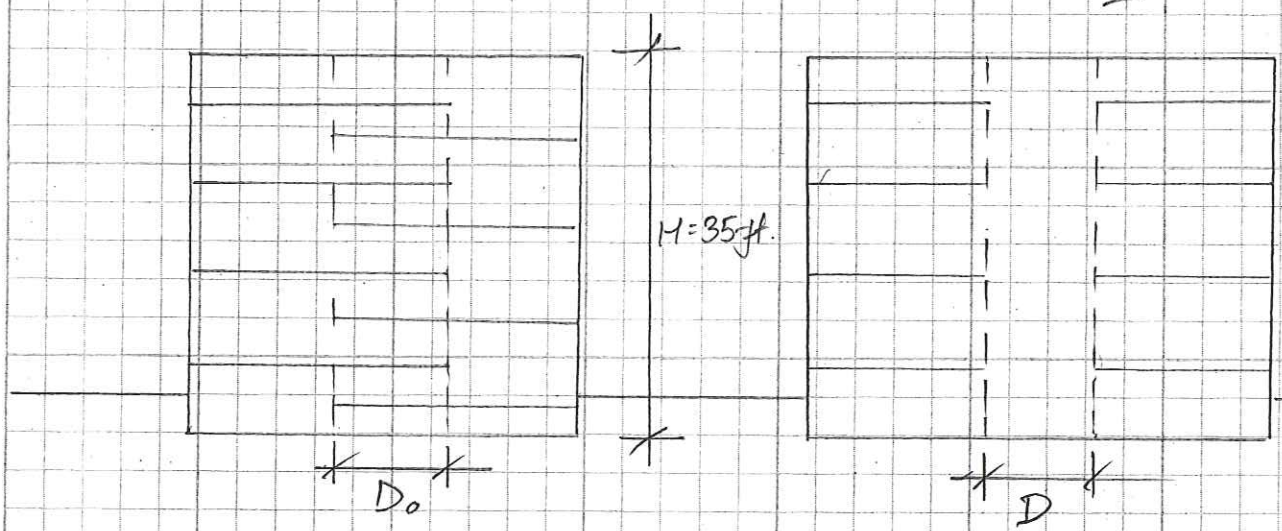
BACK TO BACK WALLS

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

$0.3H = \underline{10.5 > D_o}$ ∴ THERE IS REDUCED LATERAL PRESSURE

IF $D > H \tan(45 - \phi/2)$ where, ϕ = FRICTION ANGLE OF RETAINED SOIL = 28°

TOTAL LATERAL FORCE ACTS

$H\tan(45 - \phi/2) = 35 \tan\left(45 - \frac{28}{2}\right)$ (IF STRAPS DONT OVERLAP)

$= \underline{21\text{-ft.}}$

BETWEEN D & D_o LINEAR INTERPOLATION.

LINEAR INTERPOLATION

LATERAL FORCE 0% @ $D_0 = -10.5$ ft

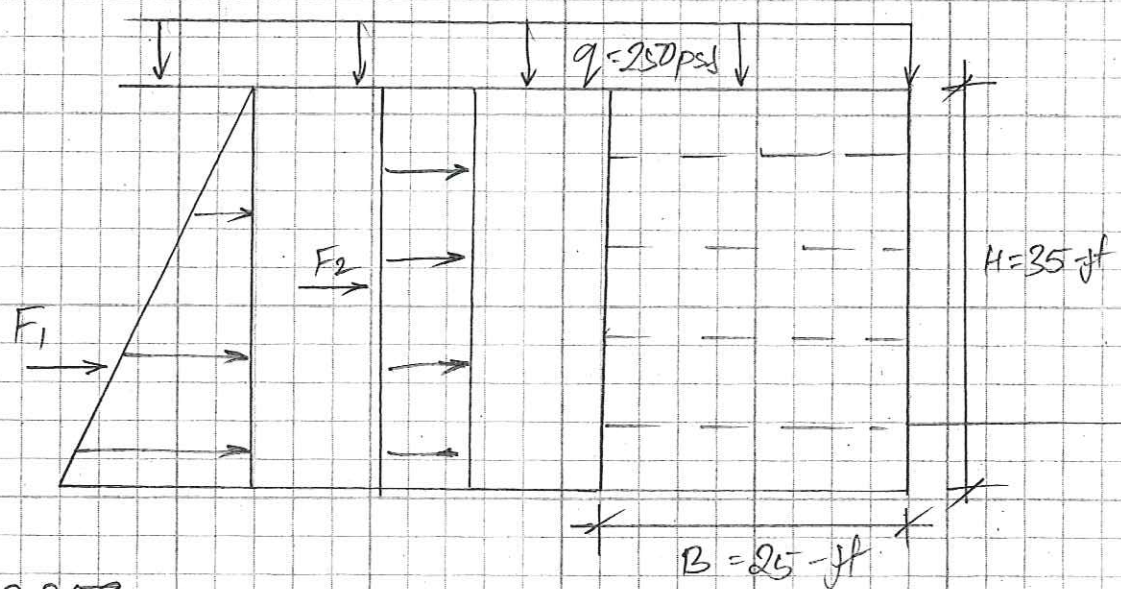
100% @ $D = 21$ ft

TOTAL DIFFERENCE = 21 + 10.5 = 31.5

$D_0 = -6$ ft ; $-6 + 10.5 = 4.5$

$\therefore$ % of LATERAL FORCE $= \frac{4.5}{31.5} = 14.3\%$

CONSIDER ONE SIDE WALL-15



$K_a = 0.259$

$F_1 = 14.3\% \, \frac{1}{2} K_a \gamma H^2 = 2836$ lb/ft

$F_2 = 14.3\% \, q K_a H = 324$ lb/ft

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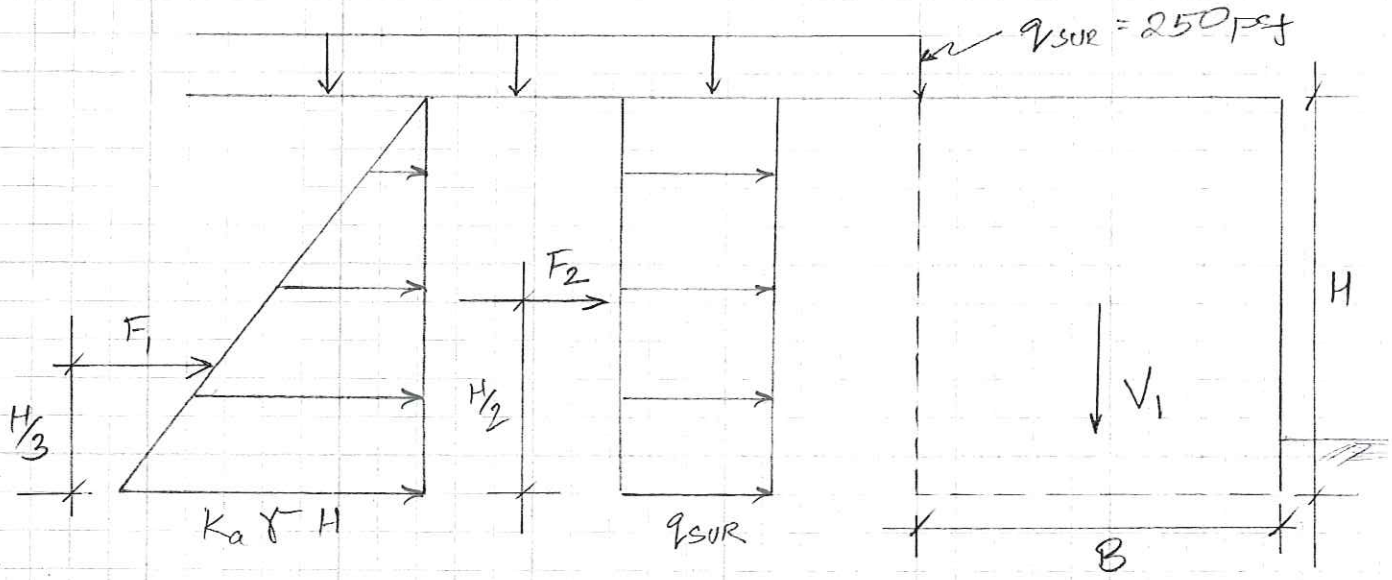
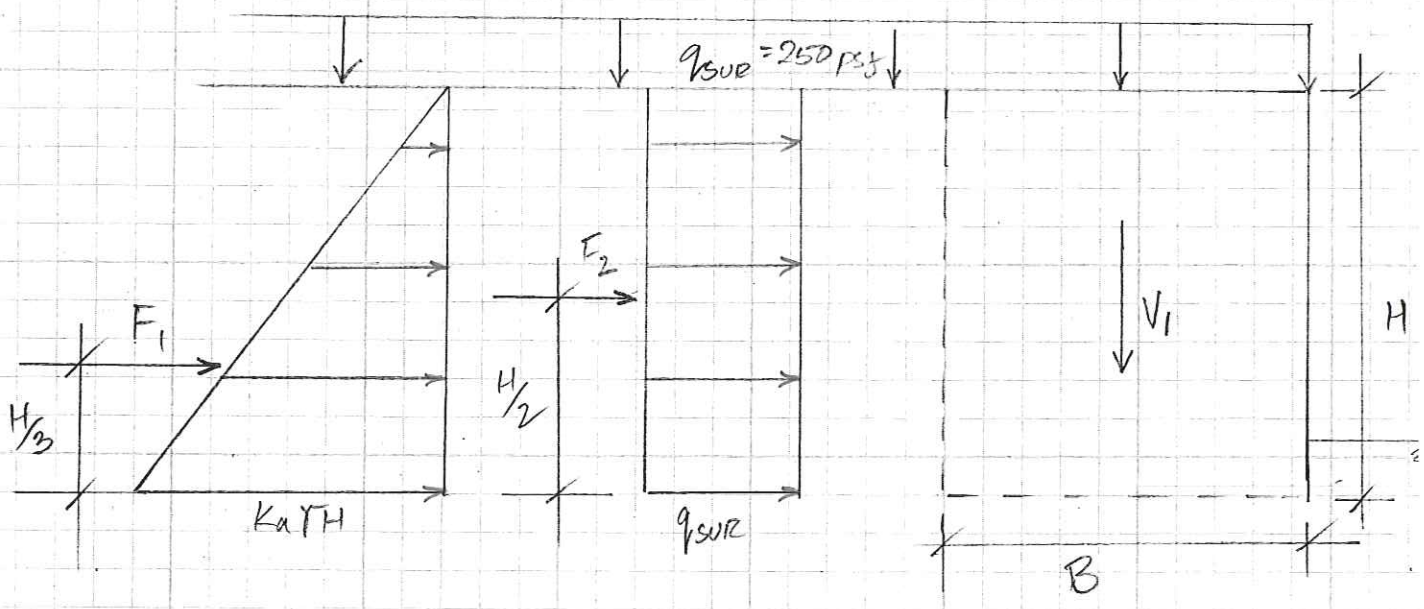
ALLOWABLE STRESS DESIGN



FOR OVERTURNING & SLIDING



FOR BEARING PRESSURE

ALLOWABLE STRESS DESIGN

CHECK FOR OVERTURNING

ECCENTRICITY

$$e = \frac{F_1 \cos\alpha \, H/3 + F_2 \cos\alpha \, H/2}{V_1}$$

$$= \frac{2836 \times \cos 0 \times 35/3 + 324 \times \cos 0 \times 35/2}{125 \times 35 \times 25}$$

$$= \frac{38756.7}{109375}$$

$$= 0.354 \text{ ft}$$

RESULTANT OF REACTION FORCES SHALL BE WITHIN $\frac{1}{3}$ OF THE CENTER BASE WIDTH

$\frac{1}{2}$ BASE WIDTH $= \frac{1}{2} \times 25 = 12.5$ ft

ECCENTRICITY $< \frac{12.5}{3}$

$0.354 < 4.17$

CHECK FOR SLIDING

TOTAL RESISTING FORCE

$R_R = V_1 \tan\delta + CB$

δ = SMALLER OF ϕ_f & ϕ_R

ϕ_f = FOUNDATION SOIL = 32°

ϕ_R = REINFORCED SOIL = 34°

C = 0 FOR GRANULAR SOIL

$R_R = 125 \times 35 \times 25 \times \tan 32°$

$= \underline{68345 \text{ lb/ft}}$

DRIVING FORCE

$R_{DR} = F_1 + F_2$

$= 2836 + 324$

$= \underline{3160 \text{ lb/ft}}$

FACTOR OF SAFETY

$F_S = \frac{R_R}{R_{DR}} = \frac{68345}{3160} = 21.6 > 1.5$ OK

BEARING CAPACITY CHECK

ECCENTRICITY

$$e = \frac{F_1 \cos\alpha \, H/3 + F_2 \cos\alpha \, H/2}{V_1 + q_{SR} B}$$

$$= \frac{2836 \times \cos 0 \times 35/3 + 324 \times \cos 0 \times 35/2}{125 \times 35 \times 25 + 250 \times 25}$$

$$= \frac{38756.7}{115625}$$

$= 0.335$ ft.

EQUIVALENT UNIFORM STRESS

$$\sigma_v = \frac{V_1 + q B}{B - 2e}$$

$$= \frac{125 \times 35 \times 25 + 250 \times 25}{25 - 2 \times 0.335}$$

$$= \frac{115625}{24.33}$$

$$= 4752.36 \text{ psf}$$

FOR BACK TO BACK WALL WITH OVERLAPPING STRAPS

CONSIDER SINGLE FOOTING

$B = 38$ ft. (DISTANCE BETWEEN BACK TO BACK WALLS)

CHECK FOR LAYERED SYSTEM

CRITICAL HEIGHT

$$H_{CRIT} = \frac{3B \ \ln(q_1/q_2)}{2\left(1 + B/L\right)}$$

WHERE

q_1 = ULTIMATE BEARING CAPACITY OF FOOTING SUPPORTED IN THE UPPER LAYER OF A TWO LAYERED SYSTEM

q_2 = ULTIMATE BEARING CAPACITY OF FOOTING SUPPORTED IN THE LOWER LAYER OF A TWO LAYERED SYSTEM

B = FOOTING WIDTH

L = LENGTH OF FOOTING.

$B = 38$ ft

$L = 1000$ ft (APPROX LENGTH OF WALL 14 & 15)

$$q_{ULT} = cN_c \cancel{s_c}^{0} i_c + \gamma D_f N_q \cancel{s_q}^{0} d_q i_q C_{wq} + \frac{1}{2}\gamma B N_\gamma S_\gamma i_\gamma C_{w\gamma}$$

CHECK FOR LONG TERM DRAINED CONDITION

$c = 0$ N_q TERM 0 FOR MSE WALLS NO INCLINATION

TOP LAYER

$$q_{1ULT} = \frac{1}{2}\gamma B N_\gamma S_\gamma C_{w\gamma}$$

$\phi = 32°$ $N_\gamma = 30.2$ Table 10.6.3.1.2a-1

$\gamma = 125$ pcf $S_\gamma = 1 - 0.4\left(\frac{B}{L}\right)$ Table 10.6.3.1.2a-3

$C_{w\gamma}$ = LINEAR INTERPOLATION 10.6.3.1.2a-2

FOR DEPTH OF WT $0 \rightarrow 0.5$ $1.5B = 57$ ft $\rightarrow 1.0$

FOR DEPTH OF 4 ft $\rightarrow 0.535$

$$q_{1ULT} = \frac{1}{2} 125 \times 38 \times 30.2 \times \left(1 - 0.4 \times \frac{38}{1000}\right) \times 0.535$$

$$= \underline{37{,}789 \text{ psf}}$$

LOWER LAYER

q_{2ULT} $\phi = 24°$ $N_\gamma = 9.4$ $\gamma = 130$ pcf

$$q_{2ULT} = \frac{1}{2} 130 \times 38 \times 9.4 \times \left(1 - 0.4 \frac{38}{1000}\right) \times 0.535$$

$$= \underline{12{,}232 \text{ psf}}$$

$$H_{CRIT} = \frac{3 \times 38 \times \ln\left(\frac{37789}{12232}\right)}{2\left(1+\frac{38}{1000}\right)}$$

$$= 62\text{-ft.}$$

THICKNESS OF SAND LAYER $H = 9$-ft.

FOUNDATION SOIL IS TWO LAYERED SYSTEM.

ULTIMATE BEARING CAPACITY FOR 2 LAYERED SYSTEM

$$q_{ULT} = q_2 \, e^{0.67[1+B/L]\,H/B}$$

$B = 38$ ft $\quad L = 1000$ ft $\quad H = 9$-ft FOR TALLEST PORTION OF WALL

$$q_{ULT} = 12\,232 \; e^{0.67\left[1+\frac{38}{1000}\right]\frac{9}{38}}$$

$$= 12{,}232 \times 1.179$$

$$= 14421 \text{ psf}$$

FACTOR OF SAFETY

$$F.S. = \frac{q_{ULT}}{\sigma_v}$$

$$= \frac{14421}{4758} = 3.0 > 2.5 \text{ ok}$$

BEARING PRESSURE FOR SETTLEMENT ANALYSIS
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$\sigma_v = 4753$ psf.

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GLOBAL STABILITY ANALYSIS ABUTMENT B

SOIL PARAMETER FOR STABILITY ANALYSIS

ELEVATION	STRATUM	γ pcf	ϕ (deg)	UNDRAINED Su (psf)	DRAINED PARAMETER
EL 70-EL82	STRATUM 1	125	32	0	—
EL 40-EL 70	STRATUM 2a	130	0	1700	SPLINE FUNCTION
EL 20-EL 40	STRATUM 2a	130	0	2500	SPLINE FUNCTION
EL 20 & BELOW	STRATUM 2a	130	0	3500	SPLINE FUNCTION

REINFORCED SOIL $\gamma = 125$ pcf $\phi = 34°$
LWEF $\gamma = 40$ pcf $S_u = 10000$ psf

SPLINE FUNCTION

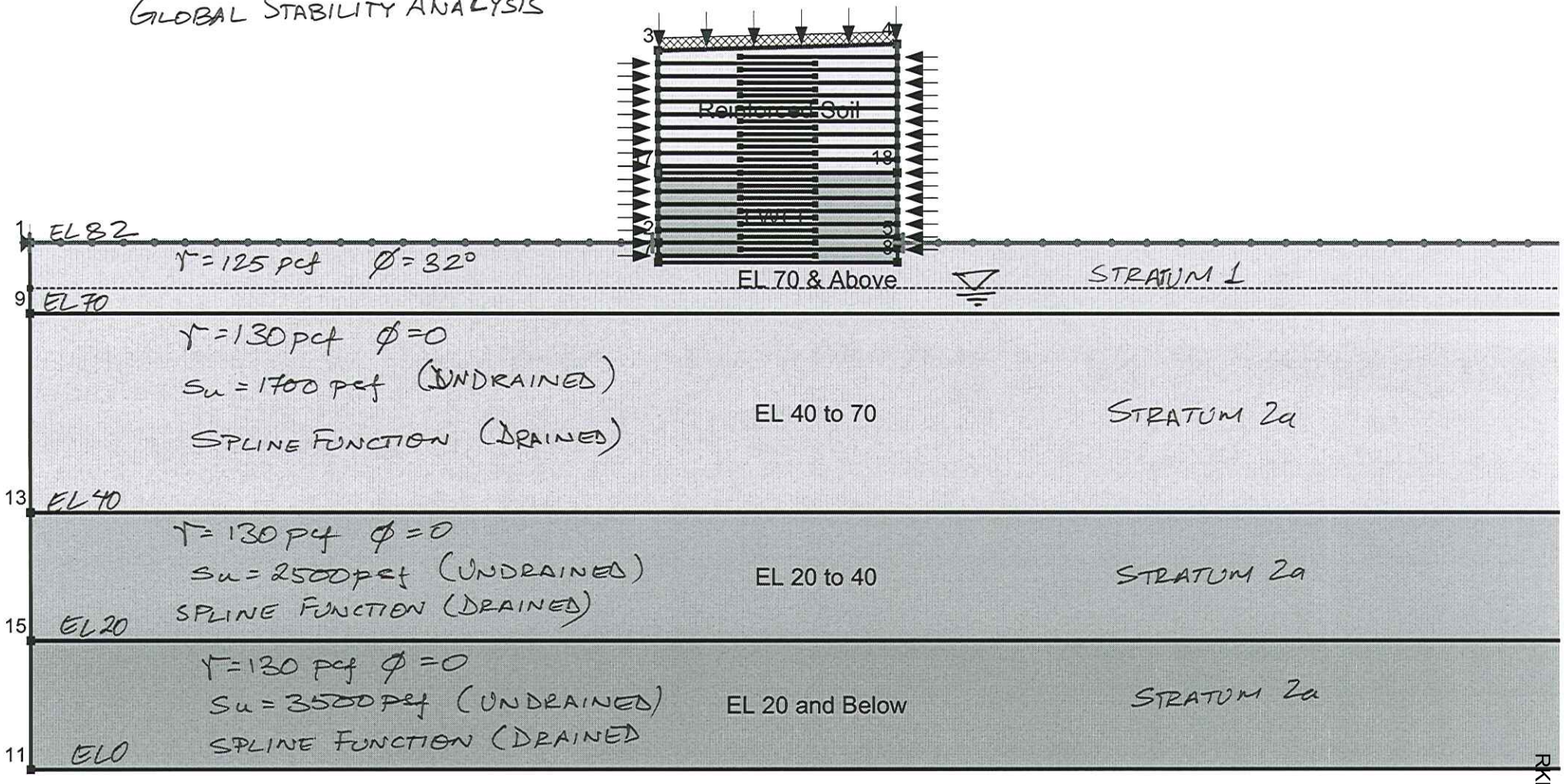
SHEAR STRENGTH = $0.7753\,(\text{NORMAL STRESS})^{0.6701}$

WATER TABLE @ EL 75

SUMMARY OF GLOBAL STABILITY RESULTS.

ANALYSIS TYPE	FACTOR OF SAFETY	RESISTANCE FACTORS	
DRAINED	3.060	0.327 < 0.65	OK
UNDRAINED	3.415	0.293 < 0.65	OK

GLOBAL STABILITY ANALYSIS



S6: ABUTMENT B

RKK S6-106

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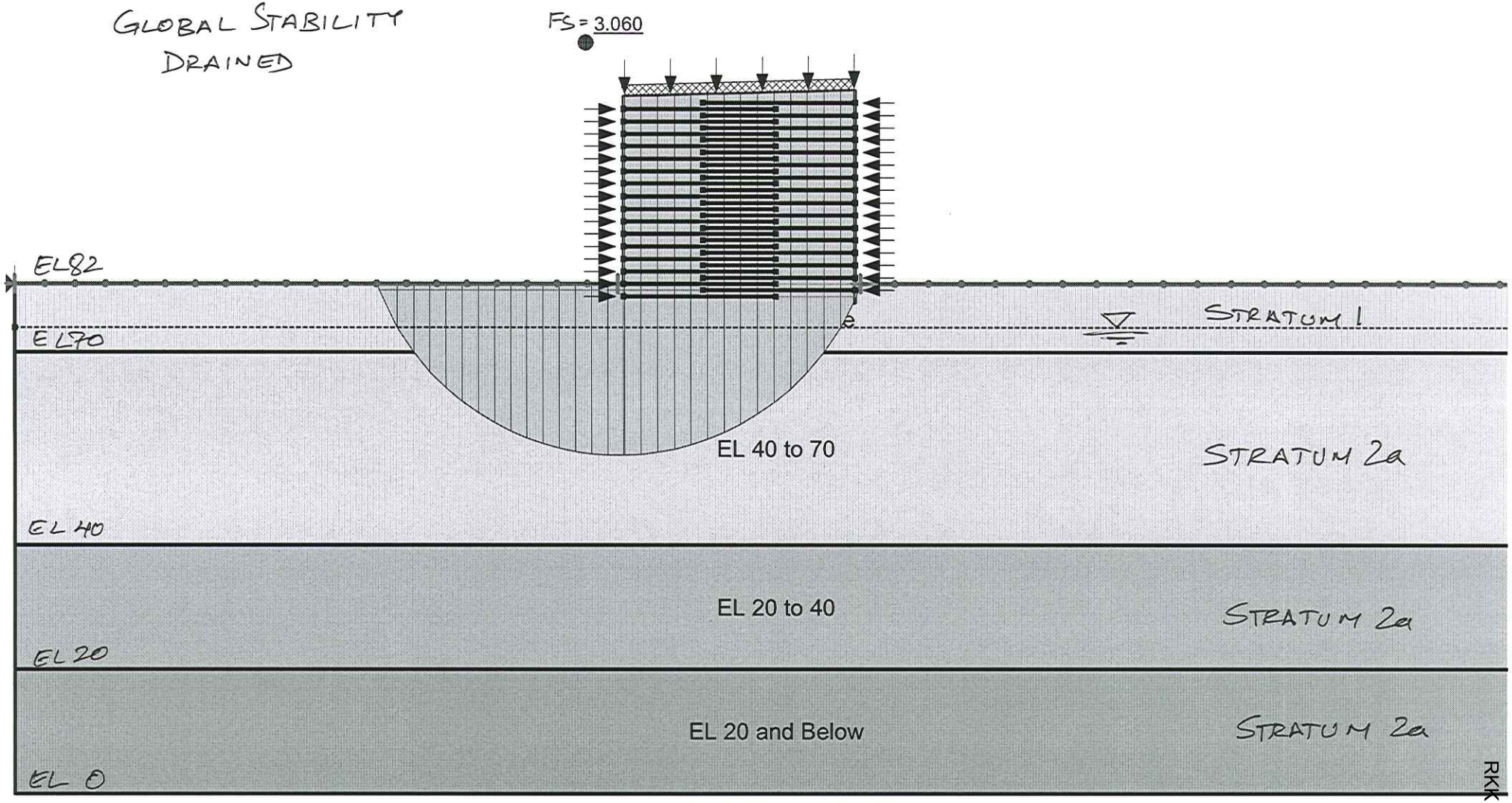
BBS 1-27-09

EMC 2/2/09

GLOBAL STABILITY
DRAINED



S6: ABUTMENT B

SLOPE/W Analysis

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File Information

Revision Number: 43
Date: 1/27/2009
Time: 1:25:12 PM
File Name: Abut B CLSM(Drained).gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Ramp B\Global Stability\
Last Solved Date: 1/27/2009
Last Solved Time: 1:25:51 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: Abutment B
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

EL 70 & Above

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 32 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

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

LWEF

Model: Undrained (Phi=0)
Unit Weight: 40 pcf
Cohesion: 10000 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, 82) ft
Left-Zone Increment: 20
Right Projection: Range
Right-Zone Left Coordinate: (139, 82) 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

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

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: (138.18, 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: 12.381 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (138, 81) ft
Inside Point: (113, 81) ft
Slip Surface Intersection: (59.884, 81) ft
Total Length: 25 ft

Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 3

Type: Fabric
Outside Point: (100, 82) ft
Inside Point: (125, 82) ft
Slip Surface Intersection: (139, 82) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 4

Type: Fabric
Outside Point: (100, 84) ft
Inside Point: (125, 84) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 5

Type: Fabric
Outside Point: (100, 86) ft
Inside Point: (125, 86) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 6

Type: Fabric
Outside Point: (100, 88) ft
Inside Point: (125, 88) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 7

Type: Fabric
Outside Point: (100, 90) ft
Inside Point: (125, 90) ft

Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 8

Type: Fabric
Outside Point: (100, 92) ft
Inside Point: (125, 92) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 9

Type: Fabric
Outside Point: (100, 94) ft
Inside Point: (125, 94) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 10

Type: Fabric
Outside Point: (100, 96) ft
Inside Point: (125, 96) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 11

Type: Fabric
Outside Point: (100, 98) ft
Inside Point: (125, 98) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 12

Type: Fabric

Outside Point: (100, 100) ft
Inside Point: (125, 100) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 13

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

Reinforcement 14

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

Reinforcement 15

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

Reinforcement 16

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

Reinforcement 17

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

Reinforcement 18

Type: Fabric
Outside Point: (138, 83) ft
Inside Point: (113, 83) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 19

Type: Fabric
Outside Point: (138, 85) ft
Inside Point: (113, 85) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 20

Type: Fabric
Outside Point: (138, 87) ft
Inside Point: (113, 87) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 21

Type: Fabric
Outside Point: (138, 89) ft
Inside Point: (113, 89) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °

Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 22

Type: Fabric
Outside Point: (138, 91) ft
Inside Point: (113, 91) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 23

Type: Fabric
Outside Point: (138, 93) ft
Inside Point: (113, 93) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 24

Type: Fabric
Outside Point: (138, 95) ft
Inside Point: (113, 95) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 25

Type: Fabric
Outside Point: (138, 97) ft
Inside Point: (113, 97) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 26

Type: Fabric
Outside Point: (138, 99) ft
Inside Point: (113, 99) ft
Slip Surface Intersection: (0, 0) ft

Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 27

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

Reinforcement 28

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

Reinforcement 29

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

Reinforcement 30

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

Reinforcement 31

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

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

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	3,4,18,17	741

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
Region 6	LWEF	17,2,7,8,5,18	532

Points

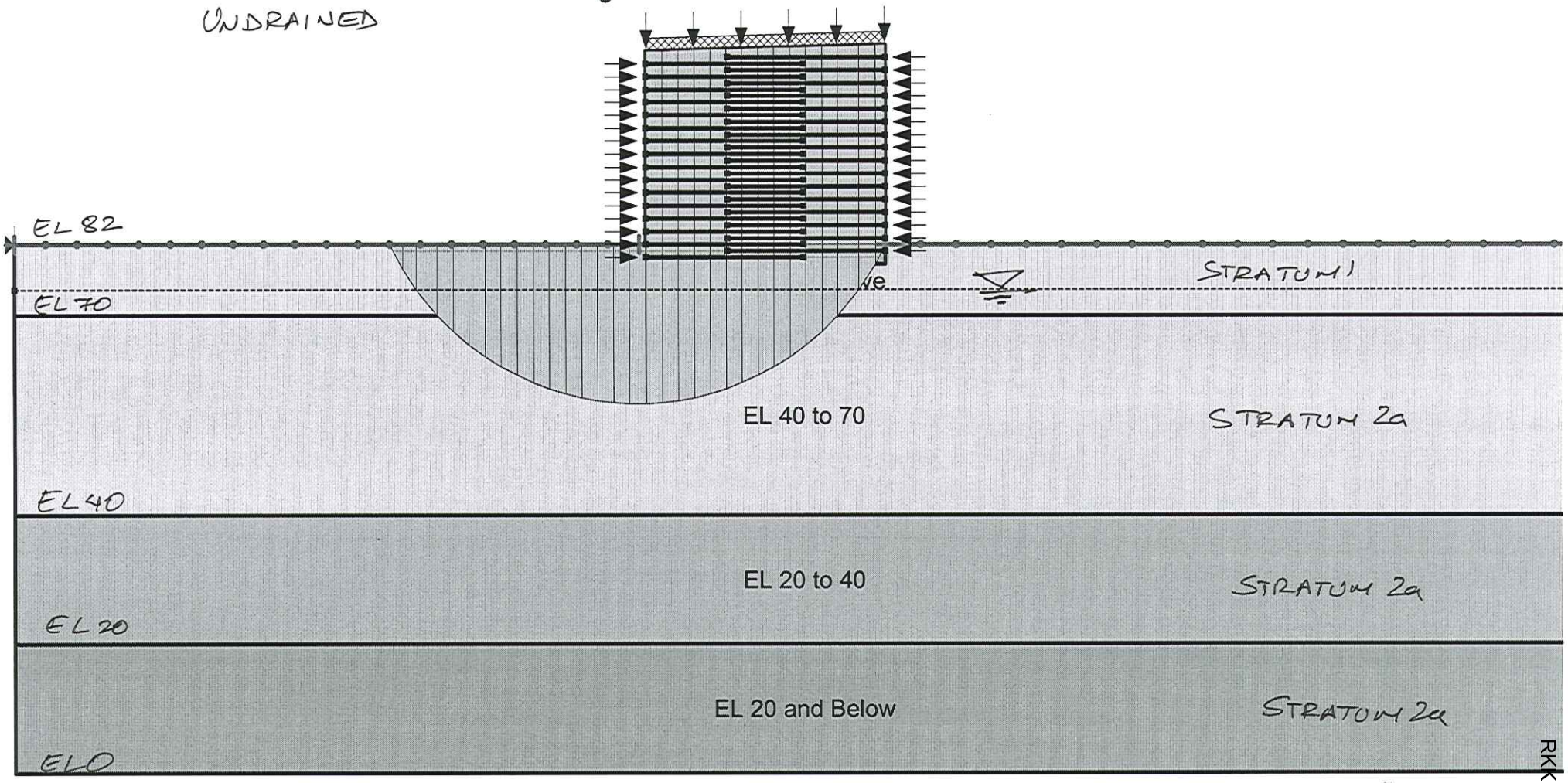
	X (ft)	Y (ft)
Point 1	0	82
Point 2	100	82
Point 3	100	112
Point 4	138	113
Point 5	138	82
Point 6	250	82
Point 7	100	79
Point 8	138	79
Point 9	0	71
Point 10	250	71
Point 11	0	0
Point 12	250	0
Point 13	0	40
Point 14	250	40
Point 15	0	20
Point 16	250	20
Point 17	100	93
Point 18	138	93

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	3791	3.060	(99.2, 96.934)	42.51	(139, 82)	(59.4, 82)

GLOBAL STABILITY
UNDRAINED

FS = 3.415



S6 : ABUTMENT B

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BRS 1-27-09
RMC 2/2/09

SLOPE/W Analysis

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File Information

Revision Number: 39
Date: 1/27/2009
Time: 1:29:26 PM
File Name: Abut B CLSM(UnDrained).gsz
Directory: M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Calculation\Ramp B\Global Stability\
Last Solved Date: 1/27/2009
Last Solved Time: 1:29:49 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: Abutment B
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

EL 70 & Above

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 32 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Line: 1

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

LWEF

Model: Undrained (Phi=0)
Unit Weight: 40 pcf
Cohesion: 10000 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, 82) ft
Left-Zone Increment: 20
Right Projection: Range
Right-Zone Left Coordinate: (138.01, 82) 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

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

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: (136.95, 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: 244.62 lbs/ft
Available Bond Length: 0 ft
Required Bond Length: 0 ft
Governing Component: Bond

Reinforcement 2

Type: Fabric
Outside Point: (138, 81) ft
Inside Point: (113, 81) ft
Slip Surface Intersection: (59.945, 81) ft
Total Length: 25 ft

Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 3

Type: Fabric
Outside Point: (100, 82) ft
Inside Point: (125, 82) ft
Slip Surface Intersection: (138.01, 82) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 4

Type: Fabric
Outside Point: (100, 84) ft
Inside Point: (125, 84) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 5

Type: Fabric
Outside Point: (100, 86) ft
Inside Point: (125, 86) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 6

Type: Fabric
Outside Point: (100, 88) ft
Inside Point: (125, 88) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 7

Type: Fabric
Outside Point: (100, 90) ft
Inside Point: (125, 90) ft

Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 8

Type: Fabric
Outside Point: (100, 92) ft
Inside Point: (125, 92) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 9

Type: Fabric
Outside Point: (100, 94) ft
Inside Point: (125, 94) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 10

Type: Fabric
Outside Point: (100, 96) ft
Inside Point: (125, 96) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 11

Type: Fabric
Outside Point: (100, 98) ft
Inside Point: (125, 98) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 12

Type: Fabric

Outside Point: (100, 100) ft
Inside Point: (125, 100) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 180 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 13

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

Reinforcement 14

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

Reinforcement 15

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

Reinforcement 16

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

Reinforcement 17

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

Reinforcement 18

Type: Fabric
Outside Point: (138, 83) ft
Inside Point: (113, 83) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 19

Type: Fabric
Outside Point: (138, 85) ft
Inside Point: (113, 85) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 20

Type: Fabric
Outside Point: (138, 87) ft
Inside Point: (113, 87) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 21

Type: Fabric
Outside Point: (138, 89) ft
Inside Point: (113, 89) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °

Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 22

Type: Fabric
Outside Point: (138, 91) ft
Inside Point: (113, 91) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 23

Type: Fabric
Outside Point: (138, 93) ft
Inside Point: (113, 93) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 24

Type: Fabric
Outside Point: (138, 95) ft
Inside Point: (113, 95) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 25

Type: Fabric
Outside Point: (138, 97) ft
Inside Point: (113, 97) ft
Slip Surface Intersection: (0, 0) ft
Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 26

Type: Fabric
Outside Point: (138, 99) ft
Inside Point: (113, 99) ft
Slip Surface Intersection: (0, 0) ft

Total Length: 25 ft
Reinforcement Direction: 0 °
Applied Load Option: Variable
F of S Dependent: Yes

Reinforcement 27

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

Reinforcement 28

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

Reinforcement 29

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

Reinforcement 30

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

Reinforcement 31

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

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

Regions

	Material	Points	Area (ft²)
Region 1	Reinforced Soil	3,4,18,17	741
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
Region 6	LWEF	7,8,5,18,17,2	532

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
Point 17	100	93
Point 18	138	93

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	3790	3.415	(98.705, 100.912)	43.618	(138.01, 82)	(59.4, 82)

Slices of Slip Surface: 3790

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	3790	60.454455	80.06527	-316.0769	363.91164	227.39723	0
2	3790	62.563365	76.56527	-97.673356	931.96087	582.35378	0
3	3790	65.288385	73	124.80069	1404.0558	799.36729	0
4	3790	68.22976	69.756935	327.1668	2021.3632	0	1700
5	3790	70.77138	67.452935	470.92694	2248.9842	0	1700
6	3790	73.313	65.48126	593.9722	2445.9899	0	1700
7	3790	75.85462	63.78832	699.61679	2615.4209	0	1700
8	3790	78.39624	62.337075	790.15853	2759.5667	0	1700
9	3790	80.93786	61.10089	867.29886	2880.3132	0	1700
10	3790	83.47948	60.06012	932.23679	2979.0949	0	1700
11	3790	86.021095	59.200065	985.9113	3056.9989	0	1700
12	3790	88.56271	58.509675	1029.0004	3114.7819	0	1700
13	3790	91.10433	57.980725	1062.0101	3153.0992	0	1700
14	3790	93.64595	57.607275	1085.3084	3172.2175	0	1700
15	3790	96.18757	57.385315	1099.1545	3172.3194	0	1700
16	3790	98.72919	57.312525	1103.7059	3153.3444	0	1700
17	3790	100.05	57.31477	1103.5747	5793.6422	0	1700

18	3790	101.36465	57.3936	1098.6305	6022.9529	0	1700
19	3790	103.8939	57.62247	1084.3391	5973.6401	0	1700
20	3790	106.42315	58.001515	1060.6882	5903.8672	0	1700
21	3790	108.9524	58.53478	1027.4196	5813.2698	0	1700
22	3790	111.48165	59.2282	984.16193	5700.0875	0	1700
23	3790	114.0109	60.08998	930.36773	5563.4739	0	1700
24	3790	116.54015	61.13111	865.42604	5400.4345	0	1700
25	3790	119.0694	62.3662	788.34931	5208.8177	0	1700
26	3790	121.59865	63.814745	697.95744	4985.0257	0	1700
27	3790	124.1279	65.50314	592.61791	4723.7287	0	1700
28	3790	126.65715	67.468065	469.9785	4417.9557	0	1700
29	3790	129.1864	69.76251	326.81151	4056.532	0	1700
30	3790	132.1216	73	124.80069	3419.912	2059.0141	0
31	3790	135.106	77	-124.80064	2855.4874	1784.3066	0
32	3790	137.1599	80.386535	-336.13552	-2134.2665	0	10000
33	3790	137.95	81.87615	-429.07394	-2991.5813	0	10000
34	3790	138.005	81.989615	-436.16764	0.94061934	0.5877642	0

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Subject SR-1/I-95 INTERCHANGE ABUT B SETTLEMENT
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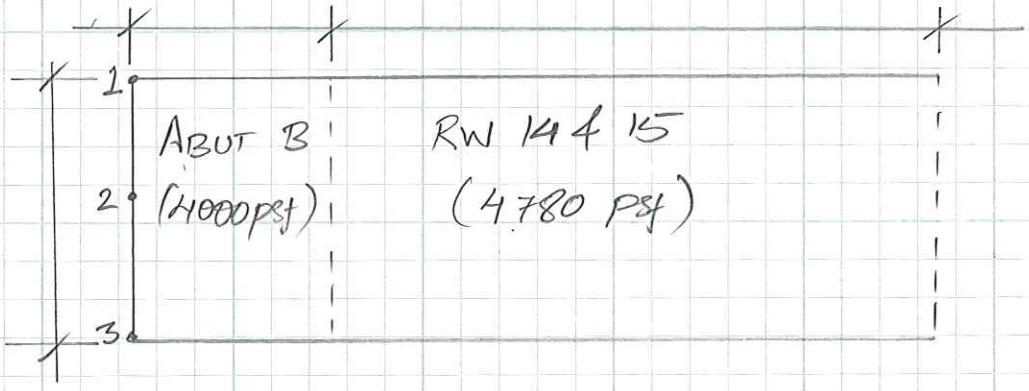
Cm. No. 103-059
Prepared By BBS Date 1-27-09 Checked By GM Date 2/2/09

SETTLEMENT ANALYSIS FOR ABUTMENT B-RAMP B BRIDGE



ABUTMENT B PLAN VIEW.

SOIL PROFILE & SOIL PARAMETERS SEE Pg-2

ELASTIC SETTLEMENT FOR COARSE GRAINED SOIL LAYER
CONSOLIDATION SETTLEMENT FOR FINE GRAINED SOIL LAYER

SETTLEMENT ESTIMATED FOR POINTS 1, 2 & 3 ON FACE OF ABUTMENT

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SUMMARY OF SETTLEMENTS

POINTS	ELASTIC (ft)	ELASTIC (in)	CONSOLIDATION (ft)	CONSOLIDATION (in)	TOTAL (ft)	TOTAL (in)
1	0.0036	0.043	0.09	1.08	0.0936	1.12
2	0.0076	0.091	0.12	1.44	0.1276	1.53
3	0.0035	0.042	0.09	1.08	0.0935	1.12

DIFFERENTIAL SETTLEMENT BETWEEN POINTS 1 & 2

$\Delta = 1.53 - 1.12$

$= 0.41$ - inches.

DISTANCE BETWEEN 1 & 2

$D = 38/2$

$= 19$ - ft

$$\text{RATIO} = \frac{\Delta}{12} \times \frac{1}{D}$$

$$= \frac{0.41}{12 \times 19} = \frac{1}{556} < \frac{1}{100} \quad \text{OK}$$

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BBS 1-27-09

EM 2/2/09

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:
ABUTMENT B Settlement Analysis

Company's information:

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

Original file path and name: M:\project ..... IGN 2008\Calculation\Ramp B\Abut Settle\Abut B.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/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 – 2 footings

INPUT DATA OF WATER

Point #	Coordinates (X, Z) : (X) [ft.]	(Z) [ft.]
1	300.00	175.00

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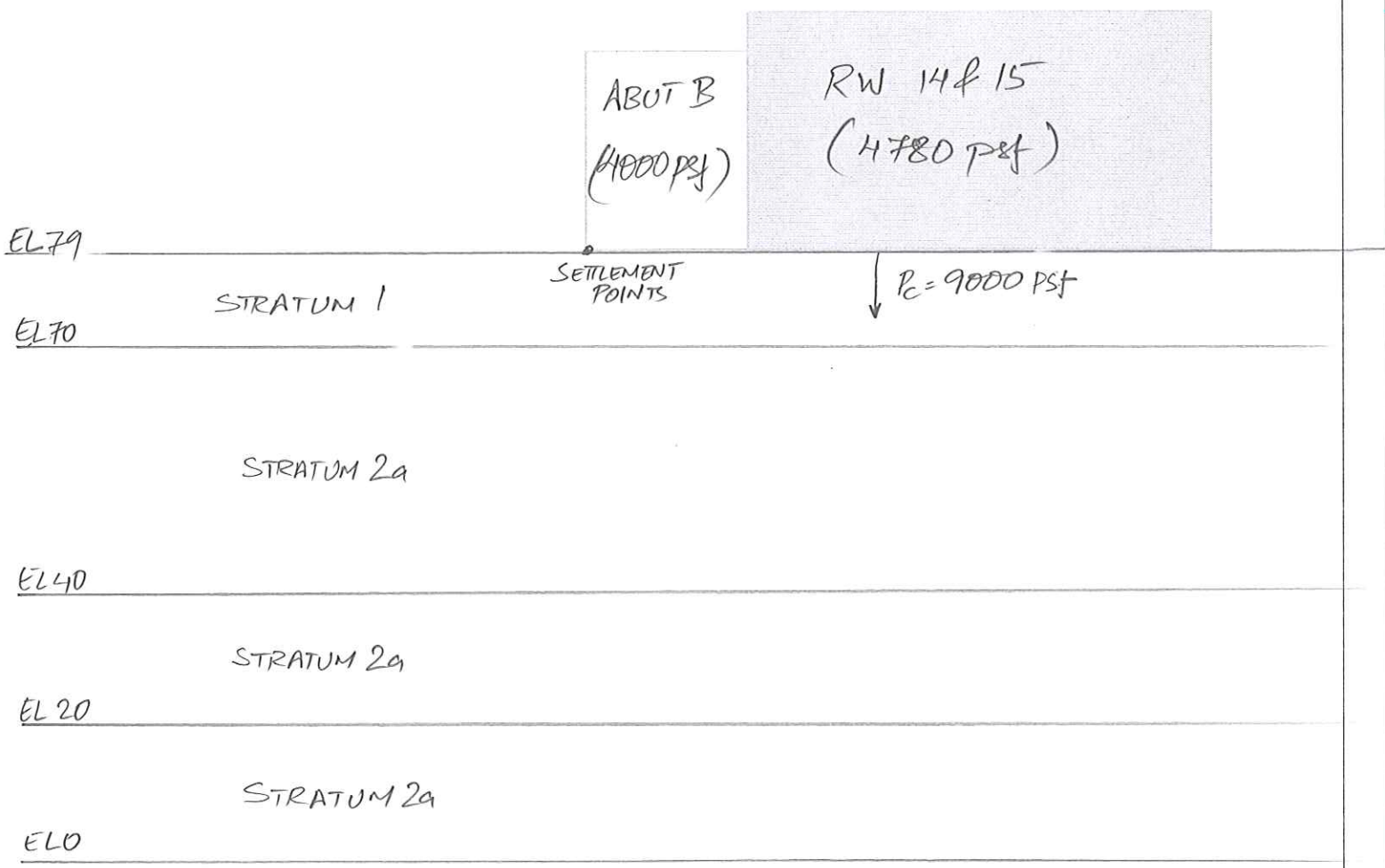
DRAWING OF SPECIFIED GEOMETRY



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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 [ft ²/day]	Drains at :
1	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Yes	8150.0	6150.0	0.24	0.01	0.75	1.6500	Top
3	Yes	6150.0	4800.0	0.22	0.01	0.84	1.6500	Top
4	Yes	4800.0	3450.0	0.22	0.01	0.84	0.8400	Bottom
5	Yes	3450.0	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

CALCULATE $(\sigma_p' - \sigma_o')$

$\sigma_p' = 9000$ psf
WT @ EL75

EL70 – EL40 STRATUM 2a
TOP = 9000 - (125)x4 - (125 - 62.4)x5 = 8187 ≈ 8150 psf
BOTTOM = 8187 - (130 - 62.4)x30 = 6159 ≈ 6150 psf

EL40 - EL20 STRATUM 2a
TOP = 6150 psf
BOTTOM = 6159 - (130 - 62.4) x 20 = 4807 ≈ 4800 psf

EL20 - EL0 STRATUM 2a
TOP = 4807 - (130 - 62.4)x20 = 3455 ≈ 3450 psf
BOTTOM = 3455 - (130 - 62.4) x 20 = 2103 ≈ 2100 psf.

EL0 & BELOW STRATUM 2a
TOP = 2100 psf
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	282.50	19.00	1	1500000	0.3000	0.0036	179.00	178.93	~~0.07~~ 0.0036
			2	~~818000~~	~~0.4000~~	~~0.0208~~			
			3	~~818000~~	~~0.4000~~	~~0.0146~~			
			4	~~818000~~	~~0.4000~~	~~0.0130~~			
			5	~~1364000~~	~~0.4000~~	~~0.0152~~			
			6	~~1364000~~	~~0.3000~~	~~0.0056~~			
2	282.50	0.00	1	1500000	0.3000	0.0076	179.00	178.90	~~0.10~~ 0.0076
			2	818000	0.4000	~~0.0398~~			
			3	818000	0.4000	~~0.0194~~			
			4	818000	0.4000	~~0.0153~~			
			5	1364000	0.4000	~~0.0166~~			
			6	1364000	0.3000	~~0.0058~~			
3	282.50	-19.00	1	1500000	0.3000	0.0035	179.00	178.93	~~0.07~~ 0.0035
			2	818000	0.4000	~~0.0208~~			
			3	818000	0.4000	~~0.0146~~			
			4	818000	0.4000	~~0.0130~~			
			5	1364000	0.4000	~~0.0152~~			
			6	1364000	0.3000	~~0.0056~~			

*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	282.50	19.00	179.00	0.09	178.91
2	282.50	0.00	179.00	0.12	178.88
3	282.50	-19.00	179.00	0.09	178.91

*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	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	

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TABULATED GEOMETRY: INPUT OF MULTIPLE FOOTINGS – 2 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
2	100.00	38.00	367.50	0.00	4780.00

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Set 3

Foundation Design for Abutments and Piers

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Subject SR-1/I-95 INTERCHANGE DEEP FOUNDATION Page 1 of 67
Cm. No. 103-059
Prepared By BBS Date 1-28-09 Checked By EM Date 2/2/09

PURPOSE: DESIGN OF DEEP FOUNDATION FOR RAMP B BRIDGE ABUTMENTS & PIERS.

REFERENCE: AASHTO LRFD BRIDGE DESIGN SPECIFICATION CUSTOMARY US UNITS 14th EDITION 2007

SOFTWARE: ALL PILE 7.4K
GRLWEAP

SYMBOLS:

UNIT WEIGHT → γ

FRICTION ANGLE → ϕ

UNDRAINED SHEAR STRENGTH → S_u

HORIZONTAL SUBGRADE REACTION → K_h

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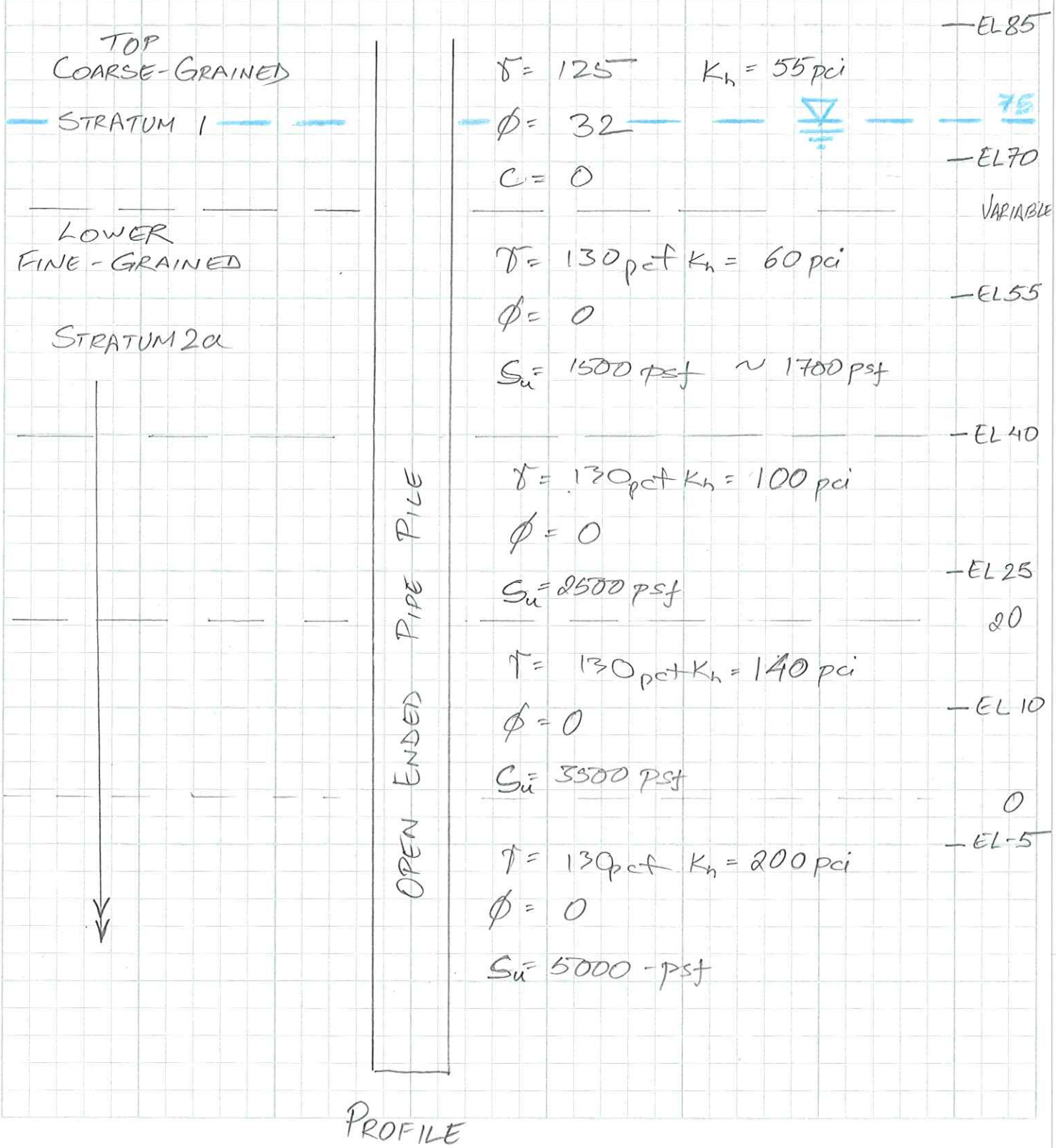
Subject SR-1 INTERCHANGE RAMP B BRIDGE FOUNDATION Page 2 of 67
Cm. No.
Prepared By BBS Date 9-11-08 Checked By DM Date 9/28/08

SOIL PARAMETERS



PROFILE

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Subject SR-1 INTERCHANGE Page 3 of 67
RAMP B BRIDGE FOUNDATION Cm. No.
Prepared By BBS Date 9-12-08 Checked By EMIC Date 9/28/08

COEFFICIENT OF HORIZONTAL SUBGRADE REACTION

$K_h = n_h \times \frac{x}{B}$ x is Depth
B is Width of PILE

n_h = coefficient of Modulus Variation.
(FROM FIGURE 6-20 pg 225 GARASSINO ET AL. (PILE DESIGN & CONSTRUCTION PRACTICE MJ TOMLINSON)

FOR STRATUM 1

Avg SPT N = 10 bpf → $D_r = 35\%$ MEDIUM DENSE ~ LOOSE

FROM CHART $n_h = 2.0\ MN/m^3 = 7.37\ P/in^3$

$K_h = 7.37 \frac{x}{1}$

$= 7.37\ x$.

FOR OUR CASE

x = MID POINT OF LAYER

TAKE LAYER THICKNESS = 15-ft.

$x = 7.5$-ft.

$K_h = 55$ pci

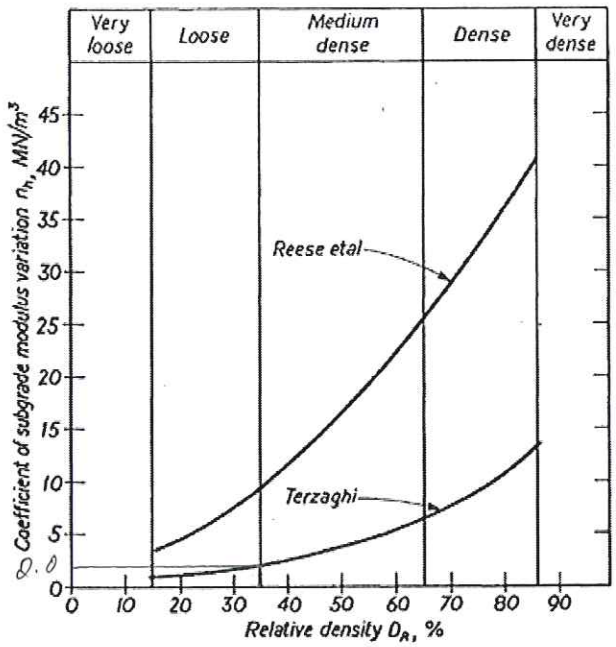

Fig. 6.20 Relationship between coefficient of modulus variation and relative density of sands (after Garassino et al[6-18])

$$K_h = n_h \times \frac{x}{B}$$

DEPTH

PILE WIDTH (USE 1 FT)

FOR STRATUM 2a

$K_h = n_h \times \frac{x}{B}$ (FOR FINE GRAINED SOIL)

SEE FIG-9 pg 7.2-236 NAVFAC 7.02

$K_h = \frac{f_z}{D}$, f IN TCF, z IN Ft, D IN Ft

EL 40-65

$f = n_h = 10 \text{ tons/ft}^3 = 11.57 \text{ pci}$

$K_h = 11.57 \times \frac{25}{1}$ MIDPOINT OF LAYER, USE 1-ft.

$= \underline{289 \text{ pci}} \approx 290 \text{ pci}$ $\left[x = 15 + \frac{20}{2} = 25\text{-ft} \right]$

EL 20-40

$K_h = 11.57 \times \frac{45}{1}$ $\left[x = 15 + 20 + \frac{20}{2} = 45\text{-ft} \right]$

$= \underline{520.65 \text{ pci}} \approx 520 \text{ pci}$

EL 0-20

$K_h = 11.57 \times \frac{65}{1}$ $\left[x = 15 + 20 + 20 + \frac{20}{2} = 65\text{-ft} \right]$

$= \underline{752 \text{ pci}} \approx 750 \text{ pci}$

EL 0 ~ BELOW

$K_h = 11.57 \times \frac{85}{1}$ $\left[x = 15 + 20 \times 3 + \frac{20}{2} = 85\text{-ft} \right]$

$= \underline{983 \text{ pci}} \approx 960 \text{ pci}$

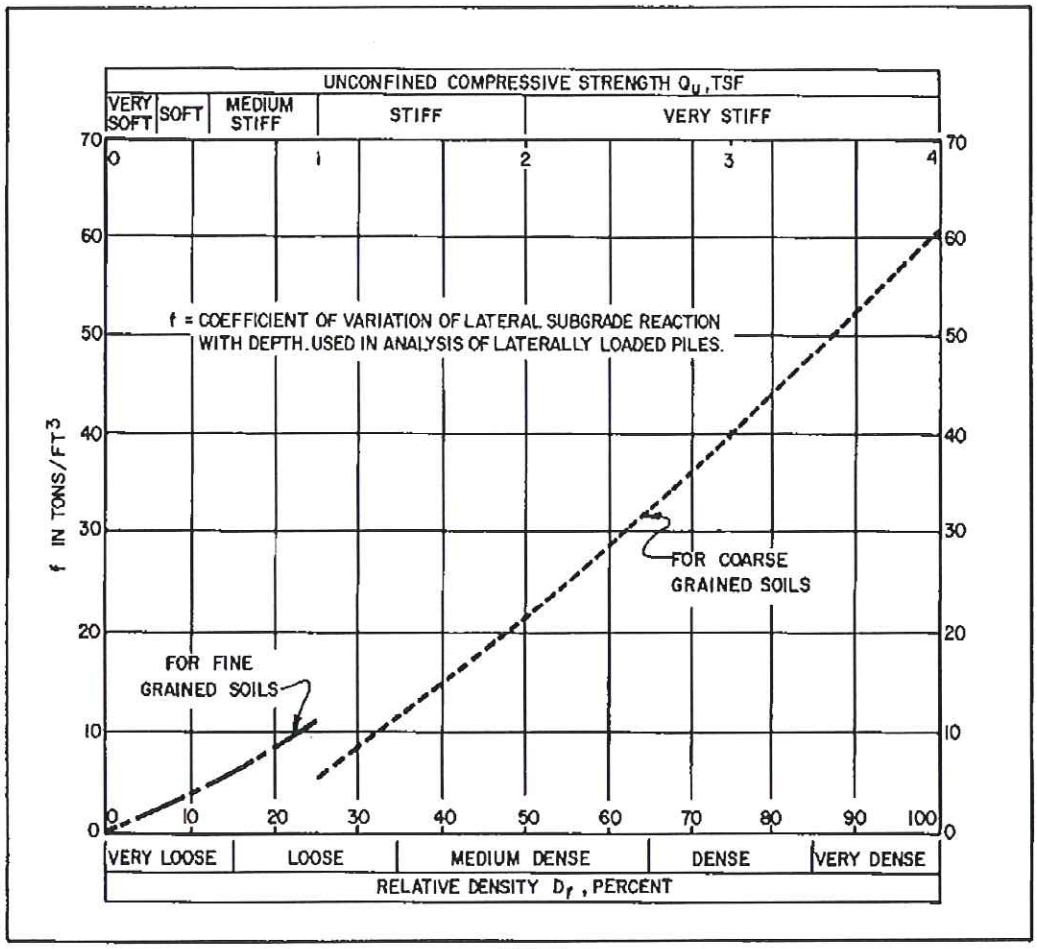

FIGURE 9
Coefficient of Variation of Subgrade Reaction

$$k_h = \frac{fz}{D}$$

f = COEFF. OF VARIATION OF LATERAL SUBGRADE REACTION WITH DEPTH (TCF)
z = DEPTH (ft)
D = PILE DIA (ft)

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Subject SR-1 INTERCHANGE RAMP B BRIDGE FOUNDATION Page 7 of 67 Cm. No.
Prepared By BBS Date 9-12-08 Checked By EM Date 9/28/08

ALTERNATE METHOD TO CALCULATE K_h FOR FINE GRAINED SOIL STRATUM 2a

EL 40-65 $K_h = 67\ S_u$ in Rcf.

$= 67 \times 1500$

$= 100500$ pcf $= 58$ pci ≈ 60 pci

EL 20-40

$K_h = 67 \times 2500$

$= 167500$ pcf $= 96$ pci ≈ 100 pci

EL 0-20 $K_h = 67 \times 3500$

$= 234500$ $= 135$ pci ≈ 140 pci

EL 0~BELOW $K_h = 67 \times 5000$

$= 335000$ pcf $= 193$ pci ≈ 200 pci

K_h VALUES TO USE.

EL 40-65 $K_h = 60$ pci
EL 20-40 $K_h = 100$ pci
EL 0-20 $K_h = 140$ pci
EL 0~BELOW $K_h = 200$ pci

Ramp B (Summary of Foundation Loads per Foundation Element)

Structure	Service Limit State Reactions							
	Vertical F_y (Kips)	Lateral F_x (Kips)	Lateral F_z (Kips)	Resultant Lateral (Kips)	M_x (kip-ft)	Torsion M_y (kip-ft)	M_z (kip-ft)	Maximum Moment (kip-ft)
Abutment 1	718	29	31	42.4				0
Pier 1	2799	525	50	527.4	2050	190	11000	11000
Pier 2	1285	25	390	390.8	4200	100	400	4200
Pier 3	2405	710	60	712.5	2452	400	12000	12000
Abutment 2	590	62	23	66.1				0

Structure	Strength Limit State Reactions							
	Vertical F_y (Kips)	Lateral F_x (Kips)	Lateral F_z (Kips)	Resultant Lateral (Kips)	M_x (kip-ft)	Torsion M_y (kip-ft)	M_z (kip-ft)	Maximum Moment (kip-ft)
Abutment 1	1051	36	25	43.8				0
Pier 1	3771	500	50	502.5	3755	270	11500	11500
Pier 2	1865	25	515	515.6	5580	100	200	5580
Pier 3	3470	665	50	666.9	3630	150	11000	11000
Abutment 2	885	29	49	56.9				0

AXIAL CAPACITY OF OPEN ENDED PIPE PILES

ESTIMATE PILE LENGTH REQUIRED FOR AXIAL CAPACITY

$R_F \leq \phi_{dyn} R_n = \phi_{STAT} R_{nSTAT}$

R_F = FACTORED LOADS (FROM STRUCTURES)

R_n = NOMINAL BEARING RESISTANCE OF PILE (ULTIMATE)

R_{nSTAT} = PREDICTED NOMINAL RESISTANCE FOR STATIC ANALYSIS

$\phi_{dyn} = 0.65$ (PDA TABLE 10.5.5.2.3-1)

$\phi_{STAT} = 0.35$ (α METHOD TABLE 10.5.5.2.3-1)

$$R_{nSTAT} = \frac{R_F}{\phi_{STAT}}$$

$$R_n = \frac{\phi_{STAT} R_{nSTAT}}{\phi_{dyn}} \geq \frac{R_F}{\phi_{dyn}}$$

STRUCTURE	R_F (kips)	REQD R_{nSTAT} (kips)	REQD R_n (kips)	PILE DIAMETER (in)	REQD PILE LENGTH (ft)
ABUTMENT A	131	374	202	24	51+35 = 86
PIER 1	516	1474	794	36	80
PIER 2	220	629	339	36	57
PIER 3	482	1377	742	36	76
ABUTMENT B	111	317	171	24	38+35 = 73

+35-ft FOR ABUTMENTS MSE STICK UP

SEE ALL PILE RUN OUTPUTS FOR PILE LENGTH

STRUCTURAL CAPACITY $= 0.6 f_y A_s$

$f_y = 50$ ksi

FOR 24-inch PIPE PILE (0.5 inch THICKNESS) $= 0.6 \times 50 \times \frac{\pi}{4} (24^2 - 23^2)$

$= \underline{\underline{1107 \text{ Kips}}}$

FOR 36-inch PIPE PILE (0.625 inch THICKNESS $= 0.6 \times 50 \times \frac{\pi}{4} (36^2 - 34.75^2)$

$= \underline{\underline{2083 \text{ Kips}}}$

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Subject SR-1 | I-95 INTERCHANGE Page 11 of 67
RAMP B LATERAL CAPACITY Cm. No. 103-059
Prepared By BBS Date 1-11-09 Checked By [illegible] Date 1/14/09

LATERAL CAPACITY OF PIPE PILES

1) PIPE PILE ANALYSIS FOR LATERAL CAPACITY ASSUMING HOLLOW PILE

2) GROUP EFFEC ANALYZED FOR LATERAL CAPACITY.

3) LATERAL CAPACITY OF PILES ANALYZED FOR SERVICE LOADS

i) RESULTANT HORIZONTAL LOAD USED FOR SHEAR

ii) MAXIMUM MOMENT USED

iii) TORSION

SUMMARY OF LATERAL CAPACITY, DEFLECTION & POINT OF FIXITY

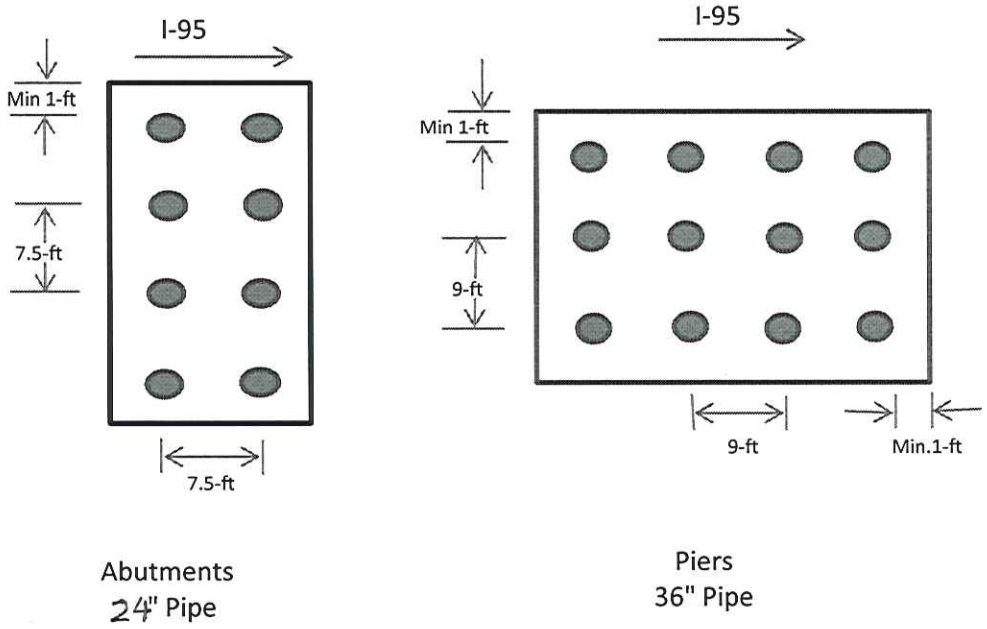
STRUCTURES	HORIZONTAL LOAD (Kips)	MAX MOMENT (ft Kips)	TORSION (ft-kips)	DEFLECTION (in)	POINT OF FIXITY (Ft)
ABUTMENT A	42.4	0	0	0.02	17.2
PIER 1	527.4	11000	190	0.14	23.7
PIER 2	390.8	4200	100	0.10	23.3
PIER 3	712.5	12000	400	0.22	23.7
ABUTMENT B	66.1	0	0	0.03	17.1

Summary of Pile Capacity

Schedule 20 Pipe Pile (Pipe Thickness 0.5-inches)

Structure	Pile Size (inches)	Factored Axial Loads (kips)	Nominal Bearing Resistance (kips)	Length of Pile (ft)	Estimated Pile Tip Elevation	Maximum Lateral Deflection (inches)	Depth of Point of Fixity (ft)
Abutment 1	**24**	131	202	86	EL +35	0.02	17.2
Pier 1	**36**	516	794	80	EL +6	0.14	23.7
Pier 2	**36**	220	338	51	EL +33	0.10	23.3
Pier 3	**36**	482	742	76	EL +8	0.22	23.7
Abutment 2	**24**	111	171	73	EL +41	0.03	17.1

The abutment piles includes an estimated 35-ft stickup for the MSE wall.



Pile Layout for Ramp B

Soil Parameters for Ramp B

Soil Strata	Elevation	Unit weight (pcf)	Friction Angle (deg)	Undrained Shear Strength (psf)	Spring Constant (lb/in)
MSE Wall Fill		105	34	0	15
Coarse Grained Stratum 1		125	32	0	55
Fine Grained Stratum 2a (i)	Above EL +40	130	0	1700	60
Fine Grained Stratum 2a (ii)	EL +20 - EL +40	130	0	2500	100
Fine Grained Stratum 2a (iii)	EL 0 - EL +20	130	0	3500	140
Fine Grained Stratum 2a (iv)	EL 0 and Below	130	0	5000	200

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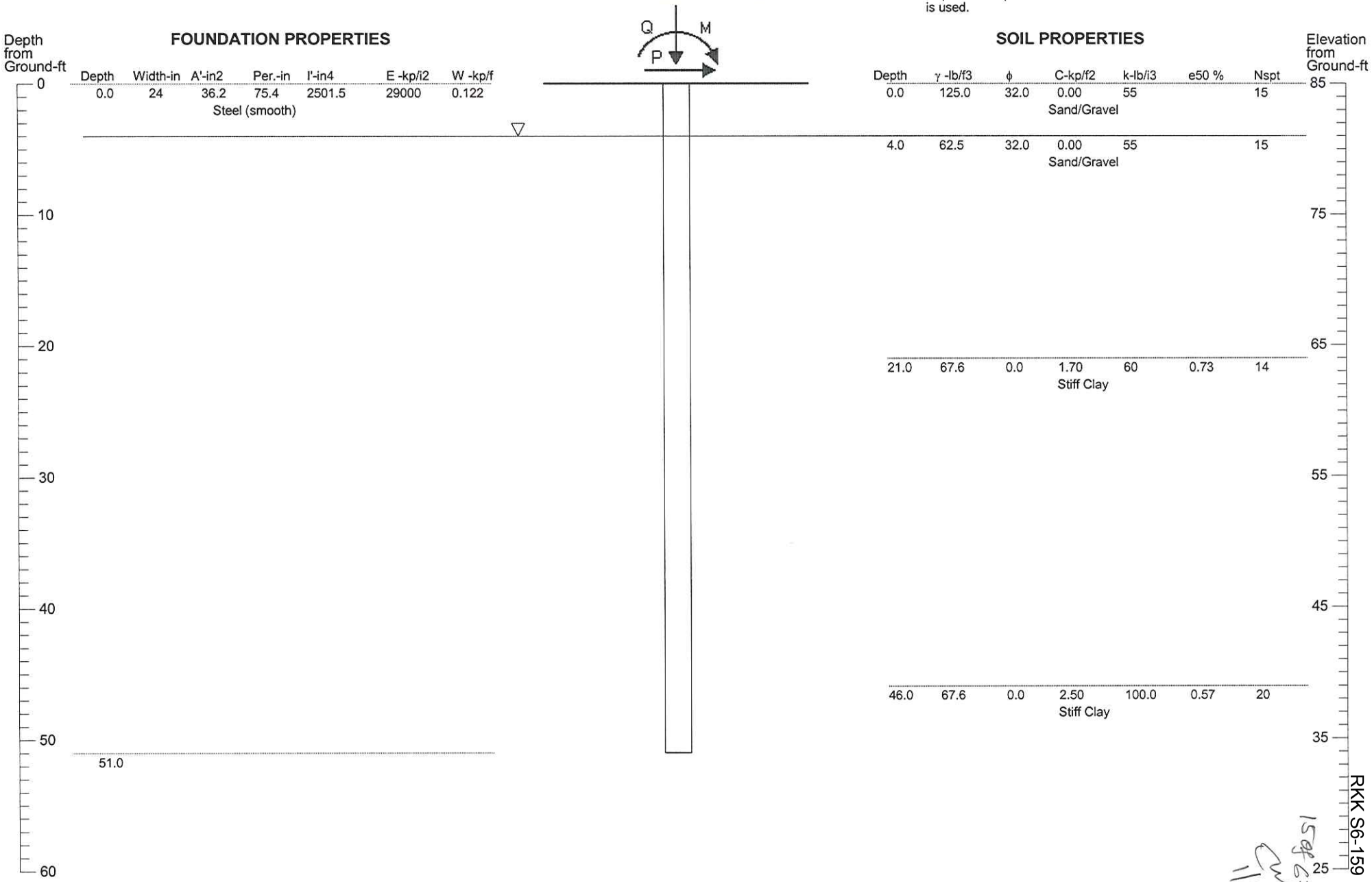
FOUNDATION PROFILE & SOIL CONDITIONS

Non-displacement pile: H pile or open-ended pipe. Little soil is displaced. Friction is less than displacement pile. Effective area is used.



FOUNDATION PROPERTIES

Depth	Width-in	A'-in2	Per.-in	I'-in4	E -kp/i2	W -kp/f
0.0	24	36.2	75.4	2501.5	29000	0.122

Steel (smooth)

SOIL PROPERTIES

Depth	γ -lb/f3	ϕ	C-kp/f2	k-lb/i3	e50 %	Nspt	
0.0	125.0	32.0	0.00	55		15	Sand/Gravel
4.0	62.5	32.0	0.00	55		15	Sand/Gravel
21.0	67.6	0.0	1.70	60	0.73	14	Stiff Clay
46.0	67.6	0.0	2.50	100.0	0.57	20	Stiff Clay

Batter Angle=0 (Pile diameter not to scale) Surface Angle=0

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CivilTech Software

SR-1 Interchange Ramp B
Abutment A Strength Limit State (24-inch Pipe Pile)

Figure 1

VERTICAL ANALYSIS

Figure 1

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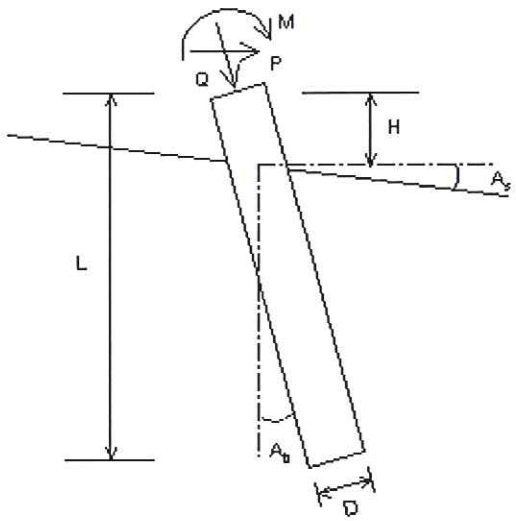


Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 375.0 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 51.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= 0

Fixed Head Condition

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	125.0	32.0	0.00	55	45.16	15
4	62.5	32.0	0.00	55	45.73	15
21	67.6	0.0	1.70	60	0.73	14
46	67.6	0.0	2.50	100.0	0.57	20
66	67.6	0.0	3.50	140.0	0.45	30
86	67.6	0.0	5.00	200	0.38	40

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	24	36.2	75.4	2501.5	29000	0.122
51.0						

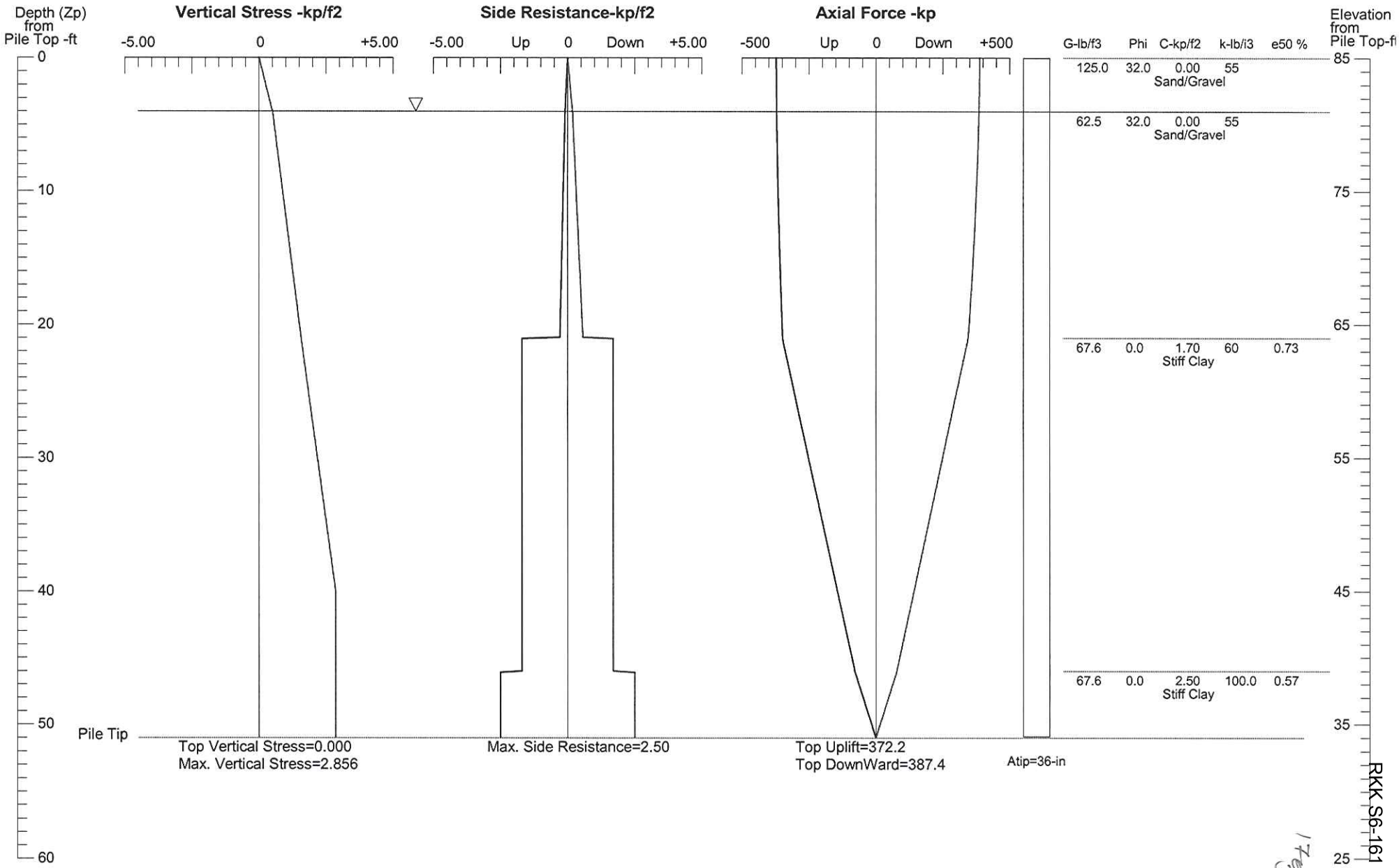
Vertical capacity:
Weight above Ground= 0.00 Total Weight= 6.22-kp *Soil Weight is not included
Side Resistance (Down)= 387.444-kp Side Resistance (Up)= 365.989-kp
Tip Resistance (Down)= 0.000-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 387.444-kp Total Ultimate Capacity (Up)= 372.211-kp
Total Allowable Capacity (Down)= 387.444-kp Total Allowable Capacity (Up)= 372.211-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 375.00-kp Settlement= 0.14434-in
At Xallow= 1.00-in Qallow= 99999.00000-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

SOIL STRESS, SIDE RESISTANCE, & AXIAL FORCE vs DEPTH

Based on Ultimate Load Condition



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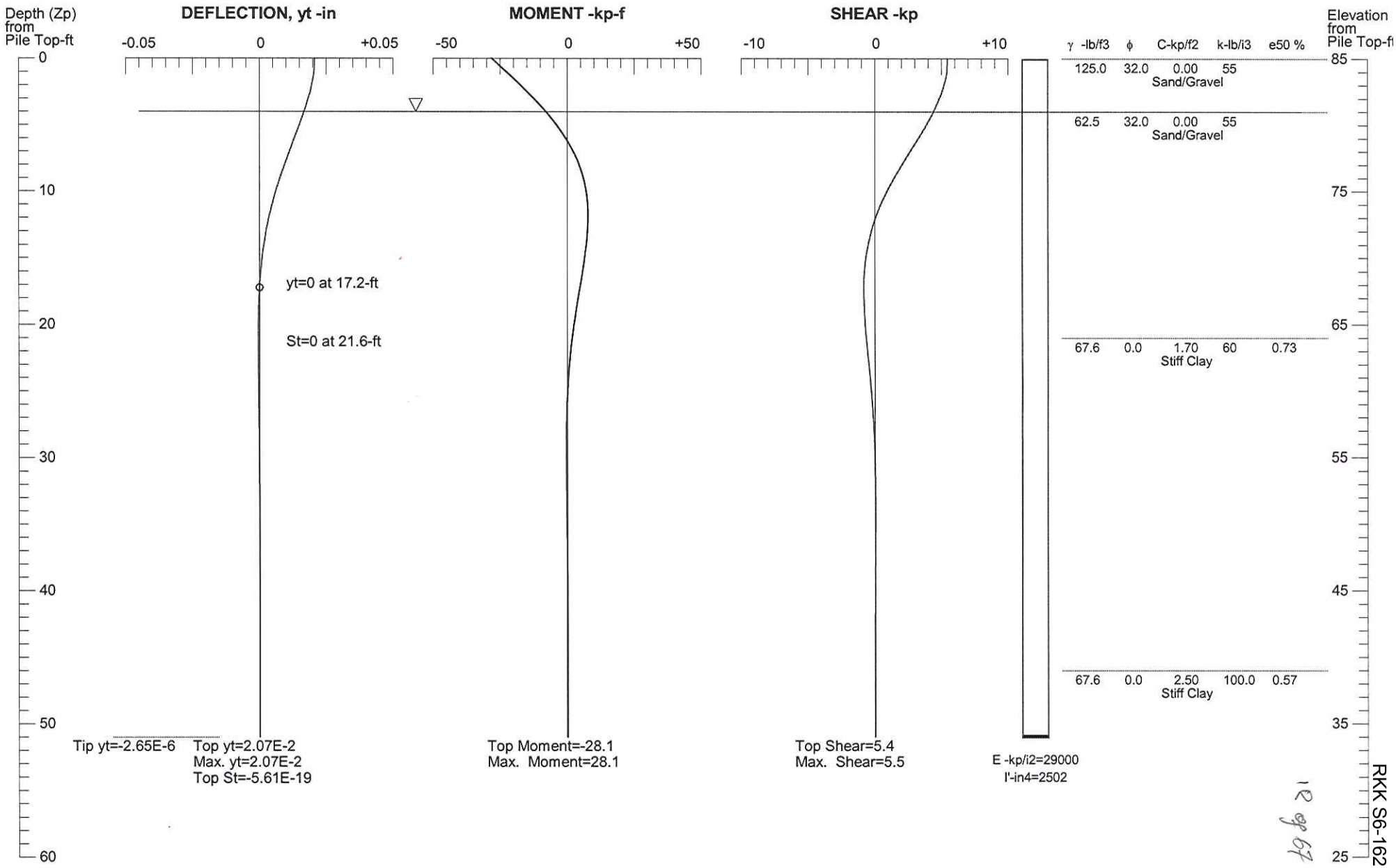
CivilTech Software

SR-1 Interchange Ramp B
Abutment A Strength Limit State (24-inch Pipe Pile)

Figure 1

PILE DEFLECTION & FORCE vs DEPTH

Y-Front,Single Pile, Kbc =2



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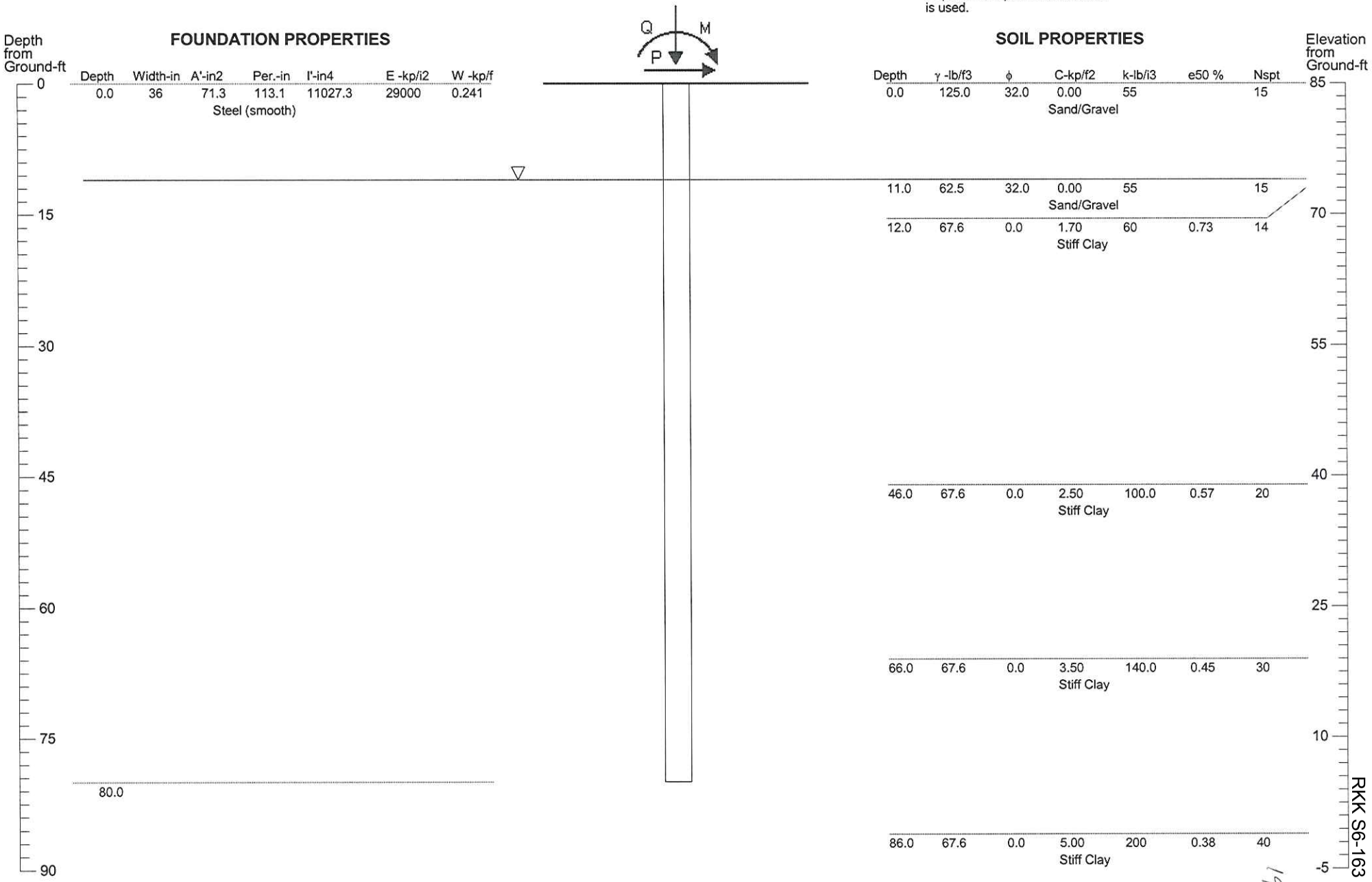
CivilTech Software

SR-1 Interchange Ramp B
Abutment A Service Limit State (24-inch Pipe Pile) Group

Figure 2

FOUNDATION PROFILE & SOIL CONDITIONS

Non-displacement pile: H pile or open-ended pipe. Little soil is displaced. Friction is less than displacement pile. Effective area is used.



FOUNDATION PROPERTIES

Depth	Width-in	A'-in2	Per.-in	I'-in4	E -kp/i2	W -kp/f
0.0	36	71.3	113.1	11027.3	29000	0.241
Steel (smooth)						
80.0						

SOIL PROPERTIES

Depth	γ -lb/f3	ϕ	C-kp/f2	k-lb/i3	e50 %	Nspt	
0.0	125.0	32.0	0.00	55		15	Sand/Gravel
11.0	62.5	32.0	0.00	55		15	Sand/Gravel
12.0	67.6	0.0	1.70	60	0.73	14	Stiff Clay
46.0	67.6	0.0	2.50	100.0	0.57	20	Stiff Clay
66.0	67.6	0.0	3.50	140.0	0.45	30	Stiff Clay
86.0	67.6	0.0	5.00	200	0.38	40	Stiff Clay

Batter Angle=0 (Pile diameter not to scale) Surface Angle=0

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CivilTech Software

SR-1 Interchange Ramp B
Pier 1 Strength Limit State (36-inch Pipe Pile)

Figure 1

VERTICAL ANALYSIS

Figure 1

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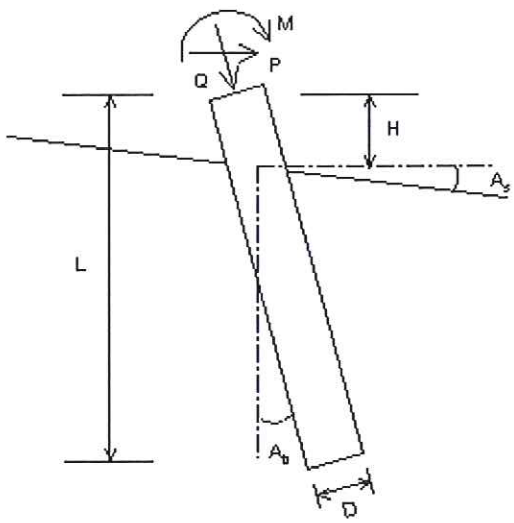


Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 1475.0 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 80.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= 0

Fixed Head Condition

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	125.0	32.0	0.00	55	45.16	15
11	62.5	32.0	0.00	55	45.73	15
12	67.6	0.0	1.70	60	0.73	14
46	67.6	0.0	2.50	100.0	0.57	20
66	67.6	0.0	3.50	140.0	0.45	30
86	67.6	0.0	5.00	200	0.38	40

Pile Data:

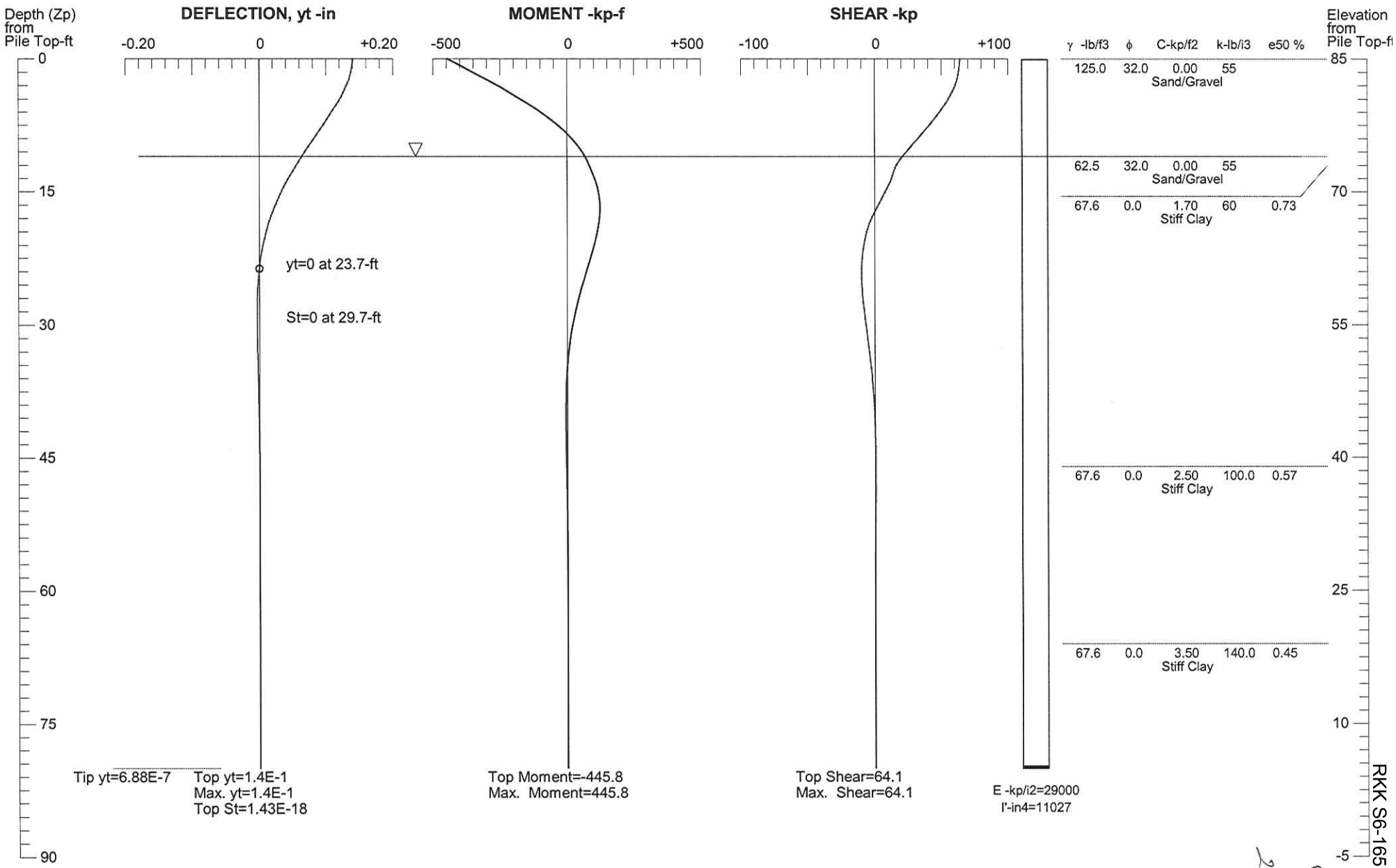
Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	36	71.3	113.1	11027.3	29000	0.241
80.0						

Vertical capacity:
Weight above Ground= 0.00 Total Weight= 19.28-kp *Soil Weight is not included
Side Resistance (Down)= 1507.782-kp Side Resistance (Up)= 1492.335-kp
Tip Resistance (Down)= 0.000-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 1507.782-kp Total Ultimate Capacity (Up)= 1511.615-kp
Total Allowable Capacity (Down)= 1507.782-kp Total Allowable Capacity (Up)= 1511.615-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 1475.00-kp Settlement= 0.42639-in
At Xallow= 1.00-in Qallow= 1026.03503-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH
X-Front, Single Pile, Kbc=2



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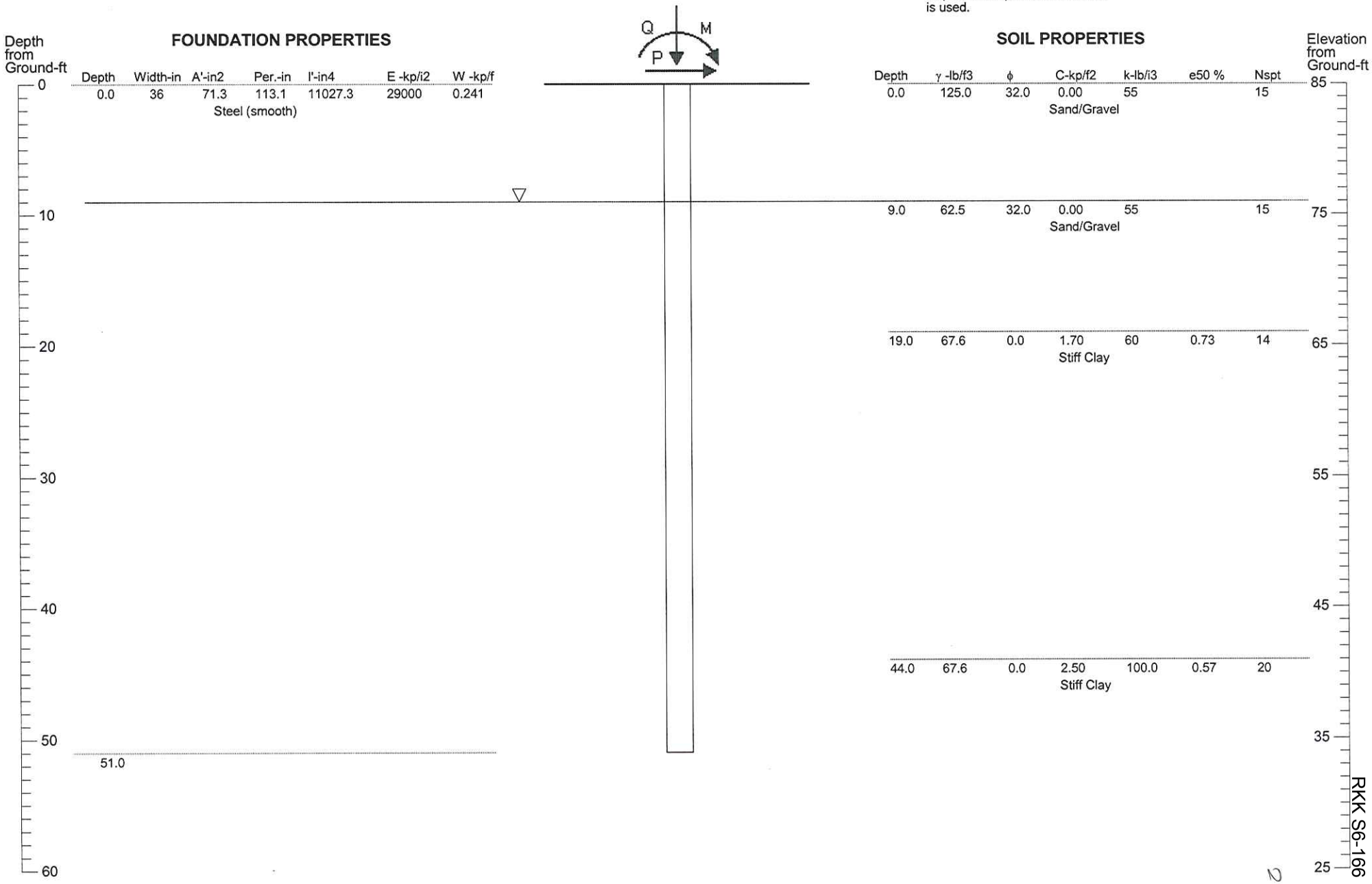
CivilTech Software

SR-1 Interchange Ramp B
Pier 1 Service Limit State (36-inch Pipe Pile) Group

Figure 2

FOUNDATION PROFILE & SOIL CONDITIONS

Non-displacement pile: H pile or open-ended pipe. Little soil is displaced. Friction is less than displacement pile. Effective area is used.



FOUNDATION PROPERTIES

Depth	Width-in	A'-in2	Per.-in	I'-in4	E -kp/i2	W -kp/f
0.0	36	71.3	113.1	11027.3	29000	0.241
Steel (smooth)						
51.0						

SOIL PROPERTIES

Depth	γ -lb/f3	ϕ	C-kp/f2	k-lb/i3	e50 %	Nspt	
0.0	125.0	32.0	0.00	55		15	Sand/Gravel
9.0	62.5	32.0	0.00	55		15	Sand/Gravel
19.0	67.6	0.0	1.70	60	0.73	14	Stiff Clay
44.0	67.6	0.0	2.50	100.0	0.57	20	Stiff Clay

Batter Angle=0 (Pile diameter not to scale) Surface Angle=0

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CivilTech Software

SR-1 Interchange Ramp B
Pier 2 Strength Limit State (36-inch Pipe Pile)

Figure 1

VERTICAL ANALYSIS

Figure 1

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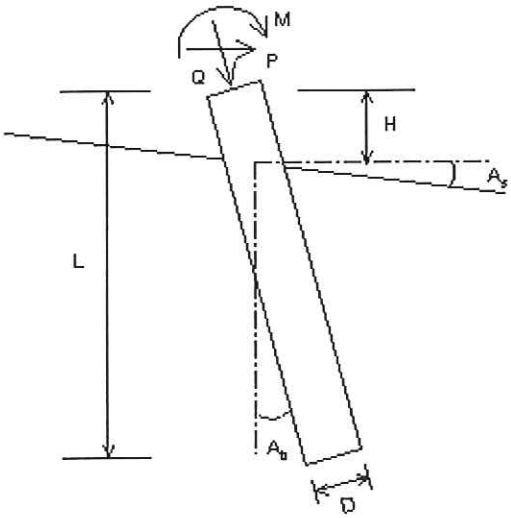


Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 629.0 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 51.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= 0

Fixed Head Condition

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	125.0	32.0	0.00	55	45.16	15
9	62.5	32.0	0.00	55	45.73	15
19	67.6	0.0	1.70	60	0.73	14
44	67.6	0.0	2.50	100.0	0.57	20
64	67.6	0.0	3.50	140.0	0.45	30
84	67.6	0.0	5.00	200	0.38	40

Pile Data:

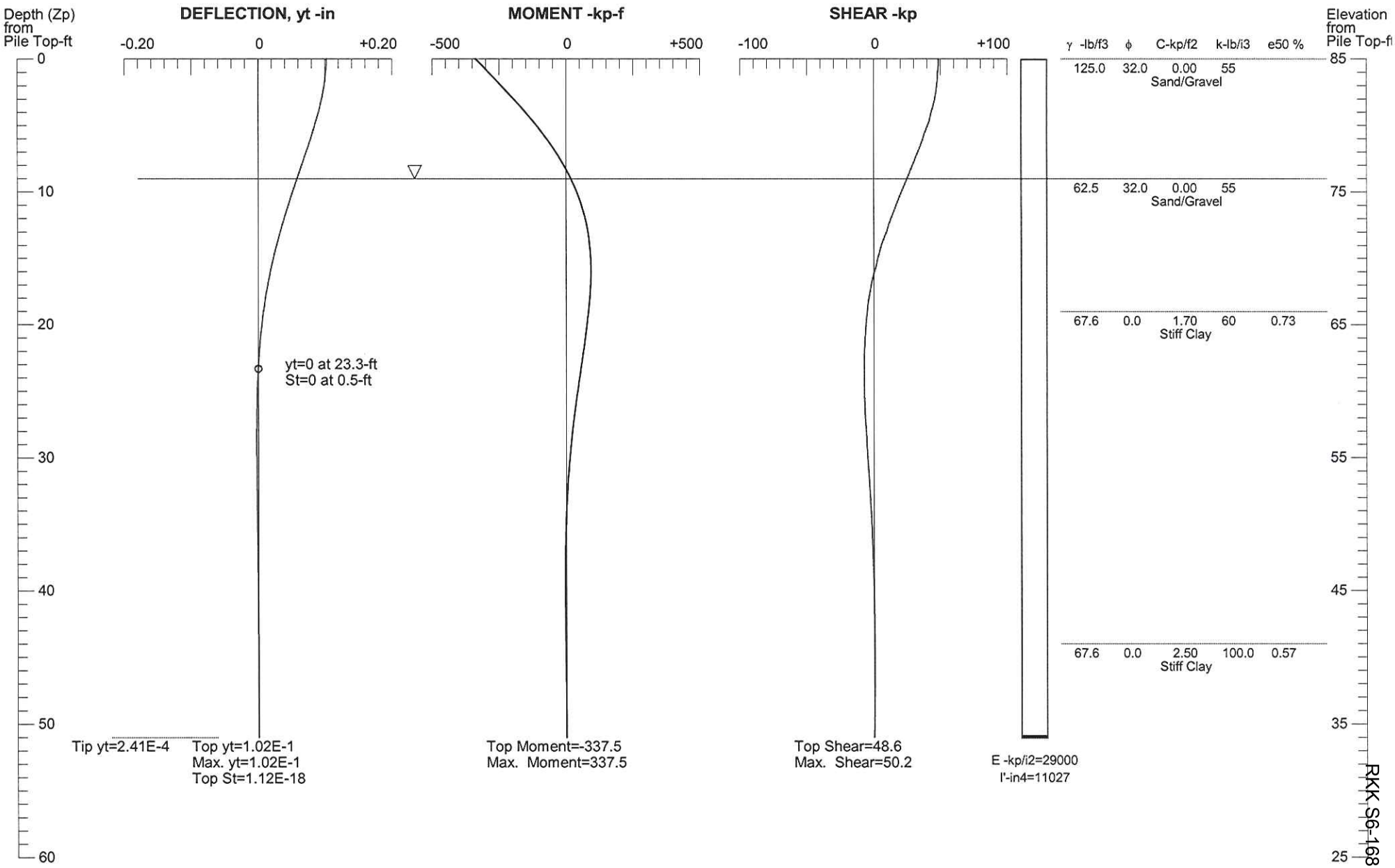
Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	36	71.3	113.1	11027.3	29000	0.241
51.0						

Vertical capacity:
Weight above Ground= 0.00 Total Weight= 12.29-kp *Soil Weight is not included
Side Resistance (Down)= 632.015-kp Side Resistance (Up)= 598.489-kp
Tip Resistance (Down)= 0.000-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 632.015-kp Total Ultimate Capacity (Up)= 610.780-kp
Total Allowable Capacity (Down)= 632.015-kp Total Allowable Capacity (Up)= 610.780-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 629.00-kp Settlement= 0.12490-in
At Xallow= 1.00-in Qallow= 99999.00000-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH
X-Front, Single Pile, Kbc=2



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CivilTech Software

SR-1 Interchange Ramp B
Pier 2 Service Limit State (36-inch Pipe Pile) Group

Figure 2

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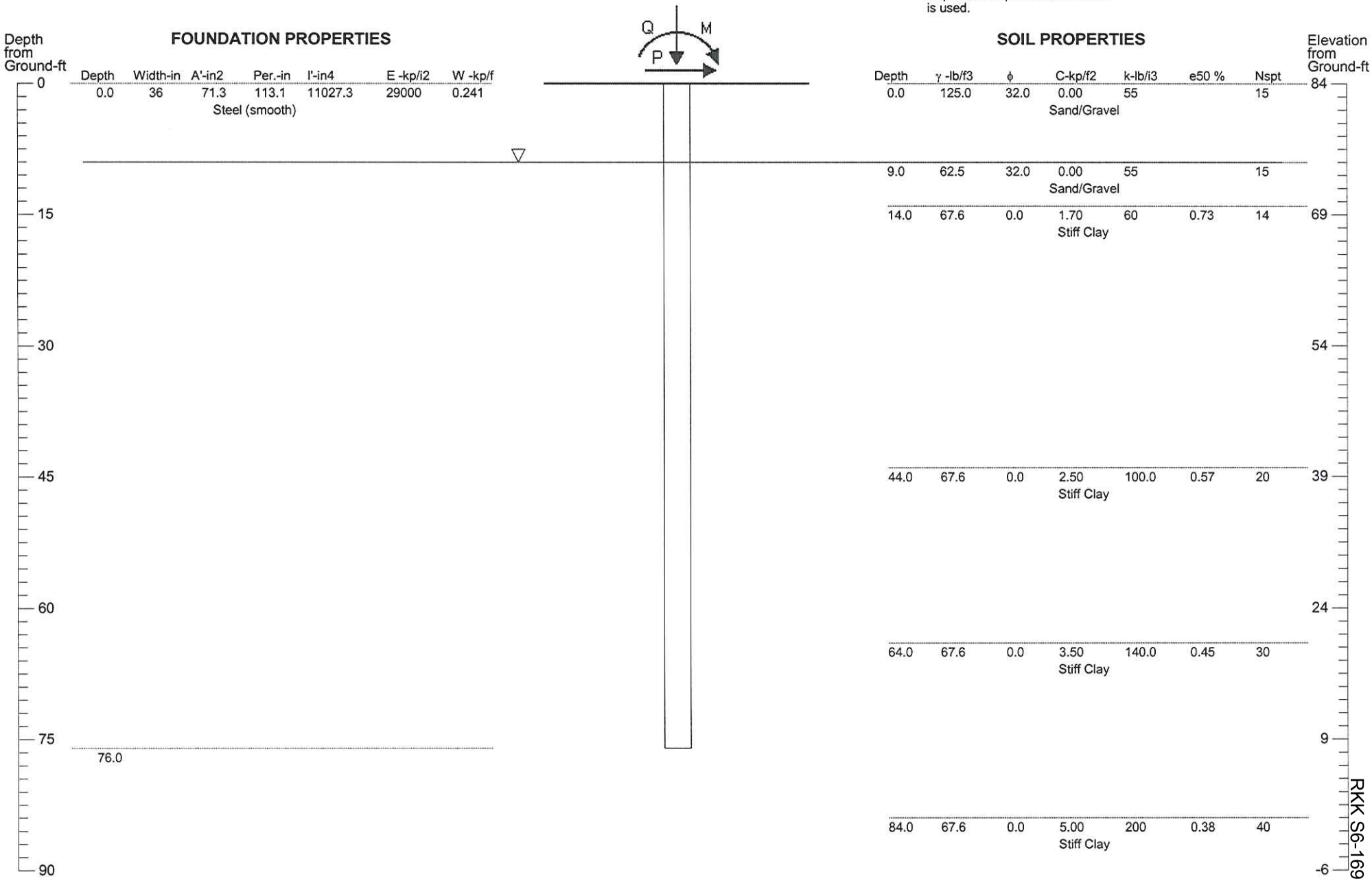
FOUNDATION PROFILE & SOIL CONDITIONS

Non-displacement pile: H pile or open-ended pipe. Little soil is displaced. Friction is less than displacement pile. Effective area is used.



FOUNDATION PROPERTIES

Depth	Width-in	A'-in2	Per.-in	I'-in4	E -kp/i2	W -kp/f
0.0	36	71.3	113.1	11027.3	29000	0.241

Steel (smooth)

SOIL PROPERTIES

Depth	γ -lb/f3	ϕ	C-kp/f2	k-lb/i3	e50 %	Nspt	
0.0	125.0	32.0	0.00	55		15	Sand/Gravel
9.0	62.5	32.0	0.00	55		15	Sand/Gravel
14.0	67.6	0.0	1.70	60	0.73	14	Stiff Clay
44.0	67.6	0.0	2.50	100.0	0.57	20	Stiff Clay
64.0	67.6	0.0	3.50	140.0	0.45	30	Stiff Clay
84.0	67.6	0.0	5.00	200	0.38	40	Stiff Clay

Batter Angle=0 (Pile diameter not to scale) Surface Angle=0

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CivilTech Software

SR-1 Interchange Ramp B
Pier 3 Strength Limit State (36-inch Pipe Pile)

Figure 1

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VERTICAL ANALYSIS

Figure 1

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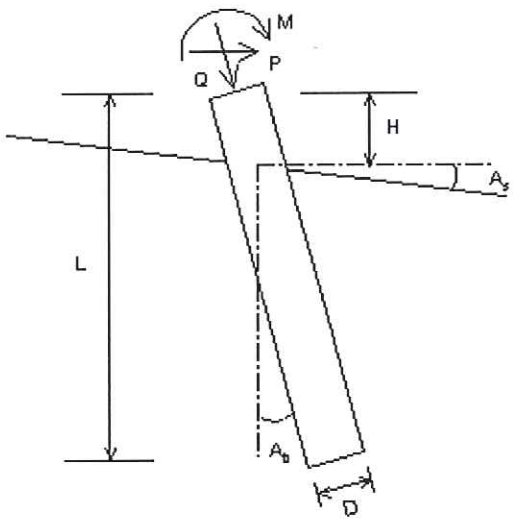


Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 1377.0 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 76.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= 0

Fixed Head Condition

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	125.0	32.0	0.00	55	45.16	15
9	62.5	32.0	0.00	55	45.73	15
14	67.6	0.0	1.70	60	0.73	14
44	67.6	0.0	2.50	100.0	0.57	20
64	67.6	0.0	3.50	140.0	0.45	30
84	67.6	0.0	5.00	200	0.38	40

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	36	71.3	113.1	11027.3	29000	0.241
76.0						

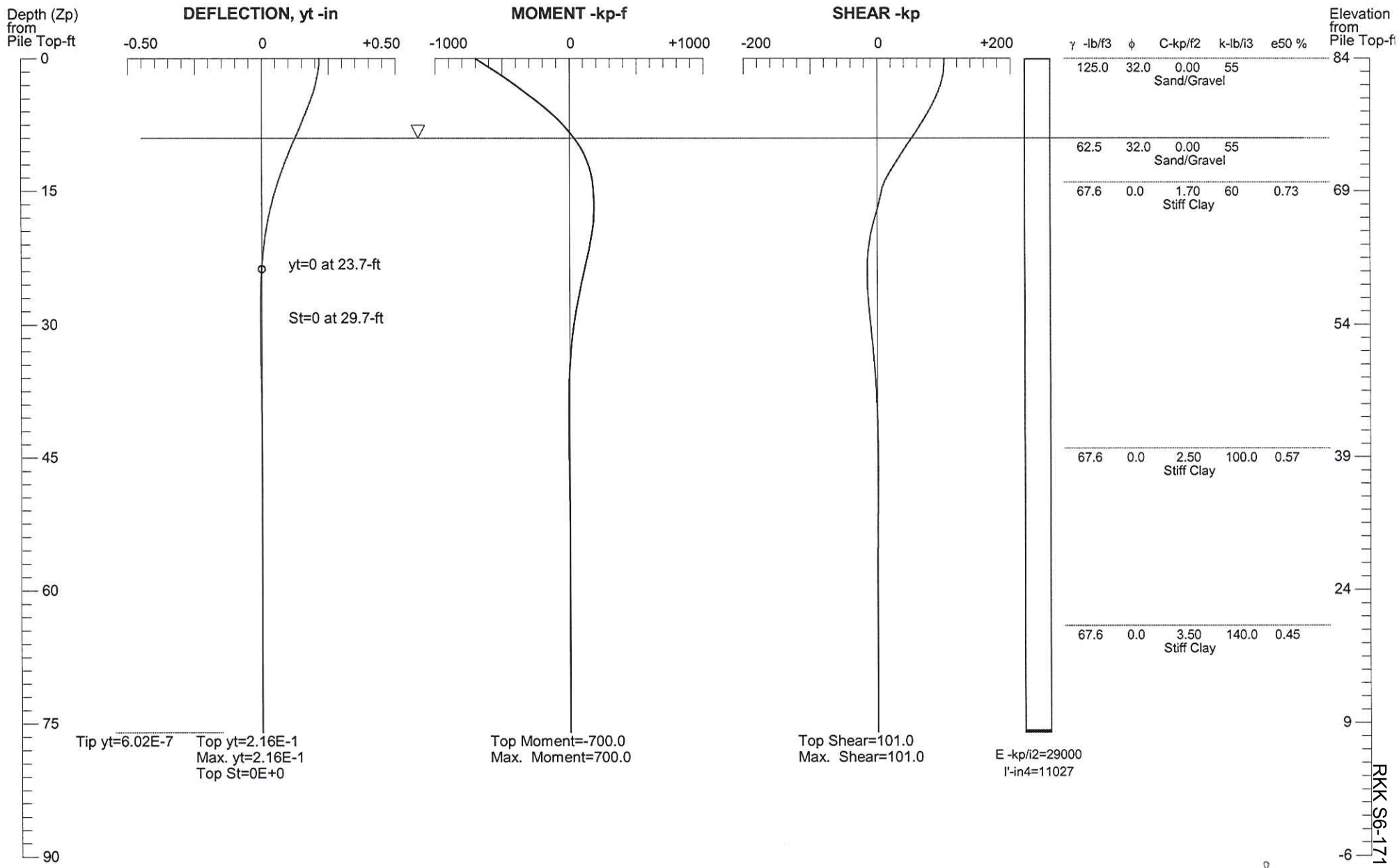
Vertical capacity:
Weight above Ground= 0.00 Total Weight= 18.32-kp *Soil Weight is not included
Side Resistance (Down)= 1385.958-kp Side Resistance (Up)= 1366.146-kp
Tip Resistance (Down)= 0.000-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 1385.958-kp Total Ultimate Capacity (Up)= 1384.462-kp
Total Allowable Capacity (Down)= 1385.958-kp Total Allowable Capacity (Up)= 1384.462-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 1377.00-kp Settlement= 0.39353-in
At Xallow= 1.00-in Qallow= 852.84320-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH

X-Front, Single Pile, Kbc=2



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CivilTech Software

SR-1 Interchange Ramp B
Pier 3 Service Limit State (36-inch Pipe Pile) Group

Figure 2

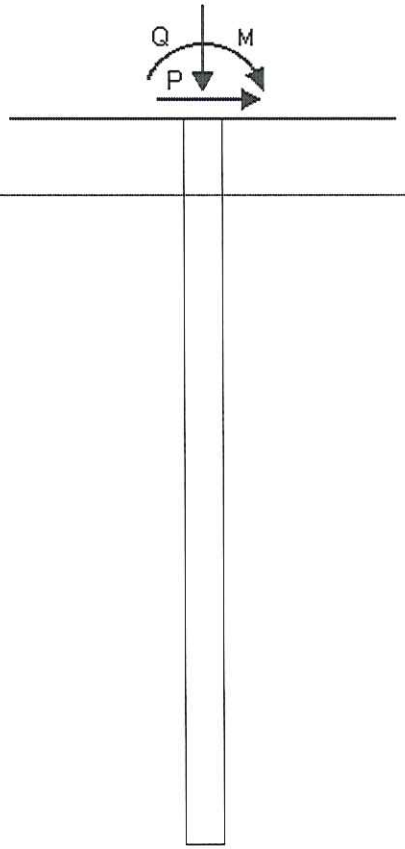
FOUNDATION PROFILE & SOIL CONDITIONS

Non-displacement pile: H pile or open-ended pipe. Little soil is displaced. Friction is less than displacement pile. Effective area is used.

Depth from Ground-ft

FOUNDATION PROPERTIES

Depth	Width-in	A'-in2	Per.-in	I'-in4	E -kp/i2	W -kp/f
0.0	24	36.2	75.4	2501.5	29000	0.122
		Steel (smooth)				
38.0						



SOIL PROPERTIES

Depth	γ -lb/f3	ϕ	C-kp/f2	k-lb/i3	e50 %	Nspt
0.0	125.0	32.0	0.00	55		15
			Sand/Gravel			
4.0	62.5	32.0	0.00	55		15
			Sand/Gravel			
9.0	67.6	0.0	1.70	60	0.73	14
			Stiff Clay			
39.0	67.6	0.0	2.50	100.0	0.57	20
			Stiff Clay			
59.0	67.6	0.0	3.50	140.0	0.45	30
			Stiff Clay			

Elevation from Ground-ft

Batter Angle=0 (Pile diameter not to scale) Surface Angle=0

CivilTech Software

SR-1 Interchange Ramp B
Abutment B Strength Limit State (24-inch Pipe Pile)

Figure 1

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VERTICAL ANALYSIS

Figure 1

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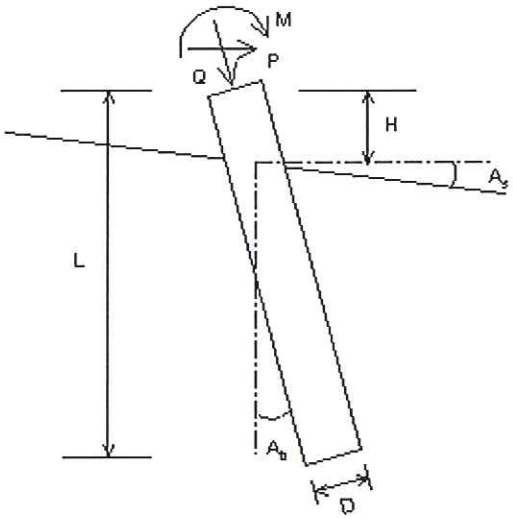


Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 317.0 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 38.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= 0

Fixed Head Condition

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	125.0	32.0	0.00	55	45.16	15
4	62.5	32.0	0.00	55	45.73	15
9	67.6	0.0	1.70	60	0.73	14
39	67.6	0.0	2.50	100.0	0.57	20
59	67.6	0.0	3.50	140.0	0.45	30
79	67.6	0.0	5.00	200	0.38	40

Pile Data:

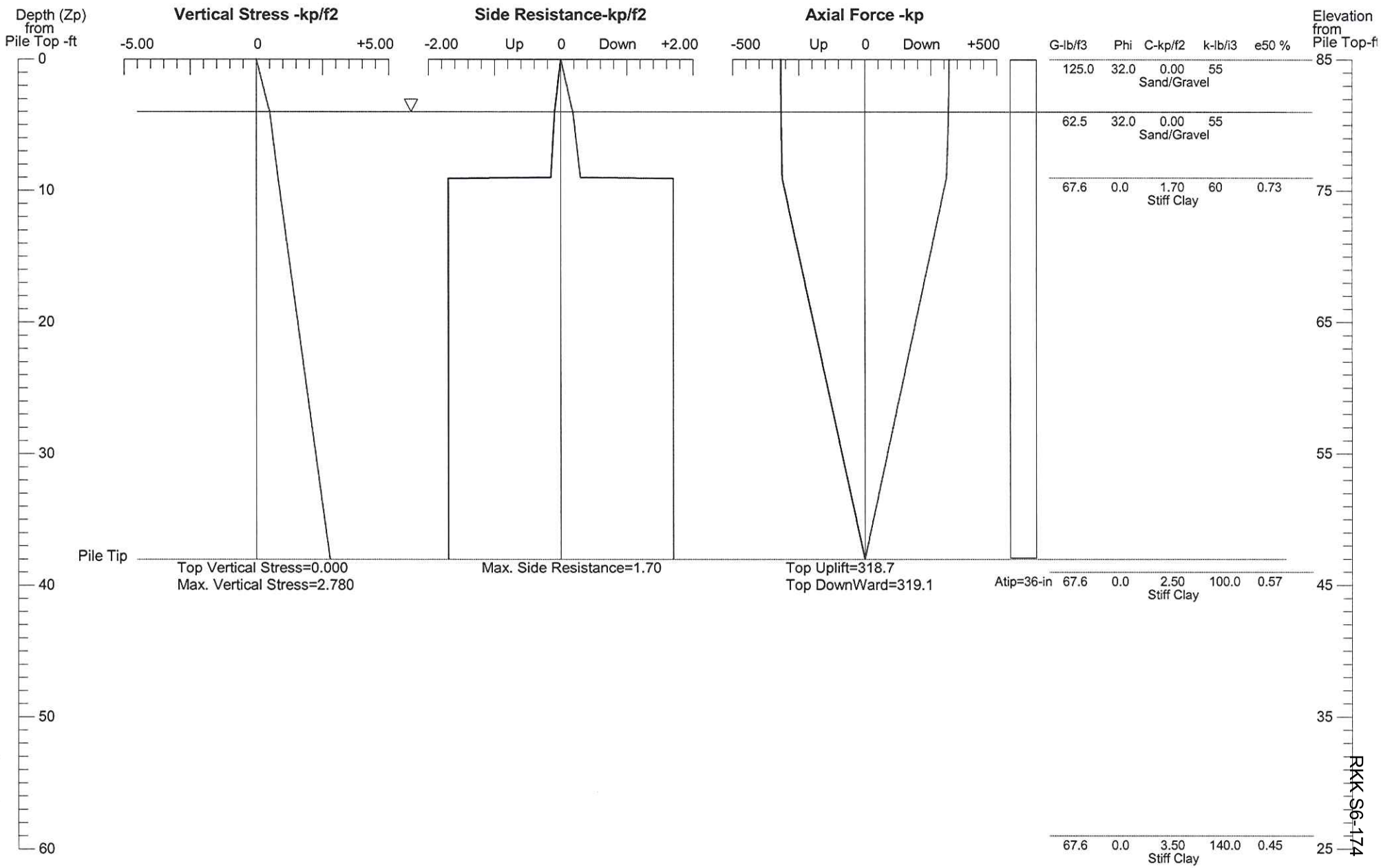
Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	24	36.2	75.4	2501.5	29000	0.122
38.0						

Vertical capacity:
Weight above Ground= 0.00 Total Weight= 4.64-kp *Soil Weight is not included
Side Resistance (Down)= 319.065-kp Side Resistance (Up)= 314.084-kp
Tip Resistance (Down)= 0.000-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 319.065-kp Total Ultimate Capacity (Up)= 318.721-kp
Total Allowable Capacity (Down)= 319.065-kp Total Allowable Capacity (Up)= 318.721-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 317.00-kp Settlement= 0.08338-in
At Xallow= 1.00-in Qallow= 99999.00000-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

SOIL STRESS, SIDE RESISTANCE, & AXIAL FORCE vs DEPTH
Based on Ultimate Load Condition



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CivilTech Software

SR-1 Interchange Ramp B
Abutment B Strength Limit State (24-inch Pipe Pile)

Figure 1

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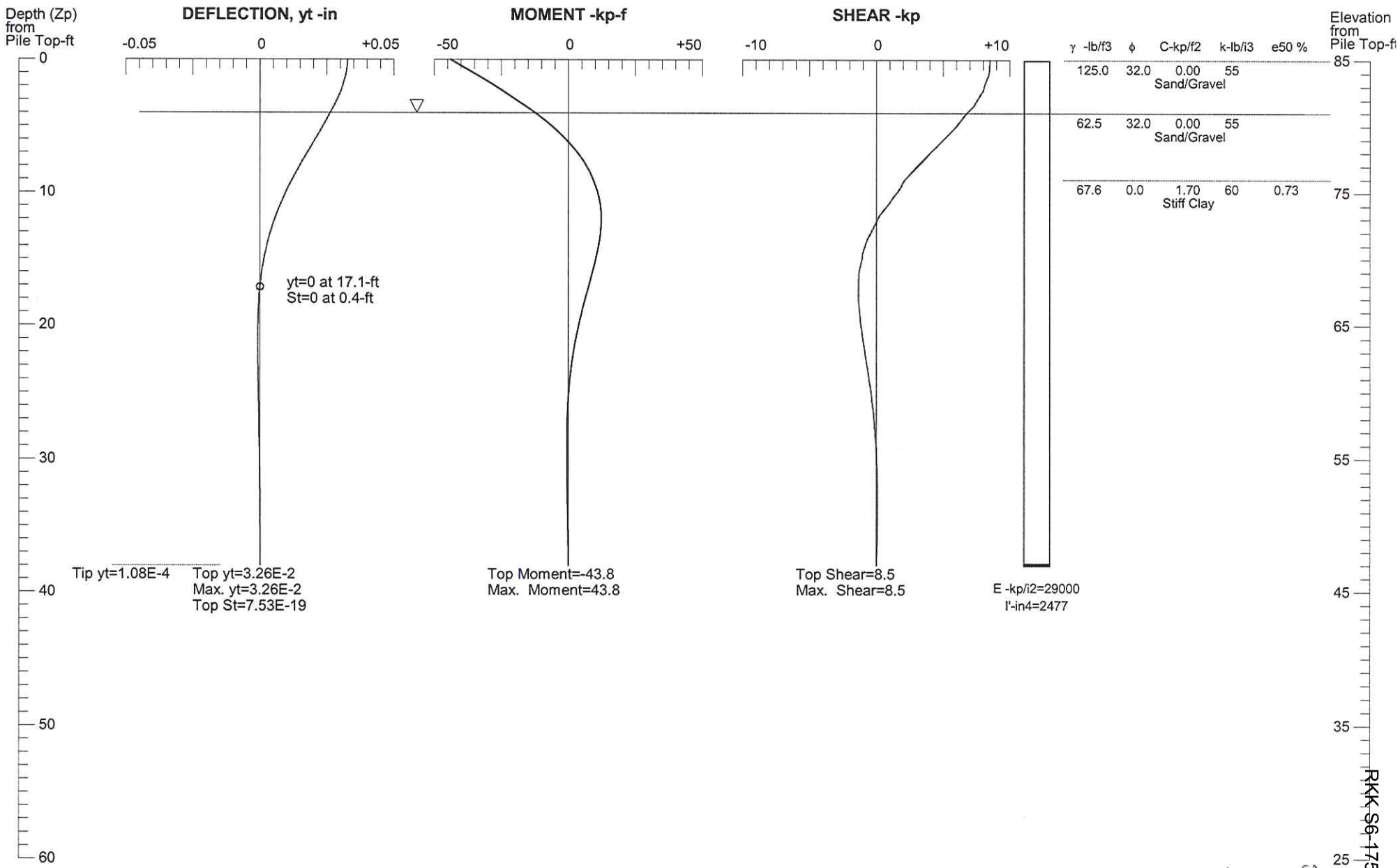
1/14/09

PILE DEFLECTION & FORCE vs DEPTH
X-Front, Single Pile, Kbc=2



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CivilTech Software

SR-1 Interchange Ramp B
Abutment B Service Limit State (24-inch Pipe Pile) Group

Figure 2

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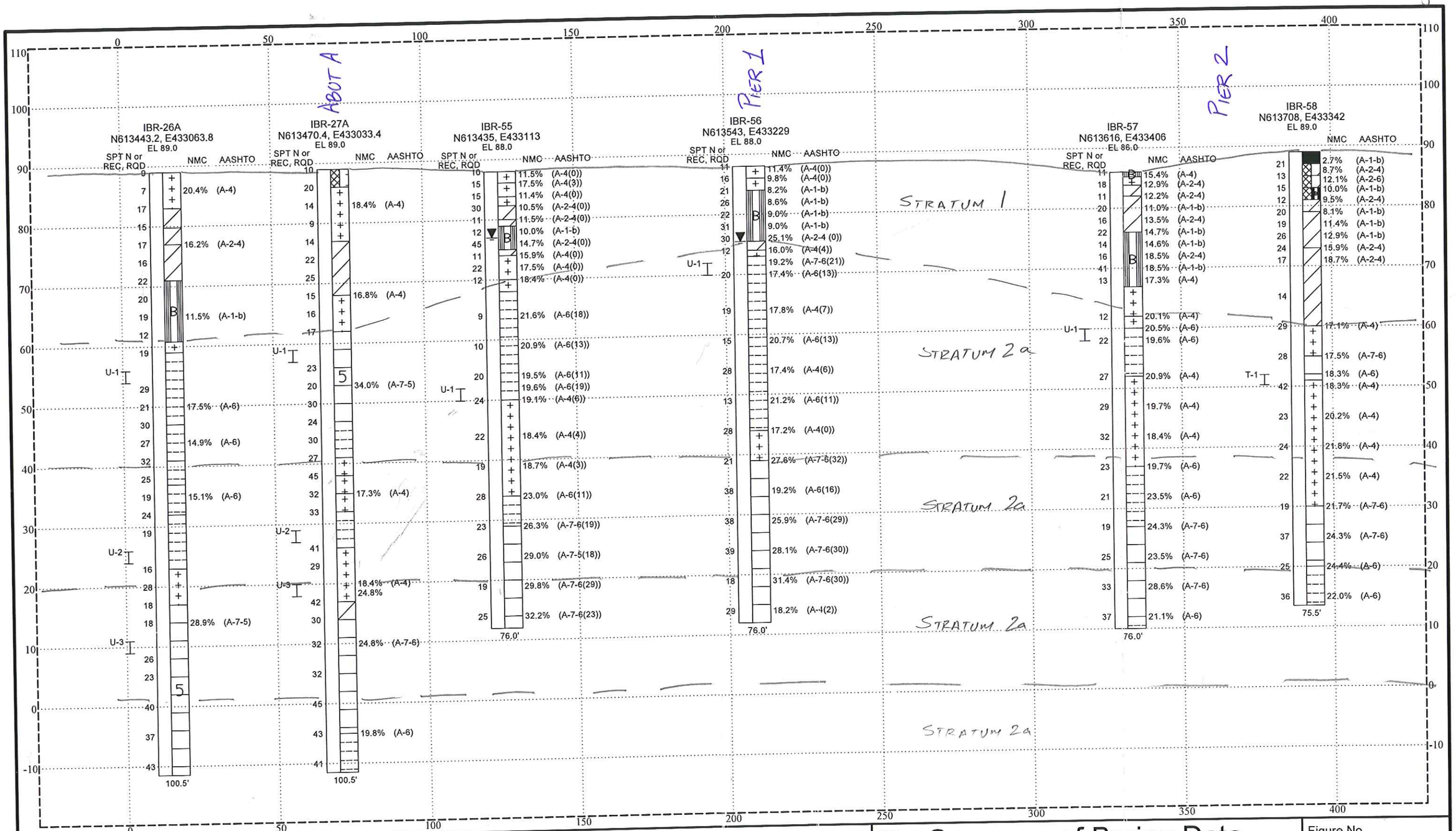
1/14/09



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

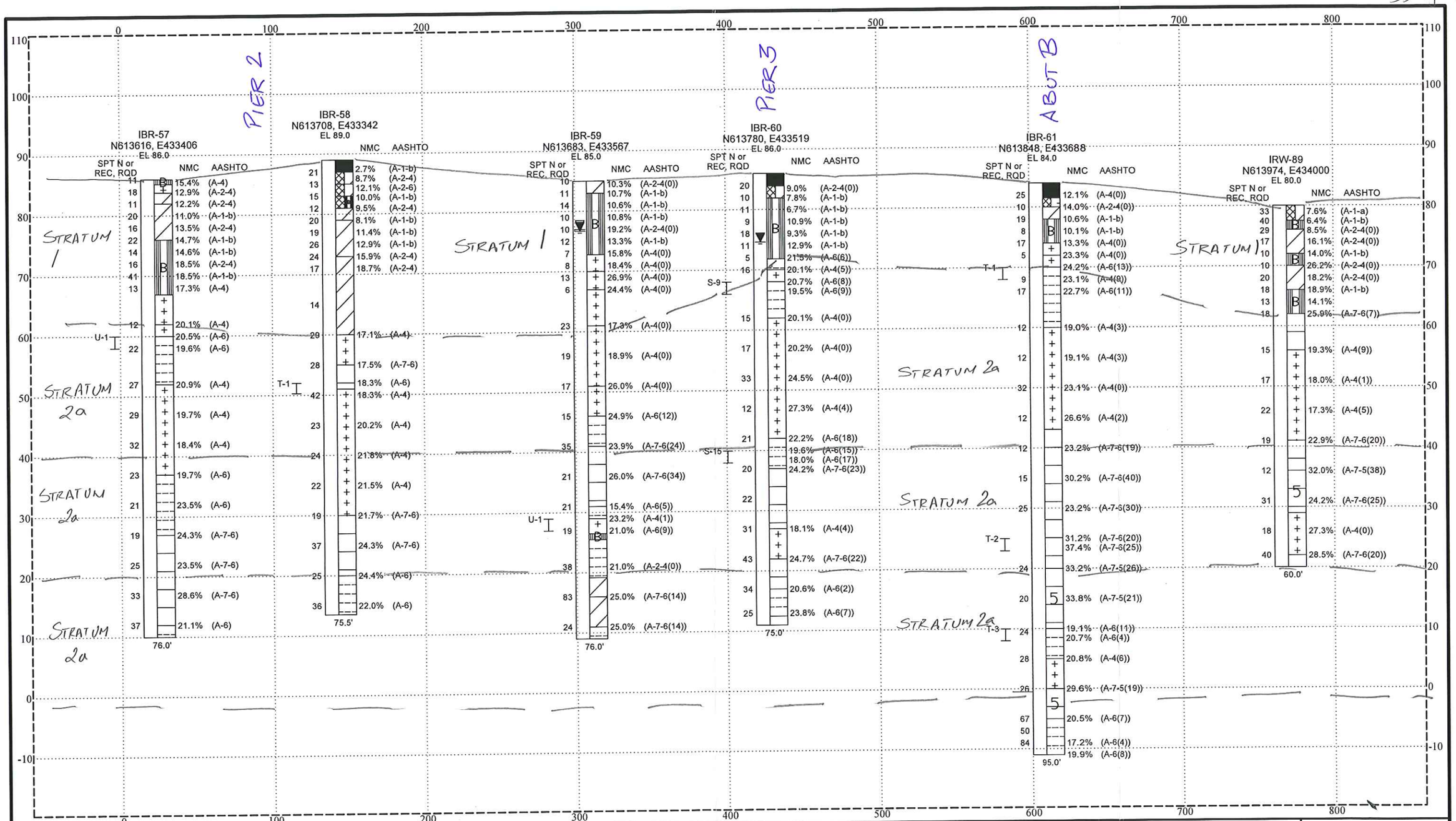
Rummel, Klepper & Kahl, LLP
Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data
Ramp B Bridge

Figure No. A-1a

Drawn: BBS | Approved: EMK | Date: 12/4/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 12/4/08



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

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Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data

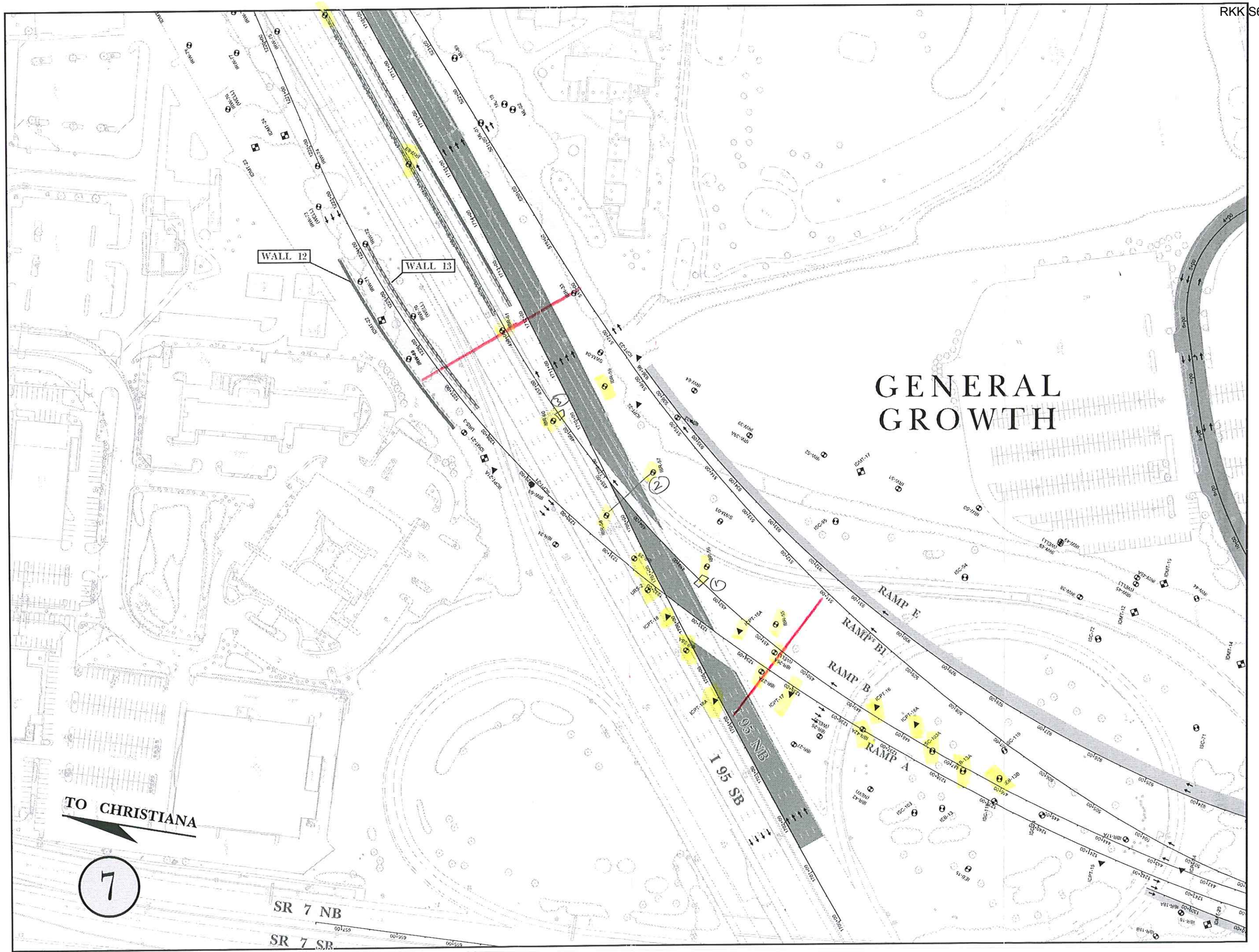
Ramp B Bridge

Figure No. A-1b

Drawn: BBS | Approved: EMK | Date: 12/4/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 12/4/08

0.65" / 100' 1" / 153'


WALL 12
WALL 13
GENERAL GROWTH
RAMP E
RAMP B1
RAMP B
RAMP A
I 95 NB
I 95 SB
TO CHRISTIANA
7
SR 7 NB
SR 7 SB

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Subject SR-1 INTERCHANGE RAMP B
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Cm. No. 103-059-27U
Prepared By BBG Date 1-5-09 Checked By CM Date 2/2/09

SUMMARY OF FOUNDATION LOAD FINAL ITTERATION

SEE SPREADSHEET FOR LOADS IN ABUTMENTS & PIERS.

FOUNDATION LOADS PROVIDED BY MIKE MILLER (STRUCT RK&K)
(12-24-08)

SUMMARY OF INDIVIDUAL PILE
SEE ATTACHED SHEETS.

Ramp B (Summary of Foundation Loads per Foundation Element)

Structure	Service Limit State Reactions							
	Vertical F_y (Kips)	Lateral F_x (Kips)	Lateral F_z (Kips)	Resultant Lateral (Kips)	M_x (kip-ft)	Torsion M_y (kip-ft)	M_z (kip-ft)	Maximum Moment (kip-ft)
Abutment 1	718	29	31	42.4				0
Pier 1	2799	525	50	527.4	2050	190	11000	11000
Pier 2	1285	25	390	390.8	4200	100	400	4200
Pier 3	2405	710	60	712.5	2452	400	12000	12000
Abutment 2	590	62	23	66.1				0

Structure	Strength Limit State Reactions							
	Vertical F_y (Kips)	Lateral F_x (Kips)	Lateral F_z (Kips)	Resultant Lateral (Kips)	M_x (kip-ft)	Torsion M_y (kip-ft)	M_z (kip-ft)	Maximum Moment (kip-ft)
Abutment 1	1051	36	25	43.8				0
Pier 1	3771	500	50	502.5	3755	270	11500	11500
Pier 2	1865	25	515	515.6	5580	100	200	5580
Pier 3	3470	665	50	666.9	3630	150	11000	11000
Abutment 2	885	29	49	56.9				0

Calculation of Individual Pile Loads (36-inch Pipe Pile)

Structure	Service Limit State		Strength Limit State	
	Axial Load (kips)	Lateral Load (kips)	Axial Load (kips)	Lateral Load (kips)
Abutment 1	90	5	131	5
Pier 1	409	46	516	44
Pier 2	159	33	220	44
Pier 3	394	63	482	57
Abutment 2	74	8	111	7

ABUTMENT PILES ARE 24-in OD PIPE PILES;
SINCE THERE ARE NO MOMENTS IN THE ABUTMENT FOUNDATIONS
THE INDIVIDUAL LOADS ARE INDEPENDENT OF PILE SIZE & SPACING.

Calculation of Individual Pile Loads (Abutment 4)

Pier Loads on Pile Cap							
	Vertical (F_y) (Kips)	Lateral (F_x) (Kips)	Lateral (F_z) (Kips)	Resultant Lateral (F_l) (Kips)	Moment (M_x) (Kip-ft)	Moment (M_z) (Kip-ft)	Torsion (M_y) (Kip-ft)
Service Limit State	718	29	31	42	0	0	0
Strength Limit State	1051	36	25	44	0	0	0

Pile Size	36	inches	(Pipe Piles)		
No. of Piles in X direction	2			No. of Piles in Z direction	4
Pile Spacing in X direction	9	ft		Pile Spacing in Z direction	9 ft
Total No. of Piles	8				

Calculation of Total Axial Load in a Single Pile (Maximum)

Section Modulus in X-direction

M_x = 0

X Direction	No of Piles (A)	Distance from CG to Pile (normal) (d)	Ad^2
1	4	4.5	81
2	4	4.5	81
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
		$\sum Ad^2$=	162
		Maximum Distance =	4.5
		S_x =	36

Section Modulus in Z-direction

M_z = 0

Z Direction	No of Piles (A)	Distance from CG to Pile (normal) (d)	Ad^2
1	2	13.5	364.5
2	2	4.5	40.5
3	2	13.5	364.5
4	2	4.5	40.5
5	0	0	0
6	0	0	0
		$\sum Ad^2$=	810
		Maximum Distance =	13.5
		S_z=	60.0

Maximum Compression Load on a Single Pile

$$V = \frac{F_y}{n} + \frac{M_x}{S_x} + \frac{M_z}{S_z}$$

Compression		
	(Service) V=	90 Kips
	(Strength) V=	131 Kips

Maximum Tension Load on a Single Pile

$$T = \frac{F_y}{n} - \frac{M_x}{S_x} - \frac{M_z}{S_z}$$

Tension		
	(Service) T=	0 Kips
	(Strenght) T=	0 Kips

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Calculation of Total Lateral Load in a Single Pile (Maximum)

(Torsion) M_y = 0 Service
0 Strength

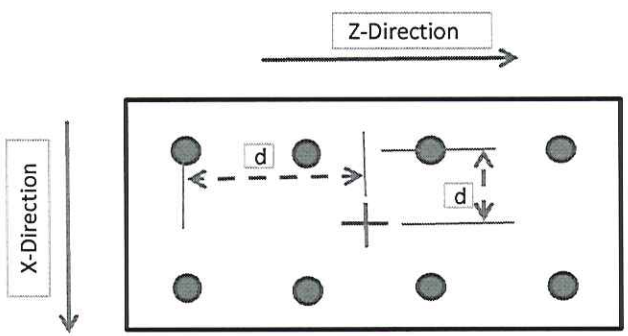
(Lateral Force Calculated in Service State for Deflection Calculation)

Pile Number	Distance from CG to Pile (shortest) d (ft)	d^2	Resultant Service Lateral Force (R_m) (kips)	Resultant Strength Lateral Force (R_m) (kips)	
1	13.086	171.2	0.0	0.0	
2	13.086	171.2	0.0	0.0	
3	6.364	40.5	0.0	0.0	
4	6.364	40.5	0.0	0.0	
5	6.364	40.5	0.0	0.0	
6	6.364	40.5	0.0	0.0	
7	13.086	171.2	0.0	0.0	
8	13.086	171.2	0.0	0.0	
9	0	0.0	0.0	0.0	
10	0	0.0	0.0	0.0	
11	0	0.0	0.0	0.0	
12	0	0.0	0.0	0.0	
	$\sum d^2$ =	847.0	**0.0**	**0.0**	(Maximum)

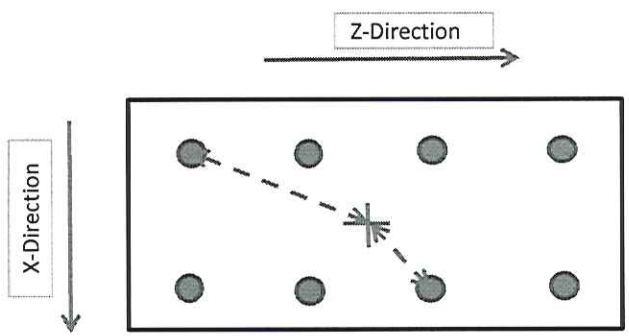
Maximum Lateral Force on a Single Pile

$$F_L = \frac{F_l}{n} + R_m$$

(Service) F_L =	**5 kips**
(Strength) F_L =	**5 kips**



Vertical Load Calculation



Horizontal Load Calculation

Calculation of Individual Pile Loads (Pier 1)

Pier Loads on Pile Cap							
	Vertical (F_y) (Kips)	Lateral (F_x) (Kips)	Lateral (F_z) (Kips)	Resultant Lateral (F_l) (Kips)	Moment (M_x) (Kip-ft)	Moment (M_z) (Kip-ft)	Torsion (M_y) (Kip-ft)
Service Limit State	2799	525	50	527	2050	11000	190
Strength Limit State	3771	500	50	502	3755	11500	270

Pile Size	36	inches	(Pipe Piles)		
No. of Piles in X direction	4			No. of Piles in Z direction	3
Pile Spacing in X direction	9	ft		Pile Spacing in Z direction	9 ft
Total No. of Piles	12				

Calculation of Total Axial Load in a Single Pile (Maximum)

Section Modulus in X-direction

M_x = 3755 kip-ft

X Direction	No of Piles (A)	Distance from CG to Pile (normal) (d)	Ad^2
1	3	13.5	546.75
2	3	4.5	60.75
3	3	4.5	60.75
4	3	13.5	546.75
5	0	0	0
6	0	0	0
		$\sum Ad^2$=	1215
		Maximum Distance =	13.5
		S_x =	90

Section Modulus in Z-direction

M_z = 11500 kip-ft

Z Direction	No of Piles (A)	Distance from CG to Pile (normal) (d)	Ad^2
1	4	9	324
2	4	0	0
3	4	9	324
4	0	0	0
5	0	0	0
6	0	0	0
		$\sum Ad^2$=	648
		Maximum Distance =	9
		S_z=	72

Maximum Compression Load on a Single Pile

$$V = \frac{F_y}{n} + \frac{M_x}{S_x} + \frac{M_z}{S_z}$$

Compression		
	(Service) V=	409 Kips
	(Strength) V=	516 Kips

Maximum Tension Load on a Single Pile

$$T = \frac{F_y}{n} - \frac{M_x}{S_x} - \frac{M_z}{S_z}$$

Tension		
	(Service) T=	0 Kips
	(Strength) T=	0 Kips

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Calculation of Total Lateral Load in a Single Pile (Maximum)

(Torsion) M_y = 190 Service
270 Strength

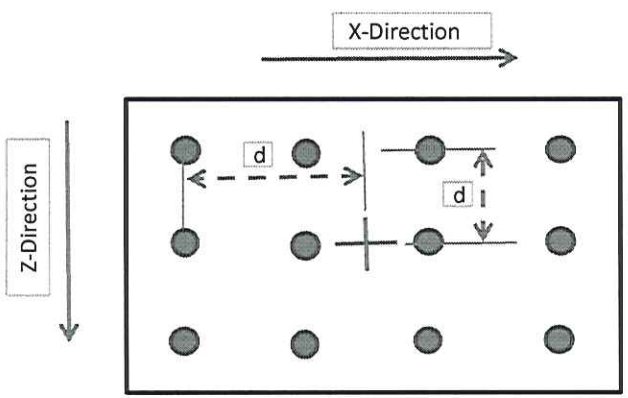
(Lateral Force Calculated in Service State for Deflection Calculation)

Pile Number	Distance from CG to Pile (shortest) d (ft)	d^2	Resultant Service Lateral Force (R_m) (kips)	Resultant Strength Lateral Force (R_m) (kips)	
1	16.22	263.1	1.7	2.4	
2	13.5	182.3	1.4	2.0	
3	16.22	263.1	1.7	2.4	
4	10.06	101.2	1.0	1.5	
5	4.5	20.3	0.5	0.7	
6	10.06	101.2	1.0	1.5	
7	10.06	101.2	1.0	1.5	
8	4.5	20.3	0.5	0.7	
9	10.06	101.2	1.0	1.5	
10	16.22	263.1	1.7	2.4	
11	13.5	182.3	1.4	2.0	
12	16.22	263.1	1.7	2.4	
	$\sum d^2$ =	1862.2	**1.7**	**2.4**	(Maximum)

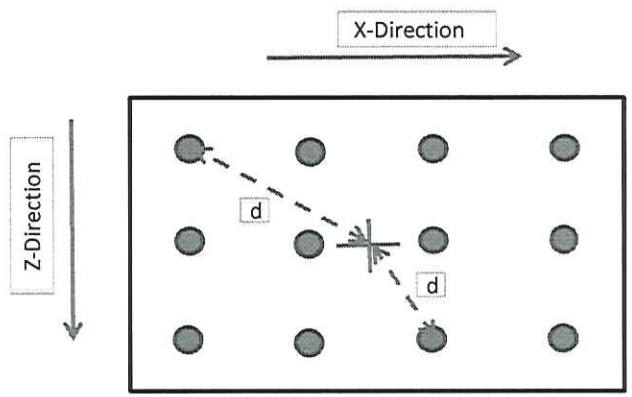
Maximum Lateral Force on a Single Pile

$$F_L = \frac{F_l}{n} + R_m$$

(Service) F_L =	**46 kips**
(Strength) F_L =	**44 kips**



Vertical Load Calculation



Horizontal Load Calculation

Calculation of Individual Pile Loads (Pier 2)

Pier Loads on Pile Cap							
	Vertical (F_y) (Kips)	Lateral (F_x) (Kips)	Lateral (F_z) (Kips)	Resultant Lateral (F_l) (Kips)	Moment (M_x) (Kip-ft)	Moment (M_z) (Kip-ft)	Torsion (M_y) (Kip-ft)
Service Limit State	1285	25	390	391	4200	400	100
Strength Limit State	1865	25	515	516	5580	200	100

Pile Size	36	inches	(Pipe Piles)		
No. of Piles in X direction	4			No. of Piles in Z direction	3
Pile Spacing in X direction	9	ft		Pile Spacing in Z direction	9 ft
Total No. of Piles	12				

Calculation of Total Axial Load in a Single Pile (Maximum)

Section Modulus in X-direction

M_x = 5580 kip-ft

X Direction	No of Piles (A)	Distance from CG to Pile (normal) (d)	Ad^2
1	3	13.5	546.75
2	3	4.5	60.75
3	3	4.5	60.75
4	3	13.5	546.75
5	0	0	0
6	0	0	0
		$\sum Ad^2$=	1215
		Maximum Distance =	13.5
		S_x =	90

Section Modulus in Z-direction

M_z = 200 kip-ft

Z Direction	No of Piles (A)	Distance from CG to Pile (normal) (d)	Ad^2
1	4	9	324
2	4	0	0
3	4	9	324
4	0	0	0
5	0	0	0
6	0	0	0
		$\sum Ad^2$=	648
		Maximum Distance =	9
		S_z=	72

Maximum Compression Load on a Single Pile

$$V = \frac{F_y}{n} + \frac{M_x}{S_x} + \frac{M_z}{S_z}$$

Compression		
	(Service) V=	159 Kips
	(Strength) V=	220 Kips

Maximum Tension Load on a Single Pile

$$T = \frac{F_y}{n} - \frac{M_x}{S_x} - \frac{M_z}{S_z}$$

Tension		
	(Service) T=	0 Kips
	(Strength) T=	0 Kips

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Calculation of Total Lateral Load in a Single Pile (Maximum)

(Torsion) M_y = 100 Service
100 Strength

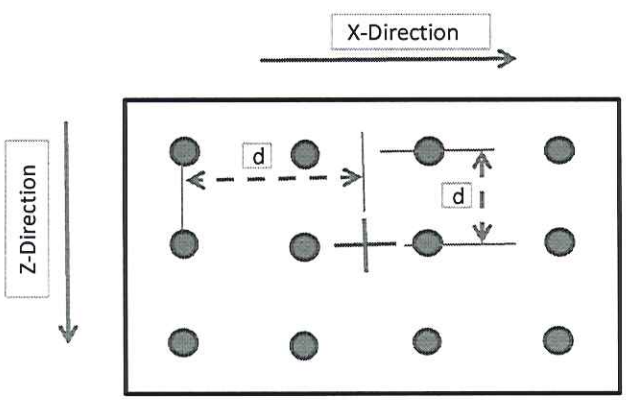
(Lateral Force Calculated in Service State for Deflection Calculation)

Pile Number	Distance from CG to Pile (shortest) d (ft)	d^2	Resultant Service Lateral Force (R_m) (kips)	Resultant Strength Lateral Force (R_m) (kips)	
1	16.22	263.1	0.9	0.9	
2	13.5	182.3	0.7	0.7	
3	16.22	263.1	0.9	0.9	
4	10.06	101.2	0.5	0.5	
5	4.5	20.3	0.2	0.2	
6	10.06	101.2	0.5	0.5	
7	10.06	101.2	0.5	0.5	
8	4.5	20.3	0.2	0.2	
9	10.06	101.2	0.5	0.5	
10	16.22	263.1	0.9	0.9	
11	13.5	182.3	0.7	0.7	
12	16.22	263.1	0.9	0.9	
	$\sum d^2$ =	1862.2	**0.9**	**0.9**	(Maximum)

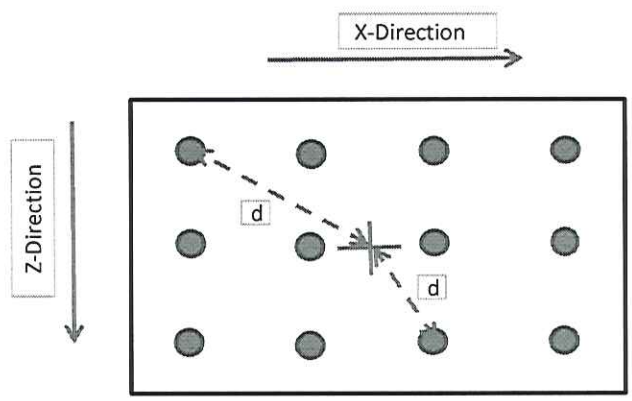
Maximum Lateral Force on a Single Pile

$$F_L = \frac{F_l}{n} + R_m$$

(Service) F_L =	**33 kips**
(Strength) F_L =	**44 kips**



Vertical Load Calculation



Horizontal Load Calculation

Calculation of Individual Pile Loads (Pier 3)

Pier Loads on Pile Cap							
	Vertical (F_y) (Kips)	Lateral (F_x) (Kips)	Lateral (F_z) (Kips)	Resultant Lateral (F_l) (Kips)	Moment (M_x) (Kip-ft)	Moment (M_z) (Kip-ft)	Torsion (M_y) (Kip-ft)
Service Limit State	2405	710	60	713	2452	12000	400
Strength Limit State	3470	665	50	667	3630	11000	150

Pile Size	36 inches	(Pipe Piles)	
No. of Piles in X direction	4	No. of Piles in Z direction	3
Pile Spacing in X direction	9 ft	Pile Spacing in Z direction	9 ft
Total No. of Piles	12		

Calculation of Total Axial Load in a Single Pile (Maximum)

Section Modulus in X-direction

M_x = 3630 kip-ft

X Direction	No of Piles (A)	Distance from CG to Pile (normal) (d)	Ad^2
1	3	13.5	546.75
2	3	4.5	60.75
3	3	4.5	60.75
4	3	13.5	546.75
5	0	0	0
6	0	0	0
		$\sum Ad^2$=	1215
		Maximum Distance =	13.5
		S_x =	90

Section Modulus in Z-direction

M_z = 11000 kip-ft

Z Direction	No of Piles (A)	Distance from CG to Pile (normal) (d)	Ad^2
1	4	9	324
2	4	0	0
3	4	9	324
4	0	0	0
5	0	0	0
6	0	0	0
		$\sum Ad^2$=	648
		Maximum Distance =	9
		S_z=	72

Maximum Compression Load on a Single Pile

$$V = \frac{F_y}{n} + \frac{M_x}{S_x} + \frac{M_z}{S_z}$$

Compression		
	(Service) V=	394 Kips
	(Strength) V=	482 Kips

Maximum Tension Load on a Single Pile

$$T = \frac{F_y}{n} - \frac{M_x}{S_x} - \frac{M_z}{S_z}$$

Tension		
	(Service) T=	0 Kips
	(Strength) T=	0 Kips

Calculation of Total Lateral Load in a Single Pile (Maximum)

(Torsion) M_y = 400 Service
150 Strength

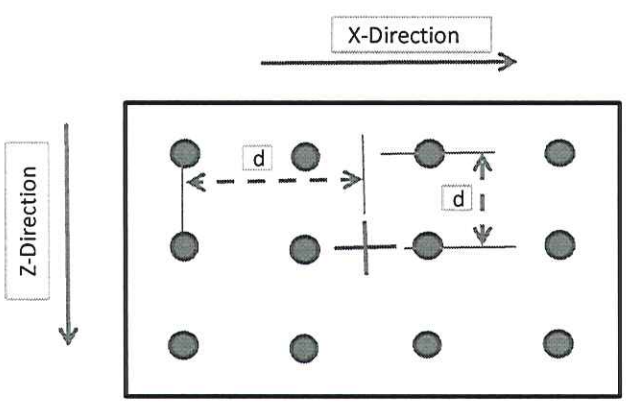
(Lateral Force Calculated in Service State for Deflection Calculation)

Pile Number	Distance from CG to Pile (shortest) d (ft)	d^2	Resultant Service Lateral Force (R_m) (kips)	Resultant Strength Lateral Force (R_m) (kips)	
1	16.22	263.1	3.5	1.3	
2	13.5	182.3	2.9	1.1	
3	16.22	263.1	3.5	1.3	
4	10.06	101.2	2.2	0.8	
5	4.5	20.3	1.0	0.4	
6	10.06	101.2	2.2	0.8	
7	10.06	101.2	2.2	0.8	
8	4.5	20.3	1.0	0.4	
9	10.06	101.2	2.2	0.8	
10	16.22	263.1	3.5	1.3	
11	13.5	182.3	2.9	1.1	
12	16.22	263.1	3.5	1.3	
	$\sum d^2$ =	1862.2	**3.5**	**1.3**	(Maximum)

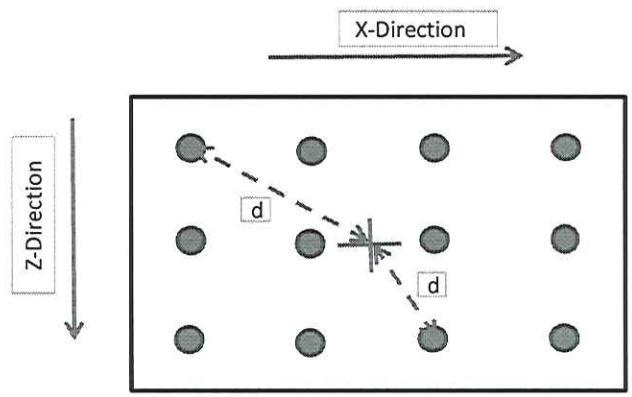
Maximum Lateral Force on a Single Pile

$$F_L = \frac{F_l}{n} + R_m$$

(Service) F_L =	**63 kips**
(Strength) F_L =	**57 kips**



Vertical Load Calculation



Horizontal Load Calculation

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Calculation of Individual Pile Loads (Abutment B)

Pier Loads on Pile Cap							
	Vertical (F_y) (Kips)	Lateral (F_x) (Kips)	Lateral (F_z) (Kips)	Resultant Lateral (F_l) (Kips)	Moment (M_x) (Kip-ft)	Moment (M_z) (Kip-ft)	Torsion (M_y) (Kip-ft)
Service Limit State	590	23	62	66	0	0	0
Strength Limit State	885	29	49	57	0	0	0

Pile Size	36	inches
No. of Piles in X direction	2	
Pile Spacing in X direction	9	ft
Total No. of Piles	8	

(Pipe Piles)

No. of Piles in Z direction	4	
Pile Spacing in Z direction	9	ft

Calculation of Total Axial Load in a Single Pile (Maximum)

Section Modulus in X-direction

M_x = 0

X Direction	No of Piles (A)	Distance from CG to Pile (normal) (d)	Ad^2
1	4	4.5	81
2	4	4.5	81
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
		$\sum Ad^2$=	162
		Maximum Distance =	4.5
		S_x =	36

Section Modulus in Z-direction

M_z = 0

Z Direction	No of Piles (A)	Distance from CG to Pile (normal) (d)	Ad^2
1	2	13.5	364.5
2	2	4.5	40.5
3	2	13.5	364.5
4	2	4.5	40.5
5	0	0	0
6	0	0	0
		$\sum Ad^2$=	810
		Maximum Distance =	13.5
		S_z=	60.0

Maximum Compression Load on a Single Pile

$$V = \frac{F_y}{n} + \frac{M_x}{S_x} + \frac{M_z}{S_z}$$

Compression		
	(Service) V=	74 Kips
	(Strength) V=	111 Kips

Maximum Tension Load on a Single Pile

$$T = \frac{F_y}{n} - \frac{M_x}{S_x} - \frac{M_z}{S_z}$$

Tension		
	(Service) T=	0 Kips
	(Strength) T=	0 Kips

Calculation of Total Lateral Load in a Single Pile (Maximum)

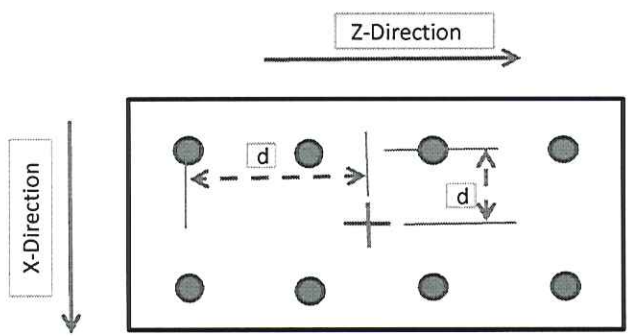
(Torsion) M_y = 0 Service (Lateral Force Calculated in Service State for Deflection Calculation)
0 Strength

Pile Number	Distance from CG to Pile (shortest) d (ft)	d^2	Resultant Service Lateral Force (R_m) (kips)	Resultant Strength Lateral Force (R_m) (kips)	
1	13.086	171.2	0.0	0.0	
2	13.086	171.2	0.0	0.0	
3	6.364	40.5	0.0	0.0	
4	6.364	40.5	0.0	0.0	
5	6.364	40.5	0.0	0.0	
6	6.364	40.5	0.0	0.0	
7	13.086	171.2	0.0	0.0	
8	13.086	171.2	0.0	0.0	
9	0	0.0	0.0	0.0	
10	0	0.0	0.0	0.0	
11	0	0.0	0.0	0.0	
12	0	0.0	0.0	0.0	
	$\sum d^2$ =	847.0	**0.0**	**0.0**	(Maximum)

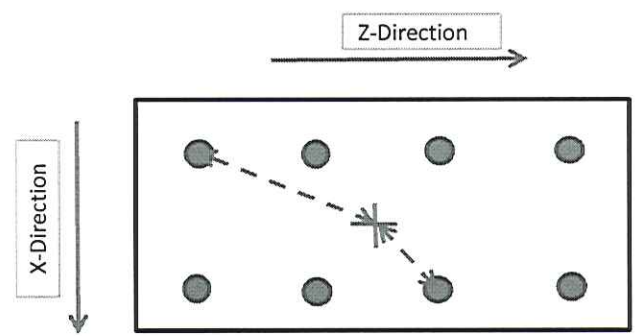
Maximum Lateral Force on a Single Pile

$$F_L = \frac{F_l}{n} + R_m$$

F_L =	**8 kips**
F_L =	**7 kips**



Vertical Load Calculation



Horizontal Load Calculation

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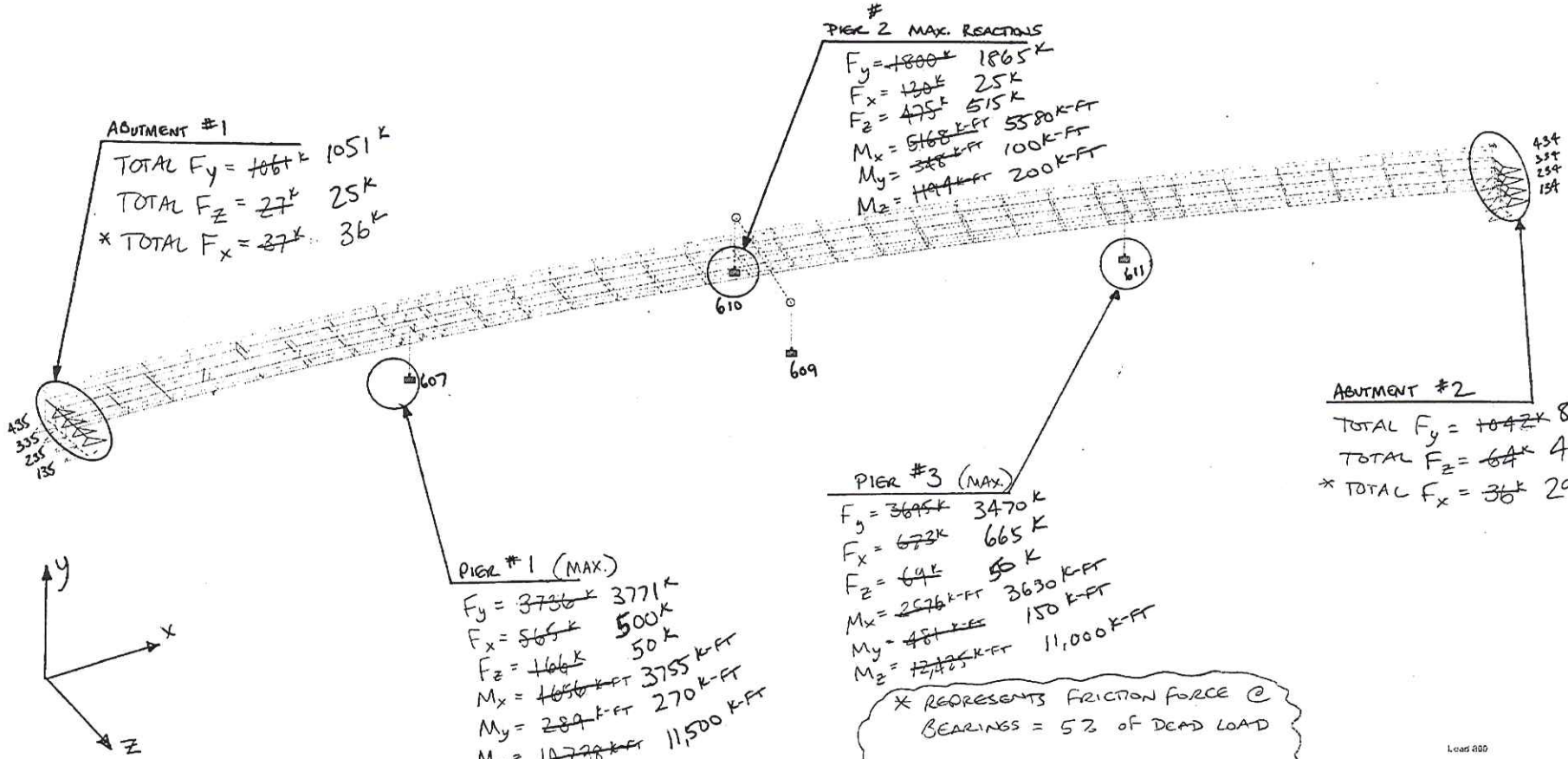
Job Title: SR1 Interchange - Ramp B over I95NB

Client: DELDOT

STRENGTH I REACTIONS (MAX.)

Job No	103-059-27K
Sheet No	1
Rev	
Part	
Ref	
By	MDM
Date	13-Aug-08
Chd	
File	RampBModel-Integral Pie
Date/Time	08-Sep-2008 16:01



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Print Time/Date: 08/09/2008 16:16

STAAD.Pro for Windows 20.07.02.15

Print Run 1 of 1

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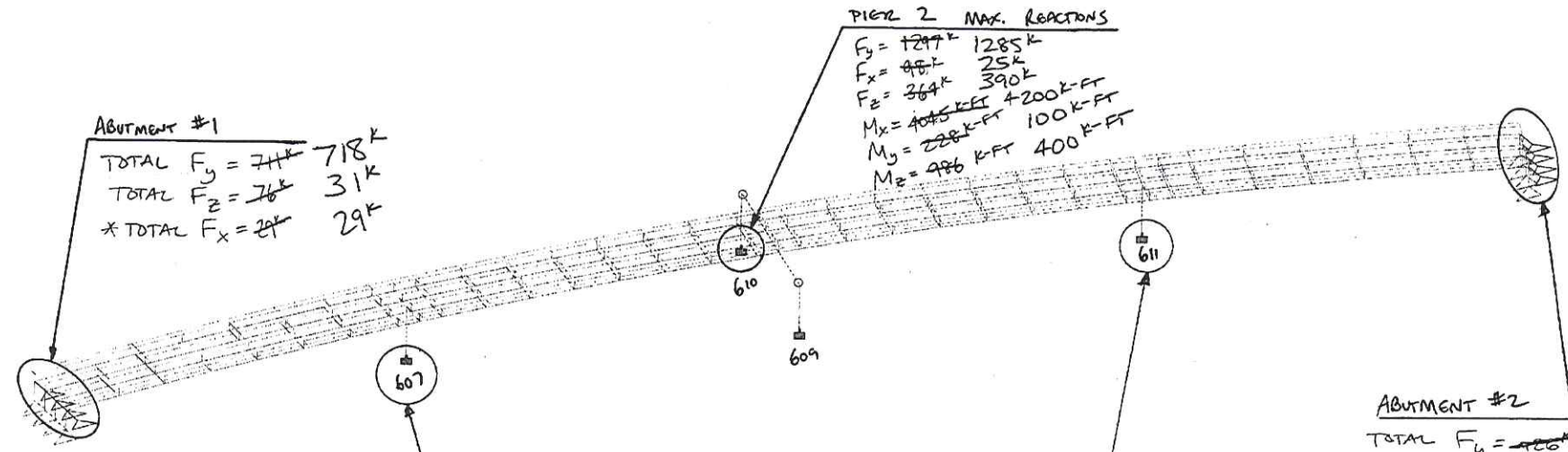
Job Title SR1 Interchange - Ramp B over I95NB

Client DELDOT

SERVICE I REACTIONS (MAX.)

Job No 103-059-27K	Sheet No 1	Rev	
Part			
Ref			
By MDM	Date 13-Aug-08	Chd	
File RampBModel-Integral Pie	Date/Time 08-Sep-2008 16:01		



ABUTMENT #1

TOTAL F_y = ~~711K~~ 718K

TOTAL F_z = ~~76K~~ 31K

* TOTAL F_x = ~~29K~~ 29K

PIER 2 MAX. REACTIONS

F_y = ~~1297K~~ 1285K

F_x = ~~98K~~ 25K

F_z = ~~364K~~ 390K

M_x = ~~4045 K-FT~~ 4200 K-FT

M_y = ~~228 K-FT~~ 100 K-FT

M_z = ~~486 K-FT~~ 400 K-FT

ABUTMENT #2

TOTAL F_y = ~~426K~~ 590K

TOTAL F_z = ~~23K~~ 62K

*TOTAL F_x = ~~28K~~ 23K

PIER #1 (MAX.)

F_y = ~~2776K~~ 2799K

F_x = ~~562K~~ 525K

F_z = ~~145K~~ 50K

M_x = ~~2971 K-FT~~ 2050 K-FT

M_y = ~~201 K-FT~~ 190 K-FT

M_z = ~~10,786 K-FT~~ 11,000 K-FT

PIER #3 (MAX.)

F_y = ~~2715K~~ 2405K

F_x = ~~673K~~ 710K

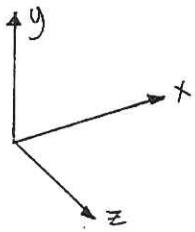
F_z = ~~83K~~ 60K

M_x = ~~2662 K-FT~~ 2452 K-FT

M_y = ~~406 K-FT~~ 400 K-FT

M_z = ~~12,461 K-FT~~ 12000 K-FT

* REPRESENTS FRICTION FORCE @ BEARINGS = 5% OF DEAD LOAD



Load 800

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Subject SR-1/I-95 INTERCHANGE WEAP ANALYSIS Page 50 of
Cm. No. 103-059
Prepared By BBS Date 2-2-09 Checked By EMC Date 2/3/09

SUMMARY OF FOUNDATION LOADS

STRUCTURE	R_F (Kips)	REQD R_{nSTAT} (Kips)	REQD R_{ndr} (Kips)	PILE DIAMETER (in)	R_{STAT} REQD PILE LENGTH (ft)	
ABUTMENT A	131	374	202	24	86	8
PIER 1	516	1474	794	36	80	12
PIER 2	220	629	339	36	57	24
PIER 3	482	1377	742	36	76	12
ABUTMENT B	111	317	171	24	73.	8
						64

ABUTMENT PILE LENGTH INCLUDE 35 ft FOR ABUTMENT STICK UP

$R_{nSTAT} = \frac{R_F}{\phi_{nSTAT}}$ $\phi_{nSTAT} = 0.35$ p 10-39 AASHTO

$R_{ndr} = R_n = \frac{R_F}{\phi_n}$ $\phi_n = 0.65$ p 10-38 ϕ_{dyn}

p 10-88 ϕ_{ndr}

SEE WEAP ANALYSIS. FOR DRIVABILITY

ABUTMENT A WEAP ANALYSIS.

SEE SOIL STRATIFICATION pg - 52

RECOMMENDED PILE - 24-inch PIPE PILE

THICKNESS = 0.5-inch ; 50 ksi STEEL

DRIVING STRESS

$\sigma_{dr} = 0.9 \phi_{da} f_y$ (10.7.8-1)

ϕ_{da} = RESISTANCE FACTOR

$= 1.0$ (10.5.5.2.3-1)

$f_y = 50$ ksi

$\sigma_{dr} = 0.9 \times 1 \times 50$

$= 45$ ksi

US ACE LIMITS PENETRATION RATES FOR PIPE PILES BETWEEN 10-20 blows per inch.

LIMIT BLOWS PER FOOT < 120 bpf = 10 bpi

ANALYZE PILE DRIVING HAMMER

DELMAG D 30-32 ENERGY → 75.438 ft kip

SEE GRL WEAP PRINT OUTS

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Subject SR-1/I-95 INTERCHANGE RAMP B WEAP ANALYSIS
Page 51 of 67
Cm. No. 103-059
Prepared By BRS Date 1-26-09 Checked By AMK Date 2/2/09

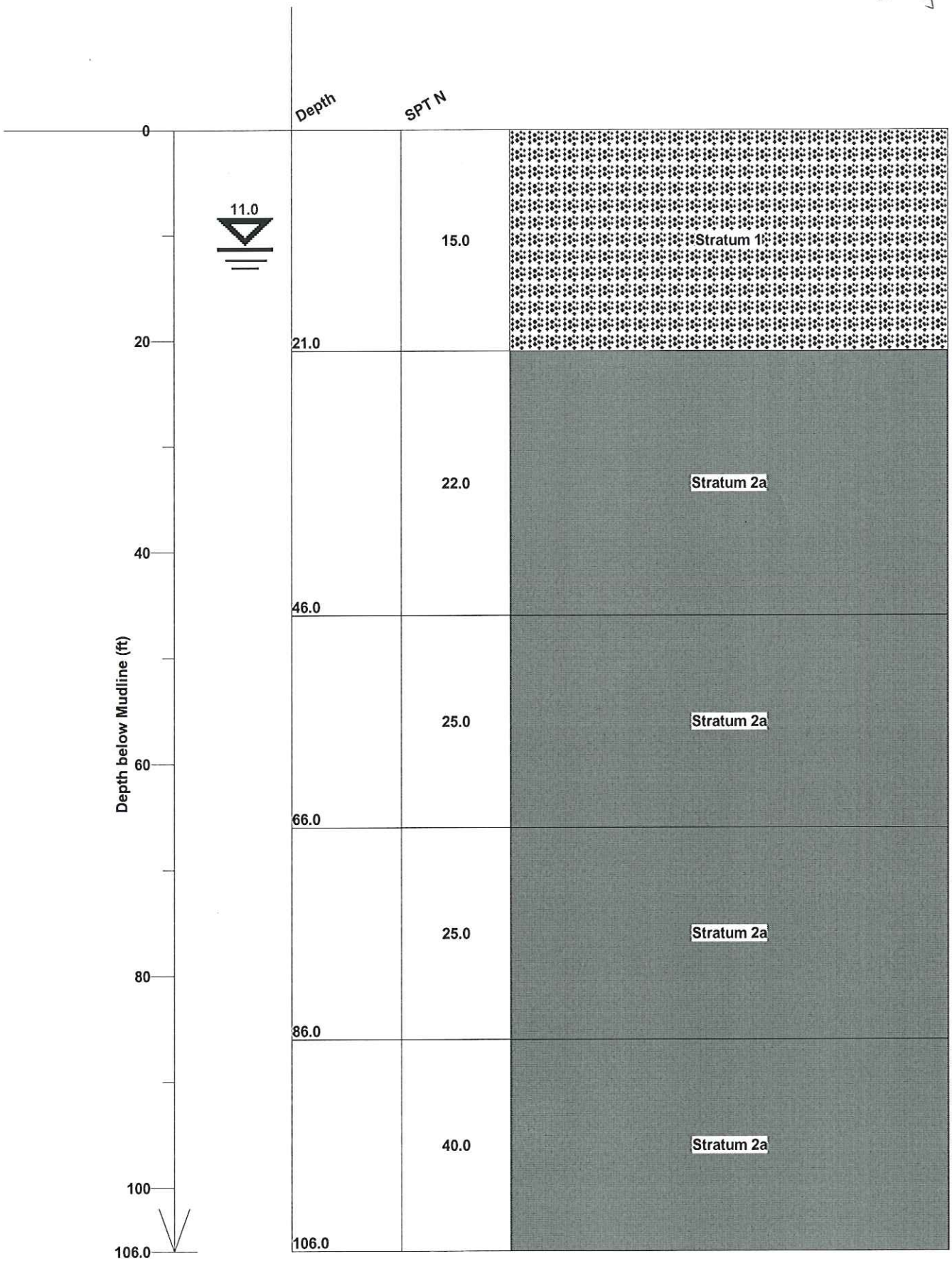
ABUTMENTS

SUMMARY OF PILE HAMMER, DRIVING STRESS & BLOW COUNT FOR PILE LENGTH CALCULATED.

PILE HAMMER	PILE LENGTH	MAX BLOW COUNT	MAXIMUM DRIVING STRESS COMPRESSION	TENSION
DELMAG D-3032	51-ft	30 bpf	35.1 ksi	20.9 ksi

SUMMARY OF PILE HAMMER, DRIVING STRESS & BLOW COUNT FOR PILE CAPACITY USING PDA

PILE HAMMER	DRIVING RESISTANCE	MAX BLOW COUNT	MAX DRIVING STRESS COMPRESSION	TENSION
DELMAG D-3032	202 kips	12 bpf	35 ksi	19.3 ksi



ABUTMENT A SOIL PROFILE:

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SR-1 Interchange Ramp B Bridge (ABUT A)

26-Jan-2009
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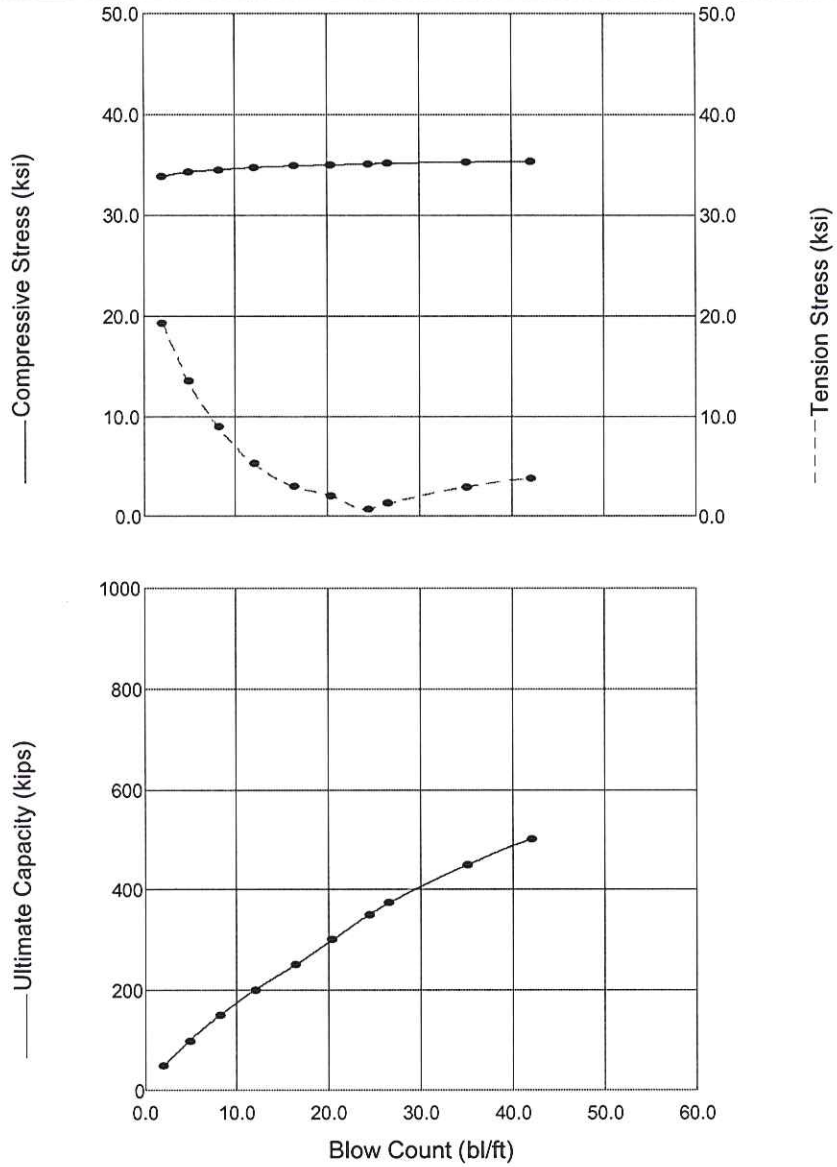
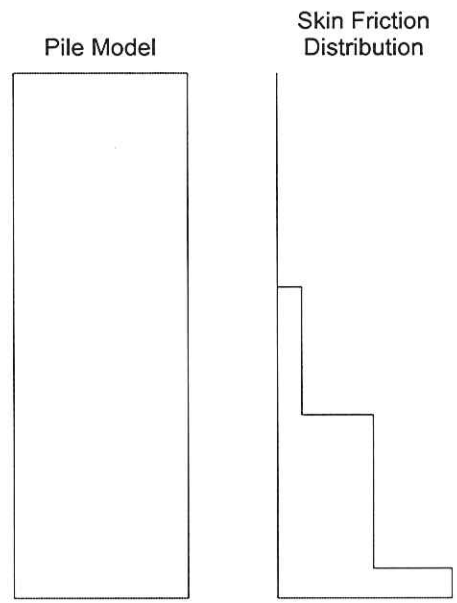


DELMAG D 30-32

Stroke	11.43	feet
Efficiency	0.800	
Helmet	3.40	kips
Hammer Cushion	109975	kips/in
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	86.00	ft
Pile Penetration	51.00	ft
Pile Top Area	36.91	in2



Res. Shaft = 100 %
(Proportional)

RKK S6-198
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SR-1 Interchange Ramp B Bridge (ABUT A) GRLWEAP (TM) Version 2003

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke feet	Energy kips-ft
50.0	33.83	19.31	2.1	11.43	68.26
100.0	34.30	13.61	4.9	11.43	59.14
150.0	34.52	9.04	8.2	11.43	53.90
200.0	34.76	5.34	12.0	11.43	50.68
250.0	34.92	3.02	16.4	11.43	47.95
300.0	35.02	2.08	20.4	11.43	45.81
350.0	35.13	0.77	24.4	11.43	45.45
374.0	35.18	1.33	26.6	11.43	45.37
450.0	35.31	2.99	35.1	11.43	45.16
500.0	35.40	3.85	42.1	11.43	45.05

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SR-1 Interchange Ramp B Bridge (ABUT A)

D-30-32

Jan 26 2009
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Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Blow Rate bpm	ENTHRU kips-ft
5.0	16.6	13.6	3.0	0.9	31.029	-20.864	47.5	66.6
10.0	30.1	27.1	3.0	1.1	32.282	-21.194	46.8	77.1
20.0	57.3	54.3	3.0	1.3	33.552	-20.500	45.4	76.6
30.0	152.1	147.5	4.6	6.8	34.314	-7.806	40.9	58.1
40.0	252.6	248.0	4.6	14.8	34.731	-1.740	39.1	48.6
45.0	302.9	298.3	4.6	20.4	35.114	-1.011	38.5	45.7
50.0	388.9	382.1	6.8	27.7	34.571	-0.086	38.1	42.4
51.0	407.3	400.5	6.8	29.4	34.955	0.000	38.0	42.0

Total Continuous Driving Time 10.00 minutes; Total Number of Blows 404

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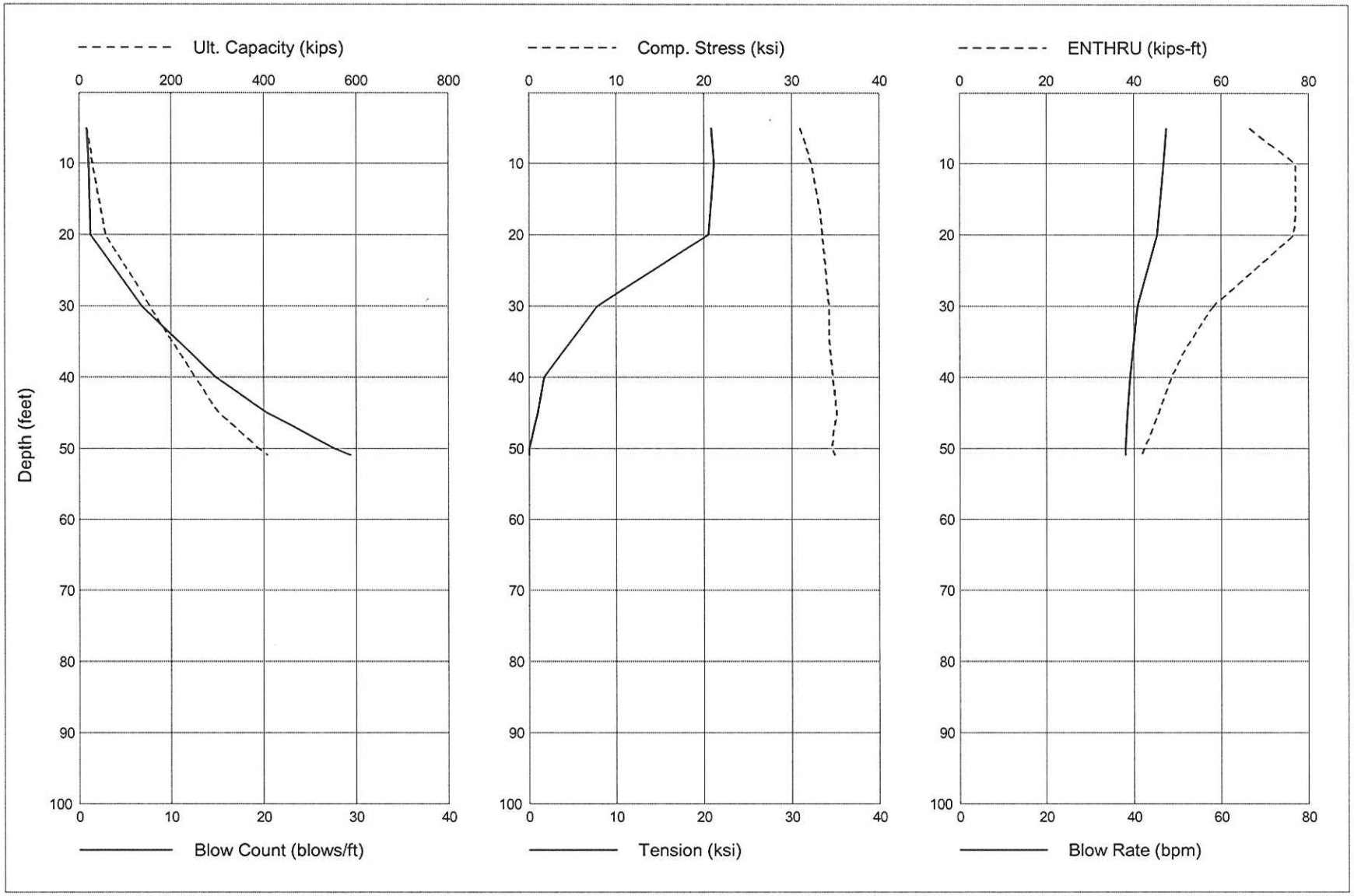
SR-1 Interchange Ramp B Bridge (ABUT A) Gain/Loss 1 at Shaft and Toe 1.000 / 1.000 GRLWEAP(TM) Version 2003



RKK S6-201
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PIER 1 PILE FOUNDATION WEAP ANALYSIS

SEE SOIL STRATIFICATION pg - 59

RECOMMENDED PILE - 36 inch PIPE PILE

THICKNESS = 0.625 inch ; 50 ksi STEEL

DRIVING STRESS

$\sigma_{dr} = 0.9\,\phi_{da} f_y$ (10.7.8-1)

ϕ_{da} = RESISTANCE FACTOR

$= 1.0$ (10.5.5.2.3-1)

$f_y = 50$ ksi

$\sigma_{dr} = 0.9 \times 1 \times 50$

$= 45$ ksi

USACE LIMITS PENETRATION RATES FOR PIPE PILES

BETWEEN 10 - 20 blows PER INCH

LIMITS BLOWS PER FOOT < 120 bpf = 10 bpi

ANALYZE PILE DRIVING HAMMER

ICE I-62 ENERGY 164.98 ft kips.

DELMAG D 62-22 ENERGY 164.603 ft kips

SEE GRL WEAP PRINT OUTS

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Subject SR-1/I-95 INTERCHANGE RAMP B WEAP ANALYSIS Page 58 of 67
Cm. No. 103-059
Prepared By BBS Date 1-26-08 Checked By EMC Date 7/2/09

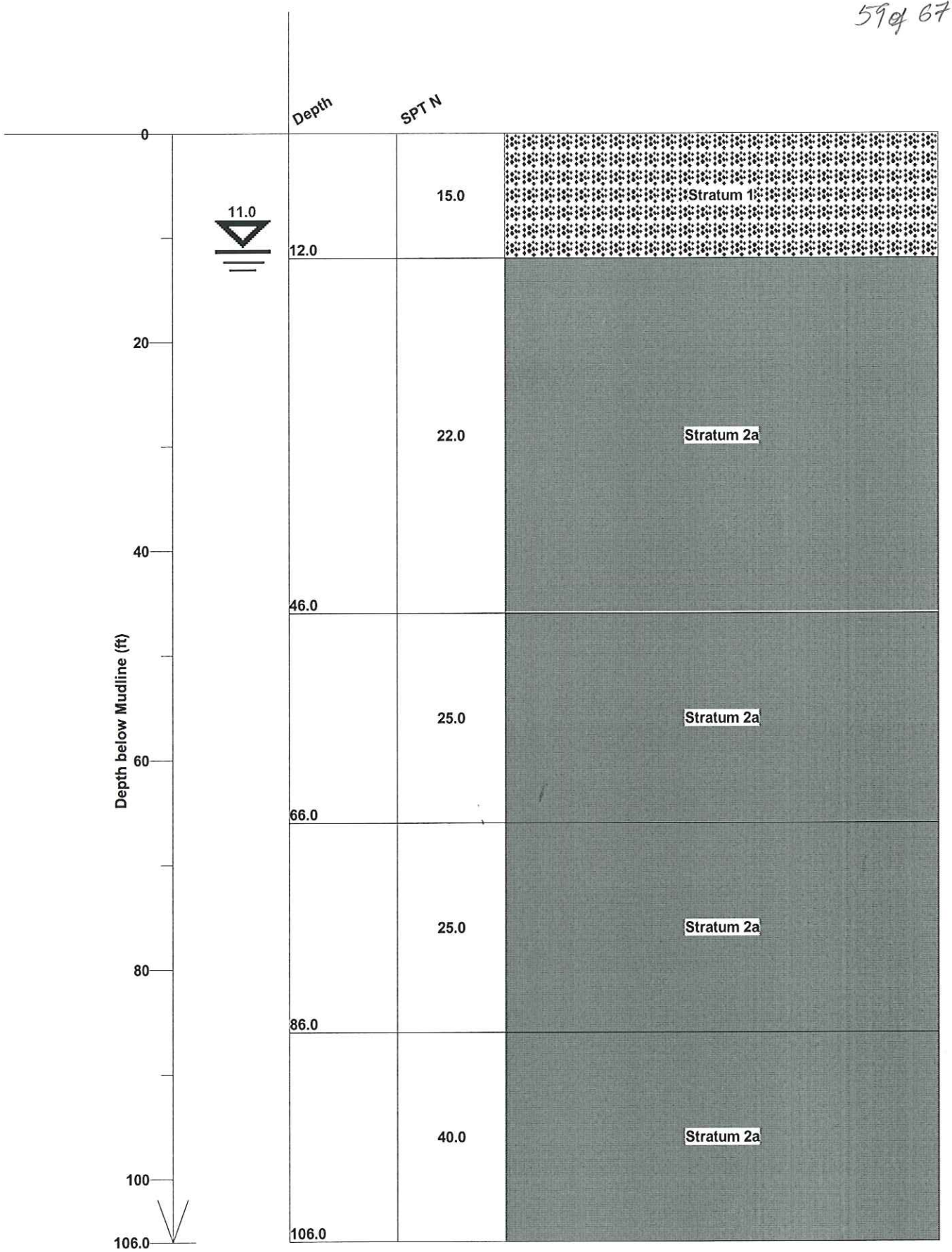
PIERS.

SUMMARY OF PILE HAMMER, DRIVING STRESS & BLOW COUNT FOR PILE LENGTH CALCULATED

PILE HAMMER	PILE LENGTH	MAX BLOW COUNT	MAXIMUM DRIVING STRESS. COMPRESSION	TENSION
DELMAG D62-22	80-ft	119 bpf	39.2 ksi	15.5 ksi
ICE I-62	80-ft	121 bpf	38.6 ksi	15.1 ksi

SUMMARY OF PILE HAMMER, DRIVING STRESS & BLOW COUNT FOR PILE CAPACITY USING PDA (DRIVING RESISTANCE)

PILE HAMMER	DRIVING RESISTANCE	MAX BLOW COUNT	MAXIMUM DRIVING STRESS COMPRESSION	TENSION
DELMAG D62-22	794 kips	35 bpf	38 ksi	16.5 ksi
ICE I-62	794 kips	35 bpf	37.7 ksi	16.1 ksi



PIER 1 SOIL PROFILE:

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SR-1 Interchange Ramp B Bridge (Pier 1)

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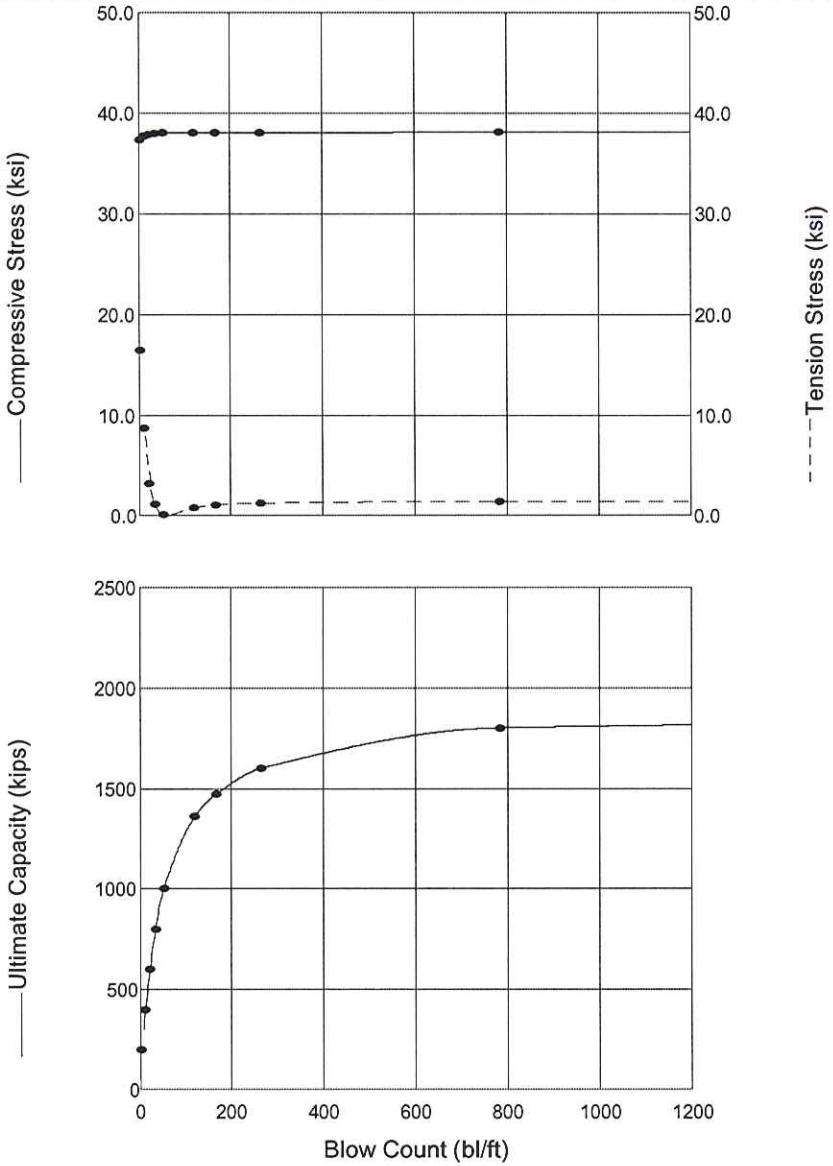
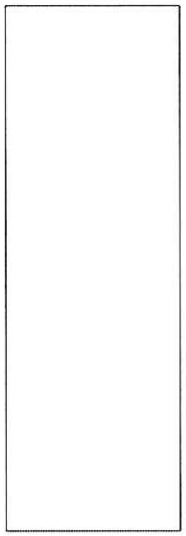


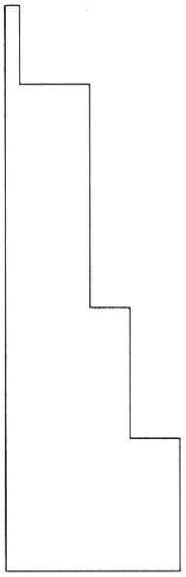
DELMAG D 62-22

Stroke	12.05	feet
Efficiency	0.800	
Helmet	3.80	kips
Hammer Cushion	55729	kips/in
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	80.00	ft
Pile Penetration	80.00	ft
Pile Top Area	69.46	in2

Pile Model



Skin Friction Distribution



Res. Shaft = 100 %
(Proportional)

RKK S6-205

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Rummel Klepper & Kahl, LLP D 62-22 26-Jan-2009
SR-1 Interchange Ramp B Bridge (Pier 1) GRLWEAP (TM) Version 2003

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke feet	Energy kips-ft
200.0	37.41	16.45	4.7	12.05	122.75
400.0	37.78	8.76	12.1	12.05	97.19
600.0	37.95	3.24	23.0	12.05	85.90
800.0	38.02	1.17	35.2	12.05	80.08
1000.0	38.06	0.17	53.1	12.05	78.82
1361.0	38.11	0.88	121.3	12.05	76.73
1474.0	38.11	1.12	168.6	12.05	76.35
1600.0	38.12	1.30	265.3	12.05	75.98
1800.0	38.14	1.48	784.2	12.05	75.42
2000.0	38.15	1.67	8545.0	12.05	74.89

Rummel Klepper & Kahl, LLP
SR-1 Interchange Ramp B Bridge (Pier 1)

D 62-22

Jan 26 2009
GRLWEAP(TM) Version 2003

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Blow Rate bpm	ENTHRU kips-ft
5.0	16.2	11.2	5.0	0.0	0.000	0.000	75.5	0.0
20.0	149.8	140.8	9.0	2.9	36.944	-15.423	40.5	140.1
40.0	434.6	425.6	9.0	13.2	38.170	-3.782	37.0	97.7
60.0	818.3	804.3	14.0	36.3	38.669	-0.485	35.6	81.7
70.0	1066.3	1047.3	19.0	59.2	38.563	-0.495	35.4	79.3
75.0	1212.9	1193.9	19.0	82.0	39.149	-0.459	35.3	78.0
80.0	1359.5	1340.5	19.0	118.5	38.517	-0.633	35.2	77.0

Total Continuous Driving Time 56.00 minutes; Total Number of Blows 2010

Rummel Klepper & Kahl, LLP

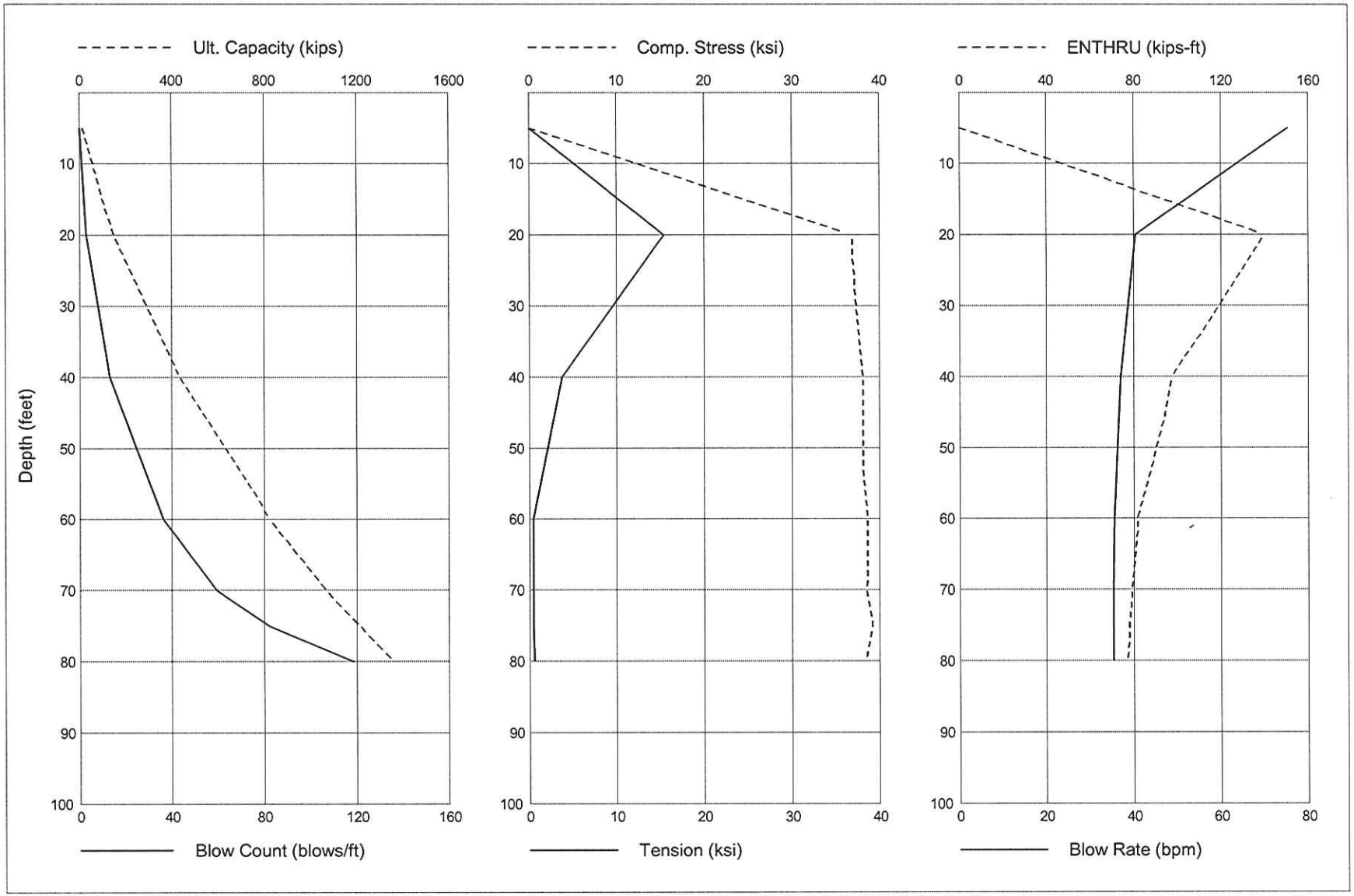
D 62-22

Jan 26 2009

SR-1 Interchange Ramp B Bridge (Pier 1)

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

GRLWEAP(TM) Version 2003



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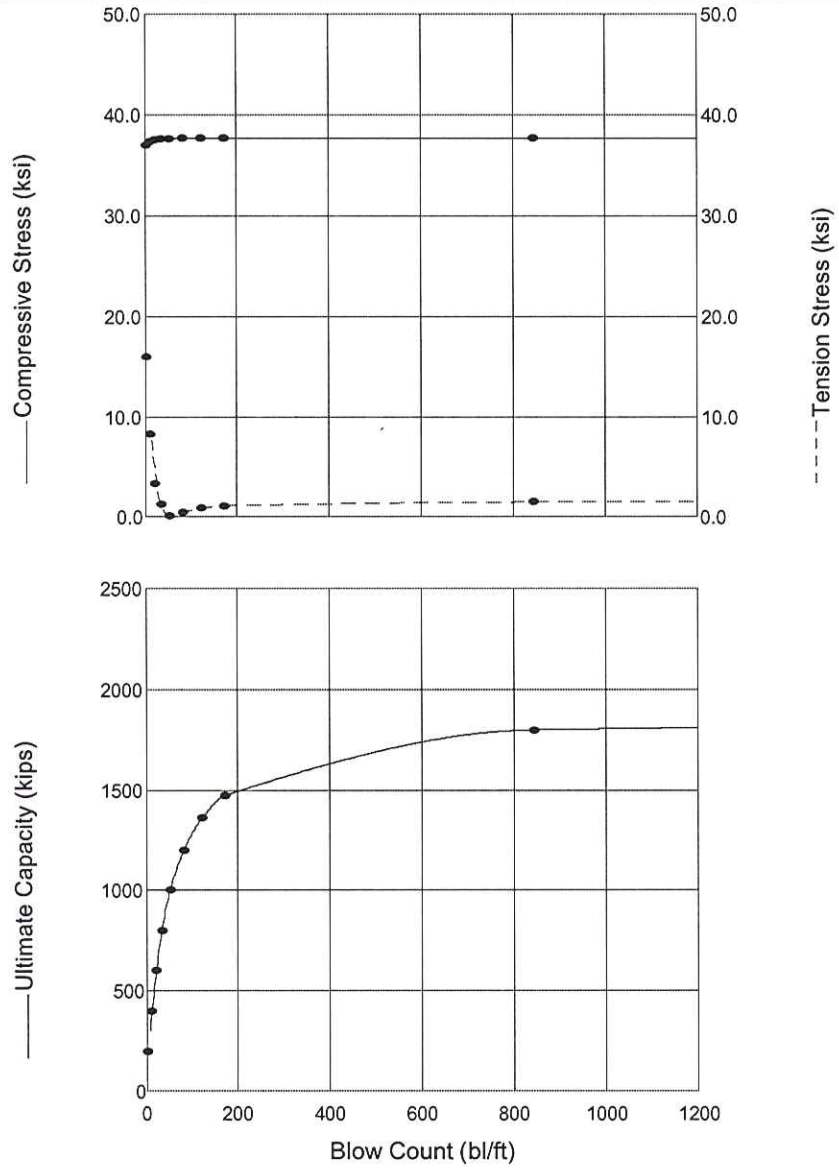
RKK S6-208

Rummel Klepper & Kahl, LLP
SR-1 Interchange Ramp B Bridge (Pier 1)

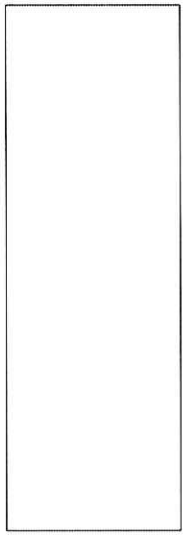
26-Jan-2009
GRLWEAP (TM) Version 2003



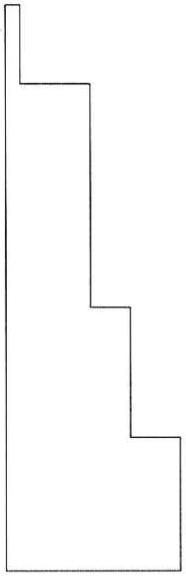
ICE I-62

Stroke	11.30	feet
Efficiency	0.800	
Helmet	3.80	kips
Hammer Cushion	55729	kips/in
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	80.00	ft
Pile Penetration	80.00	ft
Pile Top Area	69.46	in2

Pile Model



Skin Friction Distribution



Res. Shaft = 100 %
(Proportional)

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RKK S6-209

Rummel Klepper & Kahl, LLP ICE 1-62 26-Jan-2009
SR-1 Interchange Ramp B Bridge (Pier 1) GRLWEAP (TM) Version 2003

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke feet	Energy kips-ft
200.0	37.01	16.05	4.6	11.30	121.55
400.0	37.38	8.34	12.1	11.30	95.91
600.0	37.55	3.29	22.9	11.30	84.62
800.0	37.63	1.30	34.8	11.30	78.98
1000.0	37.67	0.12	52.9	11.30	77.65
1200.0	37.73	0.48	82.9	11.30	76.82
1361.0	37.75	0.93	123.4	11.30	76.36
1474.0	37.76	1.13	172.8	11.30	76.07
1800.0	37.78	1.50	845.2	11.30	75.17
2000.0	37.78	1.66	9999.0	11.30	74.57

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SR-1 Interchange Ramp B Bridge (Pier 1)

ICE 1-62

Jan 26 2009
GRLWEAP(TM) Version 2003

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Blow Rate bpm	ENTHRU kips-ft
5.0	16.2	11.2	5.0	0.0	0.000	0.000	79.0	0.0
20.0	149.8	140.8	9.0	2.9	36.518	-15.121	41.6	139.5
40.0	434.6	425.6	9.0	13.4	37.629	-3.588	37.9	95.5
60.0	818.3	804.3	14.0	36.7	38.096	-0.607	36.6	79.8
70.0	1066.3	1047.3	19.0	60.2	38.145	-0.686	36.5	77.6
75.0	1212.9	1193.9	19.0	83.6	38.584	-0.414	36.4	76.9
80.0	1359.5	1340.5	19.0	120.7	38.145	-0.678	36.3	76.1

Total Continuous Driving Time 56.00 minutes; Total Number of Blows 2042

Rummel Klepper & Kahl, LLP

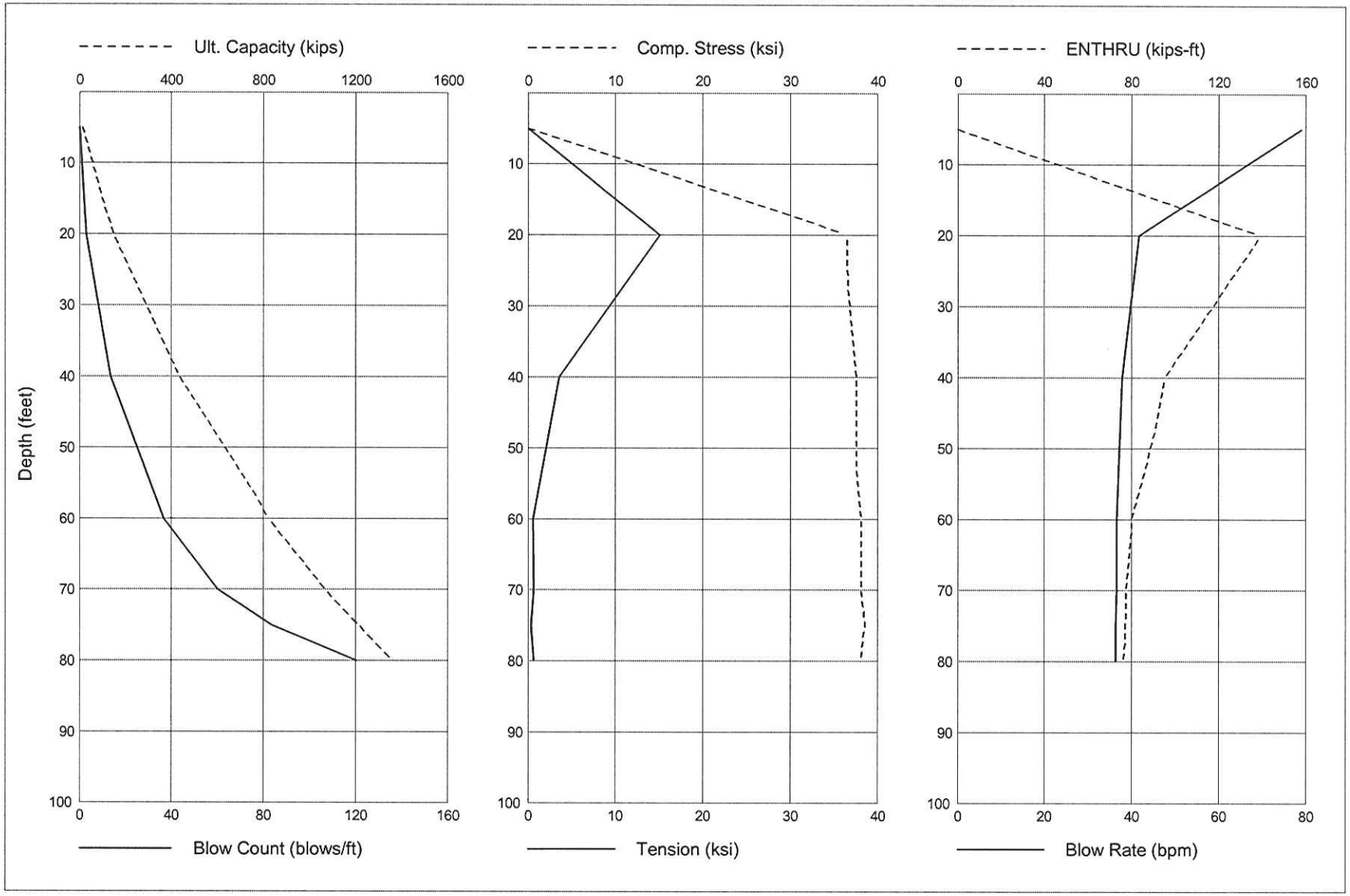
ICE 1-62

Jan 26 2009

SR-1 Interchange Ramp B Bridge (Pier 1)

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

GRLWEAP(TM) Version 2003



RKK S6-212

67 of 67

CALCULATION CHECKLIST

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

Title of Calculation Set: **Structure S7 – Ramp R1 Bridge – Foundation Design** – Abutments & Wingwalls

Project Manager: **EMK/JLT**

Calculations Prepared By: **SAB**

Calculation Checked By:

Computer Programs / Files: **AllPile**

Initial	Date	
		Subsurface Characterization approved by Project Manager
SAB	12/22/08	Calculations are neat, legible and understandable.
SAB	12/22/08	Table of Contents is provided.
SAB	12/22/08	Heading on each page filled out
SAB	12/22/08	The first page contains purpose of the calculation.
SAB	12/22/08	Symbols are defined.
SAB	12/22/08	References for data, methods, formulas and computer program names and version numbers are given.
SAB	12/22/08	Assumptions are listed and those that need to be verified later are Flagged.
SAB	12/22/08	Headings on front sheet of each set of computer input and output.
SAB	12/22/08	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JJT	1-11-09	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.

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"A Tradition Of Excellence" since 1923

Subject I-95/SR 1 Interchange (Structure S7) Ramp R1 Bridge Foundation Design
Page 1 of 18
Cm. No. 103-059-27U
Prepared By SAB Date 9/12/08 Checked By FJT Date 10-1-08
REV 12/19/08 FJT 1-11-09

Objective: 1) To estimate the required pile lengths for the abutments & wing walls of the Ramp R1 bridge over SR7 (Structure S7).

- Structural loads, pages 2a + 2b

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

Summary:

Abutment A → BOF EL 40

Pile	Required Length	Pile Tip EL
HP 12x53	67'	-27
HP 14x73	63'	-23

$R_N = 267^k$

Abutment B → BOF EL 39

Pile	Required Length	Pile Tip EL
HP 12x53	57'	-18
HP 14x73	47'	-8

$R_N = 267^k$

Wing Walls I & II → BOF EL 40

Pile	Required Length	Pile Tip EL
HP 12x53	68'	-28
HP 14x73	64'	-24

$R_N = 277^k$

Wing Walls III & IV → BOF EL 39

Pile	Required Length	Pile Tip EL
HP 12x53	65'	-26
HP 14x73	48'	-9

$R_N = 277^k$

Calculations:

Abutment A	Pages 2 – 7
Abutment B	Pages 8 – 13
References	Pages 14 – 18
Wingwalls	Pages 19 – 27

* Recommend HP 14x73

Abutment A + Wing Walls
L = 65' Tip @ EL -25

Abutment B + Wing Walls
L = 50' Tip @ EL -18

Abutment A & Wingwalls I & II: (see page 19 for wingwall calculations)

Soil Strata: See attached Fence diagram. Borings: IBR-51, 52, 3; IRW-10, 11. (p.7)

*Assume Bottom of Footing (Top of Pile) Elevation = EL 40

Stratum	Approx. EL (ft)	SPT Avg. N-value	γ_T (pcf)	ϕ (deg)	c (psf)	S_u (psf)	k (pci) → * See attach'd Tables 3.3, 3.5, 3.6 (p.15-16)
II a	40→30	16	130	–	–	800	250
II a	30→25	14	130	–	–	2,000*	250
II a	25→20	24	130	–	–	2,500*	~~250~~ 300
II b	20→10	30	130	34	–	–	75
II a	10→0	36	130	–	–	3,500	500
II b	0→-18	60	130	34	–	–	100
II a	-18→-29	34	130	–	–	5,000	500
II b	-29...	68	130	34	–	0	150

→ Water at approx. EL 45

*See page 7a for site specific Su determination using lab testing and nearby CPT & DMT testing.

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Subject SR1/I-95 Interchange — Page 2a of
S7: Ramp R1 Bridge Pile Design — Cm. No. 103-059-270
Prepared By SAB Date 12/19/08 Checked By JPT Date 1-20-09

From AASHTO p. 10-88, $\phi_{dyn}(R_n) = \phi_{stat}(R_{nstat})$ where: ϕ_{dyn} = Dynamic Analysis Resistance Factor (Table 10.5.5.2.3-1)
R_n = Total Nominal Resistance = $\phi_c P_n$
ϕ_{stat} = Static Analysis Resistance Factor (Table 10.5.5.2.3-1)
R_{nstat} = Predicted nominal resistance from static analysis

→ From AASHTO Table 10.5.5.2.3-1: (see p. 17-18)

$\phi_{dyn} = 0.65$ (Dynamic test & WEAP)
$\phi_{stat} = 0.35$ (Clay & Mixed soils, α-method)

⇒ Use Factored load in All Pile: (see p. 3-6)

Loads: Strength Resistance = 173.45^k ⇒ (From Structures, 12/11/08, see p. 2a)
Service Resistance = 119.31^k
Service Lateral Load = 0^k — 4(H):12(V) Batter = 18.4°

⇒ Factored Load = 173.5^k = $\phi_{stat} R_N$ ⇒ R_n = 173.5^k/0.35 = **495.6^k** → Evaluate for HP12x53 & HP14x73.

⇒ For WEAP, $\phi_{dyn} R_n$ ⇒ 173.5^k/0.65 = **267^k**

⇒ For HP12x53, Required Pile Length = **L = 67'** (See p. 3-4)
For HP14x73, Required Pile Length = **L = 63'** (See p. 5-6)

* Use HP 14X 73 for abutment, wingwalls, + Piers.

Manual Check: Abutment A

Ref: 1) W.O. Schmidt, "End Bearing & Shaft Friction of Piles & Piers in Sand"
2) FHWA HI 97-013, "Design and Construction of Driven Pile Foundations" Nov. 1998.

Ref 1) $Q_u = Q_p + Q_s = q_p A_p + f_s A_s$ where: q_p = unit point bearing resistance
A_p = Area of point
f_s = Unit skin resistance b/t pile & soil
A_s = embedment area w/ shaft = 14.6"/12" = 1.22 ft² (x2)

$q_p = \bar{p}_o N_q < q_\ell = 4N$ (tsf) where: $\bar{p}_o$ = effective overburden stress
N_q = Bearing capacity factor (AASHTO Table 10.6.3.1.2a-1)
q_ℓ = q_p limiting value

for Sand: $f_s = K_s \bar{p}_o \tan\phi \le f_\ell = \frac{N}{100} < 1$ tsf. where: K_s = avg. earth pressure coefficient
$\bar{p}_o$ = avg. effective overburden stress
ϕ = friction angle
f_ℓ = limiting value for skin friction $= \frac{N}{100}$ (tsf)

for Clay: (Ref 2) $f_s = c_a = \alpha c_u$ where: c_a = adhesion
α = adhesion factor (from Fig. 9.19 - see p. 2b)
c_u = Undrained shear strength

⇒ See p. 2c for calculation of f_s & $\Sigma(f_s A_s L)$.

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

S7: Ramp R1 Bridge Abutment A Manual Pile Check

1/21/2009

Pile: HP14x73 b= 1.217 ft A_s= 2.43 ft^2/ft A_p= 1.48 ft^2

Stratum	Thickness (D) (ft)	Φ (deg)	Nq	c_u (tsf)	D/b	α	c_a (tsf)	Ks	N (bpf)	Po (tsf)	f_s (tsf)	N/100 (tsf)	Q_s (tons)	Skin Friction Q_{si} (tons)	Σ Skin Friction Qsi (tons)
IIa EL 40-30	10	-	-	0.4	8.2	0.95	0.38	1.0	16	0.169	0.38	0.16	0.925	9.25	9.25
IIa EL 30-25	5	-	-	1	4.1	0.65	0.65	1.0	14	0.423	0.65	0.14	1.582	7.91	17.16
IIa EL 25-20	5	-	-	1.25	4.1	0.38	0.48	1.0	24	0.592	0.48	0.24	1.156	5.78	22.93
IIb EL 20-10	10	34	29.4	-	8.2	-	-	1.5	30	0.845	0.855	0.30	2.080	20.80	43.74
IIa EL 10-0	10	-	-	1.75	8.2	1.0	1.75	1.0	36	1.183	1.75	0.36	4.258	42.58	86.32
IIb EL 0 - -18	18 58'	34	29.4	-	14.8	-	-	1.5	60	1.656	1	0.60	2.433	43.80	130.12
IIa EL -18 - 29	11 69	-	-	2.5	9.0	1.0	2.5	1.0	34	2.146	2.50	0.34	6.083	66.92	197.04
IIb EL -29...	5 74'	34	29.4	-		-	-	1.5	68	2.332	1	0.68	2.433	1215	2092

RKK-S7-6

M:\projects\2003\03059_deltrnpk\Geotech\INTERCHANGE FINAL DESIGN 2008\Ramp R1 Bridge\Abutments\Final Design\Abut A Manual Pile Check.xls

$A_p = 14.6^{in^2}/144 in^2/ft^2 = 1.48 ft^2$

$q_p = 2.33(29.4) = 68$ tsf or $4N = 4(68) = 272$ tsf → limit to 150 tsf IN SAND

$Q_p = 68(1.48 ft^2) = 100.6$ tons

→ $Q_u = 496^k = 248^{tons} = 100.6 + Q_{si}$

$147.4 = Q_{si}$

$147.4 = 130.12 + 6.083L$

$17.3 = 6.083L$

$L = 2.8' = 3'$

So, Pile Length = 10' + 5' + 5' + 10' + 10' + 18' + 3' = 61'

But, if pile length is 58-64', tip is in CLAY:

So, $q_p = N_c S_u = 5.14(2.5 tsf) = 12.8$ tsf

⇒ $Q_p = 12.8 tsf(1.48 ft^2) = 18.9$ tons

→ $Q_u = 248$ tons $= 18.9 + Q_{si}$

$229.1 = 130.12 + 6.083L$
$99 = 6.083L$
$L = 16.3' = 17'$ → CLAY layer is only 11' deep, so pile extends into SAND.

⇒ To use q_p for sand, pile tip must extend 5b into soil. So, pile must extend to EL -34. ∴ Pile Length = 94' (or 5' INTO SAND LAYER)
$Q_u = 209.2^T + 100^T = 309$ TONS

USING ALLPILE, L = 67' & $Q_s + Q_p = 493.6 + 2.267$ KIPS
$= 248.2$ TONS

SR1 / I-95 Interchange 103-059-270 2e

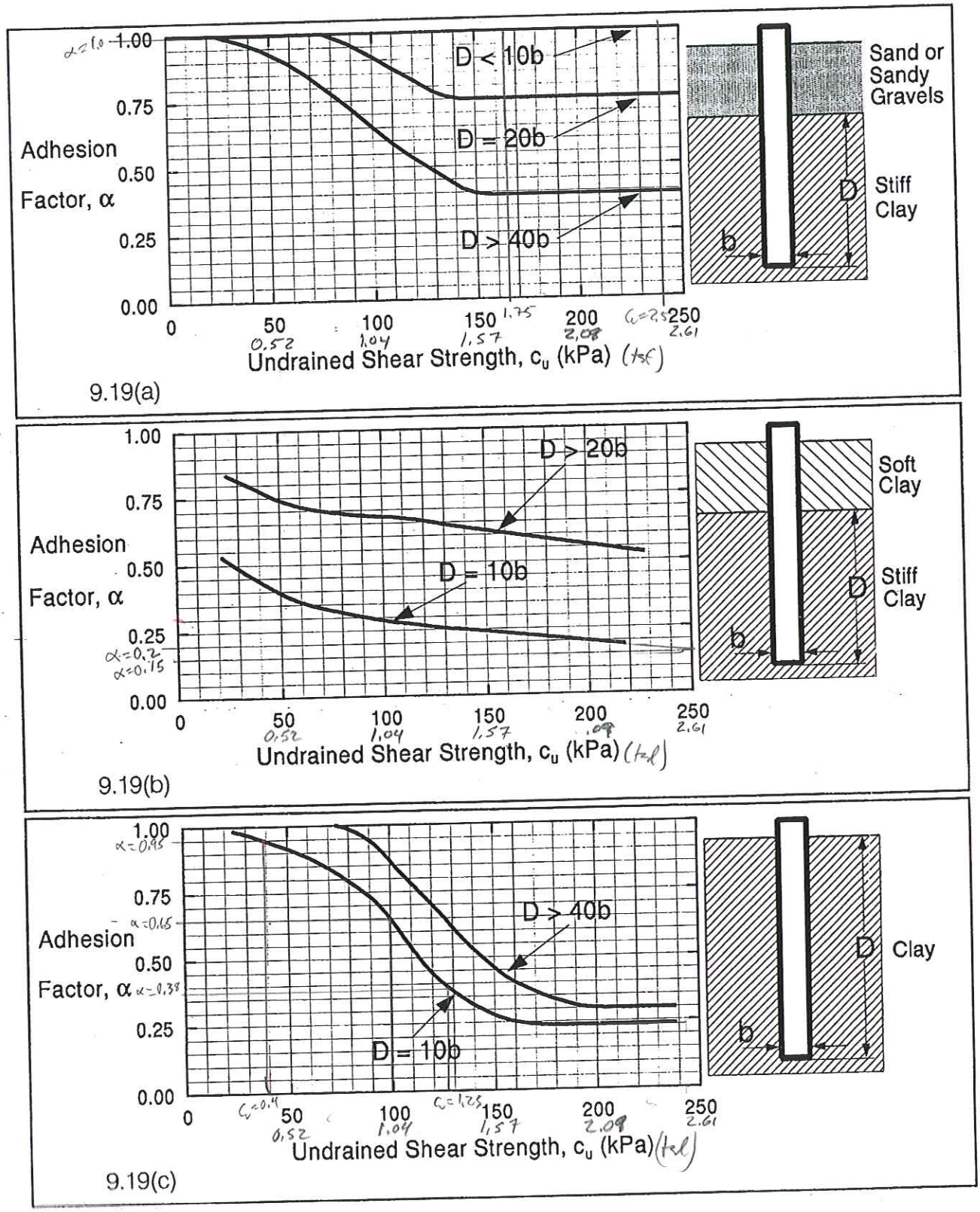


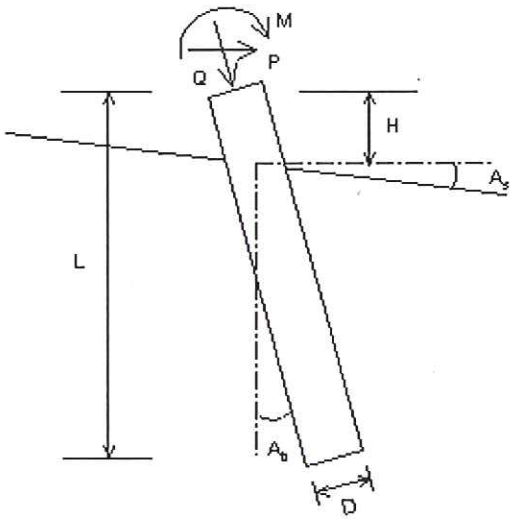
Figure 9.19 Adhesion Factors for Driven Piles in Clay (after Tomlinson, 1980)

VERTICAL ANALYSIS

Figure 1

RKK S7-9

JGT 1-12-09



Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 495.6 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 67.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= -12.4

Fixed Head Condition

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	62.6	0.0	0.80	250.0	0.66	16
10	67.6	0.0	2.0	250	0.61	14
15	67.6	0.0	2.5	300	0.57	24
20	67.6	34.0	0.00	75.0	85.51	30
30	67.6	0.0	3.50	500.0	0.40	36
40	67.6	34.0	0.00	100.0	95.94	60
58	67.6	0.0	5.00	500.0	0.41	34
69	67.6	34.0	0.00	150	95.94	60

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	12.0	15.5	47.7	393.0	29000	0.05
67.0						

Vertical capacity:
Weight above Ground= 0.00 Total Weight= 3.27-kp *Soil Weight is not included
Side Resistance (Down)= 493.600-kp Side Resistance (Up)= 460.652-kp
Tip Resistance (Down)= 2.767-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 496.366-kp Total Ultimate Capacity (Up)= 463.923-kp
Total Allowable Capacity (Down)= 496.366-kp Total Allowable Capacity (Up)= 463.923-kp
OK! Qallow > Q

$A_s = 67'(4\,SF/FT) = 268\,SF$

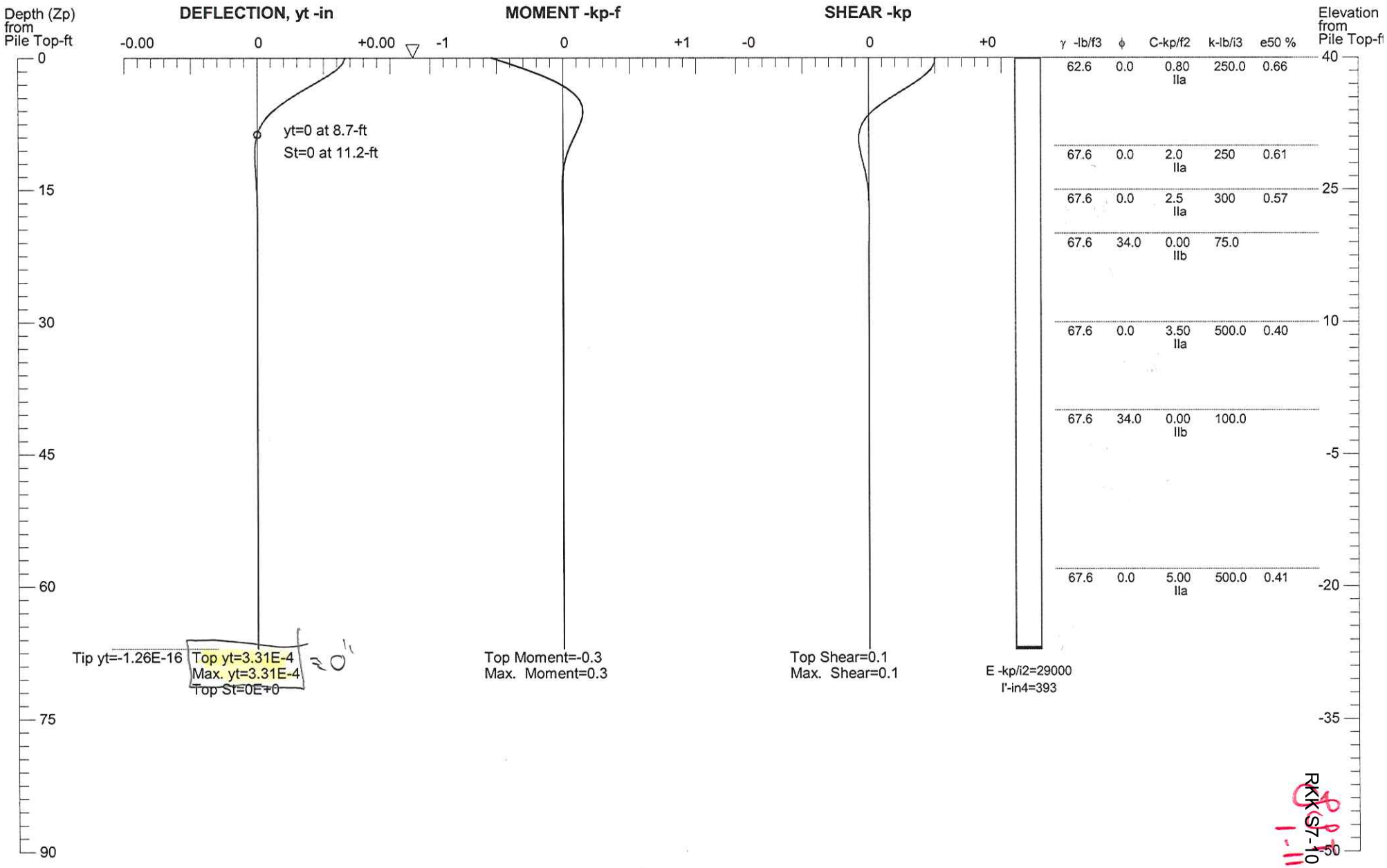
$f_s = \frac{443.6\,K}{268\,SF} = 1.84\,KSF < 1\,tsf \therefore OK$

Settlement Calculation:
At Q= 495.60-kp Settlement= 0.56493-in
At Xallow= 1.00-in Qallow= 424.59628-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH

Single Pile, Khead=5, Kbc=2



RKK (S7-10)

CivilTech Software

SR 1/I-95 Interchange Structure S-7 - Ramp R1 Bridge over SR 7
103-059-27U Abutment A Pile Design HP12x53

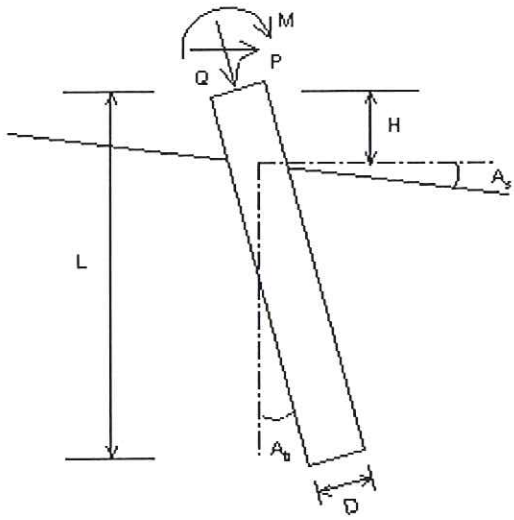
Figure 2

VERTICAL ANALYSIS

Figure 1

RKK-S7-11

JGT 1-11-09



Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 495.6 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 63.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= -12.4

Fixed Head Condition

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	62.6	0.0	0.80	250.0	0.66	16
10	67.6	0.0	2.0	250	0.61	14
15	67.6	0.0	2.5	300	0.57	24
20	67.6	34.0	0.00	75.0	85.51	30
30	67.6	0.0	3.50	500.0	0.40	36
40	67.6	34.0	0.00	100.0	95.94	60
58	67.6	0.0	5.00	500.0	0.41	34
69	67.6	34.0	0.00	150	95.94	60

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	14.6	21.4	56.4	729.0	29000	0.07
63.0						

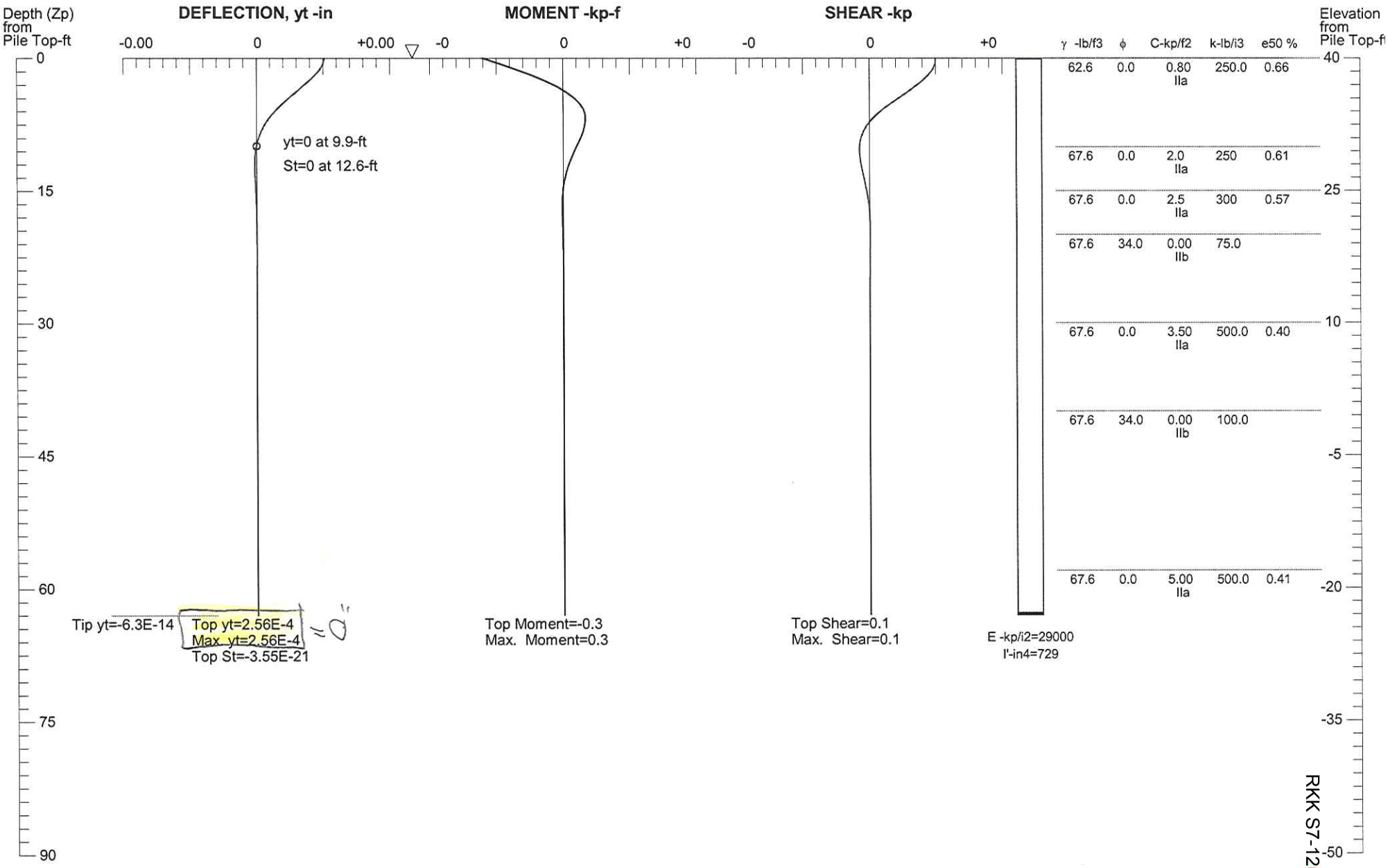
Vertical capacity:
Weight above Ground= 0.00 Total Weight= 4.31-kp *Soil Weight is not included
Side Resistance (Down)= 507.729-kp Side Resistance (Up)= 460.616-kp
Tip Resistance (Down)= 4.655-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 512.384-kp Total Ultimate Capacity (Up)= 464.923-kp
Total Allowable Capacity (Down)= 512.384-kp Total Allowable Capacity (Up)= 464.923-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 495.60-kp Settlement= 0.33868-in
At Xallow= 1.00-in Qallow= 383.80566-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH

Single Pile, Khead=5, Kbc=2



RKK S7-12

JOT 1-11-09

CivilTech Software

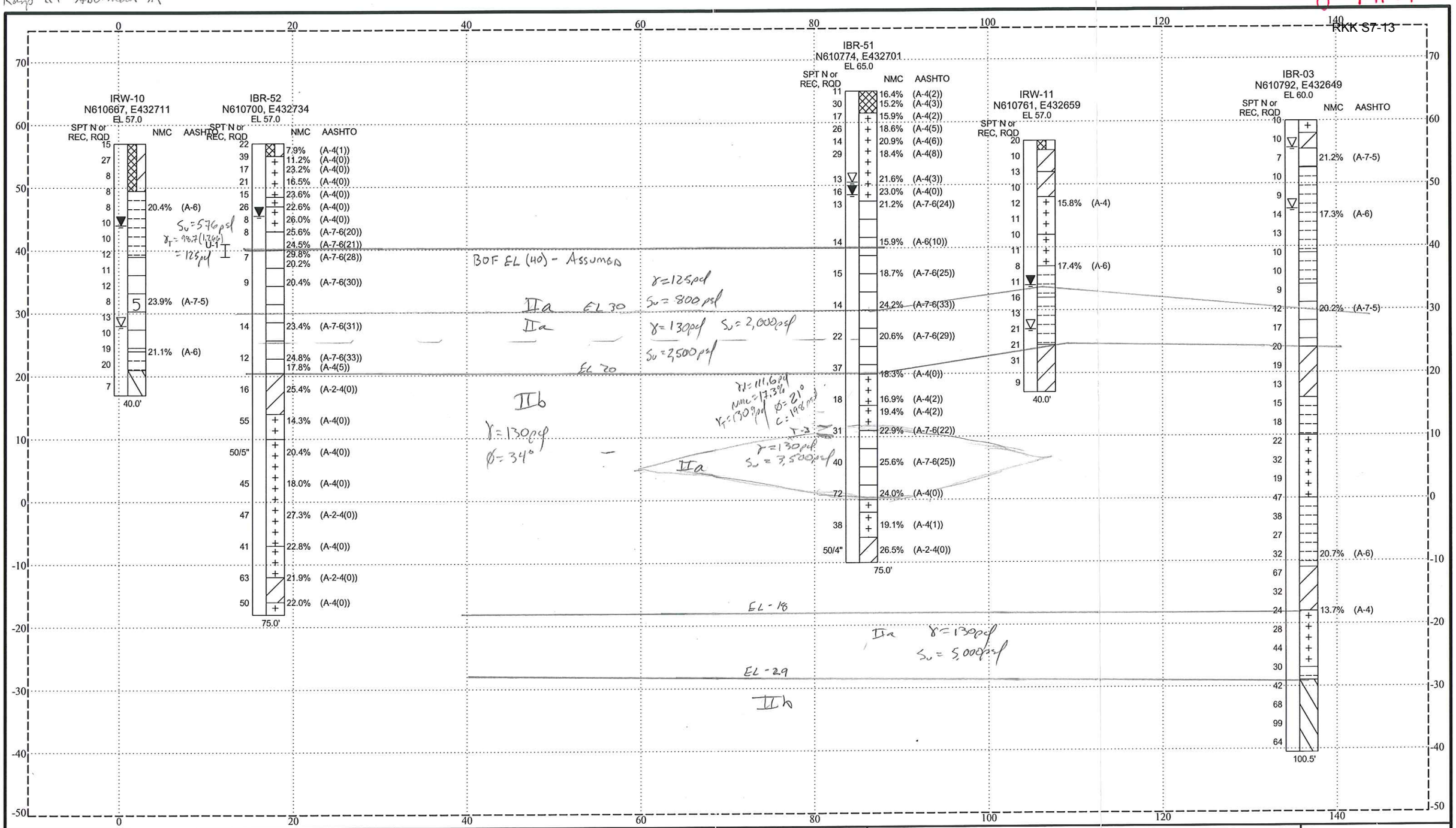
SR 1/I-95 Interchange Structure S-7 - Ramp R1 Bridge over SR 7
103-059-27U Abutment A Pile Design HP14x73

Figure 2

SR1/I-95 Interchange 103-059-27U 12/19/08
Ramp R1 Abutment A

JPT 1-11-09

7



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
Ramp R1 over SR 7 - Abutment A

Figure No. A-4a

Drawn: SAB | Approved: EMK | Date: 12/19/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 12/19/08

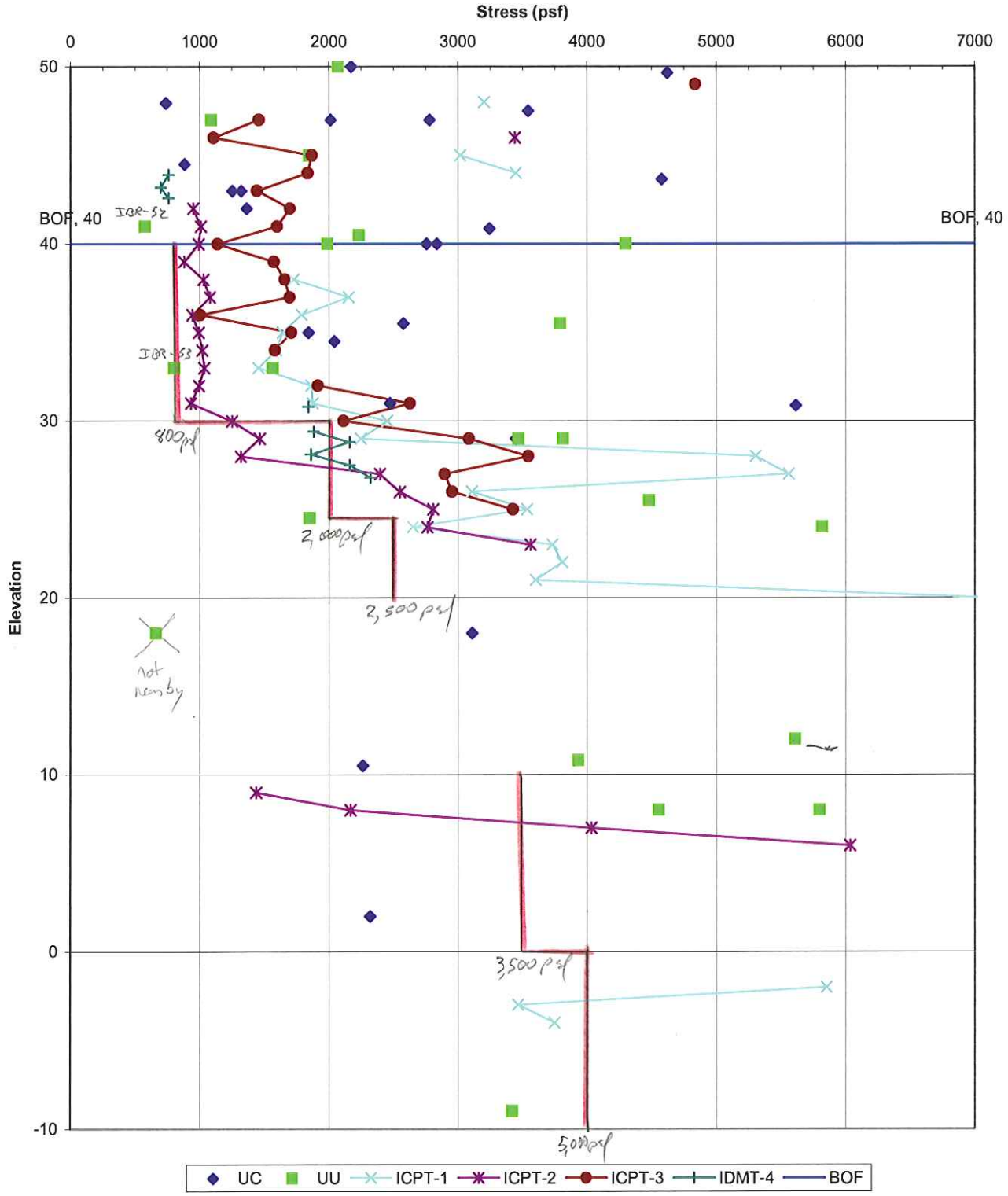
SR1 / I-95 Interchange 103-059-270
12/19/08

7a

JOT 1-11-09

RKK S7-14

Summary of Stratum IIa Undrained Shear Strength
Ramp R1 Bridge (Structure 7)



Abutment B & Wingwalls III & IV: (see page 19 for wingwall calculations)

Soil Strata: See attached force diagram (Abutment B). Borings: IBR-1, 49, 54. (p. 13)

* Assume Bottom of Footing (Top of Pile) Elevation = EL 39 (See attached Plan/Profile, p. 14)

Stratum	Approx. EL (ft)	Av. N-value	γ_T (pcf)	ϕ (deg)	c (psf)	S_u (psf)	k (pci) * → See pages 15-16
IIa	39-28	13	130	–	–	1,000	250
IIa	28-18	23	125	–	–	2,500	250
IIb	18-13	33	130	34	–	–	75
IIa	13-12	39	130	–	–	3,500	300
IIb	-12→...	60+	130	34	–	–	100
Water	~40		62.4				

From AASHTO, p. 10-88, $\phi_{dyn}(R_n) = \phi_{stat}(R_{nstat})$, $\phi_{dyn} = 0.65$, $\phi_{stat} = 0.35$ (See p. 17-18)

⇒ Use Factored Load in AllPile: File = Abutment B Pile Design.alp (See attached pages 9-12)

Loads: Strength Resistance = 173.45^k (From Structures, 12/11/08, p. 2a)
Service Resistance = 119.31^k
Lateral Load = 0^k 4(H):12(V) Batter = 18.4°

⇒ Factored Load = 187.3^k = $\phi_{stat} R_n$ ⇒ R_n = 173.45^k/0.35 = 495.6^k → For axial analysis

→ Evaluate for HP 12x53 & HP14x73

⇒ For HP12x53, required pile length = L = 57' (see p. 9-10)

For HP14x73, required pile length = L = 47' (see p. 11-12)

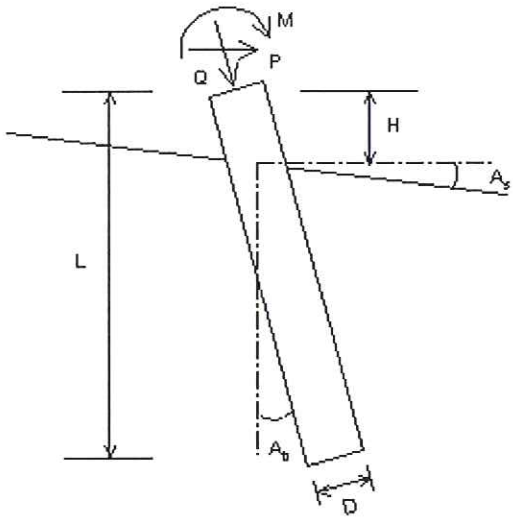
For Plans/WEAP:

R_n = 173.5^k/0.65 = 267^k
ϕ_{dyn}

VERTICAL ANALYSIS

Figure 1

RKK S7-16 JJT 1-11-09



Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 495.6 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 57.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= -18.4

Fixed Head Condition

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	67.6	0.0	1	250	0.75	13
11	62.6	0.0	2.5	250	0.53	23
21	67.6	34	0.00	75	68.44	33
26	67.6	0	3.5	300	0.38	39
51	67.6	34	0.00	100	95.94	60

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	12.0	15.5	47.7	393.0	29000	0.05
57.0						

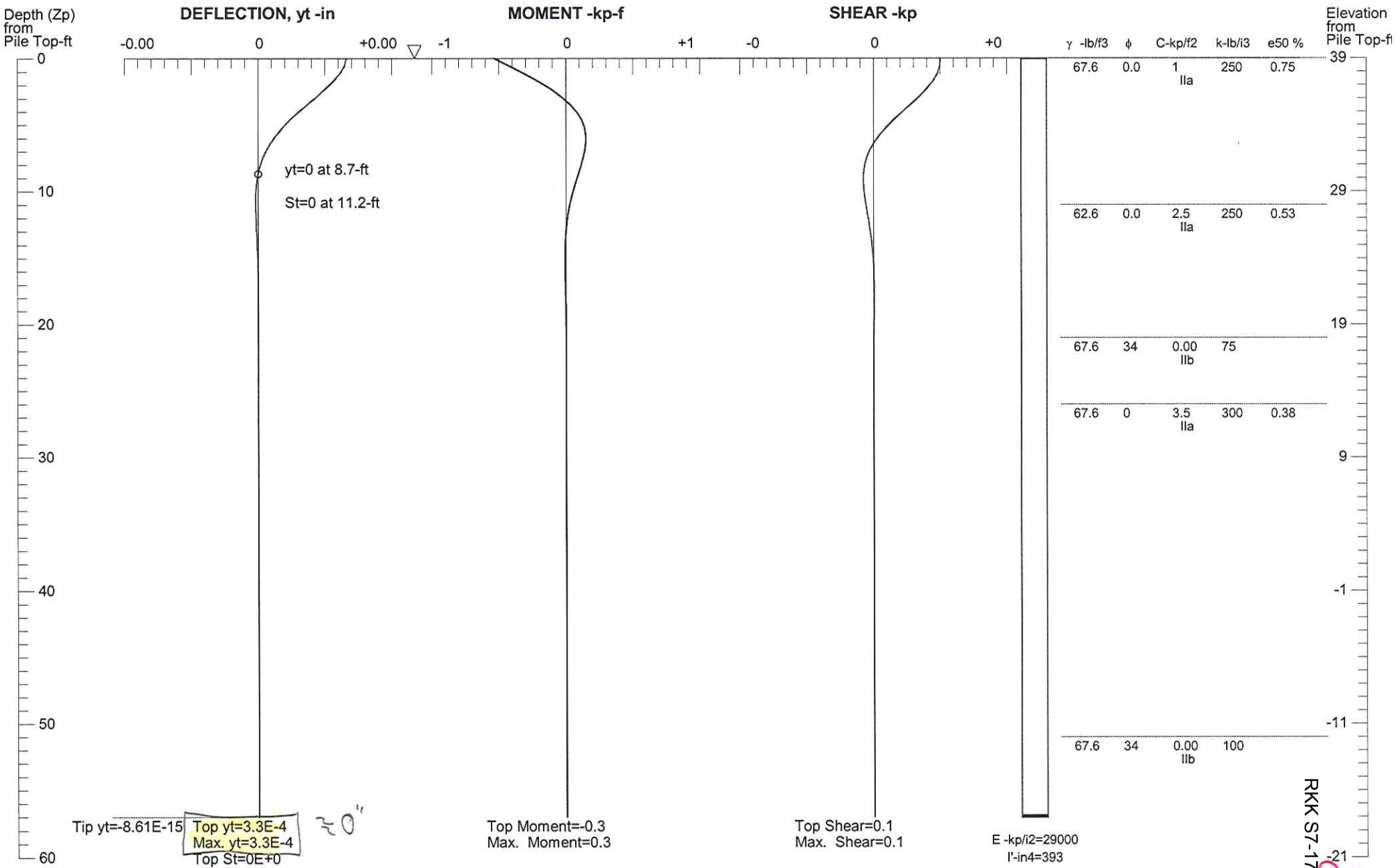
Vertical capacity:
Weight above Ground= 0.00 Total Weight= 2.70-kp *Soil Weight is not included
Side Resistance (Down)= 491.022-kp Side Resistance (Up)= 478.383-kp
Tip Resistance (Down)= 5.532-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 496.554-kp Total Ultimate Capacity (Up)= 481.087-kp
Total Allowable Capacity (Down)= 496.554-kp Total Allowable Capacity (Up)= 481.087-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 495.60-kp Settlement= 0.44313-in
At Xallow= 1.00-in Qallow= 99999.00000-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH

Single Pile, Khead=5, Kbc=2



RKK S7-17

JDT 1-11-09

CivilTech Software

SR 1/I-95 Interchange Structure S-7 - Ramp R1 Bridge over S2 7
103-059-27U Abutment B Pile Design HP12x53

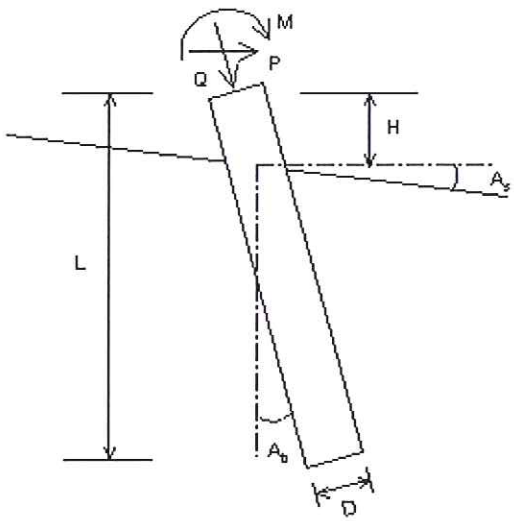
Figure 2

10

VERTICAL ANALYSIS

Figure 1

RKK S7-18 JJT 1-11-09



Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 495.6 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 47.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= -18.4

Fixed Head Condition

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	67.6	0.0	1	250	0.75	13
11	62.6	0.0	2.5	250	0.53	23
21	67.6	34	0.00	75	68.44	33
26	67.6	0	3.5	300	0.38	39
51	67.6	34	0.00	100	95.94	60

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	14.6	21.4	56.4	729.0	29000	0.07
47.0						

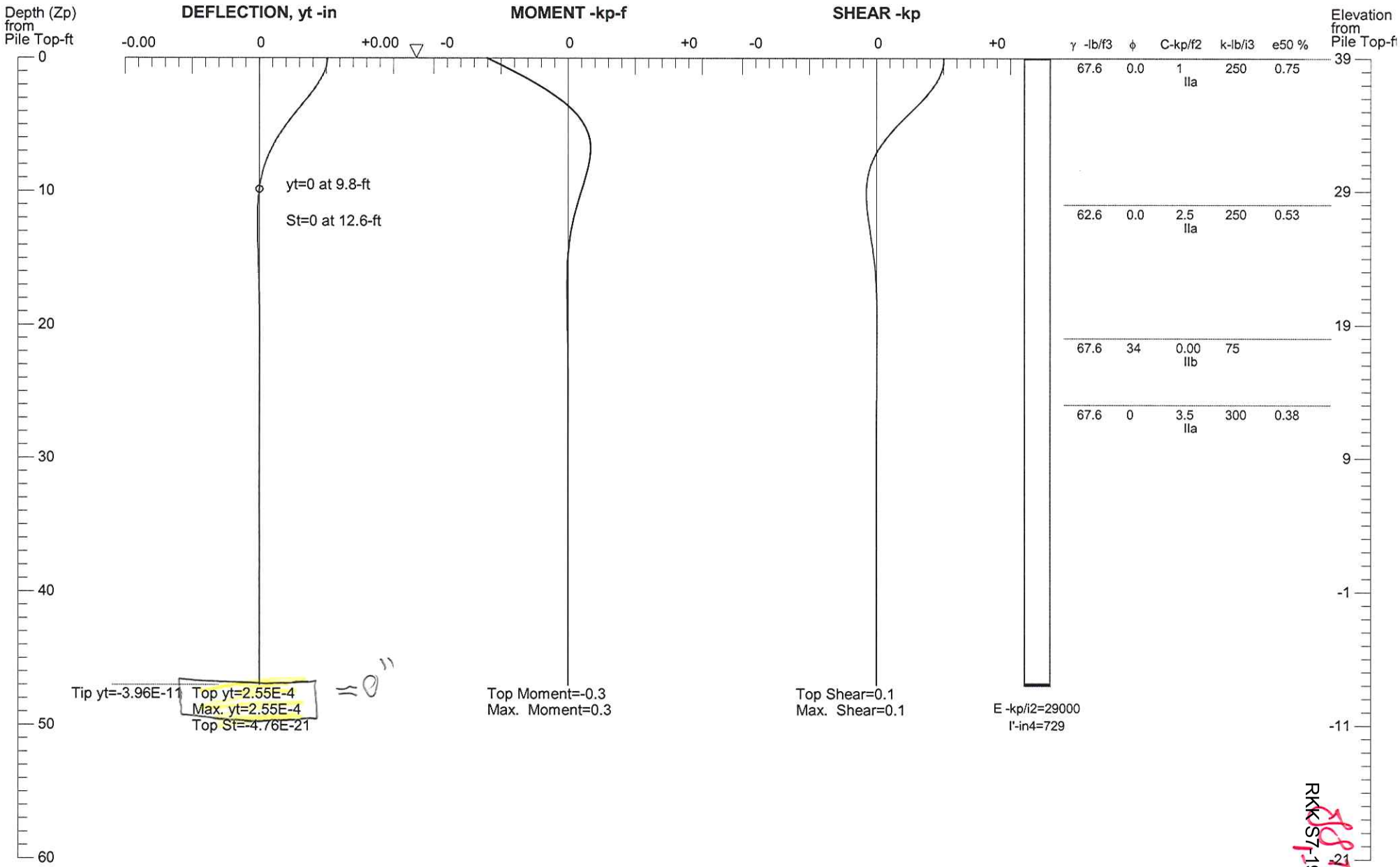
Vertical capacity:
Weight above Ground= 0.00 Total Weight= 3.12-kp *Soil Weight is not included
Side Resistance (Down)= 502.937-kp Side Resistance (Up)= 494.889-kp
Tip Resistance (Down)= 3.309-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 506.246-kp Total Ultimate Capacity (Up)= 498.011-kp
Total Allowable Capacity (Down)= 506.246-kp Total Allowable Capacity (Up)= 498.011-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 495.60-kp Settlement= 0.29639-in
At Xallow= 1.00-in Qallow= 377.44476-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH

Single Pile, Khead=5, Kbc=2



RKK S7-191-09

CivilTech Software

SR 1/I-95 Interchange Structure S-7 - Ramp R1 Bridge over SR 7
103-059-27U Abutment B Pile Design HP14x73

Figure 2

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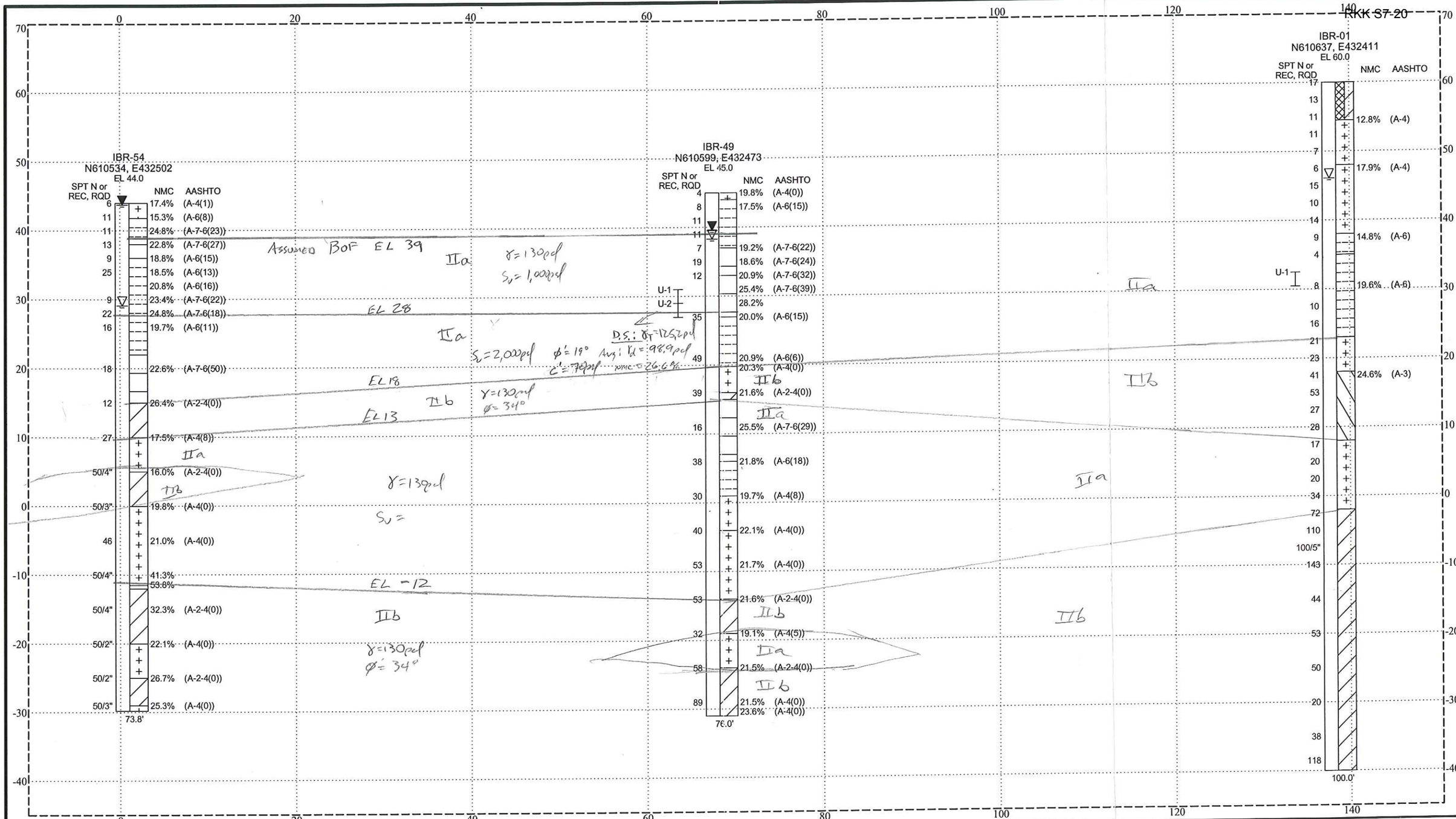
PGT-11-09



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

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Consulting Engineers
81 Mosher Street,
Baltimore, MD 21217
(410) 728-2900

Title: Summary of Boring Data

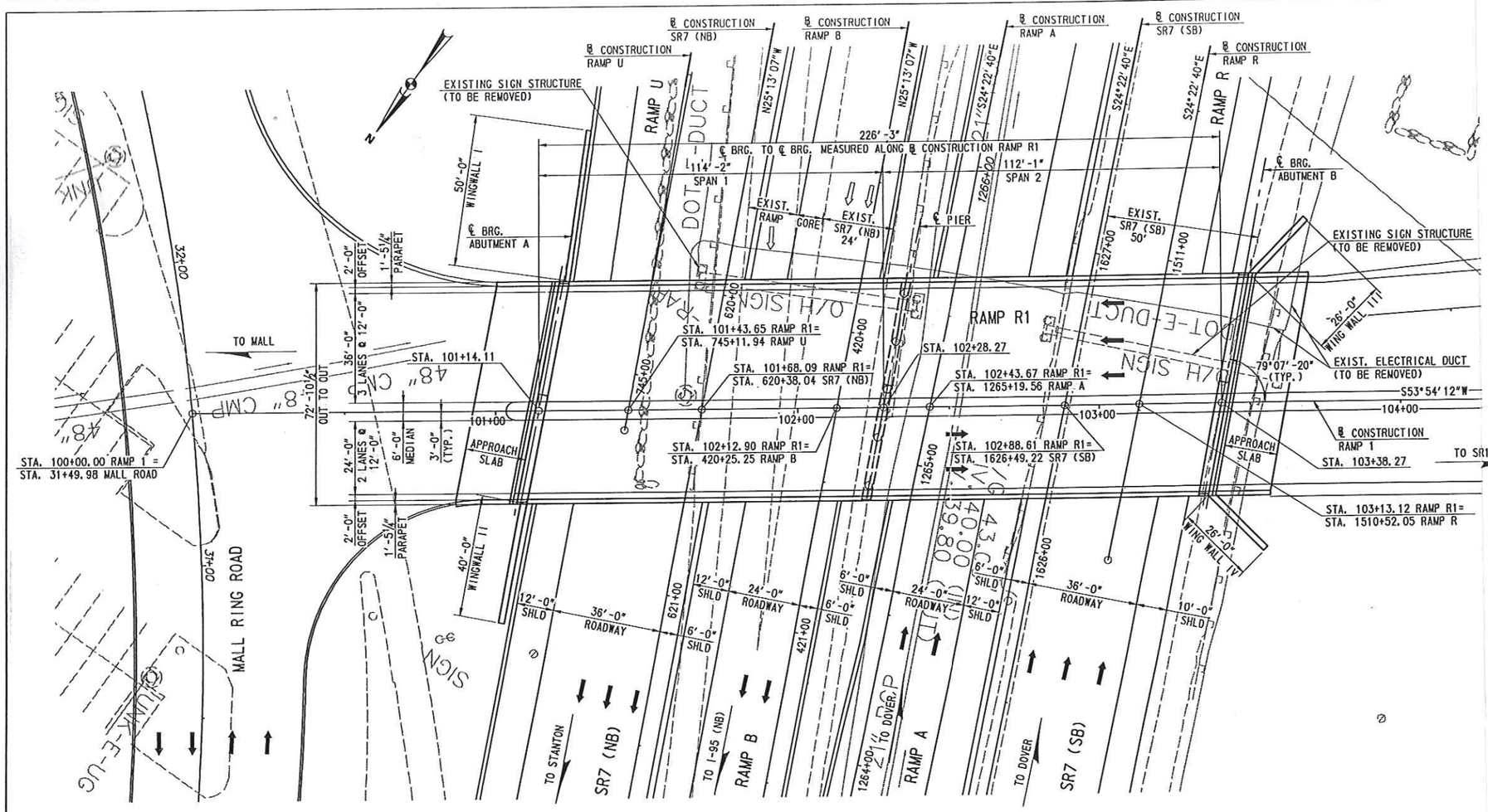
S7: Ramp R1 over SR 7 - Abutment B

Figure No. A-4c

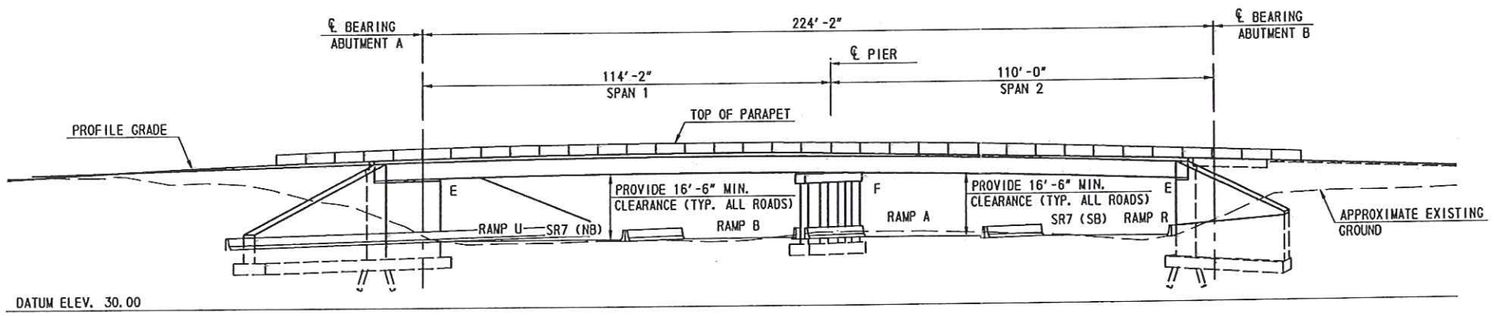
Drawn: SAB | Approved: EMK | Date: 12/19/08 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 12/19/08

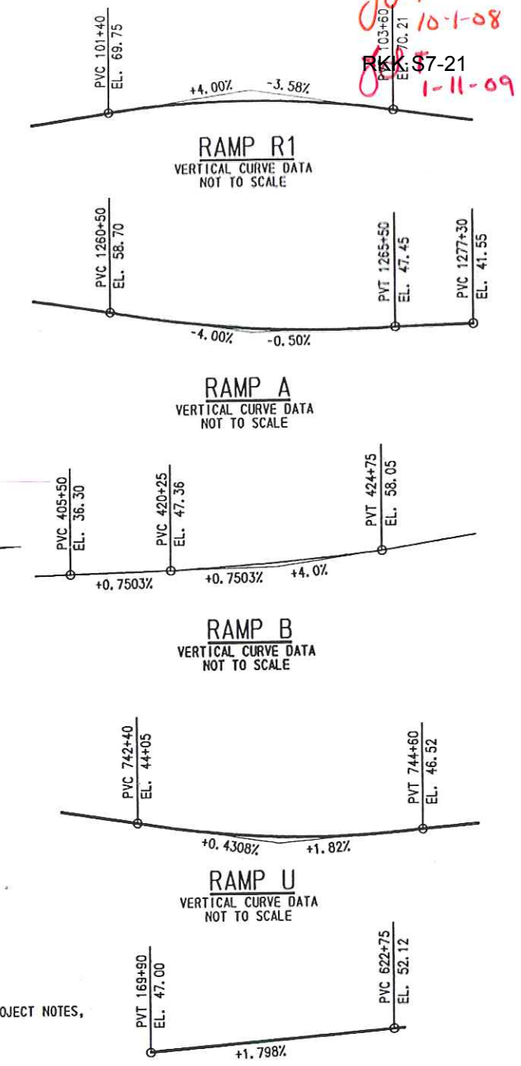
SBT 10-1-08
RKK S7-21
1-11-09



PLAN
SCALE: 1"=20'



ELEVATION
SCALE: 1"=20'



NOTES:
1. FOR GENERAL NOTES AND PROJECT NOTES, SEE DWG. NO. S2-102.

0 10 20 30 40 80
SCALE IN FEET

DELAWARE DEPARTMENT OF TRANSPORTATION	ADDENDUMS / REVISIONS	SR 1 MALL INTERCHANGE	CONTRACT 28-090-03	BRIDGE NO. XXX-XXX	RAMP R1 OVER SR-7 GENERAL PLAN AND ELEVATION	SHEET NO. X
			COUNTY NEW CASTLE	DESIGNED BY: JSW		TOTAL SHTS. X
				CHECKED BY: XXX		

S7-01

2:30:35 PM
9/22/2008
P:\projects\2003\03059_deltrans\preliminary\roadway\ce701_Bridge R1_sr1.dgn
PCF03059_SRW.dgn

JJT 10-1-08 15
JJT 1-11-09
RKK S7-22

TABLE 3.5. TERZAGHI'S RECOMMENDATIONS FOR VALUES OF k FOR LATERALLY LOADED PILES IN SAND

Relative Density of Sand	Loose	Medium	Dense
Dry or moist, k, MN/m^3 ($lb/in.^3$)	0.95-2.8 (3.5 - 10.4)	3.5-10.9 (13.0 - 40.0)	13.8-27.7 (51.0 - 102.0)
Submerged sand, k, MN/m^3 ($lb/in.^3$)	0.57-1.7 (2.1 - 6.4)	2.2- 7.3 (8.0 - 27.0)	8.7-17.9 (32.0 - 64.0)

TABLE 3.6. REPRESENTATIVE VALUES OF k FOR SUBMERGED SAND

RELATIVE DENSITY	LOOSE	MEDIUM	DENSE
Recommended k MN/m^3 ($lb/in.^3$)	5.4 (20.0)	16.3 (60.0)	34 (125.0)

TABLE 3.7. REPRESENTATIVE VALUES OF k FOR SAND ABOVE WATER TABLE (Static and Cyclic Loading)

RELATIVE DENSITY	LOOSE	MEDIUM	DENSE
Recommended k MN/m^3 ($lb/in.^3$)	6.8 (25.0)	24.4 (90.0)	61.0 (225.0)

TABLE 3.1. TERZAGHI'S RECOMMENDATIONS FOR SOIL MODULUS α_T FOR LATERALLY LOADED PILES IN STIFF CLAY

Consistency of Clay	Stiff	Very Stiff	Hard
q_u, kPa (T/sq ft)	100-200 (1 - 2)	200-400 (2 - 4)	> 400 (> 4)
α_T, MPa (lb/sq in.)	3.2-6.4 (460-925)	6.4-12.8 (925-1850)	12.8 up (1850 up)

TABLE 3.2. REPRESENTATIVE VALUES OF ε_{50}

Consistency of Clay	ε_{50}
Soft	0.020
Medium	0.010
Stiff	0.005

TABLE 3.3. REPRESENTATIVE VALUES OF k FOR STIFF CLAYS

	AVERAGE UNDRAINED SHEAR STRENGTH* kPa		
	50-100	100-200	300-400
	1-2 ksf	2-4 ksf	6-8 ksf
k_s (static) MN/m^3 (lb/in.^{3})	135 (500)	270 (1000)	540 (2000)
k_c (cyclic) MN/m^3 (lb/in.^{3})	55 (200)	110 (400)	540 (2000)

*The average shear strength should be computed from the shear strength of the soil to a depth of 5 pile diameters. It should be defined as half the total maximum principal stress difference in an unconsolidated undrained triaxial test.

TABLE 3.4. REPRESENTATIVE VALUES OF ε_{50} FOR STIFF CLAYS

kPa/ATEK

	AVERAGE UNDRAINED SHEAR STRENGTH kPa		
	50-100	100-200	300-400
	1-2	2-4	5-6
ε_{50}	0.007	0.005	0.004

JJT 10-1-08 JJT 7-21-09 17

RKK S7-24

Table 10.5.5.2.3-1 Resistance Factors for Driven Piles.

Condition/Resistance Determination Method		Resistance Factor
Nominal Resistance of Single Pile in Axial Compression—Dynamic Analysis and Static Load Test Methods, φ_{dyn}	Driving criteria established by static load test(s); quality control by dynamic testing and/or calibrated wave equation, or minimum driving resistance combined with minimum delivered hammer energy from the load test(s). For the last case, the hammer used for the test pile(s) shall be used for the production piles.	Values in Table 2
	Driving criteria established by dynamic test with signal matching at beginning of redrive conditions only of at least one production pile per pier, but no less than the number of tests per site provided in Table 3. Quality control of remaining piles by calibrated wave equation and/or dynamic testing.	0.65 SEE TABLE 3
	Wave equation analysis, without pile dynamic measurements or load test, at end of drive conditions only	0.40
	FHWA-modified Gates dynamic pile formula (End of Drive condition only)	0.40
	Engineering News Record (as defined in Article 10.7.3.8.5) dynamic pile formula (End of Drive condition only)	0.10 LRFD ONLY

SEE PAGE 10-88

$$\phi_{dyn}(R_n) = \phi_{stat}(R_{n\,stat})$$

BASED ON CALC'S

SEE TABLE 1

$$\frac{\text{FACT LOAD}}{\#\text{ OF PILES}} = \phi_c P_n$$

6.9.2.1

SEE TABLE 1

$$R_n = \frac{\phi_{stat}}{\phi_{dyn}}(R_{n\,stat})$$

IF NON-REDUNDANT: REDUCE FACTORS BY 20%

SEE PAGE 10-33

JST 10-1-08 JST 1-11-08 RKK S7-25 C10.7.3.3-1

Table 10.5.5.2.3-1 Resistance Factors for Driven Piles (continued). $\phi_{dyn}(R_n) = \phi_{stat}(R_{n\,stat})$

Condition/Resistance Determination Method		Resistance Factor
Nominal Resistance of Single Pile in Axial Compression—Static Analysis Methods, φ_{stat}	Skin Friction and End Bearing: Clay and Mixed Soils	
	α-method (*Tomlinson, 1987*; *Skempton, 1951*)	0.35
	β-method (*Esrig & Kirby, 1979*; *Skempton, 1951*)	0.25
	λ-method (*Vijayvergiya & Focht, 1972*; *Skempton, 1951*)	0.40
	Skin Friction and End Bearing: Sand	
	Nordlund/Thurman Method (*Hannigan et al., 2005*)	0.45
	SPT-method (Meyerhof)	0.30
	CPT-method (Schmertmann)	0.50
	End bearing in rock (*Canadian Geotech. Society, 1985*)	0.45
Block Failure, φ_{bl}	Clay	0.60
Uplift Resistance of Single Piles, φ_{up}	Nordlund Method	0.35
	α-method	0.25
	β-method	0.20
	λ-method	0.30
	SPT-method	0.25
	CPT-method	0.40
	Load test	0.60
Group Uplift Resistance, φ_{ug}	Sand and clay	0.50
Horizontal Geotechnical Resistance of Single Pile or Pile Group	All soils and rock	1.0
Structural Limit State	Steel piles: See the provisions of Article 6.5.4.2	
	Concrete piles: See the provisions of Article 5.5.4.2.1	
	Timber piles: See the provisions of Article 8.5.2.2 and 8.5.2.3	
Pile Drivability Analysis, φ_{da} 10.7.8	Steel piles: See the provisions of Article 6.5.4.2	
	Concrete piles: See the provisions of Article 5.5.4.2.1	
	Timber piles: See the provisions of Article 8.5.2.2	
	In all three Articles identified above, use φ identified as "resistance during pile driving"	

Table 10.5.5.2.3-2 Relationship between Number of Static Load Tests Conducted per Site and φ (after *Paikowsky et al., 2004*).

Number of Static Load Tests per Site	Resistance Factor, φ — Site Variability[a]		
	Low[a]	Medium[a]	High[a]
1	0.80	0.70	0.55
2	0.90	0.75	0.65
3	0.90	0.85	0.75
≥4	0.90	0.90	0.80
	COV < 25%	COV ≥ 25% < 40%	COV ≥ 40%

a See commentary.

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Subject I-95/SR1 Interchange — Page 19 of
S7 Ramp R1 Bridge Wingwall Foundations — Cm. No. 103-059-27U
Prepared By SAB Date 9/30/06 Checked By JDT Date 10-1-08
REV 12/22/06 JDT 1-11-09

Wingwalls: * Wingwalls I & II are at Abutment A and are based on that soil profile (see p. 2) – Assume some BOF EL (EL 40)

* Wingwalls III & IV are at Abutment B and are based on that soil profile. (see p. 8) – Assume some BOF EL (EL 39)
* Evaluate for HP12x53 & HP14x73 piles.

Loads: Same for all 4 wingwalls. (See p. 2b)

Strength Resistance = 180.1^k ?
Service Resistance = 122.6^k
Lateral (Service) Load = 0^k

* 4(H):12(V) Batter = 18.4°

From AASHTO p. 10-88, $\phi_{dyn} R_n = \phi_{stat} R_{resist}$; $\phi_{dyn} = 0.65$, $\phi_{stat} = 0.35$ (See p. 17-18)

→ Use Factored Loads in AllPile; Files: Wingwalls I and II Pile Design HP 12x53.alp
Wingwalls I and II Pile Design HP 14x73.alp
" III and IV " " HP 12x53.alp
" III and IV " " HP 14x73.alp

Factored Load = 180.1^k = $\phi_{stat} R_n$ = 180.1^k/0.35 = 514.6^k

R_N = 180.1^k/0.65 = 277^k for Plans/WEAP

Summary of Results:

Structure	Pile	Required Length	Pile Tip EL	Pages
Wingwalls I & II	HP12x53	66'	-29	20-21
Wingwalls I & II	HP14x73	64'	-25	22-23
Wingwalls III & IV	HP12x53	65'	-26	24-25
Wingwalls III & IV	HP14x73	48'	-9	26-27

* Use HP 14x73 use Common depth w/ Abutments for Tip EL + Length.

See Summary Sheet for rec. Lengths + Tip EL.

VERTICAL ANALYSIS

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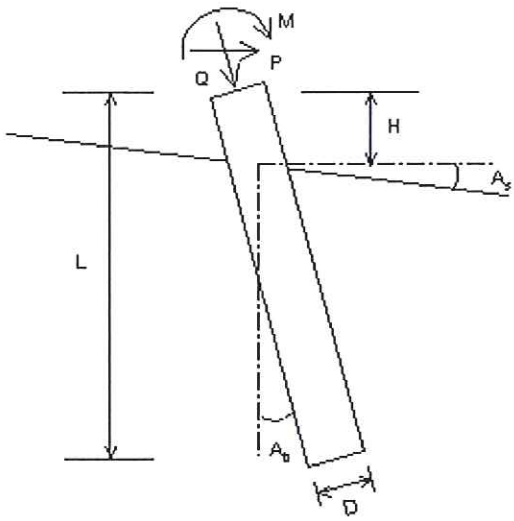
Figure 1

RKK S7-27



Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 514.6 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length L= 68.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= -12.4

Fixed Head Condition

Abutment A Wing Walls

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	62.6	0.0	0.80	250.0	0.66	16
10	67.6	0.0	2.0	250	0.61	14
15	67.6	0.0	2.5	300	0.57	24
20	67.6	34.0	0.00	75.0	85.51	30
30	67.6	0.0	3.50	500.0	0.40	36
40	67.6	34.0	0.00	100.0	95.94	60
58	67.6	0.0	5.00	500.0	0.41	34
69	67.6	34.0	0.00	150	95.94	60

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	12.0	15.5	47.7	393.0	29000	0.05
68.0						

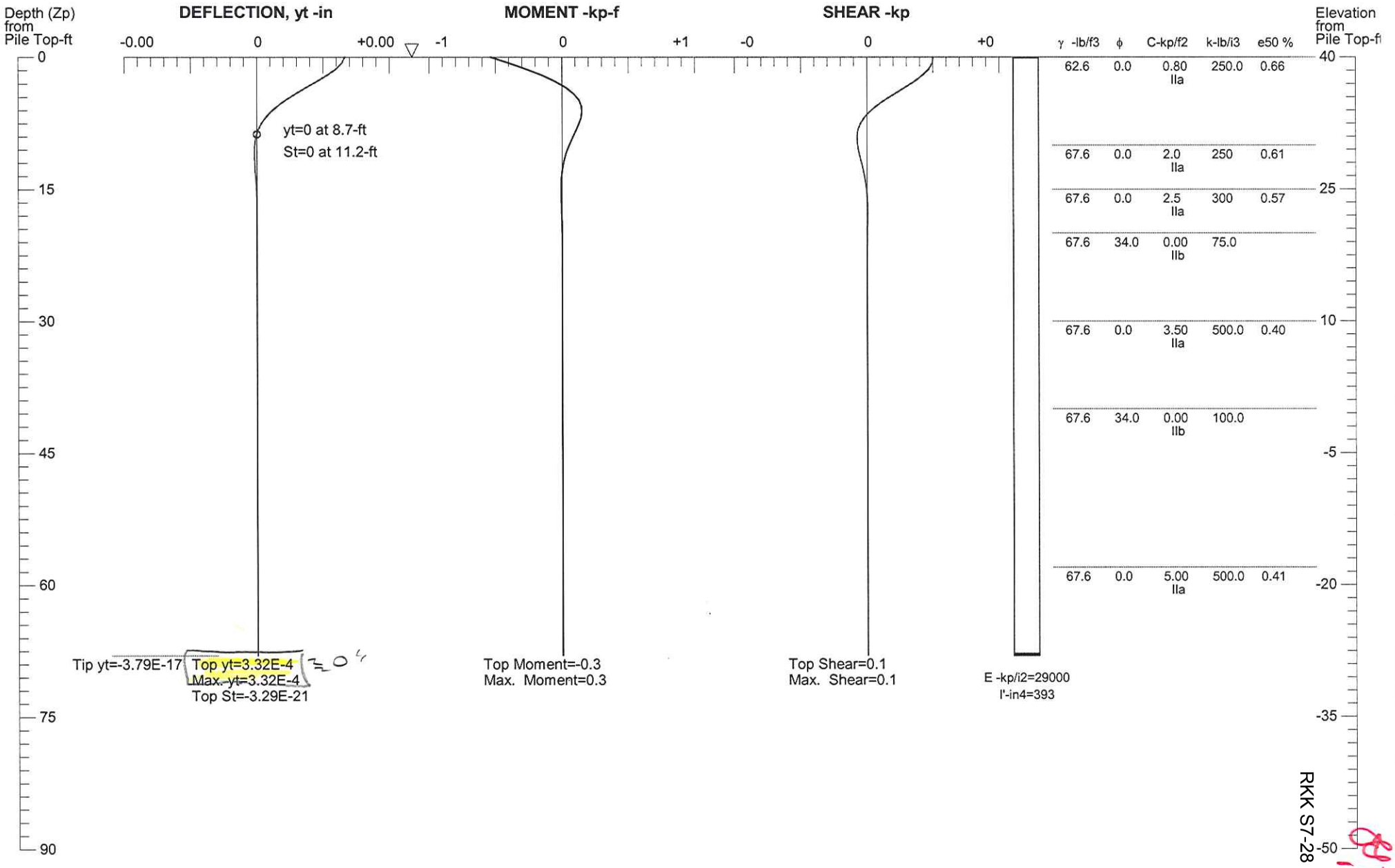
Vertical capacity:
Weight above Ground= 0.00 Total Weight= 3.32-kp *Soil Weight is not included
Side Resistance (Down)= 512.363-kp Side Resistance (Up)= 479.360-kp
Tip Resistance (Down)= 3.624-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 515.987-kp Total Ultimate Capacity (Up)= 482.681-kp
Total Allowable Capacity (Down)= 515.987-kp Total Allowable Capacity (Up)= 482.681-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 514.60-kp Settlement= 0.59175-in
At Xallow= 1.00-in Qallow= 446.13284-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH

Single Pile, Khead=5, Kbc=2



RKK S7-28

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SR 1/I-95 Interchange Structure S-7 - Ramp R1 Bridge over S

103-059-27U Wingwalls I & II Pile Design HP12x53

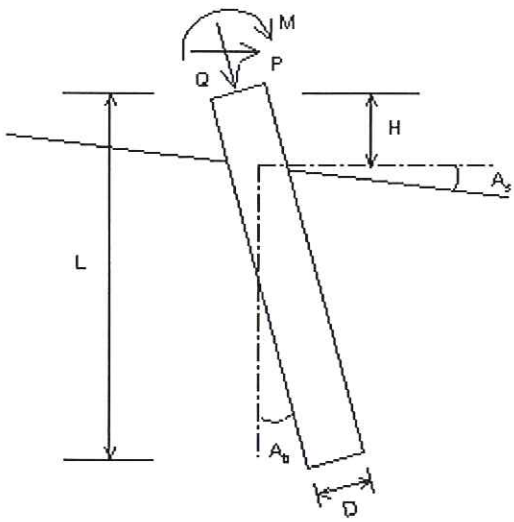
Figure 2

VERTICAL ANALYSIS

JJT 1-11-09

Figure 1

RKK S7-29



Driving Steel Pile (Open end)

Loads:

Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 514.6 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:

Pile Length, L= 64.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= -12.4

Fixed Head Condition

Abutment A Wing walls

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	62.6	0.0	0.80	250.0	0.66	16
10	67.6	0.0	2.0	250	0.61	14
15	67.6	0.0	2.5	300	0.57	24
20	67.6	34.0	0.00	75.0	85.51	30
30	67.6	0.0	3.50	500.0	0.40	36
40	67.6	34.0	0.00	100.0	95.94	60
58	67.6	0.0	5.00	500.0	0.41	34
69	67.6	34.0	0.00	150	95.94	60

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	14.6	21.4	56.4	729.0	29000	0.07
64.0						

Vertical capacity:

Weight above Ground= 0.00 Total Weight= 4.38-kp *Soil Weight is not included
Side Resistance (Down)= 530.622-kp Side Resistance (Up)= 483.409-kp
Tip Resistance (Down)= 4.351-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 534.972-kp Total Ultimate Capacity (Up)= 487.785-kp
Total Allowable Capacity (Down)= 534.972-kp Total Allowable Capacity (Up)= 487.785-kp
OK! Qallow > Q

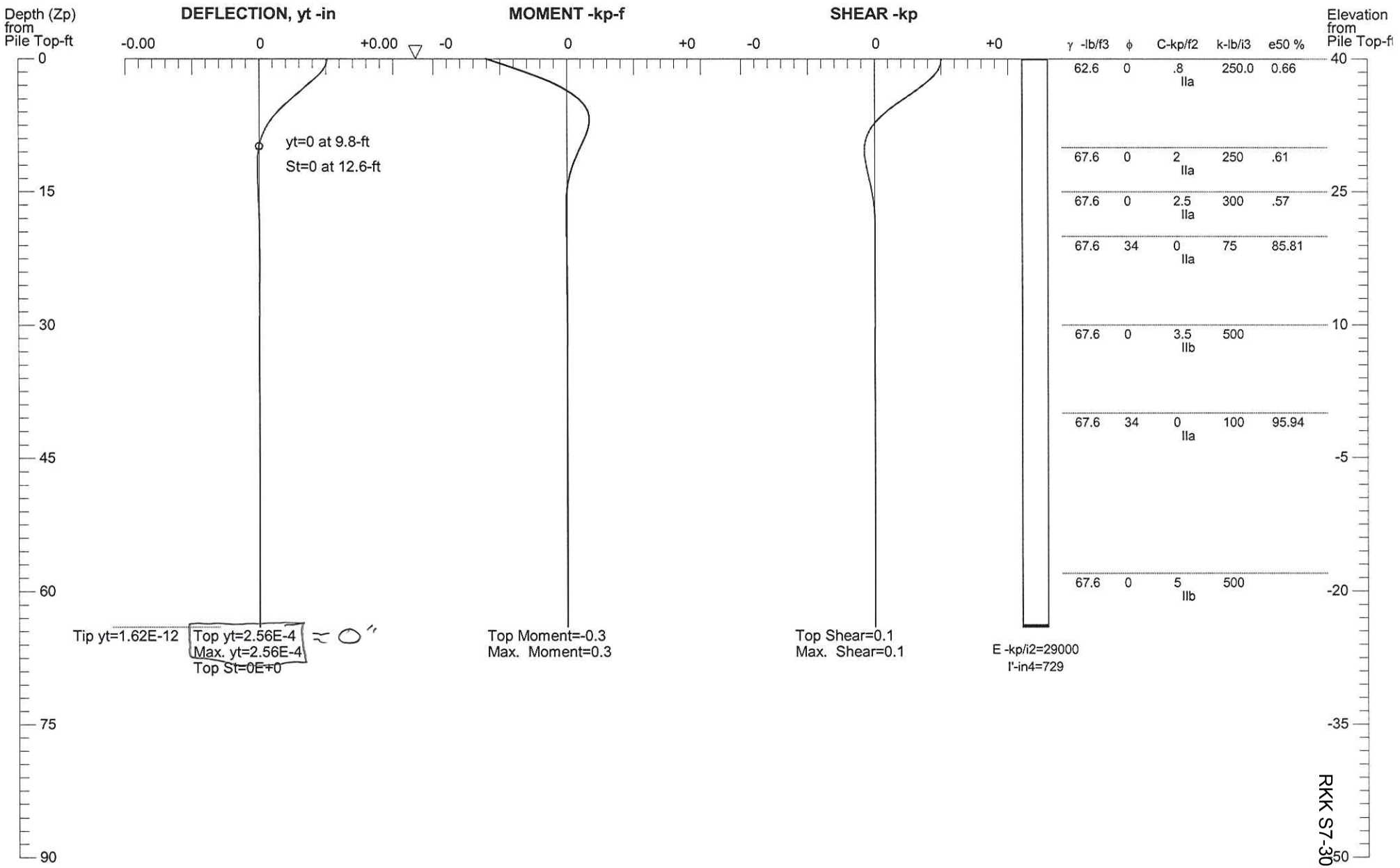
Settlement Calculation:

At Q= 514.60-kp Settlement= 0.36174-in
At Xallow= 1.00-in Qallow= 415.15744-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH

Single Pile, Khead=5, Kbc=2



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SR 1/I95 Interchange Structure S7 - Ramp R1 Bridge over SR7
103-059-27U Wingwalls I and II Pile Design HP14x73

Figure 2

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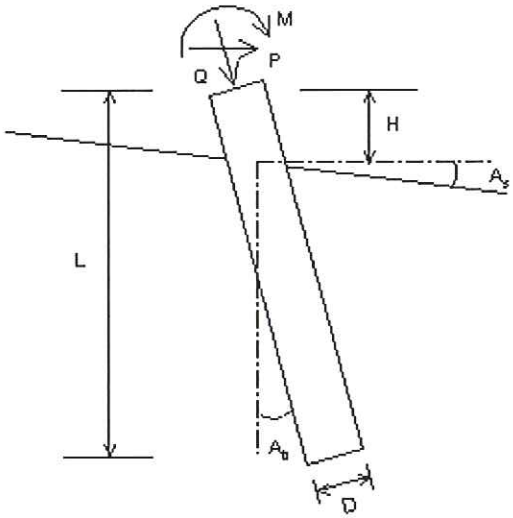
VERTICAL ANALYSIS

JJT 1-11-09

Figure 1

RKK S7-31



Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 514.6 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 65.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= -18.4

Fixed Head Condition

Abutment B Wing Walls

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	67.6	0.0	1	250	0.75	13
11	62.6	0.0	2.5	250	0.53	23
21	67.6	34	0.00	75	68.44	33
26	67.6	0	3.5	300	0.38	39
51	67.6	34	0.00	100	95.94	60

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	12.0	15.5	47.7	393.0	29000	0.05
65.0						

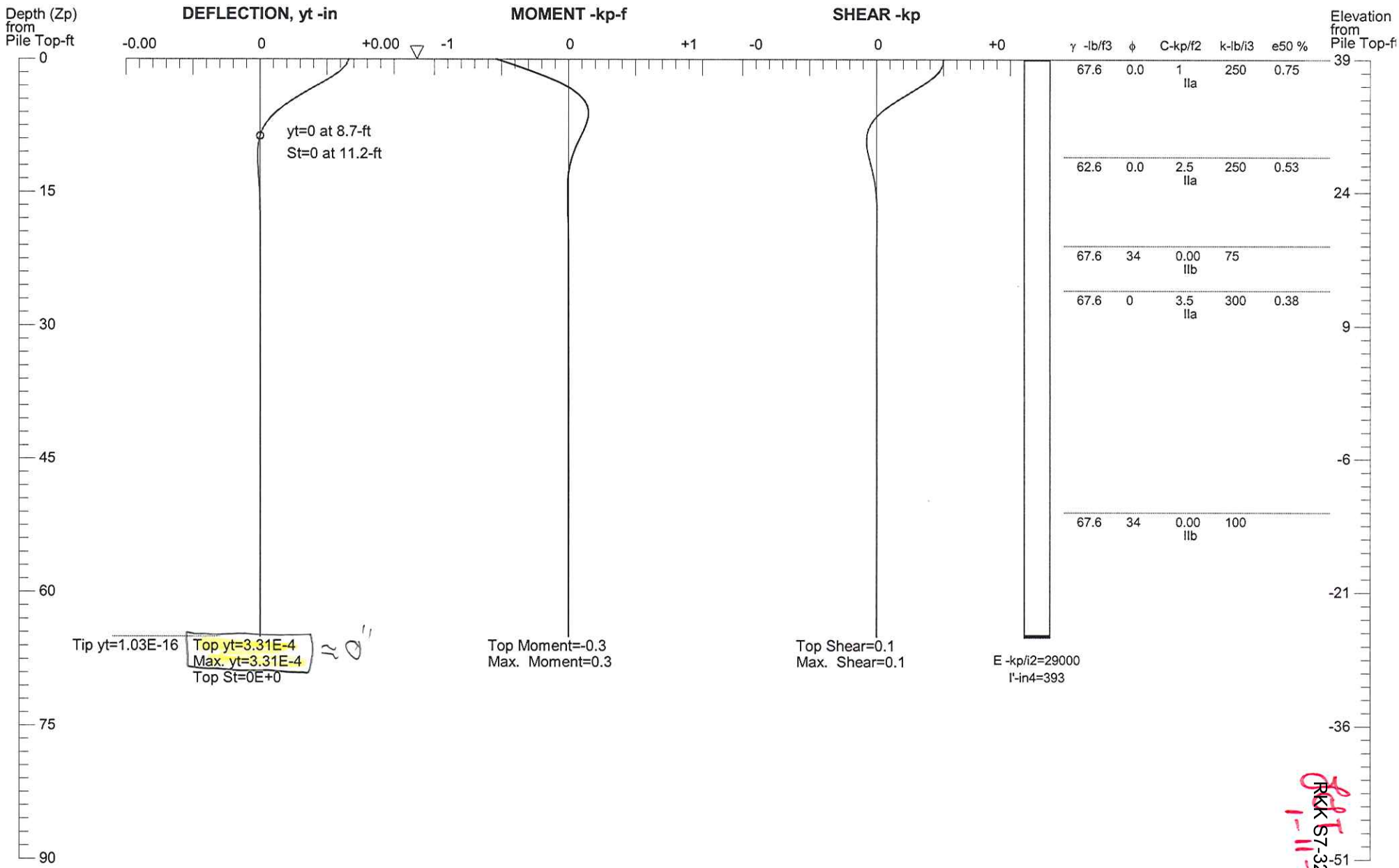
Vertical capacity:
Weight above Ground= 0.00 Total Weight= 3.08-kp *Soil Weight is not included
Side Resistance (Down)= 509.933-kp Side Resistance (Up)= 488.218-kp
Tip Resistance (Down)= 5.519-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 515.451-kp Total Ultimate Capacity (Up)= 491.302-kp
Total Allowable Capacity (Down)= 515.451-kp Total Allowable Capacity (Up)= 491.302-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 514.60-kp Settlement= 0.46895-in
At Xallow= 1.00-in Qallow= 99999.00000-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH

Single Pile, Khead=5, Kbc=2



RKK S7-32
1-11-09

CivilTech Software

SR 1/I-95 Interchange Structure S-7 - Ramp R1 Bridge over S
103-059-27U Wingwalls III & IV Pile Design HP12x53

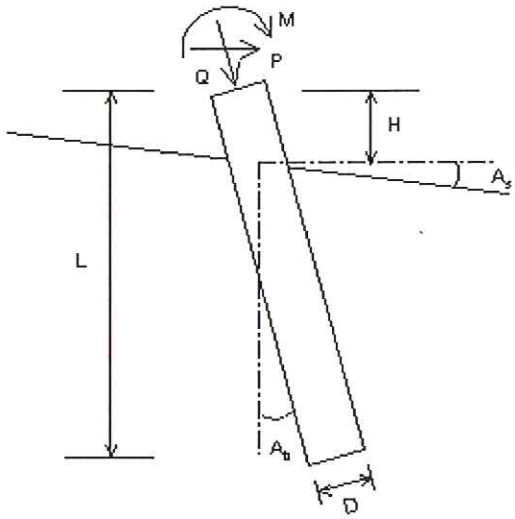
Figure 2

VERTICAL ANALYSIS

Figure 1

RKK S7-33

JGP 1-11-09



Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 514.6 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 48.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= -18.4

Fixed Head Condition

Abutment B Wing Walls

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	67.6	0.0	1	250	0.75	13
11	62.6	0.0	2.5	250	0.53	23
21	67.6	34	0.00	75	68.44	33
26	67.6	0	3.5	300	0.38	39
51	67.6	34	0.00	100	95.94	60

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	14.6	21.4	56.4	729.0	29000	0.07
48.0						

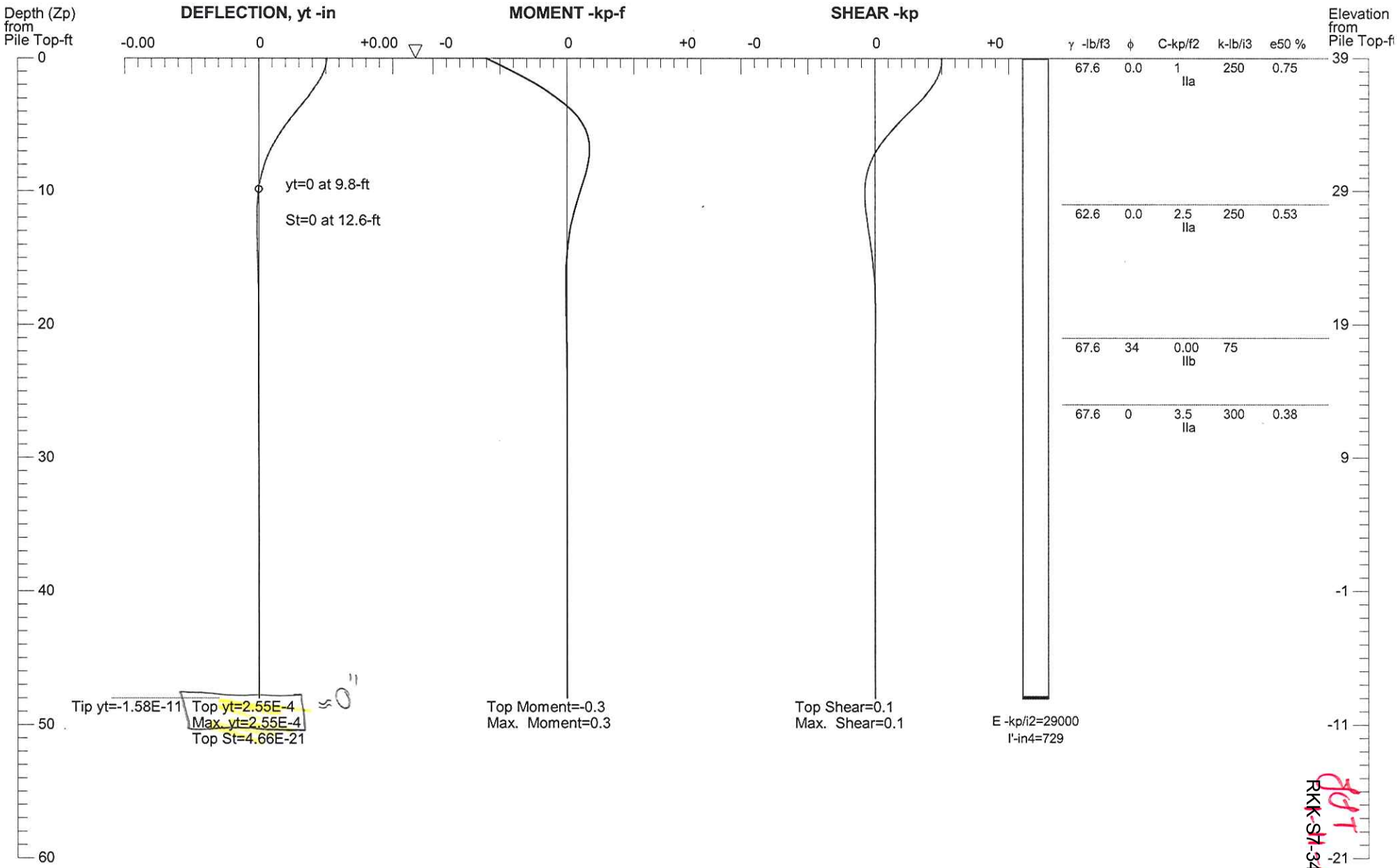
Vertical capacity:
Weight above Ground= 0.00 Total Weight= 3.19-kp *Soil Weight is not included
Side Resistance (Down)= 519.036-kp Side Resistance (Up)= 511.121-kp
Tip Resistance (Down)= 3.402-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 522.438-kp Total Ultimate Capacity (Up)= 514.309-kp
Total Allowable Capacity (Down)= 522.438-kp Total Allowable Capacity (Up)= 514.309-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 514.60-kp Settlement= 0.31692-in
At Xallow= 1.00-in Qallow= 394.40283-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH

Single Pile, Khead=5, Kbc=2



RKK-SH-34

CivilTech Software

SR 1/I-95 Interchange Structure S-7 - Ramp R1 Bridge over S
103-059-27U Wingwalls III & IV Pile Design HP14x73

Figure 2

27

CALCULATION CHECKLIST

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

Title of Calculation Set: Structure 7: Ramp R1 Bridge WEAP Analysis (Abutments)

Project Manager: **EMK/JLT**

Calculations Prepared By: **SAB**

Calculation Checked By:

Computer Programs / Files: GRLWEAP 2003

Initial	Date	
		Subsurface Characterization approved by Project Manager
SAB	1/5/09	Calculations are neat, legible and understandable.
SAB	1/5/09	Table of Contents is provided.
SAB	1/5/09	Heading on each page filled out
SAB	1/5/09	The first page contains purpose of the calculation.
SAB	1/5/09	Symbols are defined.
SAB	1/5/09	References for data, methods, formulas and computer program names and version numbers are given.
SAB	1/5/09	Assumptions are listed and those that need to be verified later are Flagged.
SAB	1/5/09	Headings on front sheet of each set of computer input and output.
SAB	1/5/09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JPT	1-20-09	All calculations checked and each calculation sheet initialed by checker.
OM	2/2/09	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.

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Subject SR1/I-95 Interchange — S7: Ramp R1 Bridge WEAP Analysis
Page 1 of 23
Cm. No. 103-059-29W
Prepared By SAB Date 12/30/08 Checked By JCT Date 1-20-09

Objective: To perform a drivability analysis of the piles for the Ramp R1 Bridge Abutments.

Software: Analysis performed using GRLWEAP 2003 (Wave Equation Analysis of Pile Driving)

References: AASHTO LRFD Bridge Design Specifications, 4th ed.
U.S. Army Corps of Engineers EM 1110-2-2906, 15 January 1991.

Contents: Abutment A — Pages 2-12
Abutment B — Pages 13-23

SUMMARY

	Pile Size	Pile Length	Nominal Resistance R_n	Hammer	Maximum Driving Stress	Maximum Blow Count
Abutment A:	HP14x73	63'	495k	Delmag D 30-32	39.57 ksi	55 / 72 bpf
	HP14x73	63'	495k	Delmag D 25-32	41.51 ksi	72 / 114 bpf

FROM ALL PILE: L=63'
Q_S = 508 KIPS (99%)
Q_E = 4.7-KIPS (1%)
Q_T = 512-KIP
FOR L=55' Q_T = 389-KIP < 495 ∴ NO GOOD

Abutment B:	HP14x73	48'	495k	Delmag D 30-32	42.17	114 bpf
	HP14x73	48'	495k	Delmag D 25-32	39.78	146 bpf

FROM ALL PILE: Q_S = 503 KIPS, Q_E = 3.3 KIPS } 506 KIPS = Q_T

∴ drivability feasible. Contractor to provide actual WEAP analysis @ time of Construction w/ specific equipment

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Subject SR1/I-95 Interchange
S7: Ramp R1 Bridge WEAP
Page 2 of
Cm. No. 103-059-270
Prepared By SAB Date 12/30/08 Checked By JT Date 1-20-09

Abutment A

Soils: See Abutment A Pile design calculations & p. 3-4

Driving Stress: $\sigma_{Ir} = 0.9\,\phi_h f_y$ (AASHTO 10.7.8-1) where: $\phi_h = 1.0$ (AASHTO 10.5.5.2.3-1)
f_y = Yield strength of steel
$= 0.9(1.0)(50\text{ ksi}) = 45\text{ ksi}$

→ USACE limits penetration rates for steel H-piles between 10-20 blows per inch

⇒ Limit blows to < 150 blows per foot = 13 blows/in.

$R_N = 495^k$, Pile Length = 63' (from design calculations)

→ Check drivability with: 1) DELMAG D 30-32 (see p. 5-8)
2) DELMAG D 25-32 (see p. 9-12)

Assume Hammer eff = 80%

Abutment A

SUMMARY

Hammer	Max. Driving Stress (ksi)	Pile Capacity (kips) @ tip	Maximum Blow Count (bpf)
DELMAG D 30-32	39.57	511.1	55* (@ 63'; higher (65-80 bpf) in Hard CLAY from 45'-55')
DELMAG D 25-32	41.51	542.2	72* (@ 63'; higher (114 bpf) @ 55' in Hard CLAY)

* See p. 2a: Pile must extend through Hard CLAY layer into SAND for adequate capacity.

∴ drivability feasible. Contractor to provide actual WEAP Analysis @ time of Construction w/ specific equipment.

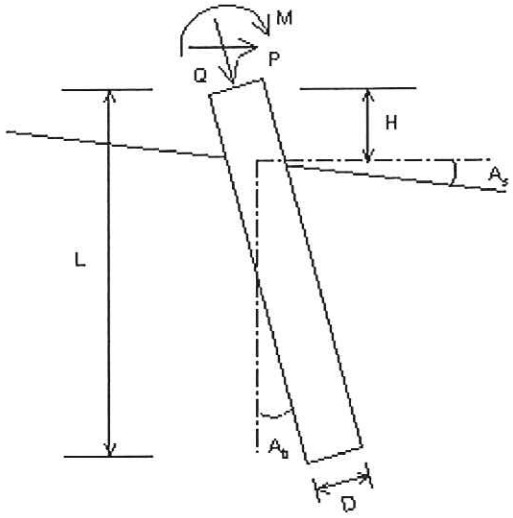
2a

VERTICAL ANALYSIS

Figure 1

RKK S7-38

JdT 1-20-09



Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 495.6 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 55.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= -12.4

Fixed Head Condition

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	62.6	0.0	0.80	250.0	0.66	16
10	67.6	0.0	2.0	250	0.61	14
15	67.6	0.0	2.5	300	0.57	24
20	67.6	34.0	0.00	75.0	85.51	30
30	67.6	0.0	3.50	500.0	0.40	36
40	67.6	34.0	0.00	100.0	95.94	60
58	67.6	0.0	5.00	500.0	0.41	34
69	67.6	34.0	0.00	150	95.94	60

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	14.6	21.4	56.4	729.0	29000	0.07
55.0						

Vertical capacity:
Weight above Ground= 0.00 Total Weight= 3.76-kp *Soil Weight is not included
Side Resistance (Down)= 383.660-kp Side Resistance (Up)= 341.667-kp
Tip Resistance (Down)= 5.619-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 389.279-kp Total Ultimate Capacity (Up)= 345.427-kp
Total Allowable Capacity (Down)= 389.279-kp Total Allowable Capacity (Up)= 345.427-kp
N/G! Qallow < Q → 389<496 → No Good! ⇒ Pile must be longer than 55' for adequate capacity!

Settlement Calculation:
At Q= 495.60-kp Settlement= 99999.00000-in
At Xallow= 1.00-in Qallow= 99999.00000-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

SR1/I-95 Interchange 103-059-270 12/30/08

S7: Ramp R1 Bridge-Abutment A

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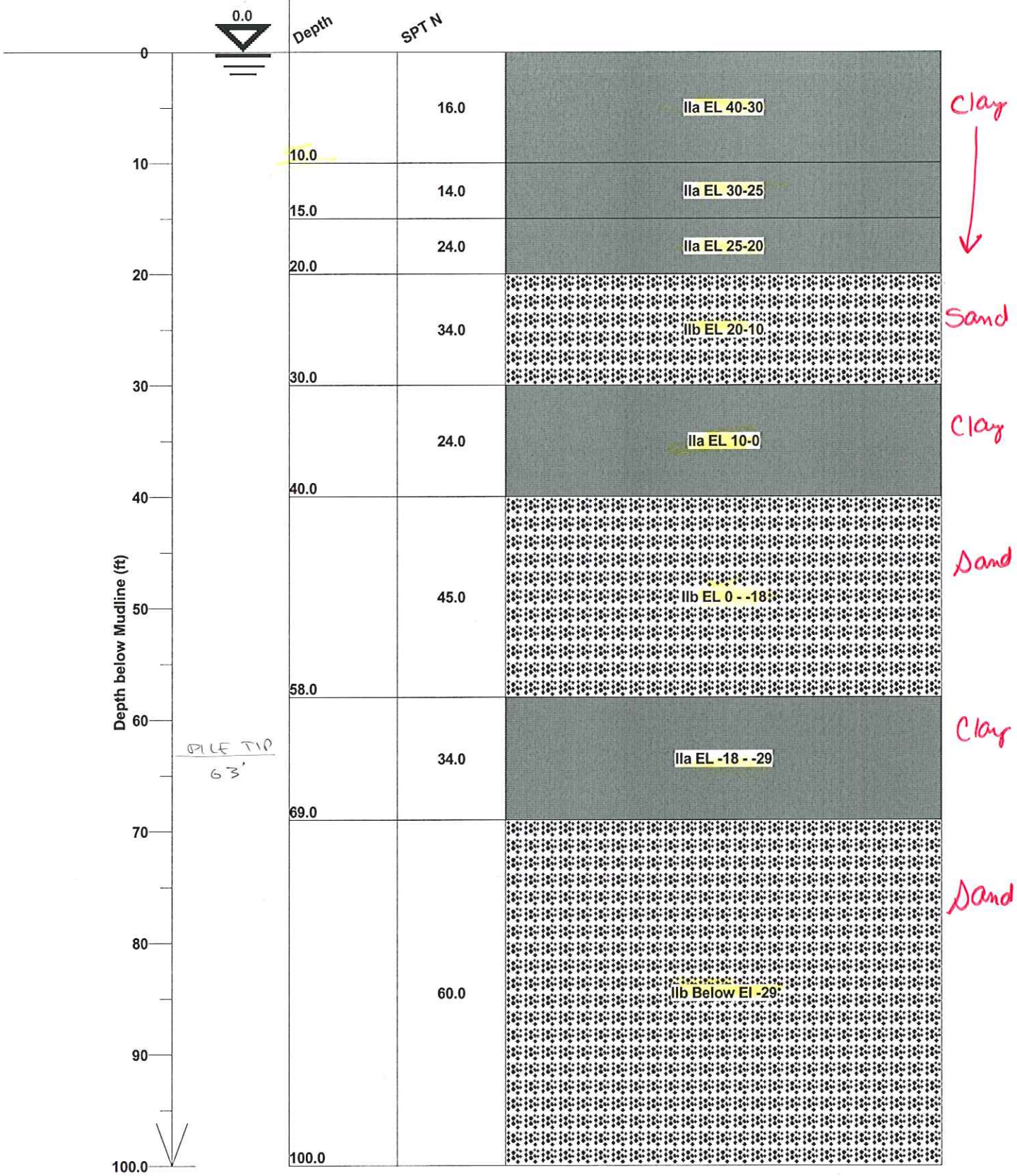

RKK S7-40

JJT 1-20-09

Abut A Skin Friction.txt

From AllPile

Abutment A:
Depth vs. Soil Stress, Side Resistance, and Pile Axial Force:

****

4.67 SF/Ft

Zp -ft	Sv -kp/f2	Sf_dw -kp/f2	Sf_up -kp/f2	Q_dw -kp	Q_up -kp	SF	Qsi
0.0	0.00	0.00	0.00	512.4	464.9		
0.1	0.01	0.78	0.78	511.9	464.5	45.8	35.7
10.0	0.63	0.78	0.78	475.8	427.6		
10.1	0.64	1.95	1.95	475.3	427.1	22.9	44.7
14.9	0.96	1.95	1.95	431.2	382.8		
15.0	0.97	2.44	2.44	430.1	381.6	22.9	55.9
19.9	1.30	2.44	2.44	373.6	324.8		
20.1	1.31	0.60	avg .35			46.2	27.7
29.9							
30.0	1.59	3.42	3.42	339.4	306.3	46.2	158
39.9	1.59	3.42	3.42	181.2	147.4		
40.0	1.59	0.73	0.36	179.2	145.3	83.6	61.0
57.9	1.59	0.73	0.36	118.1	113.6		
58.1	1.59	4.88	4.88	117.7	113.3	23.4	114
63.0	1.59	4.88	4.88	4.7	0.0		

497 kips

Zs - Soil Depth, Depth from Ground Surface
Zp - Pile Depth, Depth from Pile Top
Sv - Vertical Effective Stress in Soils
Sf_dw - Uplift Side Resistance between Soil and Pile
Sf_up - Uplift Side Resistance between Soil and Pile
Q_dw - Downward Axial Force in Pile Shaft (Ultimate Uplift Capacity)
Q_up - Uplift Axial Force in Pile Shaft (Ultimate Uplift Capacity)

welmag 30-32

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S7: Ramp R1 Bridge - Abutment A

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

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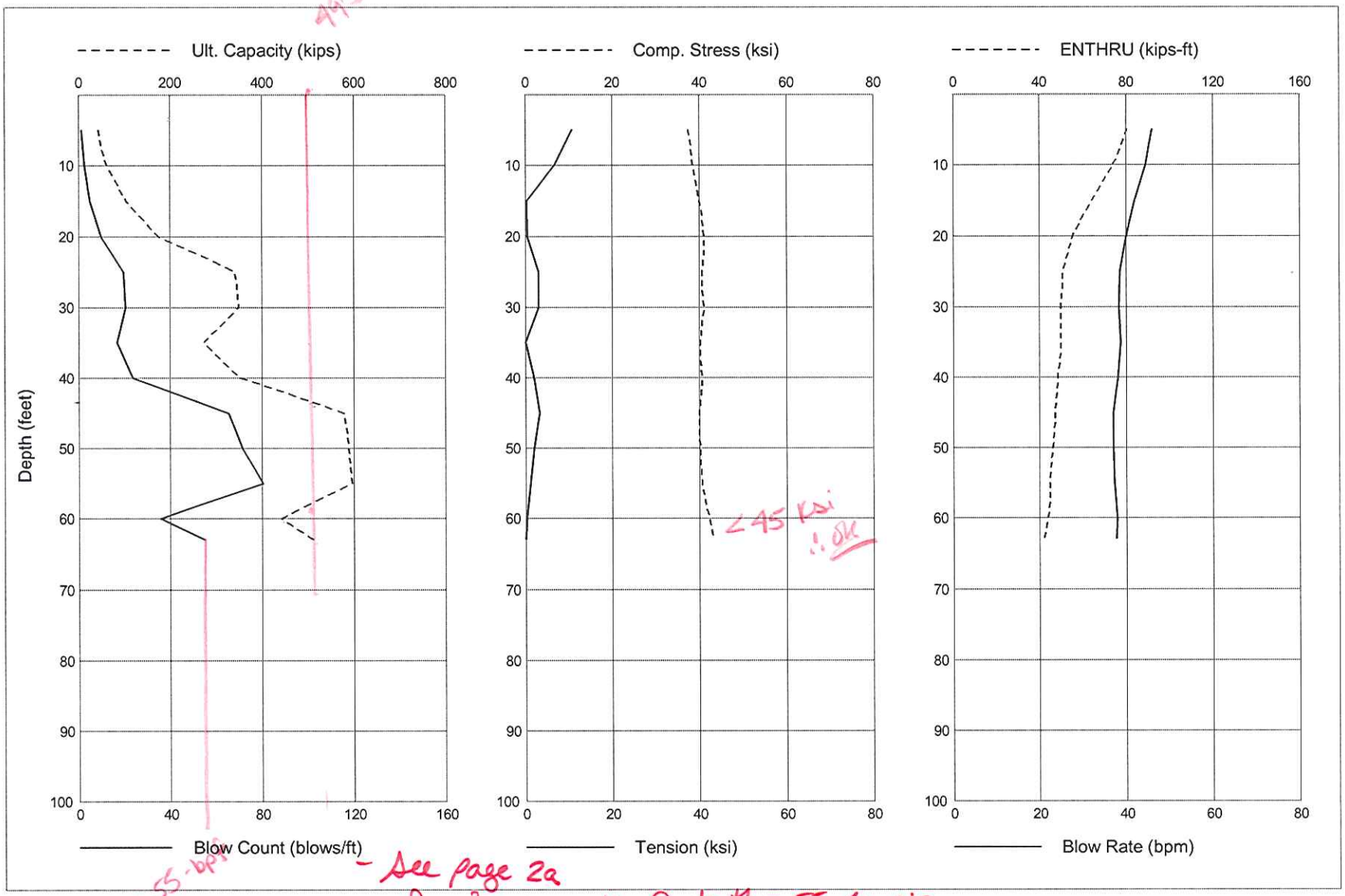

- See page 2a for pile capacity @ depth = 55-ft NG
- pile to be driven to depth of 63-ft for capacity.

JDT 12-30-09

RKK S7-410

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JJT 1-20-09

Delmag 30-32 RKK S7-42

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S7: Ramp R1 Bridge - Abutment A

Dec 30 2008
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Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Blow Rate bpm	ENTHRU kips-ft
5.0	42.8	18.2	24.6	1.6	37.359	-10.680	45.9	80.4
10.0	61.0	36.4	24.6	2.6	38.534	-6.692	44.4	74.2
15.0	103.4	81.9	21.5	5.1	40.066	-0.293	42.0	64.3
20.0	175.7	138.8	36.8	9.9	40.993	-0.465	40.1	55.4
25.0	340.3	147.0	193.3	19.7	40.620	-2.989	38.4	50.4
30.0	348.5	155.2	193.3	20.6	41.017	-3.067	38.3	49.8
35.0	271.8	235.0	36.8	16.8	40.230	-0.003	38.8	49.6
40.0	351.6	314.8	36.8	23.6	40.640	-1.979	38.1	48.3
45.0	579.0	323.2	255.9	65.3	39.902	-3.313	37.0	47.0
50.0	587.4	331.6	255.9	71.6	40.125	-2.076	37.1	45.8
55.0	595.8	340.0	255.9	80.3	40.638	-1.072	37.2	44.7
60.0	442.8	390.6	52.2	35.8	42.422	-0.244	37.8	43.6
63.0	511.1	458.9	52.2	54.8	43.268	0.000	37.6	42.2

Total Continuous Driving Time 48.00 minutes; Total Number of Blows 1812

> 495 kips
∴ ok

< 45 ksi
∴ ok

From Allpile

Friction: 508 - Kips
End Bearing: 5 Kips

∴ ok
Same 2o
as GRLWEAP. for
Friction + End Bearing.

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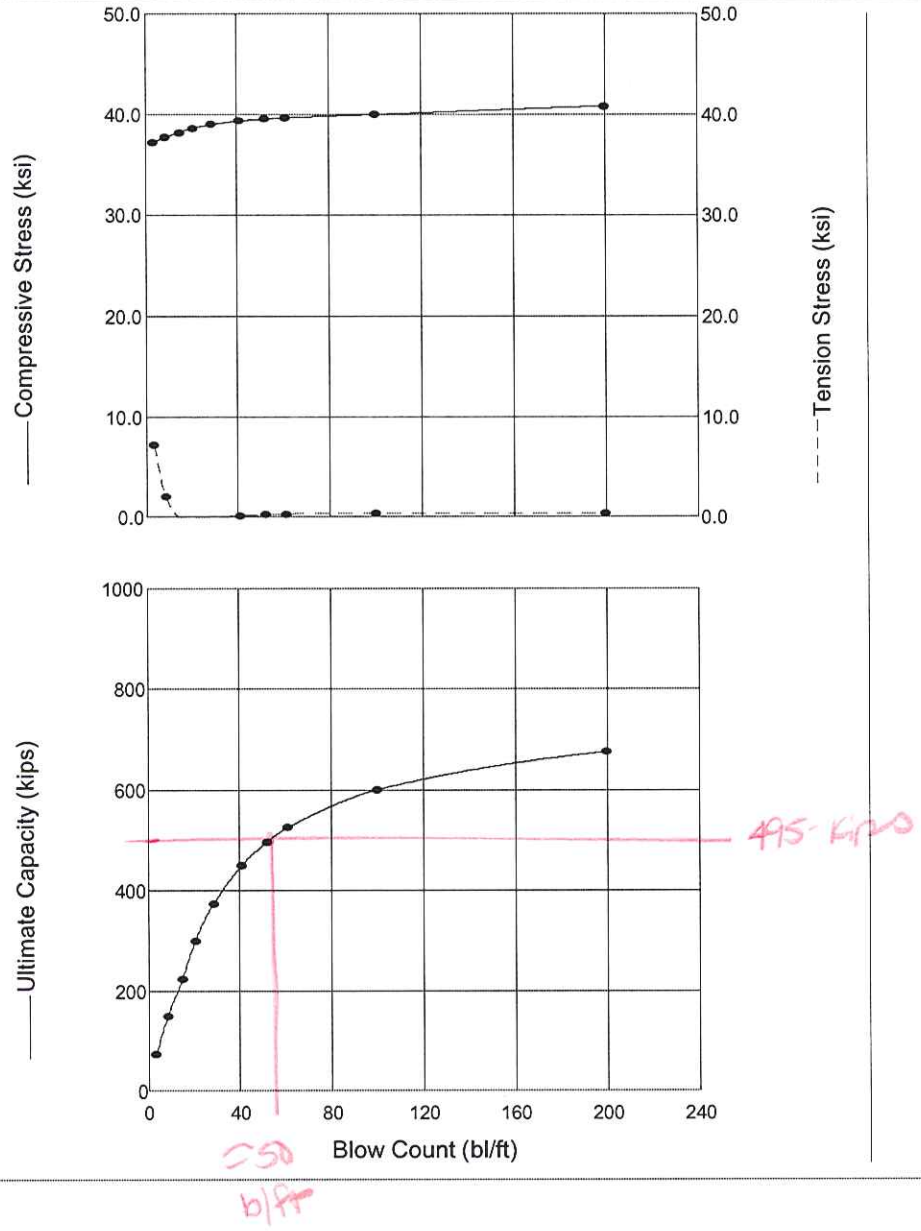
S7: Ramp R1 Bridge - Abutment A

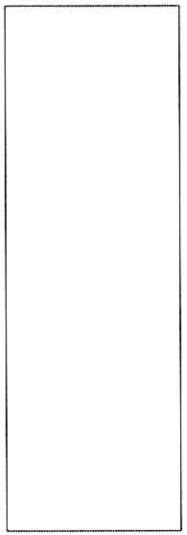
30-Dec-2008
GRLWEAP (TM) Version 2003



DELMAG D 30-32

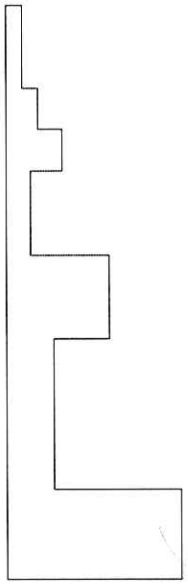
Stroke	11.43	feet
Efficiency	0.800	
Helmet	3.20	kips
Hammer Cushion	109975	kips/in
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	63.00	ft
Pile Penetration	63.00	ft
Pile Top Area	21.40	in2

Pile Model



Res. Shaft = 100 %
(Proportional)

Skin Friction Distribution



JPT 1-20-09

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JPT
1-20-09

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S7: Ramp R1 Bridge - Abutment A

30-Dec-2008
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	Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke feet	Energy kips-ft
	75.0	37.21	7.26	3.6	11.43	68.25
	150.0	37.75	2.10	8.5	11.43	55.68
	225.0	38.22	0.00	15.1	11.43	49.05
	300.0	38.64	0.00	20.8	11.43	46.39
	375.0	39.02	0.00	28.9	11.43	45.16
	450.0	39.37	0.15	41.0	11.43	44.33
R_N =	496.0	39.57	0.29	51.9	11.43	43.92
	525.0	39.70	0.34	61.1	11.43	43.67
	600.0	40.02	0.41	100.2	11.43	43.11
	675.0	40.83	0.40	199.7	11.43	42.81

< 45 ksi
OK

80%
eff

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S7: Ramp R1 Bridge - Abutment A

A95-kips

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

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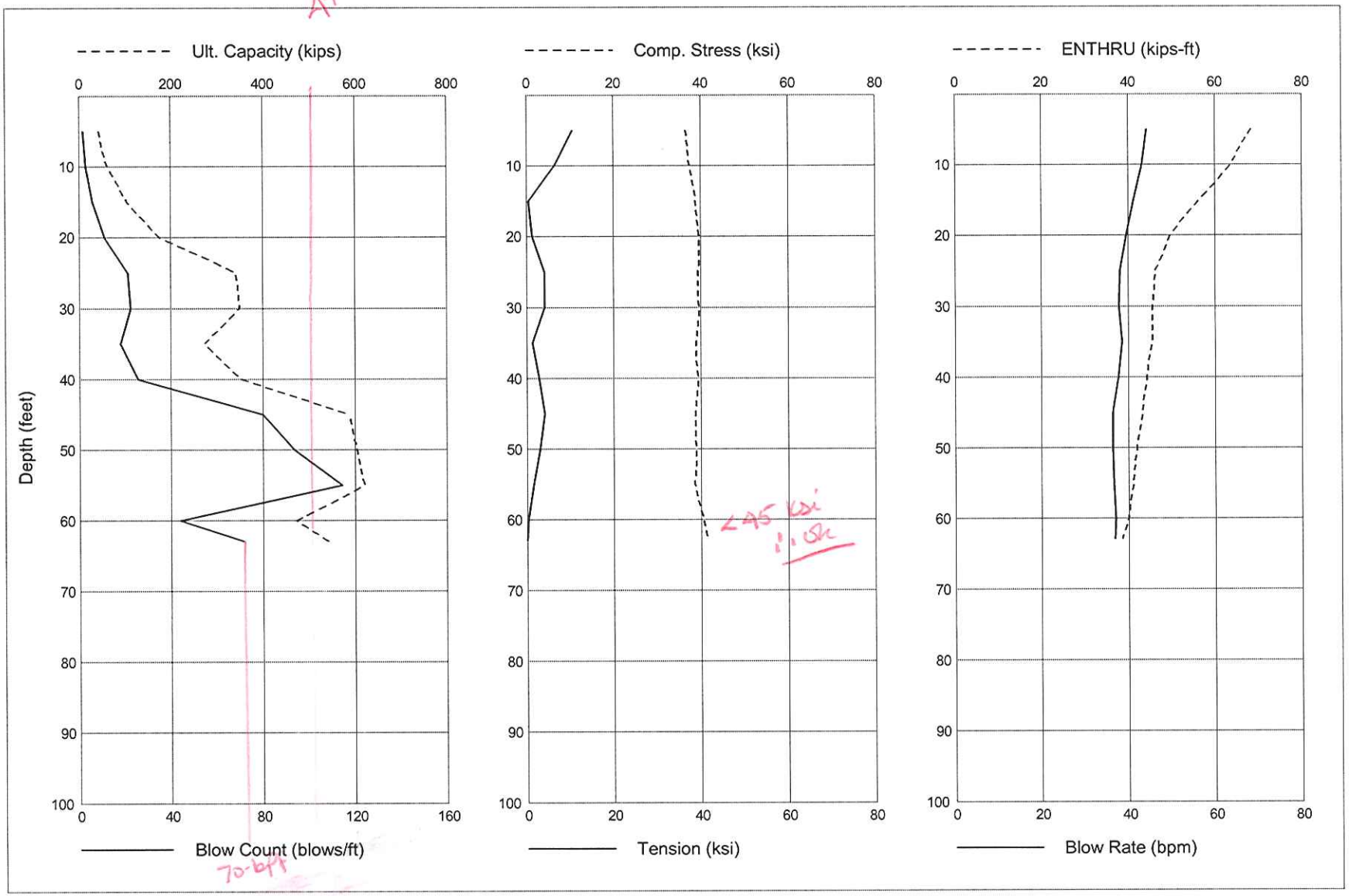

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BPT 1-20-09
Rummel 25-32

9

JJT 1-20-09 10

Wellmag RKK S7-46

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S7: Ramp R1 Bridge - Abutment A

Dec 30 2008
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Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Blow Rate bpm	ENTHRU kips-ft
5.0	42.8	18.2	24.6	1.9	36.503	-10.574	44.3	68.3
10.0	61.0	36.4	24.6	3.0	37.416	-6.539	43.2	63.7
15.0	103.4	81.9	21.5	5.8	38.746	-0.635	41.3	56.4
20.0	175.7	138.8	36.8	11.1	39.581	-1.389	39.6	49.7
25.0	340.3	147.0	193.3	21.3	39.277	-4.116	38.0	46.2
30.0	348.5	155.2	193.3	22.4	39.665	-4.064	37.9	45.6
35.0	271.8	235.0	36.8	18.0	39.004	-1.370	38.4	45.6
40.0	351.6	314.8	36.8	25.6	39.408	-2.959	37.7	44.3
45.0	587.7	331.8	255.9	80.1	38.756	-4.246	36.3	43.1
50.0	604.7	348.9	255.9	93.7	39.013	-3.076	36.4	42.0
55.0	621.7	365.9	255.9	114.4	38.477	-1.565	36.5	41.0
60.0	473.9	421.7	52.2	44.0	40.603	-0.391	37.1	40.1
63.0	542.2	490.0	52.2	71.5	41.313	0.000	36.9	38.6

Total Continuous Driving Time 61.00 minutes; Total Number of Blows 2269

> 495-kips
∴ ok

< 45 ksi
∴ ok

From All pile
Friction: 508-kips
End Bearing: 5-kips

∴ ok same % as GRLWEAP for Friction + End Bearing

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S7: Ramp R1 Bridge - Abutment A

30-Dec-2008
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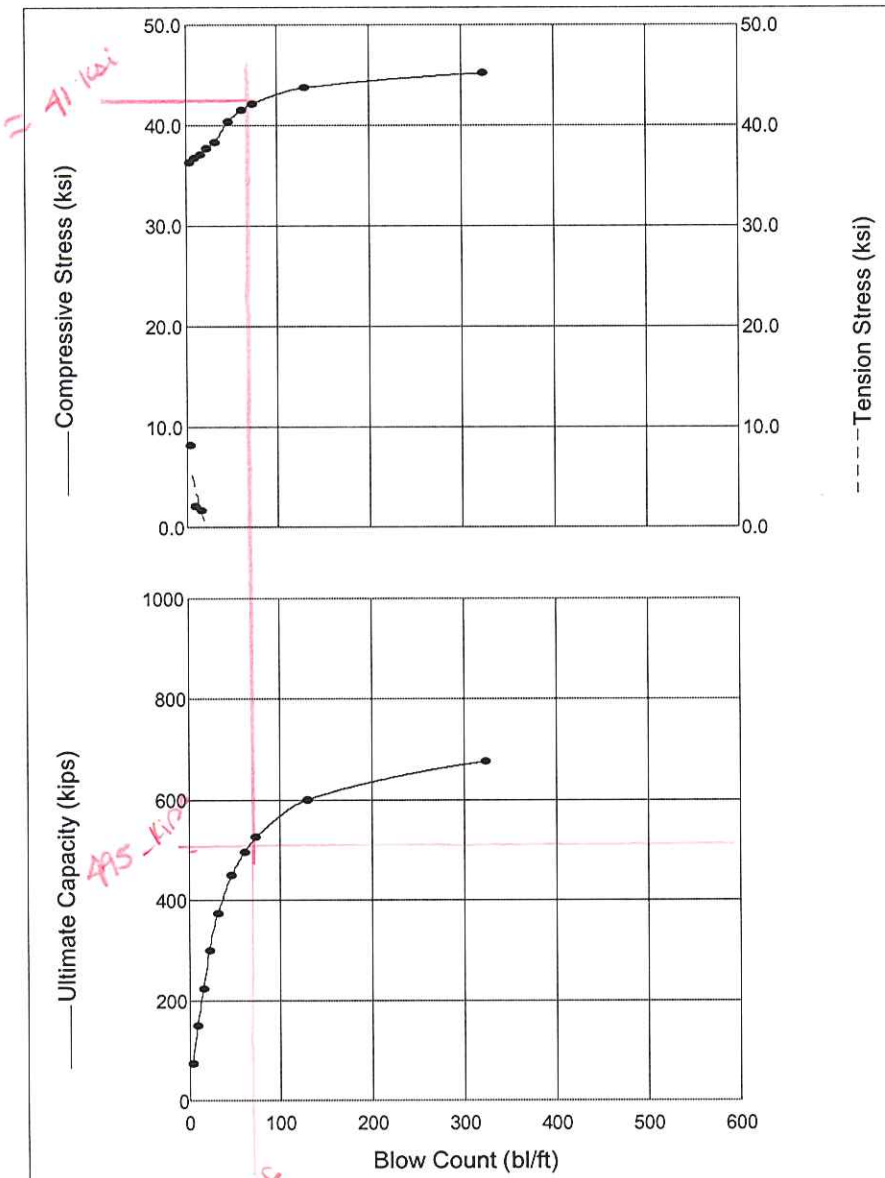
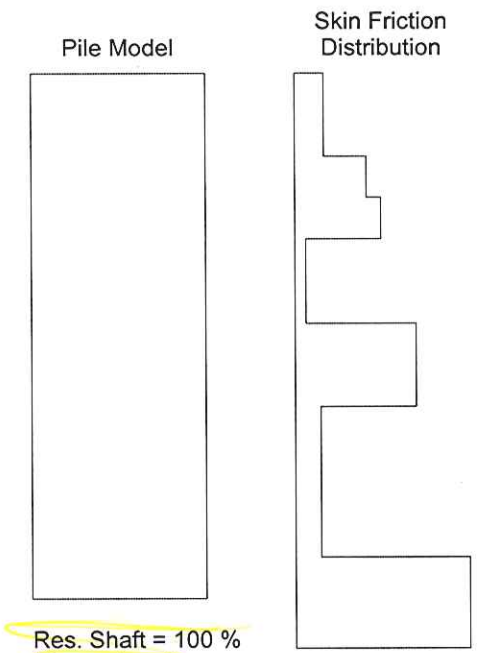


DELMAG D 25-32

Stroke	12.04	feet
Efficiency	0.800	
Helmet	3.20	kips
Hammer Cushion	109975	kips/in
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	63.00	ft
Pile Penetration	63.00	ft
Pile Top Area	21.40	in2



Res. Shaft = 100 %
(Proportional)

Delmag

RKK S7-47 25732

DPT 1-20-09

11

Delmag 25-32 SPT 1-20-09

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S7: Ramp R1 Bridge - Abutment A

30-Dec-2008
GRLWEAP (TM) Version 2003

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke feet	Energy kips-ft
75.0	36.34	8.24	4.0	12.04	58.28
150.0	36.79	2.19	9.4	12.04	48.82
225.0	37.14	1.68	16.3	12.04	43.38
300.0	37.70	0.00	22.9	12.04	40.80
375.0	38.38	0.00	32.5	12.04	39.67
450.0	40.42	0.00	47.2	12.04	38.97
496.0	41.51	0.00	61.2	12.04	38.51
525.0	42.17	0.00	73.3	12.04	38.24
600.0	43.79	0.00	129.3	12.04	37.62
675.0	45.27	0.00	323.3	12.04	37.05

<45 ksi ✓ok

80% eff

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Subject SR1/I-95 Interchange — Page 13 of
S7: Ramp R1 Bridge WEAP - Abutment B — Cm. No. 103-059-270
Prepared By SAS Date 12/30/08 Checked By SBT Date 1-20-09

Abutment B

Soils: See Abutment B Pile Design calculations at p. 14-15

Driving Stress: $\sigma_{dr} = 0.9\,\phi_{dr} f_y = 0.9(1.0)(50\text{ ksi}) = 45\text{ ksi}$

→ USACE limits penetration rates for steel H-piles between 10-20 blows/inch

⇒ Limit blows to < 150 blows/ft = 13 blows/in.

$R_N = 495^k$, Pile Length = 48' (from design calculations)

→ Check drivability with: 1) DELMAG D 30-32 (see p. 16-19)

2) DELMAG D 25-32 (see p. 20-23)

@ Tip

SUMMARY

Hammer	Max. Driving Stress (ksi)	Pile Capacity (kips)	Maximum Blow Count (bpf)
DELMAG D 30-32	42.17	575.9	114
DELMAG D 25-32	39.78	516.0	146

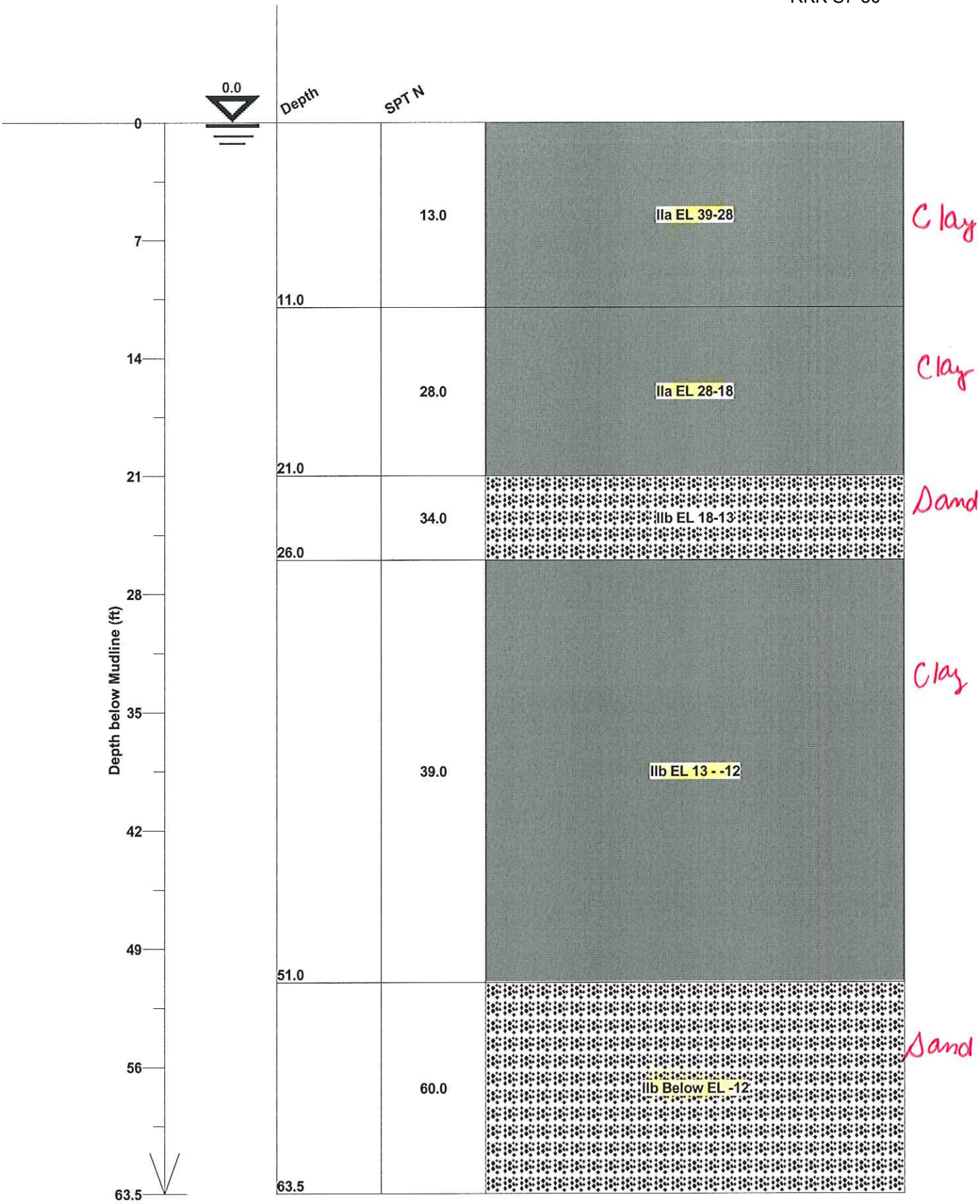
∴ drivability feasible. Contractor to provide actual WEAP analysis @ time of construction w/ specific equipment.

SR1 / I-95 Interchange 103-059-270 12/30/08
S7: Ramp R1 Bridge Abutment B

JJT 1-20-09

14

RKK S7-50



JDT 1-20-09

RKK S7-51

Abut B Skin Friction.txt

From AllPile

Depth vs. Soil Stress, Side Resistance, and Pile Axial Force:

****

Zp -ft	Sv -kp/f2	Sf_dw -kp/f2	Sf_up -kp/f2	Q_dw -kp	Q_up -kp
0.0	0.00	0.00	0.00	506.2	498.0
0.1	0.01	0.95	0.95	505.8	497.6
10.9	0.74	0.95	0.95	457.5	448.6
11.0	0.75	2.37	2.37	457.1	448.1
20.9	1.37	2.37	2.37	346.8	337.2
21.0	1.37				
26.0	1.60	avg = 0.675			
26.1	1.60	3.32	3.32	329.7	327.8
47.0	1.60	3.32	3.32	3.3	0.0

Zs - Soil Depth, Depth from Ground Surface
Zp - Pile Depth, Depth from Pile Top
Sv - Vertical Effective Stress in Soils
Sf_dw - Uplift Side Resistance between Soil and Pile
Sf_up - Uplift Side Resistance between Soil and Pile
Q_dw - Downward Axial Force in Pile Shaft (Ultimate Uplift Capacity)
Q_up - Uplift Axial Force in Pile Shaft (Ultimate Uplift Capacity)

Welmag 30-32

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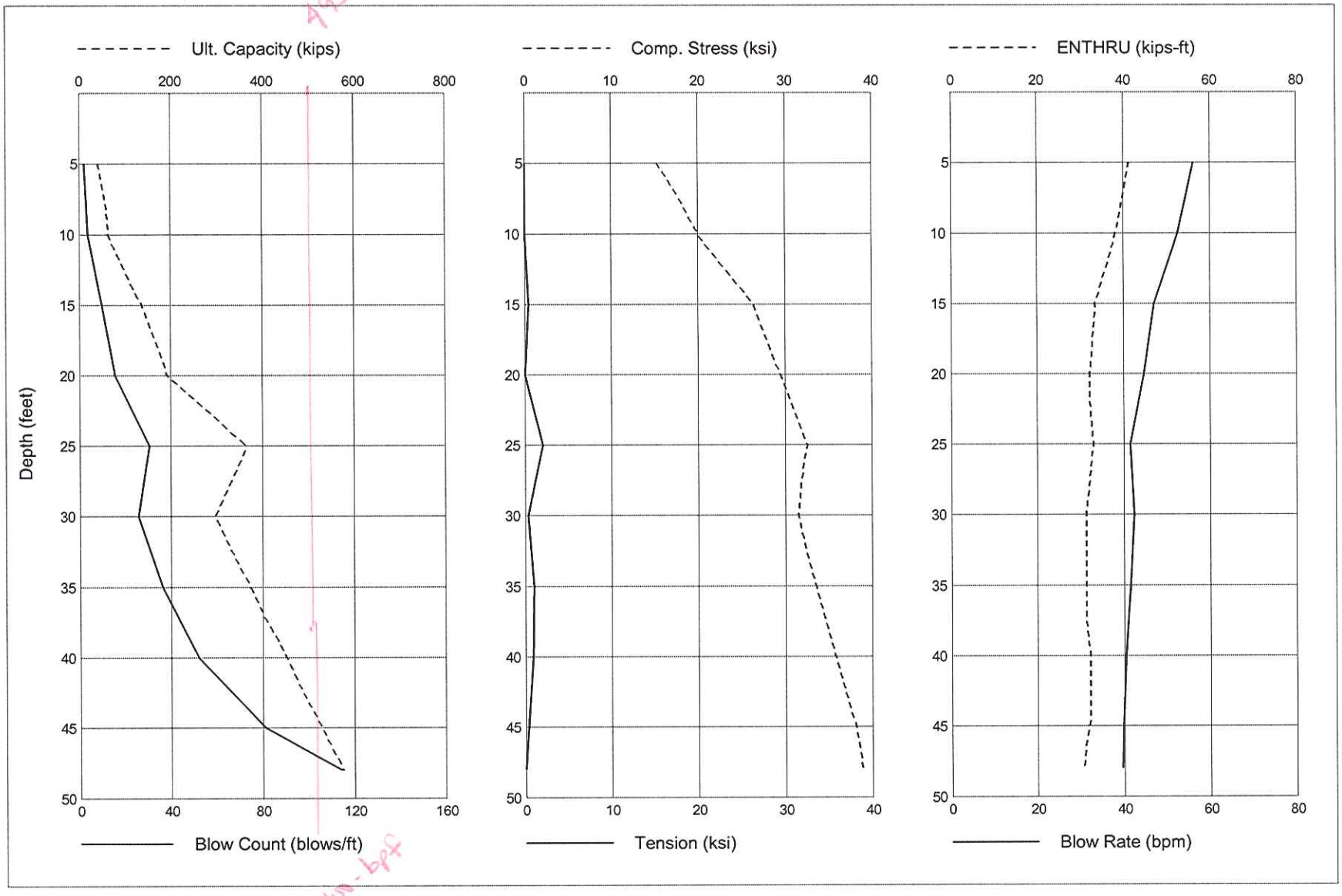
Dec 30 2008

S7: Ramp R1 Bridge - Abutment B

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

GRLWEAP(TM) Version 2003



RKK S7-52

JPT 1-20-09

16

JJT 1-2009 17

Wellmas 30-32

Rummel Klepper & Kahl, LLP
S7: Ramp R1 Bridge - Abutment B

Dec 30 2008
GRLWEAP(TM) Version 2003

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Blow Rate bpm	ENTHRU kips-ft
5.0	42.1	22.2	20.0	2.4	15.303	-0.101	56.2	41.2
10.0	64.3	44.3	20.0	4.0	19.978	0.000	52.6	38.1
15.0	136.0	93.0	43.0	9.9	26.451	-0.435	47.0	33.3
20.0	191.3	148.3	43.0	15.4	29.486	0.000	44.6	32.1
25.0	365.3	172.0	193.3	30.7	32.570	-2.037	41.5	32.9
30.0	297.0	237.1	59.9	25.8	31.569	-0.416	42.4	31.2
35.0	374.4	314.6	59.9	36.3	33.550	-1.012	41.4	31.3
40.0	451.9	392.1	59.9	51.9	35.835	-0.900	40.4	32.0
45.0	529.4	469.5	59.9	81.3	38.150	-0.407	39.8	31.8
48.0	575.9	516.0	59.9	114.4	38.875	0.000	39.6	30.7

↳ > 496 ✓ OK

Total Continuous Driving Time 33.00 minutes; Total Number of Blows 1379

< 150 bpf < 45 ksi

∴ ok

From Allpile

Friction : 503 - kips

End Bearing: 94 - kips

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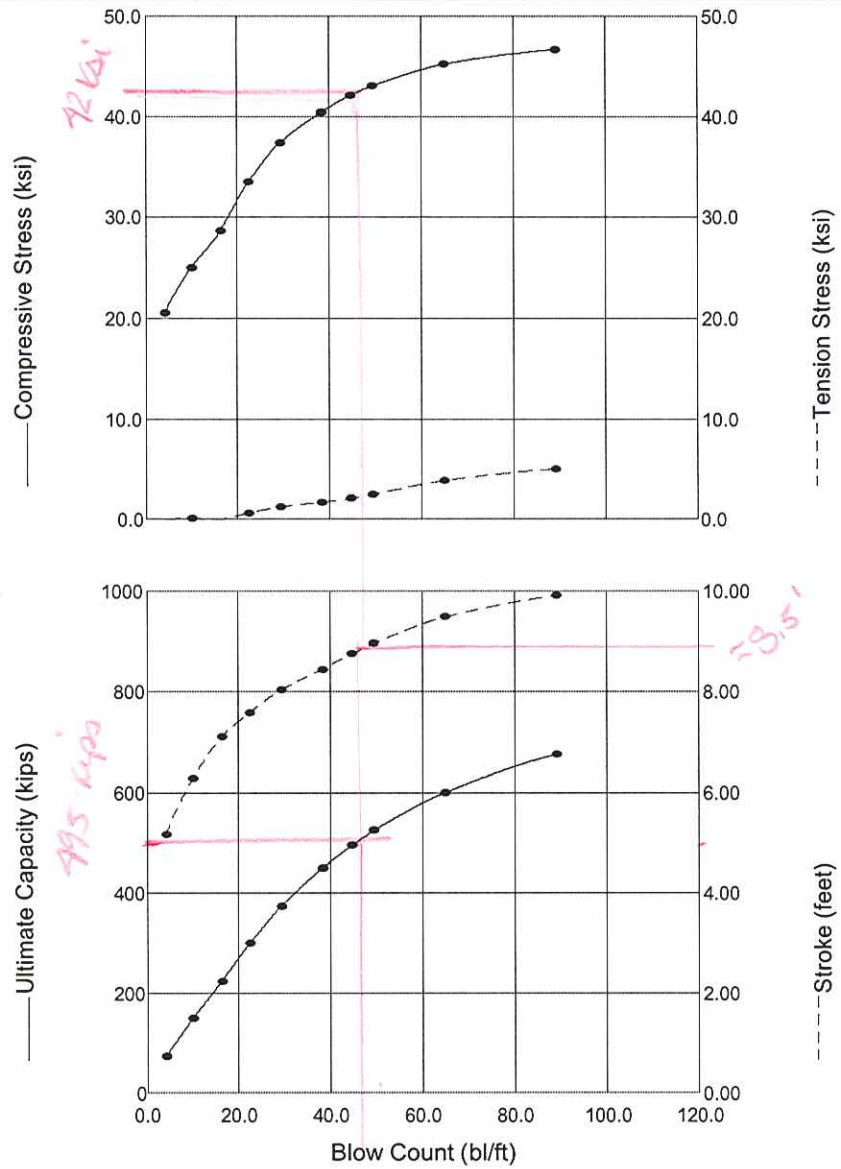
S7: Ramp R1 Bridge - Abutment B

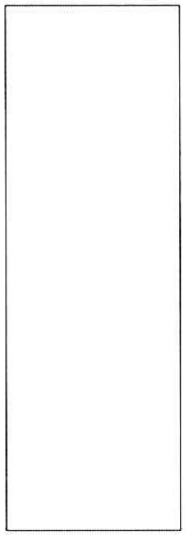
30-Dec-2008
GRLWEAP (TM) Version 2003



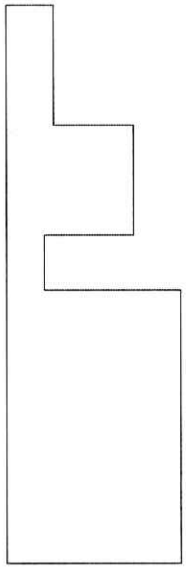
DELMAG D 30-32

Efficiency	0.800	
Helmet	3.20	kips
Hammer Cushion	109975	kips/in
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	48.00	ft
Pile Penetration	48.00	ft
Pile Top Area	21.40	in2

Pile Model



Skin Friction Distribution



Res. Shaft = 10 %
(Proportional)

RKK S7-54

JCP 1-20-09
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Wlmag 30-32

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S7: Ramp R1 Bridge - Abutment B

30-Dec-2008
GRLWEAP (TM) Version 2003

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke feet	Energy kips-ft
75.0	20.51	0.00	4.3	5.17	37.67
150.0	25.04	0.16	10.1	6.27	33.34
225.0	28.58	0.00	16.4	7.10	32.28
300.0	33.49	0.68	22.6	7.58	32.38
375.0	37.43	1.29	29.5	8.04	33.38
450.0	40.43	1.76	38.3	8.45	34.55
496.0	42.17	2.11	44.8	8.76	35.52
525.0	43.10	2.52	49.5	8.97	36.21
600.0	45.28	3.89	65.0	9.49	37.96
675.0	46.74	5.06	89.3	9.92	39.36

<45ksi OK

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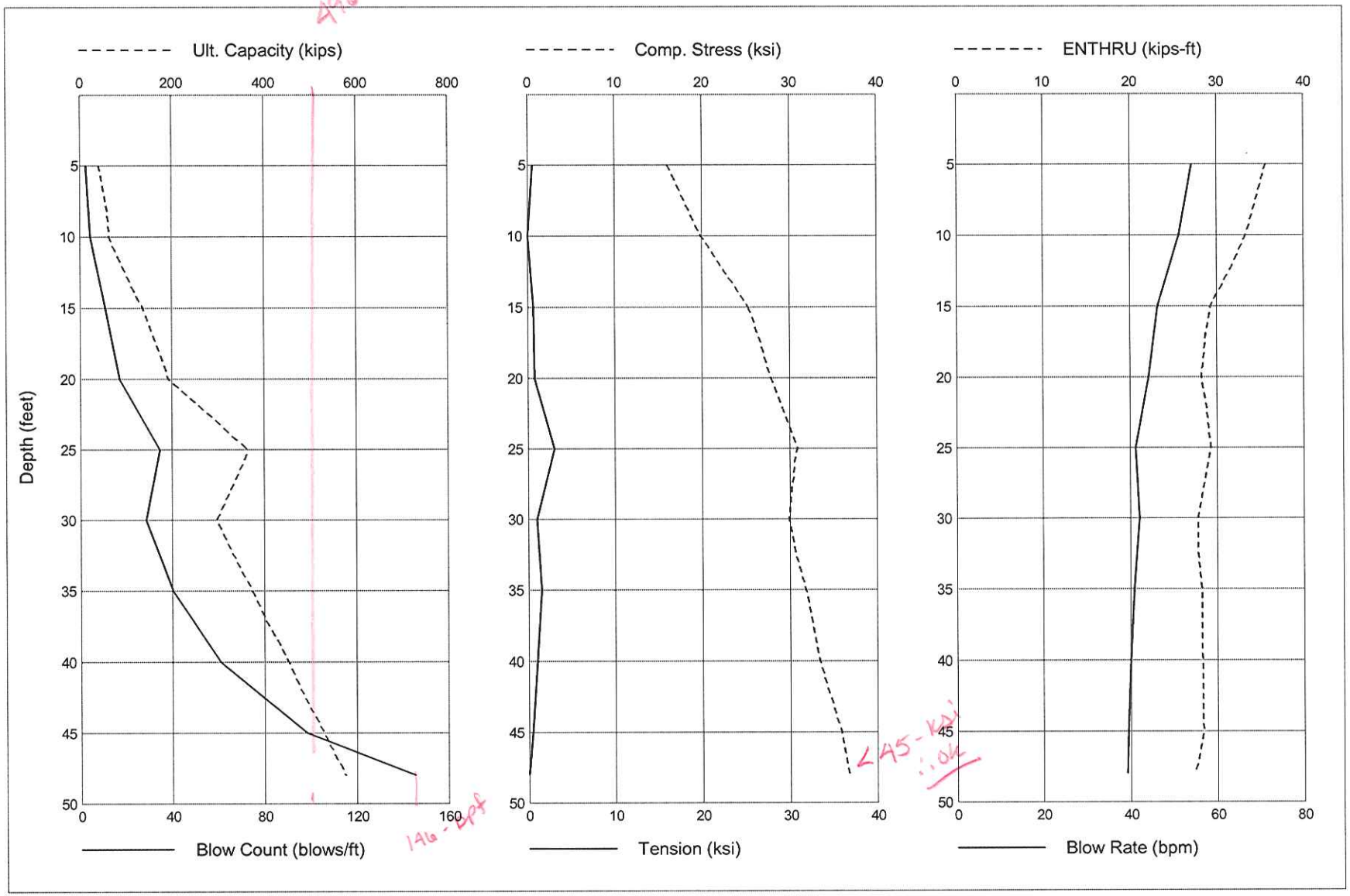
Dec 30 2008

S7: Ramp R1 Bridge - Abutment B

496 kips

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

GRLWEAP(TM) Version 2003



RKK S7-56

SCT 1-28-09

Wellman 08-32

JJT 1-20-09 21

Wellmag 25-32

RKK S7-57

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S7: Ramp R1 Bridge - Abutment B

Dec 30 2008
GRLWEAP(TM) Version 2003

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Blow Rate bpm	ENTHRU kips-ft
5.0	42.1	22.2	20.0	2.7	16.054	-0.580	54.3	35.7
10.0	64.3	44.3	20.0	4.6	19.944	-0.004	51.2	33.3
15.0	136.0	93.0	43.0	11.2	25.314	-0.742	46.4	29.3
20.0	191.3	148.3	43.0	17.3	27.890	-0.838	44.3	28.2
25.0	365.3	172.0	193.3	34.5	30.841	-3.009	41.3	29.3
30.0	297.0	237.1	59.9	28.6	29.967	-0.982	42.1	27.8
35.0	374.4	314.6	59.9	40.4	31.804	-1.517	40.9	28.2
40.0	451.9	392.1	59.9	60.9	33.435	-0.999	40.1	28.3
45.0	529.4	469.5	59.9	98.8	35.907	-0.469	39.4	28.4
48.0	575.9	516.0	59.9	145.8	36.743	0.000	39.2	27.4

Total Continuous Driving Time 40.00 minutes; Total Number of Blows 1614

> 495.6 k ✓ OK

< 45 ksi

< 150 bpf

From Allpile

Friction 503 - kips

End 4 - kips

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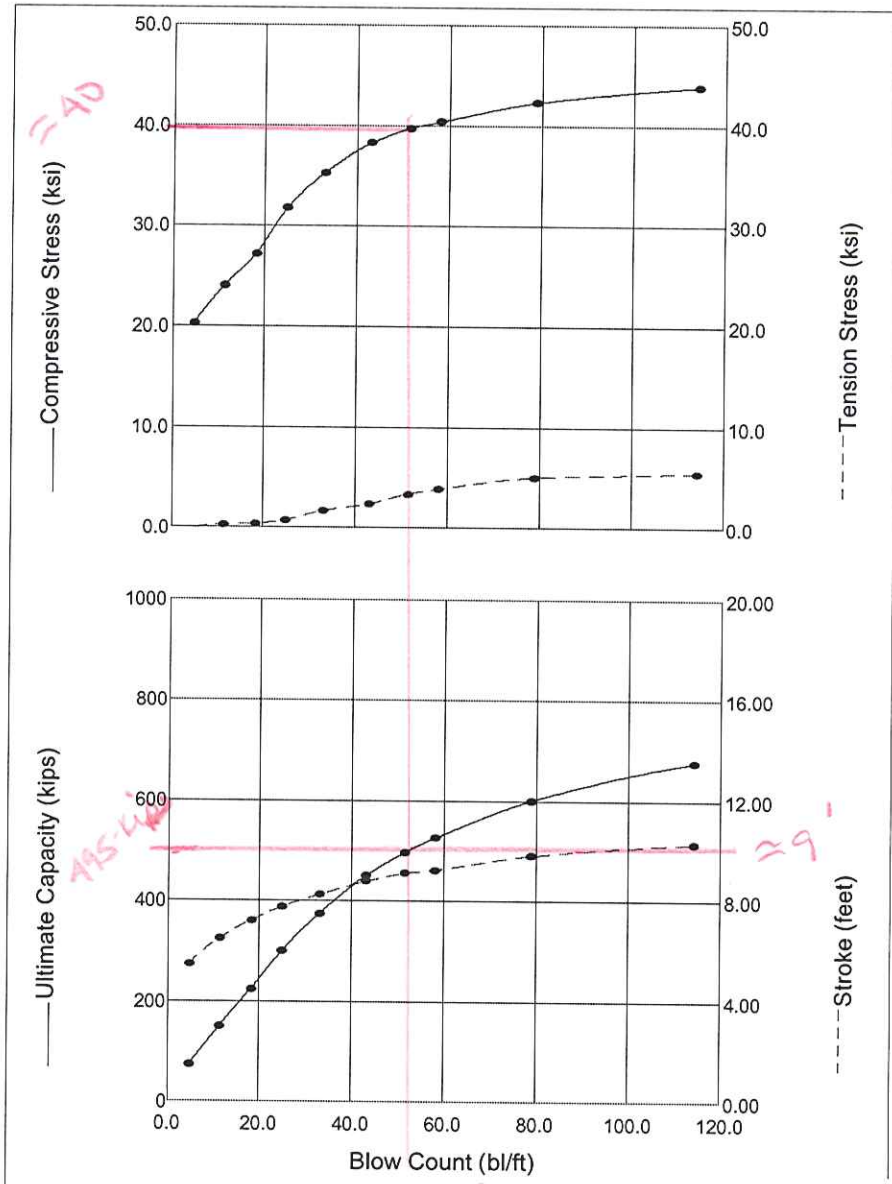
S7: Ramp R1 Bridge - Abutment B

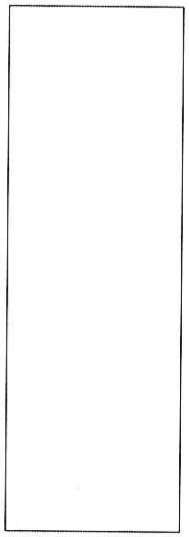
30-Dec-2008
GRLWEAP (TM) Version 2003



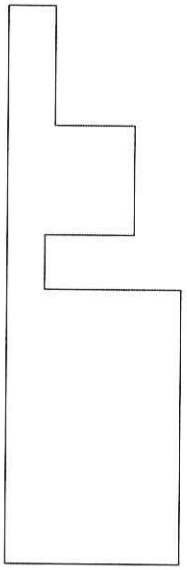
DELMAG D 25-32

Efficiency	0.800
Helmet	3.20 kips
Hammer Cushion	109975 kips/in
Skin Quake	0.100 in
Toe Quake	0.100 in
Skin Damping	0.200 sec/ft
Toe Damping	0.150 sec/ft
Pile Length	48.00 ft
Pile Penetration	48.00 ft
Pile Top Area	21.40 in2

Pile Model



Skin Friction Distribution



Res. Shaft = 10 %
(Proportional)

RKK S7-58

GRT 1-20-09
Delmag 25-32

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Wellmag 25-32

RKK S7-59

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S7: Ramp R1 Bridge - Abutment B

30-Dec-2008
GRLWEAP (TM) Version 2003

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke feet	Energy kips-ft
75.0	20.23	0.00	4.9	5.47	32.82
150.0	24.03	0.33	11.4	6.49	29.34
225.0	27.15	0.41	18.3	7.21	28.46
300.0	31.73	0.78	25.0	7.76	28.86
375.0	35.29	1.74	33.1	8.24	29.83
450.0	38.33	2.46	43.2	8.77	31.19
496.0	39.78	3.42	51.5	9.09	32.00
525.0	40.42	3.92	58.1	9.22	32.39
600.0	42.37	5.09	78.9	9.79	34.03
675.0	43.97	5.51	114.2	10.27	35.40

$\sigma < 45$ ksi OK

80% eff.

CALCULATION CHECKLIST

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

Title of Calculation Set: **Structure 7: Ramp R1 Bridge Pier Design**

Project Manager: **EMK/JLT**

Calculations Prepared By: **SAB**

Calculation Checked By:

Computer Programs / Files: **AllPile7, GRLWEAP 2003**

Initial	Date	
		Subsurface Characterization approved by Project Manager
SAB	1/5/09	Calculations are neat, legible and understandable.
SAB	1/5/09	Table of Contents is provided.
SAB	1/5/09	Heading on each page filled out
SAB	1/5/09	The first page contains purpose of the calculation.
SAB	1/5/09	Symbols are defined.
SAB	1/5/09	References for data, methods, formulas and computer program names and version numbers are given.
SAB	1/5/09	Assumptions are listed and those that need to be verified later are Flagged.
SAB	1/5/09	Headings on front sheet of each set of computer input and output.
SAB	1/5/09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JOT	1-11-09	All calculations checked and each calculation sheet initialed by checker.
EMK	1/13/09	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 I-95/SR1 Interchange
Structure 7 Ramp R1 Bridge Pier Foundation
Prepared By SAB Date 9/25/08 REV 1/5/09 Checked By JJT JJT Date 9-30-08 1-11-09
Page 2 of
Cm. No. 103-059-270

Soils: (See p. 3 for fence diagram)

Strata: Assume BOF El = EL 42

Stratum	EL	γ_t (pcf)	DRAINED ϕ' (deg)	DRAINED c' (psf)	UNDRAINED S_u (psf)	k (pci) (1)*	SPT N (bpf)
IIa	42-21	130	24	-	800	250	11
IIa	21-7	130	24	-	5,000	500	27
IIb	7...	130	34	-	-	100	58
Water	30	62.4					

* 1) k estimated using Table 3.3, 3.5, & 3.6, attached p. 9-10

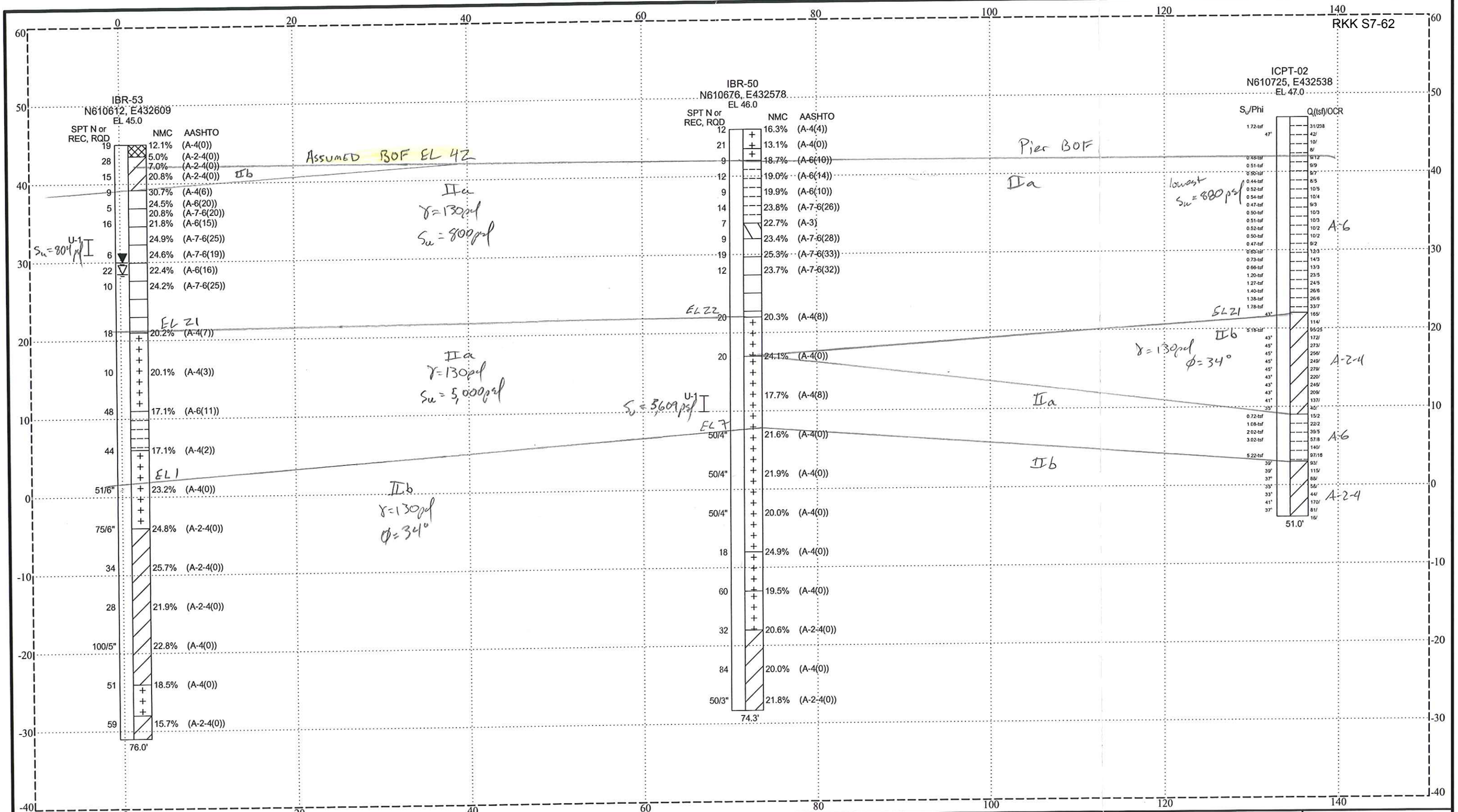
=> Use UNDRAINED soil parameters for pile analysis.

SR1/I-95 Interchange 103-059-27U

JJT 1-11-09

3

RKK S7-62



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	1	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

S7: Ramp R1 over SR 7 - Pier

Figure No. A-4b

Drawn: SAB | Approved: EMK | Date: 1/5/09 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 1/5/09

RUMMEL, KLEPPER & KAHL, LLP
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Subject I-95/SR1 Interchange
Structure 7 RAMP R1 Bridge Pier
Page 4 of
Cm. No. 103-059-270
Prepared By SAB Date 9/25/08 Checked By JJT Date 9-30-08
REV 1/6/08 JJT 1-11-09

Analysis:

From AASHTO p. 10-86, $\phi_{dyn} R_n = \phi_{stat} R_{stat}$ where: ϕ_{dyn} = Dynamic Analysis Resistance Factor
R_n = Total nominal resistance
ϕ_{stat} = Static Analysis Resistance Factor
R_{nstat} = Predicted nominal resistance from static analysis

→ From AASHTO Table 10.5.5.2.3-1, (see p. 9-10)

$\phi_{dyn} = 0.65$ (Dynamic test & WEAP) $\phi_{stat} = 0.35$ (Clay & mixed soils, α-method)

Loads: (from Structures · JMS · received 9/29/08) (see p. 13-17) (Max load on p. 16)

Strength Resistance: 153.73^k * Piles are plumb.

Service Lateral Load: None

→ Use factored load in AllPile: Files: Pier1 Pile Design HP12x53.alp
" " " HP14x73.alp

⇒ Factored load = 153.73^k = $\phi_{stat} R_n$ ⇒ R_n = 153.73^k/0.35 = 439.2^k ⇒ Evaluate for HP12x53 & for HP14x73.
For Plans/WEAP, R_n = 153.73^k/0.65 = 236.5^k

→ For HP12x53, required pile length, L = 57' (see p. 5-6)

→ For HP14x73, required pile length, L = 39' (see p. 7-8)

* Check drivability → See p. 18

57' x 53 lb/ft = 3021 lbs
39' x 73 lb/ft = 2847 lbs
174 lbs SAVINGS
+ TIME TO DRIVE 20'

SUPPORT PIER ON HP 14x73 DRIVEN 40-ft
BELOW BOF i.e. EL +2.0.

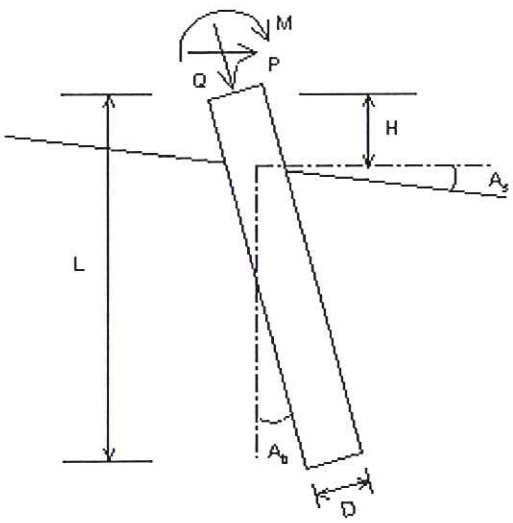
EMK 1/13/09 R_{ndr} = 240 KIPS

IT IS POSSIBLE HP 12x53 MIGHT BE MORE ECONOMICAL FOR ABUTMENTS SO COMPARE TOTAL COST FOR STRUCTURE.

VERTICAL ANALYSIS

Figure 1

RKK S7-64 JDT 1-11-09



Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 439.2 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 57.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= 0

Fixed Head Condition`

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	130	0.0	.8	250	0.84	11
12	67.6	0.0	.8	250	0.84	11
21	67.6	0.0	5	500	0.48	27
35	67.6	34	0.00	100	94.32	58

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	12.0	15.5	47.7	393.0	29000	0.05
57.0						

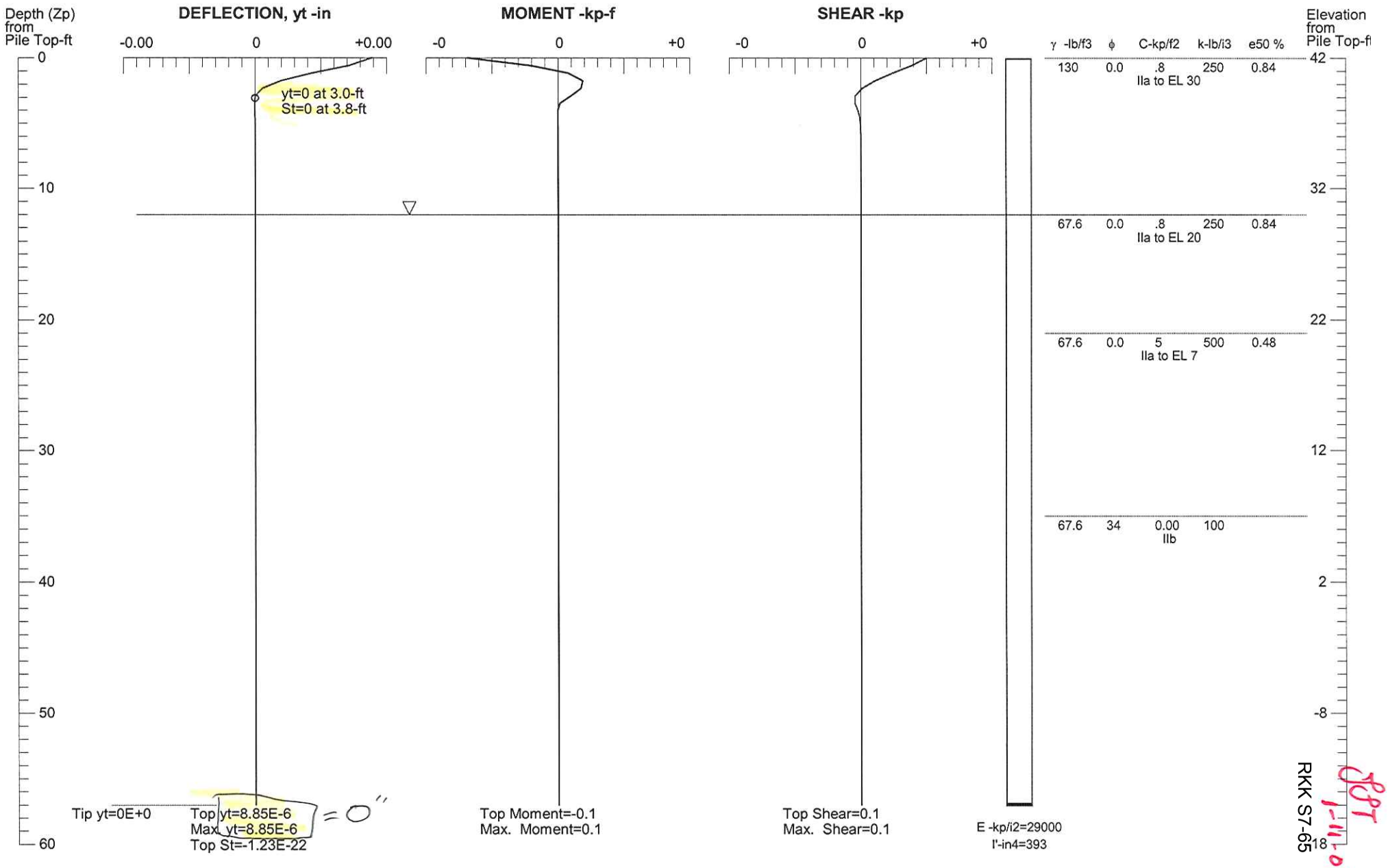
Vertical capacity:
Weight above Ground= 0.00 Total Weight= 2.85-kp *Soil Weight is not included
Side Resistance (Down)= 432.035-kp Side Resistance (Up)= 389.059-kp
Tip Resistance (Down)= 9.405-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 441.441-kp Total Ultimate Capacity (Up)= 391.909-kp
Total Allowable Capacity (Down)= 441.441-kp Total Allowable Capacity (Up)= 391.909-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 439.20-kp Settlement= 0.34160-in
At Xallow= 1.00-in Qallow= 99999.00000-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH

Single Pile, Khead=5, Kbc=2



RKK S7-65

JCPT 1-11-09

CivilTech Software

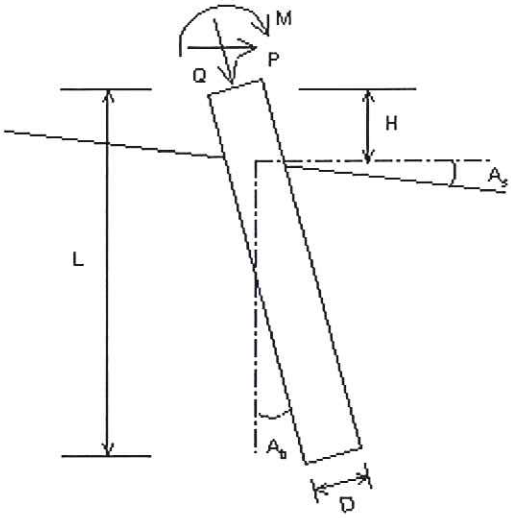
I-95/SR 1 Interchange 103-059-27U 1/5/09
Ramp R1 (Structure 7) Bridge Pier HP12x53

Figure 2

VERTICAL ANALYSIS

Figure 1

RKK S7-66 JOT 1-11-09



Driving Steel Pile (Open end)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 439.2 -kp
Shear Load, P= 0.0 -kp
Slope Restain St= 0.00 -in/-in

Profile:
Pile Length, L= 39.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= 0

Fixed Head Condition

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	130	0.0	.8	250	0.84	11
12	67.6	0.0	.8	250	0.84	11
21	67.6	0.0	5	500	0.48	27
35	67.6	34	0.00	100	94.32	58

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	14.6	21.4	56.4	729.0	29000	0.07
39.0						

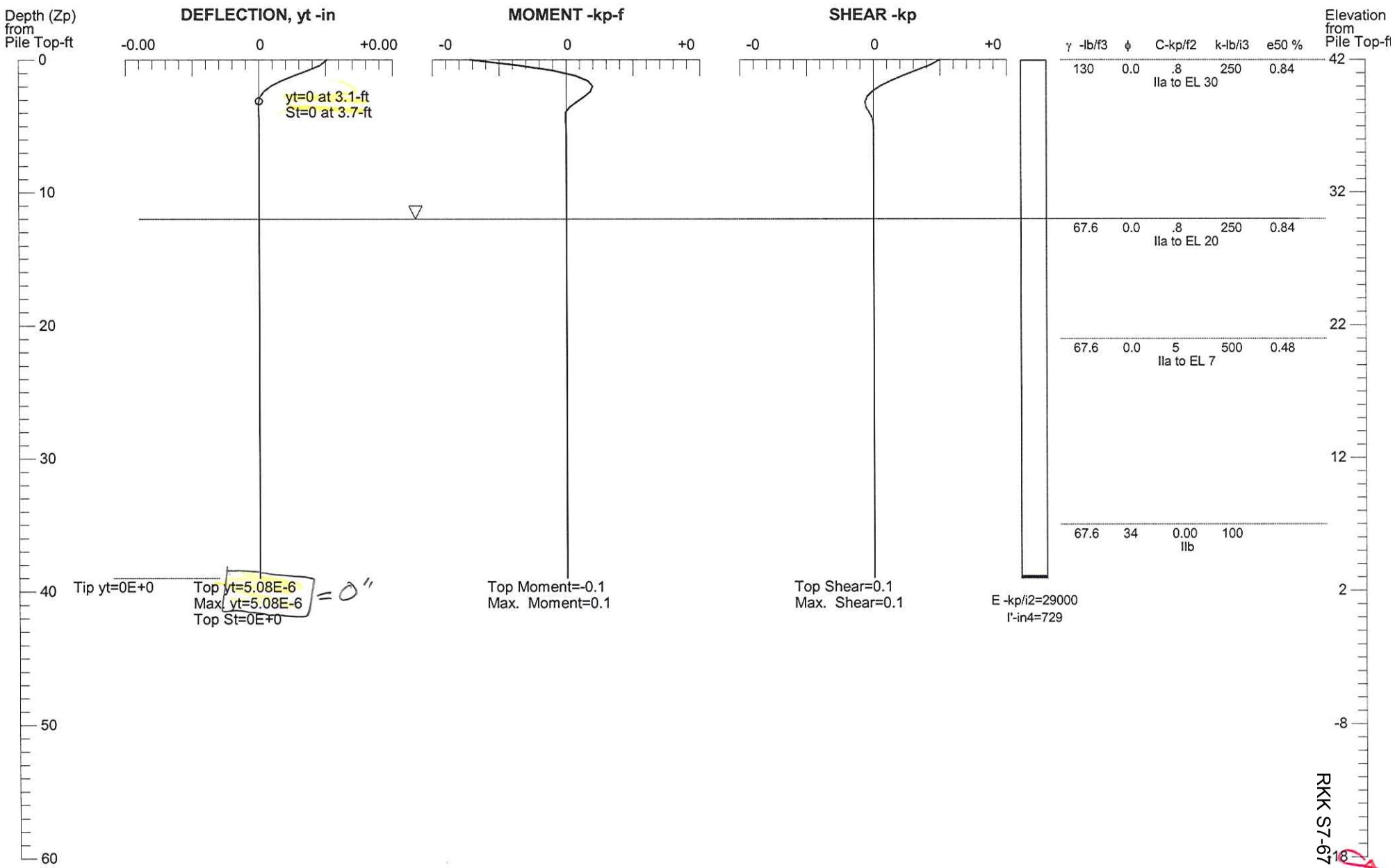
Vertical capacity:
Weight above Ground= 0.00 Total Weight= 2.73-kp *Soil Weight is not included
Side Resistance (Down)= 428.770-kp Side Resistance (Up)= 418.297-kp
Tip Resistance (Down)= 14.736-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down)= 443.506-kp Total Ultimate Capacity (Up)= 421.027-kp
Total Allowable Capacity (Down)= 443.506-kp Total Allowable Capacity (Up)= 421.027-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 439.20-kp Settlement= 0.22787-in
At Xallow= 1.00-in Qallow= 99999.00000-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

PILE DEFLECTION & FORCE vs DEPTH

Single Pile, Khead=5, Kbc=2



RKK S7-67

CivilTech Software

I-95/SR 1 Interchange 103-059-27U 1/5/09
Ramp R1 (Structure 7) Bridge Pier HP14x73

Figure 2

JJT 8-30-08 JJT 1-11-09

RKK S7-68

TABLE 3.1. TERZAGHI'S RECOMMENDATIONS FOR SOIL MODULUS α_T FOR LATERALLY LOADED PILES IN STIFF CLAY

Consistency of Clay	Stiff	Very Stiff	Hard
q_u, kPa (T/sq ft)	100-200 (1 - 2)	200-400 (2 - 4)	> 400 (> 4)
α_T, MPa (lb/sq in.)	3.2-6.4 (460-925)	6.4-12.8 (925-1850)	12.8 up (1850 up)

TABLE 3.2. REPRESENTATIVE VALUES OF ε_{50}

Consistency of Clay	ε_{50}
Soft	0.020
Medium	0.010
Stiff	0.005

TABLE 3.3. REPRESENTATIVE VALUES OF k FOR STIFF CLAYS

	AVERAGE UNDRAINED SHEAR STRENGTH* kPa		
	50-100	100-200	300-400
	1-2 ksf	2 - 4 ksf	6 - 8 ksf
k_s (static) MN/m^3 (lb/in.^{3})	135 (500)	270 (1000)	540 (2000)
k_c (cyclic) MN/m^3 (lb/in.^{3})	55 (200)	110 (400)	540 (2000)

*The average shear strength should be computed from the shear strength of the soil to a depth of 5 pile diameters. It should be defined as half the total maximum principal stress difference in an unconsolidated undrained triaxial test.

TABLE 3.4. REPRESENTATIVE VALUES OF ε_{50} FOR STIFF CLAYS

	AVERAGE UNDRAINED SHEAR STRENGTH kPa		
	50-100	100-200	300-400
	1 - 2	2 - 4	5 - 6
ε_{50}	0.007	0.005	0.004

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TABLE 3.5. TERZAGHI'S RECOMMENDATIONS FOR VALUES OF k FOR LATERALLY LOADED PILES IN SAND

JJT 1-11-09

Relative Density of Sand	Loose	Medium	Dense
Dry or moist, k, MN/m^3 ($lb/in.^3$)	0.95-2.8 (3.5 - 10.4)	3.5-10.9 (13.0 - 40.0)	13.8-27.7 (51.0 - 102.0)
Submerged sand, k, MN/m^3 ($lb/in.^3$)	0.57-1.7 (2.1 - 6.4)	2.2- 7.3 (8.0 - 27.0)	8.7-17.9 (32.0 - 64.0)

TABLE 3.6. REPRESENTATIVE VALUES OF k FOR SUBMERGED SAND

RELATIVE DENSITY	LOOSE	MEDIUM	DENSE
Recommended k MN/m^3 ($lb/in.^3$)	5.4 (20.0)	16.3 (60.0)	34 (125.0)

TABLE 3.7. REPRESENTATIVE VALUES OF k FOR SAND ABOVE WATER TABLE (Static and Cyclic Loading)

RELATIVE DENSITY	LOOSE	MEDIUM	DENSE
Recommended k MN/m^3 ($lb/in.^3$)	6.8 (25.0)	24.4 (90.0)	61.0 (225.0)

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Table 10.5.5.2.3-1 Resistance Factors for Driven Piles.

Condition/Resistance Determination Method		Resistance Factor
Nominal Resistance of Single Pile in Axial Compression—Dynamic Analysis and Static Load Test Methods, φ_{dyn}	Driving criteria established by static load test(s); quality control by dynamic testing and/or calibrated wave equation, or minimum driving resistance combined with minimum delivered hammer energy from the load test(s). For the last case, the hammer used for the test pile(s) shall be used for the production piles.	Values in Table 2
	Driving criteria established by dynamic test with signal matching at beginning of redrive conditions only of at least one production pile per pier, but no less than the number of tests per site provided in Table 3. Quality control of remaining piles by calibrated wave equation and/or dynamic testing.	0.65 SEE TABLE-3
	Wave equation analysis, without pile dynamic measurements or load test, at end of drive conditions only	0.40
	FHWA-modified Gates dynamic pile formula (End of Drive condition only)	0.40
	Engineering News Record (as defined in Article 10.7.3.8.5) dynamic pile formula (End of Drive condition only)	0.10

LRFD ONLY

SEE PAGE 10-88

$\phi_{dyn}(R_n) = \phi_{stat}(R_{n\,stat})$

BASED ON CALC'S

SEE TABLE 1

$\frac{\text{FACT LOAD}}{\text{\# OF PILES}} = \phi_c P_n$ 6.9.2.1

SEE TABLE 1

$R_n = \frac{\phi_{stat}}{\phi_{dyn}}(R_{n\,stat})$

IF NON-REDUNDANT: REDUCE FACTORS BY 20%

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Table 10.5.5.2.3-1 Resistance Factors for Driven Piles (continued). $\phi_{dyn}(R_n) = \phi_{stat}(R_n)$ RKK §7-71 C10.7.7 SST 1-11-09

Condition/Resistance Determination Method		Resistance Factor
Nominal Resistance of Single Pile in Axial Compression—Static Analysis Methods, φ_{stat}	Skin Friction and End Bearing: Clay and Mixed Soils	
	α-method (*Tomlinson, 1987*; *Skempton, 1951*)	0.35
	β-method (*Esrig & Kirby, 1979*; *Skempton, 1951*)	0.25
	λ-method (*Vijayvergiya & Focht, 1972*; *Skempton, 1951*)	0.40
	Skin Friction and End Bearing: Sand	
	Nordlund/Thurman Method (*Hannigan et al., 2005*)	0.45
	SPT-method (Meyerhof)	0.30
	CPT-method (Schmertmann)	
	End bearing in rock (*Canadian Geotech. Society, 1985*)	0.50
		0.45
Block Failure, φ_{bl}	Clay	0.60
Uplift Resistance of Single Piles, φ_{up}	Nordlund Method	0.35
	α-method	0.25
	β-method	0.20
	λ-method	0.30
	SPT-method	0.25
	CPT-method	0.40
	Load test	0.60
Group Uplift Resistance, φ_{ug}	Sand and clay	0.50
Horizontal Geotechnical Resistance of Single Pile or Pile Group	All soils and rock	1.0
Structural Limit State	Steel piles: See the provisions of Article 6.5.4.2	
	Concrete piles: See the provisions of Article 5.5.4.2.1	
	Timber piles: See the provisions of Article 8.5.2.2 and 8.5.2.3	
Pile Drivability Analysis, φ_{da} ϕ_u 7.8	Steel piles: See the provisions of Article 6.5.4.2	
	Concrete piles: See the provisions of Article 5.5.4.2.1	
	Timber piles: See the provisions of Article 8.5.2.2	
	In all three Articles identified above, use φ identified as "resistance during pile driving"	

Table 10.5.5.2.3-2 Relationship between Number of Static Load Tests Conducted per Site and φ (after *Paikowsky et al., 2004*).

Number of Static Load Tests per Site	Resistance Factor, φ — Site Variability[a]		
	Low[a]	Medium[a]	High[a]
1	0.80	0.70	0.55
2	0.90	0.75	0.65
3	0.90	0.85	0.75
≥4	0.90	0.90	0.80
	COV < 25%	COV ≥ 25% < 40%	COV ≥ 40%

a See commentary.

FOOTING DESIGN
==========

No current design available for footing: Spread Footing

From Structures
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FOOTING DESIGN
==========

No current design available for footing: Pile Footing

* see Sheet 16
For Max strength
Resistance.

COMBINED FOOTING DESIGN

Code: AASHTO LRFD 2007 (with Interims)
Units: US
Pier View : Downstation.

Geometry:
=========

Name : Pile Footing 10ft
Shape : Rectangular, Type : Pile/Shaft Cap

Bf(X) = 72.00 ft, Hf(Z) = 10.00 ft, Thickness(Y) = 45.00 in

Footing concentric.
Columns located on the footing:
Column No. 1 at x = 0.00 ft, Round D = 36.00 in
Column No. 2 at x = 16.00 ft, Round D = 36.00 in
Column No. 3 at x = 32.00 ft, Round D = 36.00 in
Column No. 4 at x = 48.00 ft, Round D = 36.00 in
Column No. 5 at x = 64.00 ft, Round D = 36.00 in

Ag = 720.00 ft^2, Ix = 465.50 ft^2, Iz = 21368.17 ft^2

Surcharge = 0.00 ksf

Piles: H-Steel Size: 14.00 in Capacity: 642.00 kips

Design Parameters:
==========

f'c = 3500.00 psi fy = 60000.00 psi
phi tens = 0.90 phi comp = 0.75 phi shear = 0.90
Tens below = 0.000 Comp Above = 0.000
Ec = 3586.6 ksi Es = 29000.0 ksi
Crack check as per 2005 Interims
Crack control Exposure = 0.00
Concrete Type : Normal Weight.

Pile Reactions, Factored:
==========

Pile	Loc(X) ft	X in	Z in	Column Loads col#	comb	Ovs	P, kips	Mxx, kft	Mzz, kft	Pile Reac. kips
1	-2.50	18.0	42.0	1	1	---	-1126.77	454.60	17.73	149.20
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	41	---	-369.09	232.10	-55.75	56.89

				2	41	---	-457.43	235.81	-70.78	RKK S7-73
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
2	-2.50	18.0	-42.0	1	2	---	-1132.63	-57.29	49.20	134.88
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	41	---	-369.09	232.10	-55.75	39.39
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
3	1.33	64.0	-42.0	1	2	---	-1132.63	-57.29	49.20	135.04
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	41	---	-369.09	232.10	-55.75	39.99
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
4	1.33	64.0	42.0	1	1	---	-1126.77	454.60	17.73	149.45
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	41	---	-369.09	232.10	-55.75	57.50
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
5	5.17	110.0	42.0	1	1	---	-1126.77	454.60	17.73	149.70
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	41	---	-369.09	232.10	-55.75	58.10
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
6	5.17	110.0	-42.0	1	2	---	-1132.63	-57.29	49.20	135.20
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	41	---	-369.09	232.10	-55.75	40.60
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
7	9.00	156.0	-42.0	1	2	---	-1132.63	-57.29	49.20	135.37
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	41	---	-369.09	232.10	-55.75	41.20
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
8	9.00	156.0	42.0	1	1	---	-1126.77	454.60	17.73	149.95
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.51

				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
9	12.83	202.0	42.0	1	1	---	-1126.77	454.60	17.73	150.21
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.52
				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
10	12.83	202.0	-42.0	1	2	---	-1132.63	-57.29	49.20	135.53
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	41	---	-369.09	232.10	-55.75	41.80
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
11	16.67	248.0	42.0	1	1	---	-1126.77	454.60	17.73	150.46
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.54
				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
12	16.67	248.0	-42.0	1	2	---	-1132.63	-57.29	49.20	135.69
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	41	---	-369.09	232.10	-55.75	42.41
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
13	20.50	294.0	-42.0	1	2	---	-1132.63	-57.29	49.20	135.86
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	41	---	-369.09	232.10	-55.75	43.01
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
14	20.50	294.0	42.0	1	1	---	-1126.77	454.60	17.73	150.71
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.56
				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
15	24.33	340.0	-42.0	1	2	---	-1132.63	-57.29	49.20	136.02
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	45	---	-429.84	333.78	-5.95	43.24

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				2	45	---	-475.85	338.86	-7.75	
				3	45	---	-468.50	337.68	-11.44	
				4	45	---	-478.38	323.12	-13.14	
				5	45	---	-423.16	309.90	-19.97	
16	24.33	340.0	42.0	1	1	---	-1126.77	454.60	17.73	150.96
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.57
				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
17	28.17	386.0	42.0	1	1	---	-1126.77	454.60	17.73	151.21
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.59
				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
18	28.17	386.0	-42.0	1	2	---	-1132.63	-57.29	49.20	136.19
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	45	---	-429.84	333.78	-5.95	43.37
				2	45	---	-475.85	338.86	-7.75	
				3	45	---	-468.50	337.68	-11.44	
				4	45	---	-478.38	323.12	-13.14	
				5	45	---	-423.16	309.90	-19.97	
19	32.00	432.0	-42.0	1	2	---	-1132.63	-57.29	49.20	136.35
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	45	---	-429.84	333.78	-5.95	43.50
				2	45	---	-475.85	338.86	-7.75	
				3	45	---	-468.50	337.68	-11.44	
				4	45	---	-478.38	323.12	-13.14	
				5	45	---	-423.16	309.90	-19.97	
20	32.00	432.0	42.0	1	1	---	-1126.77	454.60	17.73	151.47
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.60
				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
21	35.83	478.0	42.0	1	1	---	-1126.77	454.60	17.73	151.72
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.62
				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
22	35.83	478.0	-42.0	1	2	---	-1132.63	-57.29	49.20	136.51
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	45	---	-429.84	333.78	-5.95	43.64

				2	45	---	-475.85	338.86	-7.75	
				3	45	---	-468.50	337.68	-11.44	
				4	45	---	-478.38	323.12	-13.14	
				5	45	---	-423.16	309.90	-19.97	
23	39.67	524.0	-42.0	1	2	---	-1132.63	-57.29	49.20	136.68
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	45	---	-429.84	333.78	-5.95	43.77
				2	45	---	-475.85	338.86	-7.75	
				3	45	---	-468.50	337.68	-11.44	
				4	45	---	-478.38	323.12	-13.14	
				5	45	---	-423.16	309.90	-19.97	
24	39.67	524.0	42.0	1	1	---	-1126.77	454.60	17.73	151.97
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.63
				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
25	43.50	570.0	42.0	1	1	---	-1126.77	454.60	17.73	152.22
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.65
				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
26	43.50	570.0	-42.0	1	2	---	-1132.63	-57.29	49.20	136.84
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	45	---	-429.84	333.78	-5.95	43.90
				2	45	---	-475.85	338.86	-7.75	
				3	45	---	-468.50	337.68	-11.44	
				4	45	---	-478.38	323.12	-13.14	
				5	45	---	-423.16	309.90	-19.97	
27	47.33	616.0	-42.0	1	2	---	-1132.63	-57.29	49.20	137.01
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	45	---	-429.84	333.78	-5.95	44.04
				2	45	---	-475.85	338.86	-7.75	
				3	45	---	-468.50	337.68	-11.44	
				4	45	---	-478.38	323.12	-13.14	
				5	45	---	-423.16	309.90	-19.97	
28	47.33	616.0	42.0	1	1	---	-1126.77	454.60	17.73	152.47
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.66
				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
29	51.17	662.0	42.0	1	1	---	-1126.77	454.60	17.73	152.72
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.68

				2	50	---	-473.83	65.65	57.40	RKK S7-77
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
30	51.17	662.0	-42.0	1	2	---	-1132.63	-57.29	49.20	137.17
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	45	---	-429.84	333.78	-5.95	44.17
				2	45	---	-475.85	338.86	-7.75	
				3	45	---	-468.50	337.68	-11.44	
				4	45	---	-478.38	323.12	-13.14	
				5	45	---	-423.16	309.90	-19.97	
31	55.00	708.0	-42.0	1	2	---	-1132.63	-57.29	49.20	137.33
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	45	---	-429.84	333.78	-5.95	44.30
				2	45	---	-475.85	338.86	-7.75	
				3	45	---	-468.50	337.68	-11.44	
				4	45	---	-478.38	323.12	-13.14	
				5	45	---	-423.16	309.90	-19.97	
32	55.00	708.0	42.0	1	1	---	-1126.77	454.60	17.73	152.98
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.70
				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
33	58.83	754.0	42.0	1	1	---	-1126.77	454.60	17.73	153.23
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.71
				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
34	58.83	754.0	-42.0	1	2	---	-1132.63	-57.29	49.20	137.50
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	45	---	-429.84	333.78	-5.95	44.43
				2	45	---	-475.85	338.86	-7.75	
				3	45	---	-468.50	337.68	-11.44	
				4	45	---	-478.38	323.12	-13.14	
				5	45	---	-423.16	309.90	-19.97	
35	62.67	800.0	-42.0	1	2	---	-1132.63	-57.29	49.20	137.66
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	45	---	-429.84	333.78	-5.95	44.57
				2	45	---	-475.85	338.86	-7.75	
				3	45	---	-468.50	337.68	-11.44	
				4	45	---	-478.38	323.12	-13.14	
				5	45	---	-423.16	309.90	-19.97	
36	62.67	800.0	42.0	1	1	---	-1126.77	454.60	17.73	153.48
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	50	---	-436.30	63.53	55.29	58.73

				2	50	---	-473.83	65.65	57.40	
				3	50	---	-468.54	69.48	52.56	
				4	50	---	-480.39	80.99	46.59	
				5	50	---	-416.67	86.35	34.62	
37	66.50	846.0	42.0	1	1	---	-1126.77	454.60	17.73	153.73 Maximum Screw Load
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	49	---	-439.64	77.44	84.34	58.70
				2	49	---	-472.81	79.90	88.44	
				3	49	---	-468.55	83.45	82.98	
				4	49	---	-481.38	93.31	75.49	
				5	49	---	-413.34	97.38	60.97	
38	66.50	846.0	-42.0	1	2	---	-1132.63	-57.29	49.20	137.82
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	45	---	-429.84	333.78	-5.95	44.70
				2	45	---	-475.85	338.86	-7.75	
				3	45	---	-468.50	337.68	-11.44	
				4	45	---	-478.38	323.12	-13.14	
				5	45	---	-423.16	309.90	-19.97	
39	64.58	823.0	0.0	1	1	---	-1126.77	454.60	17.73	136.46
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	46	---	-497.05	165.21	105.09	54.28
				2	46	---	-492.26	168.70	120.44	
				3	46	---	-491.72	170.57	113.73	
				4	46	---	-508.19	171.61	103.59	
				5	46	---	-398.35	169.37	78.47	
40	56.92	731.0	0.0	1	1	---	-1126.77	454.60	17.73	135.95
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	46	---	-497.05	165.21	105.09	55.19
				2	46	---	-492.26	168.70	120.44	
				3	46	---	-491.72	170.57	113.73	
				4	46	---	-508.19	171.61	103.59	
				5	46	---	-398.35	169.37	78.47	
41	49.25	639.0	0.0	1	1	---	-1126.77	454.60	17.73	135.45
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	47	---	-441.84	136.43	104.28	55.47
				2	47	---	-472.15	139.82	109.63	
				3	47	---	-468.60	142.45	103.75	
				4	47	---	-482.07	146.80	94.20	
				5	47	---	-411.07	146.70	78.03	
42	41.58	547.0	0.0	1	1	---	-1126.77	454.60	17.73	134.95
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	41	---	-369.09	232.10	-55.75	55.08
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
43	33.92	455.0	0.0	1	1	---	-1126.77	454.60	17.73	134.44
				2	1	---	-1240.21	470.73	17.50	
				3	1	---	-1221.93	432.11	6.72	
				4	1	---	-1248.32	470.40	-3.95	
				5	1	---	-1102.73	452.85	-21.91	
				1	41	---	-369.09	232.10	-55.75	53.87

				2	41	---	-457.43	235.81	-70.78	RKK S7-79
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
44	26.25	363.0	0.0	1	2	---	-1132.63	-57.29	49.20	134.06
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	41	---	-369.09	232.10	-55.75	52.66
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
45	18.58	271.0	0.0	1	2	---	-1132.63	-57.29	49.20	133.74
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	41	---	-369.09	232.10	-55.75	51.46
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
46	10.92	179.0	0.0	1	2	---	-1132.63	-57.29	49.20	133.41
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	41	---	-369.09	232.10	-55.75	50.25
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
47	3.25	87.0	0.0	1	2	---	-1132.63	-57.29	49.20	133.08
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	41	---	-369.09	232.10	-55.75	49.05
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	
48	-0.58	41.0	0.0	1	2	---	-1132.63	-57.29	49.20	132.92
				2	2	---	-1238.81	-66.22	51.89	
				3	2	---	-1221.93	-24.95	40.29	
				4	2	---	-1249.57	-66.29	29.53	
				5	2	---	-1097.03	-56.61	8.13	
				1	41	---	-369.09	232.10	-55.75	48.44
				2	41	---	-457.43	235.81	-70.78	
				3	41	---	-445.32	236.59	-72.62	
				4	41	---	-450.58	232.50	-70.13	
				5	41	---	-441.48	226.88	-63.82	

Note:

Only max. force in piles is considered for design.
Pile coordinates X and Z are from the most left edge of the footing.

Max. Pile Reaction Used in Design: (without selfweight and surcharge)
==========

Factored pile reaction = 142.92 kips

Service pile reaction = 110.94 kips

One Way Shear :
==========
(Simplified Method)

Col	Dist ft	Comb	dv in	Vu kips	phi*Vc kips
X direction					
1	-4.65	----	------	Outside of Footing	
	4.65	1	36.82	253.9	470.5
2	11.35	1	36.82	426.9	470.5
	20.65	1	36.82	287.7	470.5
3	27.35	1	36.82	247.8	470.5
	36.65	1	36.82	177.8	470.5
4	43.35	1	36.82	357.7	470.5
	52.65	1	36.82	366.0	470.5
5	59.35	1	36.82	332.8	470.5
	62.35	----	------	Outside of Footing	
Z direction					
	-4.70	1	40.42	0.0	3719.3
	4.70	1	40.42	0.0	3719.3

Two Way Shear:
==========

#	Bo ft	Ao ft^2	Comb	Avg. dv in	Vu kips	phi*Vc kips
Columns:						
1	19.54	30.37	1	38.62	984.3	1920.8
2	19.54	30.37	1	38.62	1483.4	1920.8
3	19.54	30.37	1	38.62	1283.2	1920.8
4	19.54	30.37	1	38.62	1474.5	1920.8
5	19.54	30.37	1	38.62	920.2	1920.8
Piles - max:						
39	17.54	19.23	1	38.62	142.9	1724.7
Piles - min:						
1	7.39	13.64	1	38.62	142.9	726.1

Note:
TWO WAY SHEAR IN FOOTING IS NOT DESIGNED AND STIRRUPS ARE NOT CONSIDERED.

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Subject SR1 / I-95 Interchange
S7: Ramp R1 Bridge Pier WEAP
Page 18 of
Cm. No. 103-059-27U
Prepared By SAB Date 1/5/09 Checked By JJT Date 1-11-09

WEAP Analysis

Software: GRLWEAP 2003 (Wave Equation Analysis of Pile Driving)

Soils: See p. 2-3, 19

ALLOWABLE
Driving Stress: $\sigma_{d1} = 0.9\phi_{hn} f_y$ (AASHTO 10.7.8-1) where: $\phi_{hn} = 1.0$ (AASHTO 10.5.5.2.3-1)
f_y = Yield strength of steel

$= 0.9(1.0)(50\ ksi) = \underline{45\ ksi}$

→ USACE limits penetration rates to 10-20 blows/inch for steel H-piles. (120-240 B/FT)

⇒ Limit blows to < 150 blows/ft. = 13 blows/in.

$R_u = 439.2^k$, Pile Length = 39' for HP14x73

→ Check drivability with: 1) Delmag D 30-32 (see p. 21-24)
2) Delmag D 25-32 (see p. 25-28)

For hammer w/ 80% effic.

SUMMARY

Hammer	Max. Driving Stress (ksi)	Pile Capacity (k)	Max. Blow Count (bpf)	EITHER HAMMER WILL WORK W/O OVERSTRESSING PILE
Delmag D 30-32	37.66	439.2	50	w/ hammer @ 80% eff.
Delmag D 25-32	36.37	439.2	56	

∴ drivability feasible. Contractor to provide schedule WEAP analysis @ time of Construction for specific equipment.

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Subject I-95/SR1 Interchange
Structure 7 Ramp R1 Bridge Pier Foundation
Prepared By SAB Date 9/25/08 Checked By JJT Date 9-30-08
REV 1/5/09 JJT 1-11-09

Cm. No. 103-054-270

Objective: To estimate the required pile lengths for the Ramp R1 (Structure 7) Bridge pier foundation and perform a drivability analysis of the piles.

References: 1) AASHTO LRFD Bridge Design Specifications, 4th ed.
2) US Army Corps of Engineers EM 1110-2-2906, 15 January 1991

Contents:

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WEAP Analysis	Pages 18-27

Summary:

Pile	Required Length (ft)	Approx. Pile Tip EL
HP12x53	57	-15
HP14x73	39	3

> w/ BOF @ EL 42

(*) Recommend HP 14x73 w/ Length ≈ 39-ft + Tip EL near EL 3

WEAP:

Pile Size	Pile Length	Nominal Resistance, R_n	Hammer	Maximum Driving Stress	Maximum Blow Count
HP 14x73	39'	439.2k	Delmag D 30-32	38 ksi	50 bpf
HP 14x73	39'	439.2k	Delmag D 25-32	37 ksi	56 bpf

* GRLWEAP analysis assumes hammer @ 80% efficiency.

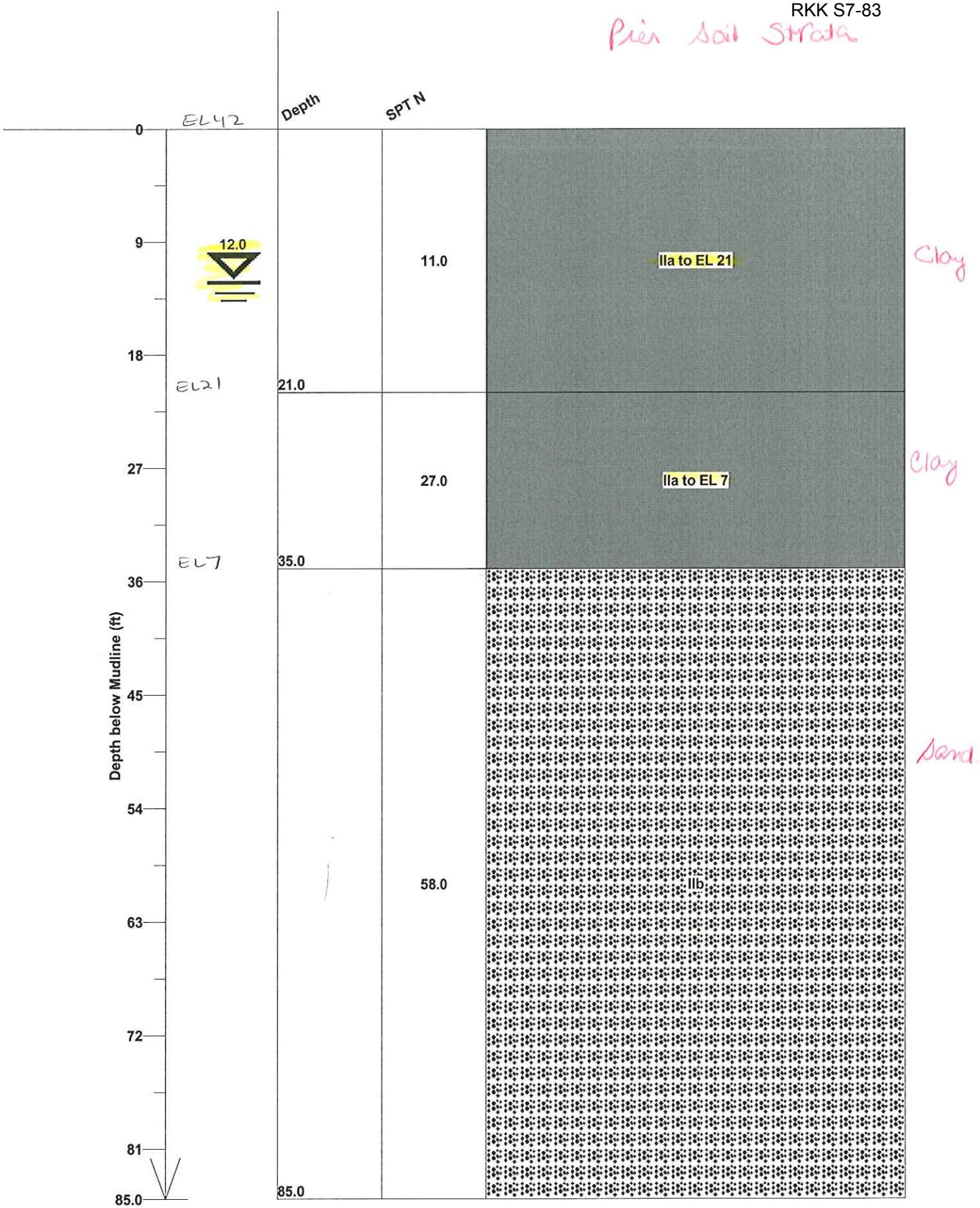
∴ driveability feasible. Contractor to provide actual WEAP analysis @ time of construction & for specific equipment

JJT 1-11-09

19

RKK S7-83

Pier Soil Strata



JJT 1-11-09

20

RKK S7-84

Depth vs. Soil Stress, Side Resistance, and Pile Axial Force:

****

AllPile Data: S7 Pier

Zp -ft	Sv -kp/f2	Sf_dw -kp/f2	Sf_up -kp/f2	Q_dw -kp	Q_up -kp
0.0	0.00	0.80	0.80	367.3	362.7
21.0	2.17	0.80	0.80	288.4	282.4
21.0	2.18	5.00	5.00	288.2	282.1
33.0	2.40	5.00	5.00	6.9	0.0

Zs - Soil Depth, Depth from Ground Surface
Zp - Pile Depth, Depth from Pile Top
Sv - Vertical Effective Stress in Soils
Sf_dw - Uplift Side Resistance between Soil and Pile
Sf_up - Uplift Side Resistance between Soil and Pile
Q_dw - Downward Axial Force in Pile Shaft (Ultimate Uplift Capacity)
Q_up - Uplift Axial Force in Pile Shaft (Ultimate Uplift Capacity)

From All pile

Per analysis

Rummel Klepper & Kahl, LLP

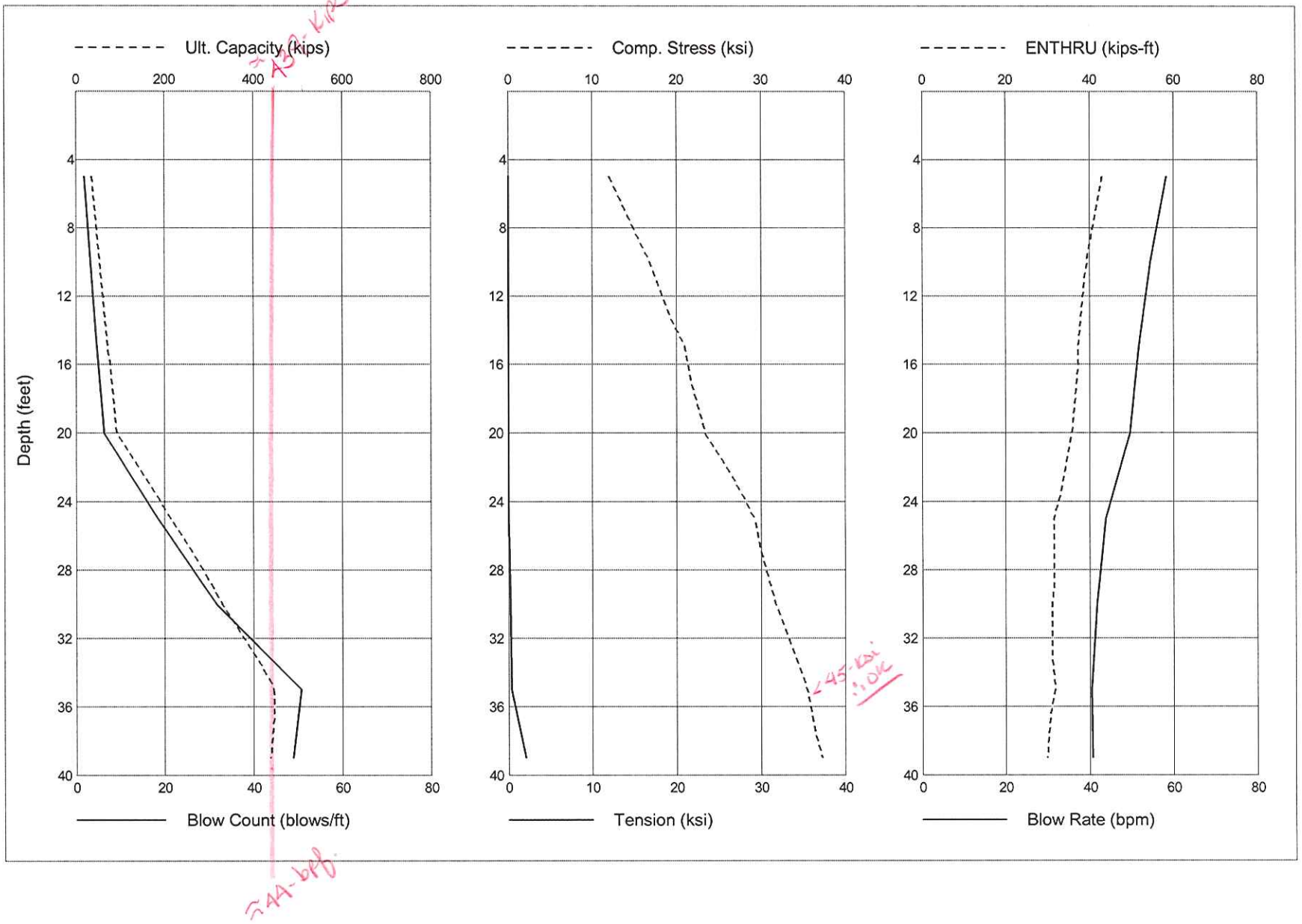
Decmaa D 30-32

Jan 09 2009

S7: Ramp R1 Bridge Pier

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

GRLWEAP(TM) Version 2003



RKK S7-85

21

22

JJT 1-11-09

RKK S7-86

DELMAG D 30-32

Rummel Klepper & Kahl, LLP
S7: Ramp R1 Bridge Pier

Jan 09 2009
GRLWEAP(TM) Version 2003

Pier Analysis

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Blow Rate bpm	ENTHRU kips-ft
5.0	35.6	18.7	16.9	2.0	12.004	0.000	58.3	42.9
10.0	54.2	37.3	16.9	3.3	16.827	0.000	54.6	39.3
15.0	72.9	56.0	16.9	4.8	20.945	0.000	51.7	37.3
20.0	91.6	74.7	16.9	6.3	23.411	0.000	49.7	35.7
25.0	213.2	171.7	41.5	18.5	29.299	0.000	43.8	31.4
30.0	329.9	288.4	41.5	31.6	31.766	-0.300	41.8	31.1
35.0	446.5	405.1	41.5	50.8	35.469	-0.414	40.4	31.7
39.0	439.2	421.2	18.0	48.9	37.295	-2.082	40.6	29.7

≥ 439.2k ✓ OK < 45 ksi ✓ OK

Total Continuous Driving Time 16.00 minutes; Total Number of Blows 658

Allpile Friction : 429 kips
End Bearing: 15 kips

∴ OK w/ GRLWEAP analysis

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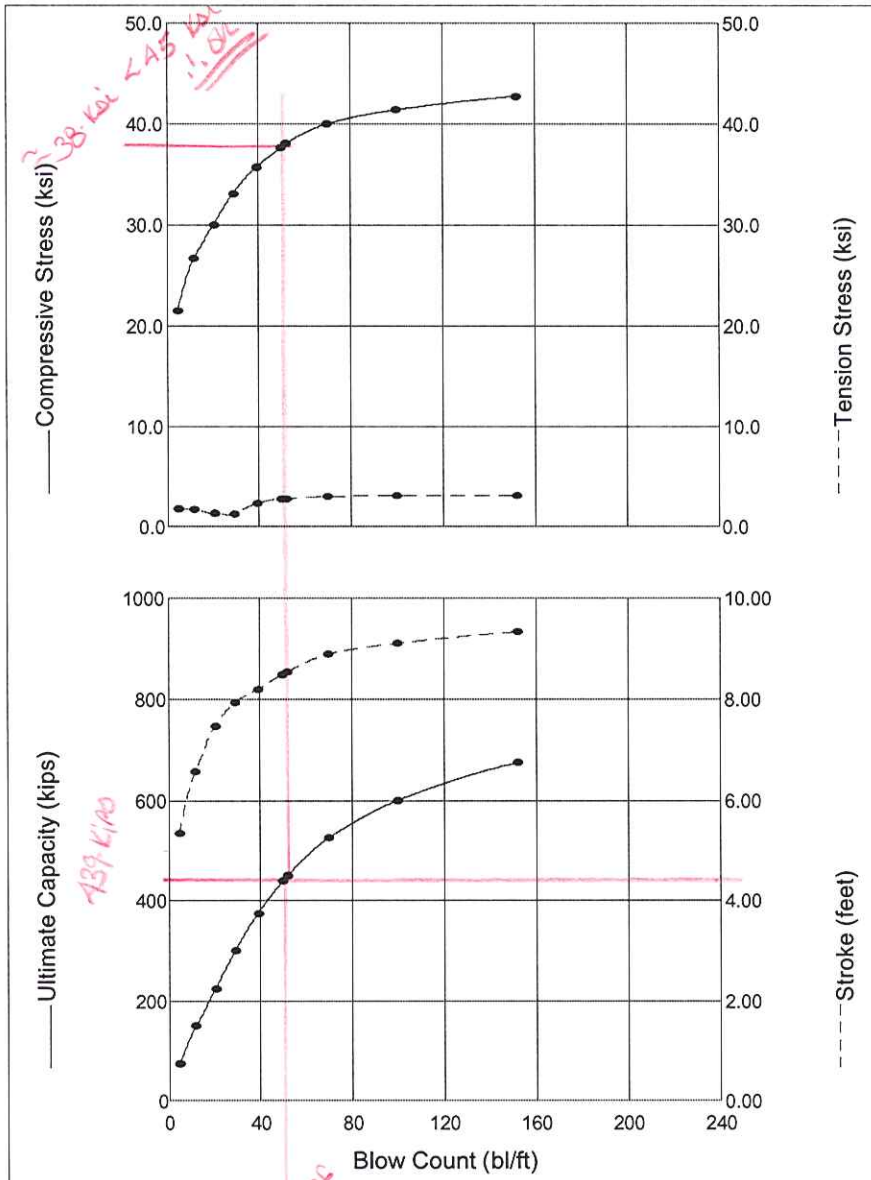
S7: Ramp R1 Bridge Pier

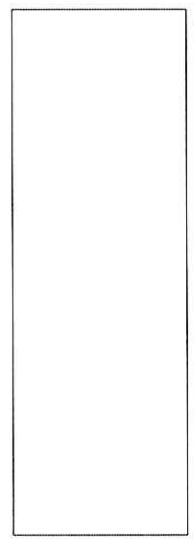
09-Jan-2009
GRLWEAP (TM) Version 2003



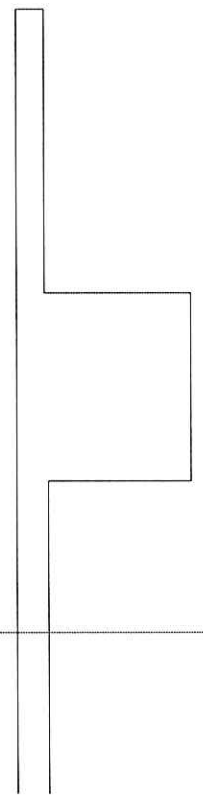
DELMAG D 30-32 – Pier

Efficiency	0.800	
Helmet	3.20	kips
Hammer Cushion	109975	kips/in
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	39.00	ft
Pile Penetration	39.00	ft
Pile Top Area	21.40	in2

Pile Model



Skin Friction Distribution



Res. Shaft = 100 %
(Proportional)

RKK S7-87

8pt
1-11-09

JOT 1-11-09 24

DELMAG D 30-32 RKK S7-88

Rummel Klepper & Kahl, LLP
S7: Ramp R1 Bridge Pier

09-Jan-2009
GRLWEAP (TM) Version 2003

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke feet	Energy kips-ft
75.0	21.53	1.81	5.1	5.35	36.21
150.0	26.68	1.74	12.0	6.58	31.59
225.0	30.03	1.34	20.7	7.47	29.98
300.0	33.12	1.30	29.1	7.93	29.07
375.0	35.72	2.35	39.1	8.20	29.15
439.2	37.66	2.78	49.9	8.50	29.58
450.0	38.05	2.78	51.8	8.55	29.81
525.0	40.01	3.03	69.7	8.90	30.48
600.0	41.42	3.13	99.7	9.11	30.62
675.0	42.78	3.15	152.4	9.34	31.00

Delmar D 25-32 for Pier

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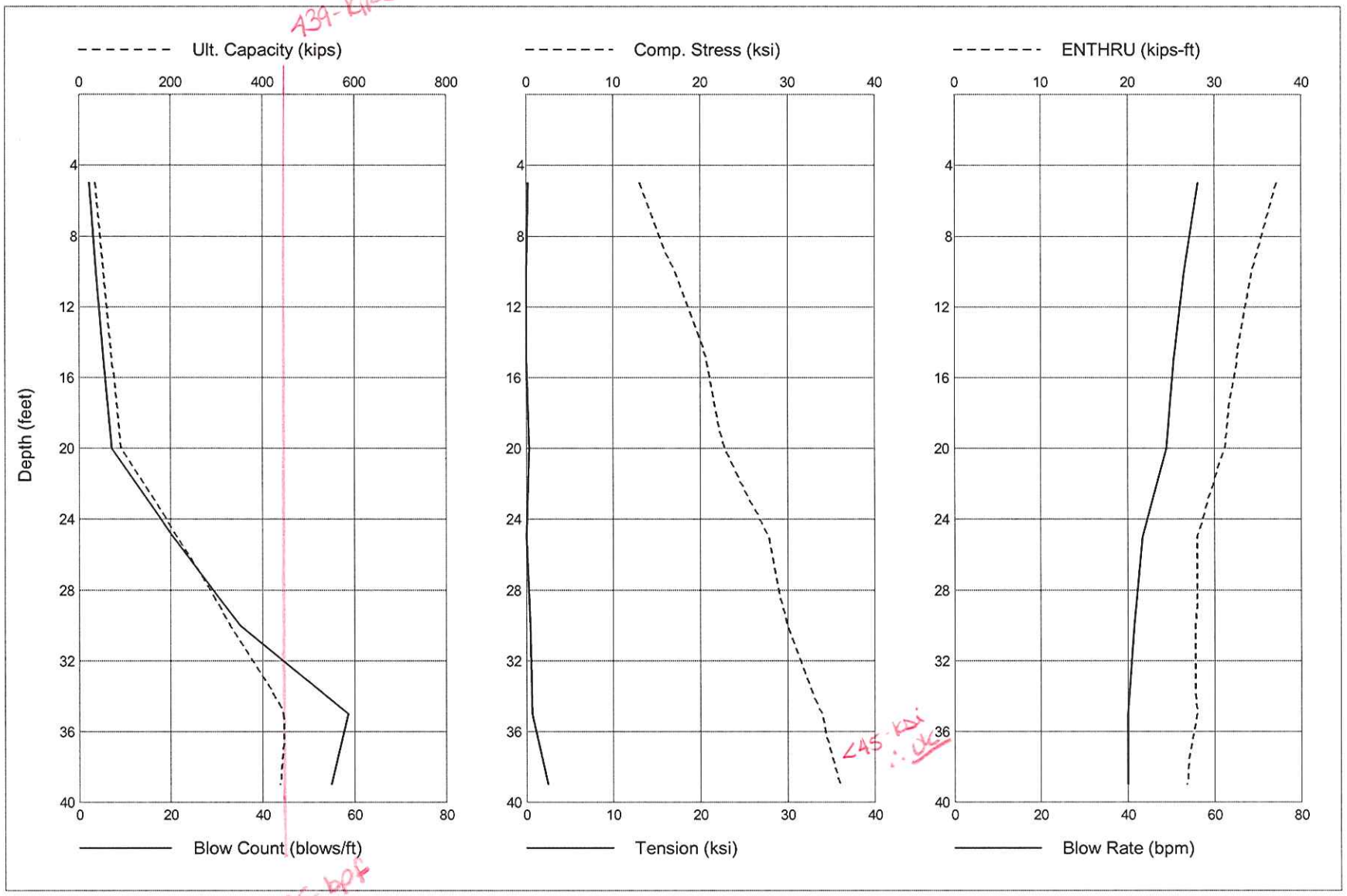
Jan 09 2009

S7: Ramp R1 Bridge Pier

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

GRLWEAP(TM) Version 2003



JPT 1-11-09

RKK S7-89

25

JJT 1-11-09

RKK S7-90

Rummel Klepper & Kahl, LLP
S7: Ramp R1 Bridge Pier

Jan 09 2009
GRLWEAP(TM) Version 2003

Gain/Loss 1 at Shaft and Toe 1.000 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Blow Rate bpm	ENTHRU kips-ft
5.0	35.6	18.7	16.9	2.3	13.116	-0.278	56.3	37.2
10.0	54.2	37.3	16.9	3.8	17.113	0.000	53.0	34.3
15.0	72.9	56.0	16.9	5.4	20.717	0.000	50.6	32.6
20.0	91.6	74.7	16.9	7.2	22.728	-0.380	48.9	31.2
25.0	213.2	171.7	41.5	20.6	27.907	-0.092	43.5	28.0
30.0	329.9	288.4	41.5	35.2	29.997	-0.524	41.4	27.8
35.0	446.5	405.1	41.5	58.7	33.981	-0.689	40.0	28.0
39.0	439.2	421.2	18.0	54.9	36.025	-2.548	40.1	26.8

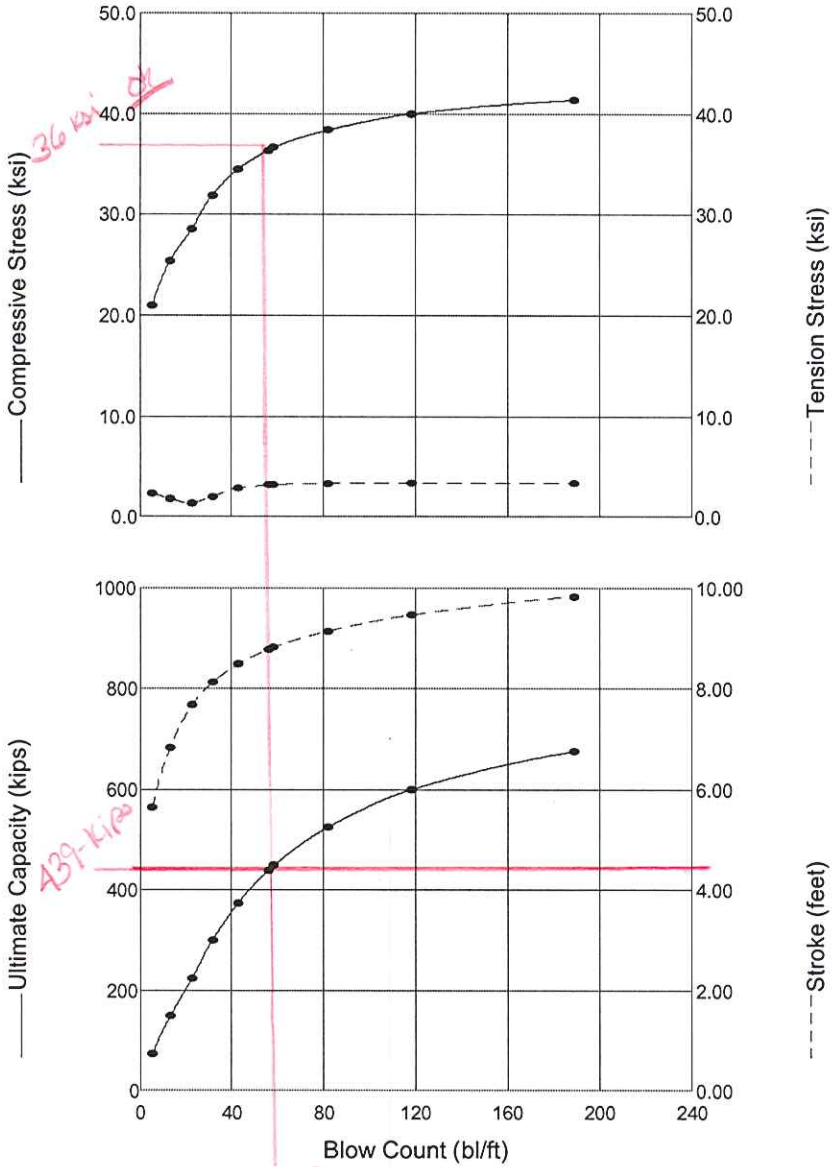
≥ 439.2k ✓ OK < 45ksi ✓ OK

Total Continuous Driving Time 18.00 minutes; Total Number of Blows 746

All pile Friction: 429 - Kip
End Bearing: 15 - Kips
∴ OK w/ GRLWEAP analysis

Rummel Klepper & Kahl, LLP
S7: Ramp R1 Bridge Pier

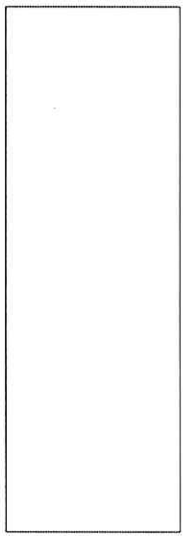
09-Jan-2009
GRLWEAP (TM) Version 2003



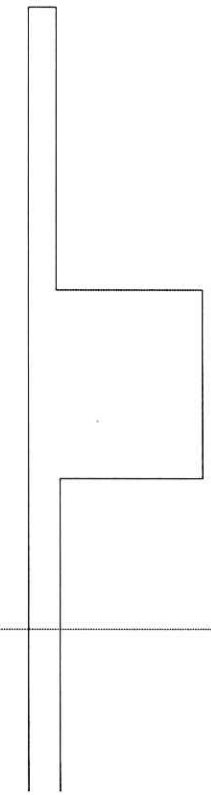
DELMAG D 25-32 for Pier

Efficiency	0.800	
Helmet	3.20	kips
Hammer Cushion	109975	kips/in
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	39.00	ft
Pile Penetration	39.00	ft
Pile Top Area	21.40	in2

Pile Model



Skin Friction Distribution



Res. Shaft = 100 %
(Proportional)

RKK S7-91

JGT 1-11-09

27

JJT 1-11-09

28

DELMAR D 25-32 - Pier

RKK S7-92

Rummel Klepper & Kahl, LLP
S7: Ramp R1 Bridge Pier

09-Jan-2009
GRLWEAP (TM) Version 2003

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke feet	Energy kips-ft
75.0	20.96	2.36	5.8	5.64	31.59
150.0	25.34	1.84	13.5	6.82	27.77
225.0	28.53	1.39	23.2	7.68	26.62
300.0	31.88	2.02	31.9	8.12	26.05
375.0	34.49	2.86	43.2	8.49	26.28
439.2	36.37	3.17	56.1	8.78	26.68
450.0	36.68	3.21	58.5	8.83	26.79
525.0	38.41	3.34	81.9	9.15	27.17
600.0	40.07	3.40	118.5	9.48	27.86
675.0	41.44	3.42	188.9	9.84	28.48

< 45 ksi ✓ OK

CALCULATION CHECKLIST

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

Title of Calculation Set: **Structure 7 – Ramp R1 Bridge – Pier Foundation Bearing Resistance** (for Spread Footing)

Project Manager: **EMK/JLT**

Calculations Prepared By: **SAB**

Calculation Checked By:

Computer Programs / Files:

Initial	Date	
		Subsurface Characterization approved by Project Manager
SAB	1/6/09	Calculations are neat, legible and understandable.
—	—	Table of Contents is provided.
SAB	1/6/09	Heading on each page filled out
SAB	1/6/09	The first page contains purpose of the calculation.
SAB	1/6/09	Symbols are defined.
SAB	1/6/09	References for data, methods, formulas and computer program names and version numbers are given.
SAB	1/6/09	Assumptions are listed and those that need to be verified later are Flagged.
—	—	Headings on front sheet of each set of computer input and output.
SAB	1/6/09	All calculations checked and each calculation sheet initialed by originator before giving to checker.
JLT	1-11-09	All calculations checked and each calculation sheet initialed by checker.
EMK	1/13/09	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 I-95/SR1 Interchange — Page 1 of 33
Structure 7 Ramp R1 Bridge Pier Foundation — Cm. No. 103-059-27U
Prepared By SAB Date 1/6/09 Checked By JJT Date 1-11-09

Objective: To evaluate the use of a spread footing to support the S7: Ramp R1 Bridge Pier.

References: 1) AASHTO LRFD Bridge Design Specifications,

⇒ Will provide foundation soil parameters to Structures (Corey Hull) to size a spread footing necessary to support the pier.

→ Computer software ABLRFD used to evaluate the spread footing.

Conclusion:

Footing Size: 73' Long, 33.25' wide, 2.67' thick, BOF EL42

Maximum Bearing Pressure: 5.86 ksf.

⇒ Due to the large footing size needed to support the pier loads, a spread footing is not economical for this pier foundation.

A deep foundation is recommended!

* See 11 pile calcs for pier design.

* Pile cap will be 72-ft long + 10-ft wide ≈ 3-ft thick.

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Subject I-95/SR1 Interchange
Structure 7 Ramp R1 Bridge Pier Foundation
Page 2 of 8
Cm. No. 103-059-270
Prepared By SAB Date 1/6/09 Checked By JJT Date 1-11-09

Soils: (See fence diagram, Pier, attached, page 3)

Ground Surface EL = EL 47 (assumed) BOF EL = EL 42 (assumed)

Stratum	EL	γ_T	ϕ_f'(deg)	c'(psf)	S_u(psf)
IIa	47-30	130	24	-	800 *
IIa	30-10	130	24	-	5,000 *
IIb	10...	130	34	-	—
Water	30	62.4			

* From laboratory test results (UU Triaxial tests) - see p. 8.

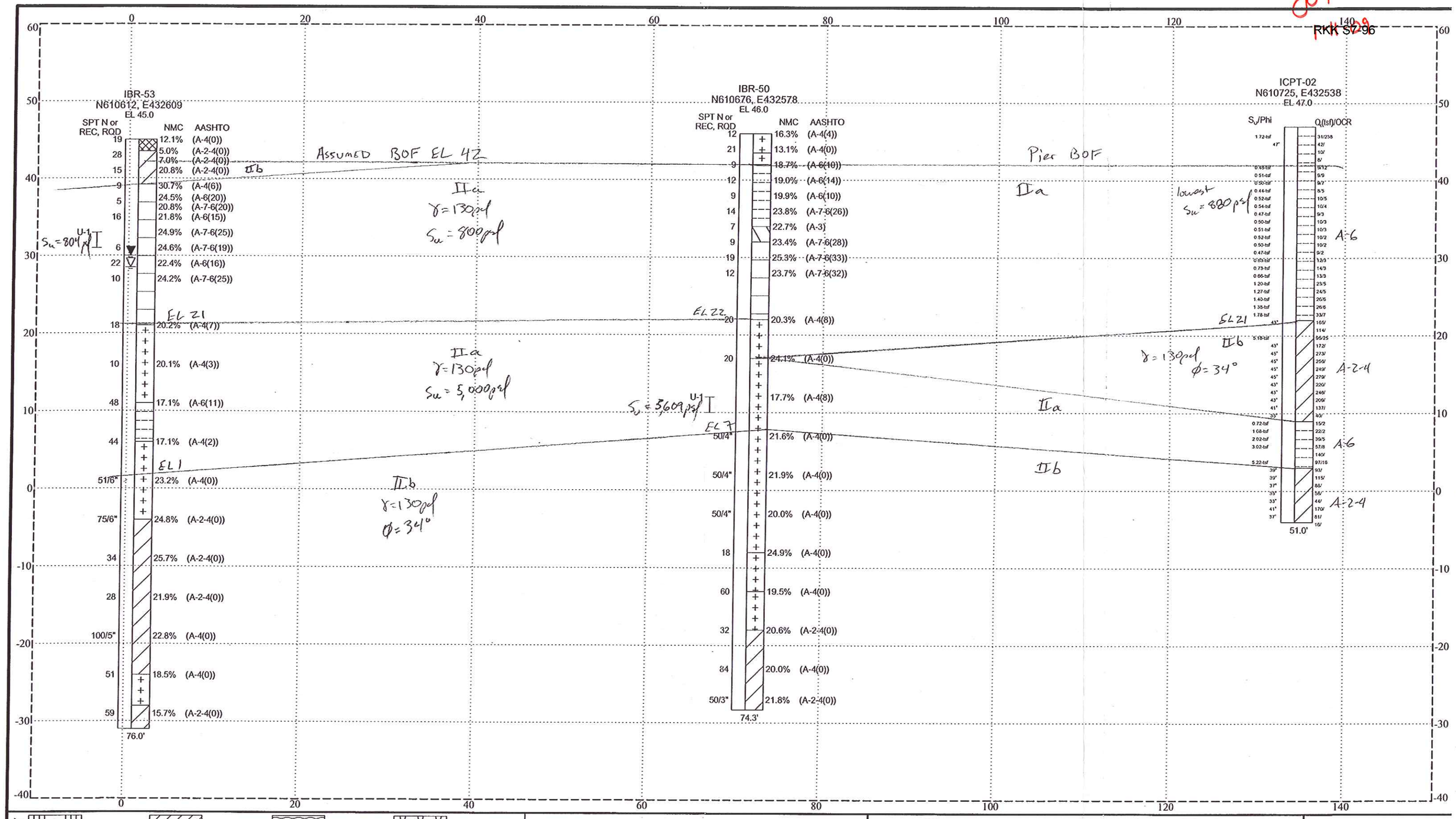
* Try WWW Soil parameters case drained analysis *

SR1/I-95 Interchange 103-059-27U

3

SPT

RKK S7-96



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

S7: Ramp R1 over SR 7 - Pier

Figure No. A-4b

Drawn: SAB | Approved: EMK | Date: 1/5/09 | Comm. No. 103-059-27U

DEL DOT AASHTO ALL DE I95 GINT FILE.GPJ RKK_CURRENT.GDT 1/5/09

S71 Ramp R1 Bridge Pier - Spread Footing Calculations - from Corey Hubbard 1/6/09 RKK 1/7/09

Spread Ramp1.OUT

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*
    *  Version                1.7.0.0
*
    *  Last Updated           02/15/2008
*
    *  Documentation          02/2008
*
    *  License No.            333509
*
    *
*
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    *  SR 1 INTERCHANGE ABUTMENTS
*
    *
*
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```

* Preliminary Analysis to verify deep foundation is needed for Pier.
* Checked input of soil parameters + bearing only

JJT 1-11-09

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SR 1 INTERCHANGE ABUTMENTS

ECHO OF INPUT FILE

Spread Ramp1.dat

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! ** Created by EngAsst **
! EngAsst Information: [Program=ABLRFD] [Version=1.7.0.0]
! ** Data Records Start Here **
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TTL SR 1 INTERCHANGE ABUTMENTS
TTL
TTL
CTL US,D,T
AT2 25.0,16,39,0,60,0.0,0.0,0.0,8,27,51,24,24,,,7,66,24,60
FTG 2,1,2,,4.5,4.0,,,2.0,3.0,1.0
SPR V
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-----------------------------------------------------------------------------
                            SR 1 INTERCHANGE ABUTMENTS

                               SUMMARY OF INPUT FILE


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       TOP BLANK LINES PER PAGE             0            (default)

     COMMAND:  CTL
       SYSTEM OF UNITS                     US
       TYPE OF RUN                          D
       FOOTING DATUM                        T

     COMMAND:  AT2
       HEIGHT                           25.0 ft
       TOP WIDTH                          16 in
       SEAT WIDTH                         39 in
       SEAT SLOPE HEIGHT                   0 in
       SEAT FACE HEIGHT                   60 in
       CORBEL WIDTH                      0.0 in
       CORBEL HEIGHT                     0.0 in
       CORBEL SLOPE HEIGHT               0.0 in
       PAVING NOTCH WIDTH                  8 in
       PAVING NOTCH HEIGHT                27 in
       BACKWALL HEIGHT                    51 in
       STEM NOTCH WIDTH                   24 in
       STEM NOTCH HEIGHT                  24 in
       FRONT FACE HORZ COMP.               *        (computed, if necessary)
       FRONT FACE VERT COMP.               *        (computed, if necessary)
       BACK  FACE HORZ COMP.               7
       BACK  FACE VERT COMP.              66
       BEARING LOCATION - X DIR           24 in
       BEARING LOCATION - Y DIR           60 in
       FRONT WATER LEVEL                   * ft     (computed, if necessary)
       BACK  WATER LEVEL                   * ft     (computed, if necessary)

     COMMAND:  FTG
       MINIMUM FOOTING THICKNESS           2 ft
       MINIMUM TOE  PROJECTION             1 ft
       MINIMUM HEEL PROJECTION             2 ft
       MINIMUM FOOTING WIDTH               * ft     (computed, if necessary)
       MAXIMUM FOOTING THICKNESS         4.5 ft
       MAXIMUM TOE  PROJECTION           4.0 ft
       MAXIMUM HEEL PROJECTION             * ft     (computed, if necessary)
       MAXIMUM FOOTING WIDTH               * ft     (computed, if necessary)
       FOOTING THICK INCREMENT           2.0 in
```

```
FOOTING WIDTH INCREMENT            3.0 in
FOOTING STEM INCREMENT             1.0 in
```

SR 1 INTERCHANGE ABUTMENTS

SUMMARY OF INPUT FILE (cont.)

Spread Ramp1.dat (cont.)

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COMMAND:  SPR
  DESIGN OPTIMIZATION                V
  COST OF CONCRETE                   * $/yd^3 (computed, if necessary)
  CUT OR FILL                        *        (computed, if necessary)
  COST OF FILL                       * $/yd^3 (computed, if necessary)
  COST OF CUT                        * $/yd^3 (computed, if necessary)
  GROUND ELEVATION                   * ft     (computed, if necessary)
  GROUND SLOPE TYPE                  *        (computed, if necessary)
  GROUND SLOPE VERT. COMP.           *        (computed, if necessary)
  GROUND SLOPE HORZ. COMP.           *        (computed, if necessary)

COMMAND:  MAT
  BACKWALL CONC. STRENGTH          4.5 ksi
  STEM     CONC. STRENGTH          3.5 ksi
  FOOTING  CONC. STRENGTH          3.5 ksi
  REINF.   YIELD STRENGTH           50 ksi
  EPOXY COAT BARS - BACK             Y
  EPOXY COAT BARS - STEM             Y
  EPOXY COAT BARS - FOOT             N
  BACKFILL FRICTION ANGLE           32 deg
  BACKFILL UNIT WEIGHT DRY         125 lb/ft^3
  BACKFILL UNIT WEIGHT SAT         130 lb/ft^3
  MIN EQUIV EARTH PRESSURE       43.37 lb/ft^3
  DENSITY OF CONC. FOR DL          150 lb/ft^3
  DENSITY OF CONC. FOR E           150 lb/ft^3

COMMAND:  SOI
  STEM TOP TO SOIL LAYER          25.0 ft
  FOOTING LENGTH (PARALLEL)       73.0 ft
  FOOTING NEAR SLOPE?                N
  SOIL LEVEL OVER TOE              1.5 ft
  ALLOWABLE SETTLEMENT             1.0 in
  BEARING CAPACITY PHI            0.50
  SLIDING PHI FACTOR              0.85
  NUMBER OF SOIL LAYERS              1
  SOIL LAYER THICKNESS             6.0 ft
  UNDRAINED SHEAR STRENGTH           * ksf    (computed, if necessary)
  MASS (dry) UNIT WEIGHT         108.0 lb/ft^3
  SATURATED UNIT WEIGHT          130.0 lb/ft^3
  ELASTIC MODULUS                   50 ksf
  POISSONS RATIO                   0.4
  COHESION                           * ksf    (computed, if necessary)
  FRICTION ANGLE (EFFECT)           24 deg
  NCQ        (NEAR SLOPE)            *        (computed, if necessary)
  N_GAMMA_Q  (NEAR SLOPE)            *        (computed, if necessary)
```

SR 1 INTERCHANGE ABUTMENTS

SUMMARY OF INPUT FILE (cont.)

Spread Ramp1.dat (cont.)

```
COMMAND:  MRD
  AGGREGATE SIZE                    .75 in
  DEVELOPMENT CORRECTION            1.0            (default)
  BACKWALL EXPOSURE                   1
  STEM     EXPOSURE                   1
  FOOTING  EXPOSURE                   2

COMMAND:  CVR
  BACKWALL BACK  - VERT.              3 in
  STEM BACK  - VERTICAL               3 in
  FOOTING TOP    PERPEND.             3 in
  FOOTING TOP    PARALLEL             3 in
  FOOTING BOTTOM PERPEND.             4 in
  FOOTING BOTTOM PARALLEL             4 in
  TOE  END COVER                      2 in
  HEEL END COVER                      2 in

COMMAND:  SPD
  MAX DIAMETER - BACKWALL         2.257 in
  MAX DIAMETER - STEM             2.257 in
  MAX DIAMETER - FOOTING          2.257 in
  HOOKED FOOTING BARS                 N
  USER REQ MIN BAR SPAC             6.0 in
  BAR SPACING INCREMENT             3.0 in

COMMAND:  LDC
  DUCTILITY  FACTOR (ETA)           1.0
  REDUNDANCY FACTOR (ETA)           1.0
  IMPORTANCE FACTOR (ETA)           1.0
  LS  (TEMP  STAGE)                 3.5 ft
  LS  (FINAL STAGE)                 3.5 ft
  ES  (TEMP  STAGE)                   0 ft
  ES  (FINAL STAGE)                   0 ft

COMMAND:  LAB
  DC - SUPERSTRUCTURE              8.15 kip
  DW - SUPERSTRUCTURE              1.02 kip
  PL - PEDESTRIAN                     * kip    (computed, if necessary)
  WS - WIND VERT ON SUP               0 kip
  WS - WIND HORZ ON SUP               0 kip
  WL - WIND ON LIVE LOAD              0 kip
  TU - THERMAL FORCE                  0 kip
  BACKWALL VERTICAL LL             3.17 kip
  BACKWALL HORIZONTAL LL              * kip    (computed, if necessary)
  WS - WIND HORZ ON SUB             0.0 kip
  FR - FRICTION FORCE               0.0 kip
```

SR 1 INTERCHANGE ABUTMENTS

SUMMARY OF INPUT FILE (cont.)

Spread Ramp1.dat (cont.)

```
COMMAND:  DLL
  LL - LIVE LOAD - DOWNWARD        4.21 kip
  LL - LIVE LOAD -   UPWARD         0.0 kip
  BR - BRAKING FORCE               0.79 kip
  CE - CENTRIFUGAL FORCE              0 kip

COMMAND:  OIN
  INPUT FILE ECHO                     1
  INPUT COMMANDS                      1
  INPUT SUMMARY                       1

COMMAND:  OUR
  FOOTING GEOMETRY                    1
  OUTPUT LEGEND                       1
  FACTORED FORCES                     1
  FOOTING STABILITY                   1
  CONTROL FOOTING FORCES              1
  FOOTING FLEXURE                     1
  REINFORCEMENT SUMMARY               1
  CRACK CONTROL                       1
  SHEAR RESULTS                       1
  DEVELOPMENT LENGTH                  1

The following are system settings:
---------------------------------
  PRINT DIMENSION FILE                N          (default)
  HISTORY FILE                        0          (default)
  SOIL HISTORY                        0          (default)
```

SR 1 INTERCHANGE ABUTMENTS

INPUT SUMMARY

CONFIGURATION

Lines per Page	Blank Lines on Top
60	0

Spread Ramp1.OUT

CONTROL

Sys of Units	Type of Run	Footing Datum
US	D	T

ABUTMENT TYPE II

Height (ft)	Top Width (in)	Seat Width (in)	Seat Slope Height (in)	Seat Face Height (in)	Corbel Width (in)	Corbel Height (in)	Corbel Slope Height (in)
25.00	16.0	39.0	0.0	60.0	0.0	0.0	0.0

Paving Notch Width (in)	Paving Notch Height (in)	Backwall Height (in)	Stem Notch Width (in)	Stem Notch Height (in)	Front Face Horizontal Component	Front Face Vertical Component
8.0	27.0	51.0	24.0	24.0	none	none

Back Face Horizontal Component	Back Face Vertical Component	Bearing X Locn (in)	Bearing Y Locn (in)	Front Water Level (ft)	Back Water Level (ft)
7.00	66.00	24.0	60.0	none	none

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
2.00	1.00	2.00	none	4.50	4.00	none	none

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

SPREAD

Cost of Concrete ($/yd^3)	Cost of Fill ($/yd^3)	Cost of Cut ($/yd^3)	Cut or Fill	Ground Elev (ft)	Ground Slope Type	Ground Slope Vert	Ground Slope Horiz	Design Optim
0.00	0.00	none	?	none	none	none	none	V

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SR 1 INTERCHANGE ABUTMENTS

INPUT SUMMARY (cont.)

MATERIALS

Backwall	Stem	Footing	Reinforcement	Epoxy Coated

Spread Ramp1.OUT

f'c (ksi)	f'c (ksi)	f'c (ksi)	fy (ksi)	Backwall	Stem	Footing
4.500	3.500	3.500	50.000	Y	Y	N

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	Concrete Density For Ec (lb/ft^3)
32.00	125.0	130.0	43.4	150.0	150.0

SOIL

Stem Top to Soil Layer (ft)	Footing Length (Parallel) (ft)	Footing Near Slope	Soil Level Over Toe (ft)	Allow Settle (in)	Bearing Cap Resistance Factor	Sliding Resist Factor
25.00	73.00	N	1.50	1.00	0.50	0.85

Soil Layer Number	Soil Layer Thick (ft)	Undrained Shear Strength (ksf)	Cohesion (ksf)	Mass Unit Weight/ Density (lb/ft^3)	Saturated Unit Weight/ Density (lb/ft^3)
1	6.00	0.00	0.00	108.00	130.00

Soil Layer Number	Effective Friction Angle (deg)	Elastic Modulus (ksf)	Poissons Ratio	Ncq	N Gamma q
1	24.00	50.00	0.40	none	none

Grained analysis for Strata IIa

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
0.75	1.00	1	1	2

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
3.0	3.0	3.0	3.0	4.0	4.0	2.0	2.0

BAR SPACING FOR DESIGN

Backwall Maximum Bar Diam (in)	Stem Maximum Bar Diam (in)	Footing Maximum Bar Diam (in)	Hooked Footing Bars	User Requested Minimum Bar Spacing (in)	Bar Spacing Increment (in)
2.26	2.26	2.26	N	6.00	3.00

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SR 1 INTERCHANGE ABUTMENTS

INPUT SUMMARY (cont.)

Spread Ramp1.OUT
LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	3.50	3.50	0.00	0.00

LOADS ON ABUTMENTS

DC (kip)	DW (kip)	PL (kip)	Vertical WSUP (kip)	Horizontal WSUP (kip)	WL (kip)	TU (kip)	Backwall Vert LL (kip)	Horiz LL (kip)
8.15	1.02	none	0.00	0.00	0.00	0.00	3.17	none

Horizontal WSUB (kip)	FR (kip)
0.0	0.00

DESIGN LIVE LOAD

Downward LL (kip)	Upward LL (kip)	BR (kip)	CE (kip)
4.21	0.00	0.79	0.00

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	1	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Reinf Summary	Footing Flexure
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

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SR 1 INTERCHANGE ABUTMENTS

ADDITIONAL INFORMATION

FOOTING GEOMETRY

Footing Thick (ft)	Footing Width (ft)	Projection Toe (ft)	Projection Heel (ft)	Effective Depth Toe (ft)	Effective Depth Heel (ft)
2.67	33.25	3.92	24.33	2.24	2.32

Moments are assumed to cause tension on the bottom face of the footing at the toe and on the top face of the footing at the heel. Effective depths are based on this assumption.

Note: The acceptable range of toe projections for this design footing size are from: 3.92 ft to 4.00 ft.

SR 1 INTERCHANGE ABUTMENTS

OUTPUT LEGEND

Abbrev	Limit State	Description
STR-I	Strength I	-
STR-III	Strength III	-
STR-V	Strength V	-
SER-I	Service I	-
CSS	Con-Sec-Stl	- Consolidation and Secondary Settlement Only

Abbrev	Load Case	Description
Max	Maximum	- Maximum downward vertical force, maximized moment, maximum shear
Min	Minimum	- Minimum downward vertical force, maximized moment, maximum shear

Abbrev	Stage	Description
Tmp	Temporary	- Temporary Construction Condition
Fin	Final	- Final Construction Condition

Symbol	Explanation
*	- Indicates a multiplication (Load Factors Report)
/	- Indicates a division (Load Factors Report)

Status Code	Description
OK	- Check was satisfied
NG	- Check failed
NC	- Not checked
NA	- Not applicable

SR 1 INTERCHANGE ABUTMENTS

FACTORED FORCES

Spread Ramp1.OUT
FOUNDATION FORCES AT FOOTING TOE - VERTICAL

Limit State	Load Case	Stage	Toe to Result (ft)	Force (kip)	Average Load Factor	Moment (kip-ft)	Average Load Factor
STR-I	Max	Tmp	16.93	135.65	1.37	-2516.80	1.38
STR-I	Min	Tmp	16.62	104.59	1.05	-1957.96	1.08
STR-I	Max	Fin	15.10	177.70	1.37	-3091.62	1.38
STR-I	Min	Fin	14.95	129.20	1.03	-2339.87	1.06
STR-III	Max	Tmp	16.84	117.21	1.32	-2125.75	1.33
STR-III	Min	Tmp	16.43	86.15	0.97	-1566.90	0.98
STR-III	Max	Fin	15.68	151.89	1.32	-2656.97	1.33
STR-III	Min	Fin	15.11	110.76	0.96	-1948.81	0.98
STR-V	Max	Tmp	16.92	133.01	1.34	-2460.94	1.35
STR-V	Min	Tmp	16.60	101.95	1.03	-1902.09	1.05
STR-V	Max	Fin	15.22	171.80	1.32	-2992.27	1.34
STR-V	Min	Fin	14.98	124.99	1.00	-2250.48	1.02
SER-I	Max	Tmp	16.92	99.28	1.00	-1820.16	1.00
SER-I	Min	Tmp	16.92	99.28	1.00	-1820.16	1.00
SER-I	Max	Fin	15.27	129.68	1.00	-2240.47	1.00
SER-I	Min	Fin	15.59	125.47	1.00	-2215.56	1.00
CSS	Max	Fin	15.73	114.93	1.00	-1992.10	1.00
CSS	Min	Fin	15.73	114.93	1.00	-1992.10	1.00

FOUNDATION FORCES AT FOOTING TOE - HORIZONTAL

Limit State	Load Case	Stage	Toe to Result (ft)	Force (kip)	Average Load Factor	Moment (kip-ft)	Average Load Factor
STR-I	Max	Tmp	16.93	22.73	1.56	219.76	1.57
STR-I	Min	Tmp	16.62	22.73	1.56	219.76	1.57
STR-I	Max	Fin	15.10	33.63	1.56	408.54	1.57
STR-I	Min	Fin	14.95	33.63	1.56	408.54	1.57
STR-III	Max	Tmp	16.84	16.71	1.50	151.52	1.50
STR-III	Min	Tmp	16.43	16.71	1.50	151.52	1.50
STR-III	Max	Fin	15.68	24.90	1.50	275.54	1.50
STR-III	Min	Fin	15.11	24.90	1.50	275.54	1.50
STR-V	Max	Tmp	16.92	21.87	1.50	210.01	1.50
STR-V	Min	Tmp	16.60	21.87	1.50	210.01	1.50
STR-V	Max	Fin	15.22	31.63	1.47	378.14	1.46
STR-V	Min	Fin	14.98	31.63	1.47	378.14	1.46
SER-I	Max	Tmp	16.92	14.58	1.00	140.01	1.00
SER-I	Min	Tmp	16.92	14.58	1.00	140.01	1.00
SER-I	Max	Fin	15.27	21.59	1.00	259.69	1.00
SER-I	Min	Fin	15.59	21.59	1.00	259.69	1.00
CSS	Max	Fin	15.73	16.60	1.00	183.69	1.00
CSS	Min	Fin	15.73	16.60	1.00	183.69	1.00

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SR 1 INTERCHANGE ABUTMENTS

FACTORED FORCES (cont.)

FOUNDATION FORCES AT FOOTING TOE - HORIZONTAL (cont.)

Spread Ramp1.OUT

Note: Moments are taken about the bottom of the footing at the toe.
Positive moment clockwise; negative moment counterclockwise;
toe on right; heel on left.

ABUTMENT BACKWALL 2.50 (ft) FROM TOP OF STRUCTURE

Limit State	Load Case	Stage	Axial (kip)	Moment (kip-ft)	Shear (kip)
STR-I	Max	Fin	6.54	6.61	0.87
STR-I	Min	Fin	0.69	1.05	0.87
STR-III	Max	Fin	0.99	0.23	0.20
STR-III	Min	Fin	0.69	0.22	0.20
STR-V	Max	Fin	5.27	5.15	0.72
STR-V	Min	Fin	0.69	0.86	0.72
SER-I	Max	Fin	3.94	3.81	0.52
SER-I	Min	Fin	0.77	0.64	0.52

ABUTMENT BACKWALL AT SEAT LEVEL 5.00 (ft) FROM TOP OF STRUCTURE

Limit State	Load Case	Stage	Axial (kip)	Moment (kip-ft)	Shear (kip)
STR-I	Max	Fin	7.47	10.52	2.14
STR-I	Min	Fin	1.37	4.96	2.14
STR-III	Max	Fin	1.93	1.65	0.81
STR-III	Min	Fin	1.37	1.64	0.81
STR-V	Max	Fin	6.21	8.49	1.84
STR-V	Min	Fin	1.37	4.20	1.84
SER-I	Max	Fin	4.68	6.18	1.30
SER-I	Min	Fin	1.51	3.01	1.30

STEM LOCATION A 10.00 (ft) FROM TOP OF STRUCTURE

Limit State	Load Case	Stage	Axial (kip)	Moment (kip-ft)	Shear (kip)
STR-I	Max	Tmp	4.03	2.86	2.14
STR-I	Min	Tmp	2.90	3.44	2.14
STR-I	Max	Fin	25.04	23.78	7.29
STR-I	Min	Fin	12.27	27.21	7.29
STR-III	Max	Tmp	4.03	-0.47	0.81
STR-III	Min	Tmp	2.90	0.12	0.81
STR-III	Max	Fin	17.67	4.53	3.25
STR-III	Min	Fin	12.27	7.01	3.25

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SR 1 INTERCHANGE ABUTMENTS

FACTORED FORCES (cont.)

STEM LOCATION A 10.00 (ft) FROM TOP OF STRUCTURE (cont.)

Spread Ramp1.OUT

Limit State	Load Case	Stage	Axial (kip)	Moment (kip-ft)	Shear (kip)
STR-V	Max	Tmp	4.03	2.38	1.95
STR-V	Min	Tmp	2.90	2.97	1.95
STR-V	Max	Fin	23.36	19.38	6.37
STR-V	Min	Fin	12.27	22.59	6.37
SER-I	Max	Tmp	3.22	1.31	1.30
SER-I	Min	Tmp	3.22	1.31	1.30
SER-I	Max	Fin	18.12	12.99	4.48
SER-I	Min	Fin	13.91	13.54	4.48

STEM LOCATION B 15.00 (ft) FROM TOP OF STRUCTURE

Limit State	Load Case	Stage	Axial (kip)	Moment (kip-ft)	Shear (kip)
STR-I	Max	Tmp	7.87	25.02	5.91
STR-I	Min	Tmp	5.67	25.36	5.91
STR-I	Max	Fin	28.88	84.58	12.69
STR-I	Min	Fin	15.04	84.68	12.69
STR-III	Max	Tmp	7.87	11.74	3.25
STR-III	Min	Tmp	5.67	12.08	3.25
STR-III	Max	Fin	21.51	39.87	7.32
STR-III	Min	Fin	15.04	40.97	7.32
STR-V	Max	Tmp	7.87	23.12	5.53
STR-V	Min	Tmp	5.67	23.46	5.53
STR-V	Max	Fin	27.20	74.36	11.46
STR-V	Min	Fin	15.04	74.69	11.46
SER-I	Max	Tmp	6.27	15.29	3.69
SER-I	Min	Tmp	6.27	15.29	3.69
SER-I	Max	Fin	21.17	51.68	7.95
SER-I	Min	Fin	16.96	51.10	7.95

STEM LOCATION C 20.00 (ft) FROM TOP OF STRUCTURE

Limit State	Load Case	Stage	Axial (kip)	Moment (kip-ft)	Shear (kip)
STR-I	Max	Tmp	12.70	73.34	11.30
STR-I	Min	Tmp	9.17	73.42	11.30
STR-I	Max	Fin	33.71	181.31	19.71
STR-I	Min	Fin	18.54	178.05	19.71
STR-III	Max	Tmp	12.70	43.46	7.32
STR-III	Min	Tmp	9.17	43.54	7.32
STR-III	Max	Fin	26.35	104.48	13.01
STR-III	Min	Fin	18.54	104.19	13.01
STR-V	Max	Tmp	12.70	69.07	10.73

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SR 1 INTERCHANGE ABUTMENTS

FACTORED FORCES (cont.)

STEM LOCATION C 20.00 (ft) FROM TOP OF STRUCTURE (cont.)

Spread Ramp1.OUT

Limit State	Load Case	Stage	Axial (kip)	Moment (kip-ft)	Shear (kip)
STR-V	Min	Tmp	9.17	69.15	10.73
STR-V	Max	Fin	32.03	163.75	18.18
STR-V	Min	Fin	18.54	161.17	18.18
SER-I	Max	Tmp	10.08	46.13	7.16
SER-I	Min	Tmp	10.08	46.13	7.16
SER-I	Max	Fin	24.98	113.73	12.50
SER-I	Min	Fin	20.77	112.04	12.50

STEM LOCATION D 25.00 (ft) FROM TOP OF STRUCTURE

Limit State	Load Case	Stage	Axial (kip)	Moment (kip-ft)	Shear (kip)
STR-I	Max	Tmp	18.53	157.59	18.32
STR-I	Min	Tmp	13.40	157.38	18.32
STR-I	Max	Fin	39.54	323.71	28.35
STR-I	Min	Fin	22.76	317.08	28.35
STR-III	Max	Tmp	18.53	104.46	13.01
STR-III	Min	Tmp	13.40	104.25	13.01
STR-III	Max	Fin	32.17	208.14	20.33
STR-III	Min	Fin	22.76	206.41	20.33
STR-V	Max	Tmp	18.53	150.00	17.56
STR-V	Min	Tmp	13.40	149.79	17.56
STR-V	Max	Fin	37.85	297.29	26.52
STR-V	Min	Fin	22.76	291.78	26.52
SER-I	Max	Tmp	14.66	100.36	11.71
SER-I	Min	Tmp	14.66	100.36	11.71
SER-I	Max	Fin	29.56	205.67	18.14
SER-I	Min	Fin	25.35	202.86	18.14

FOOTING - W/O FOUNDATION PRESSURE

Limit State	Load Case	Stage	Toe Eff D (kip)	Toe Shear at Face (kip)	Toe Moment (kip-ft)	Heel Eff D (kip)	Heel Shear at Face (kip)	Heel Moment (kip-ft)
STR-I	Max	Tmp	0.84	1.96	3.84	102.14	112.66	1373.85
STR-I	Min	Tmp	0.60	1.41	2.76	79.80	87.98	1073.36
STR-I	Max	Fin	0.84	1.96	3.84	121.37	133.70	1632.45
STR-I	Min	Fin	0.60	1.41	2.76	93.74	103.23	1260.81
STR-III	Max	Tmp	0.84	1.96	3.84	85.29	94.22	1147.21
STR-III	Min	Tmp	0.60	1.41	2.76	62.95	69.54	846.71
STR-III	Max	Fin	0.84	1.96	3.84	104.52	115.26	1405.80
STR-III	Min	Fin	0.60	1.41	2.76	76.89	84.79	1034.17
STR-V	Max	Tmp	0.84	1.96	3.84	99.74	110.03	1341.47
STR-V	Min	Tmp	0.60	1.41	2.76	77.40	85.35	1040.98

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SR 1 INTERCHANGE ABUTMENTS

FACTORED FORCES (cont.)

FOOTING - W/O FOUNDATION PRESSURE (cont.)

Spread Ramp1.OUT

Limit State	Load Case	Stage	Toe Eff D (kip)	Toe Shear at Face (kip)	Toe Moment (kip-ft)	Heel Eff D (kip)	Heel Shear at Face (kip)	Heel Moment (kip-ft)
STR-V	Max	Fin	0.84	1.96	3.84	117.52	129.49	1580.64
STR-V	Min	Fin	0.60	1.41	2.76	89.89	99.02	1209.01
SER-I	Max	Tmp	0.67	1.57	3.07	73.46	81.05	988.07
SER-I	Min	Tmp	0.67	1.57	3.07	73.46	81.05	988.07
SER-I	Max	Fin	0.67	1.57	3.07	87.63	96.56	1178.63
SER-I	Min	Fin	0.67	1.57	3.07	87.63	96.56	1178.63
CSS	Max	Fin	0.67	1.57	3.07	78.00	86.02	1049.12
CSS	Min	Fin	0.67	1.57	3.07	78.00	86.02	1049.12

Note: Moment critical sections in the footing are at the front and back face of the stem. Shear critical sections in the footing are located at the effective depth distance away from the front face of the stem for the toe and at the back face of the stem for the heel.

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SR 1 INTERCHANGE ABUTMENTS

FOOTING STABILITY

SPREAD FOOTING - BEARING RESISTANCE

Limit State	Load Case	Stage	Ecc (ft)	Allow Ecc (ft)	Ecc Perform Ratio	Footing Pressure Toe (ksf)	Footing Pressure Heel (ksf)	Uniform Bearing Pressure (ksf)	Bearing Resist (ksf)	Perform Ratio
STR-I	Max	Tmp	-0.31	11.08	35.87	3.85	4.31	4.16	6.44	1.548
STR-I	Min	Tmp	0.01	11.08	999.999	3.15	3.14	3.15	6.51	2.069
STR-I	Max	Fin	1.53	8.31	5.45	6.82	3.87	5.88	5.80	0.986
STR-I	Min	Fin	1.68	8.31	4.96	5.06	2.71	4.32	5.67	1.312
STR-III	Max	Tmp	-0.22	11.08	50.67	3.39	3.66	3.57	6.85	1.918
STR-III	Min	Tmp	0.20	11.08	56.75	2.68	2.50	2.62	6.86	2.615
STR-III	Max	Fin	0.95	8.31	8.78	5.35	3.79	4.84	6.32	1.305
STR-III	Min	Fin	1.52	8.31	5.48	4.24	2.42	3.67	6.17	1.684
STR-V	Max	Tmp	-0.30	11.08	37.24	3.79	4.22	4.07	6.44	1.581
STR-V	Min	Tmp	0.03	11.08	392.52	3.08	3.05	3.07	6.50	2.118
STR-V	Max	Fin	1.41	8.31	5.90	6.48	3.85	5.65	5.83	1.032

OK

```
  STR-V   Min  Fin     1.64     8.31    5.05     4.87     2.64       4.17
5.68    1.361
  SER-I   Max  Tmp    -0.30    11.08   37.17     2.83     3.15       3.04
6.44    2.118
  SER-I   Min  Tmp    -0.30    11.08   37.17     2.83     3.15       3.04
6.44    2.118
  SER-I   Max  Fin     1.35     8.31    6.15     4.85     2.95       4.24
5.84    1.376
  SER-I   Min  Fin     1.04     8.31    8.02     4.48     3.07       4.02
5.82    1.447

  Performance Ratio =  Bearing Resistance / Uniform Bearing Pressure
  Eccentricity Performance Ratio = Allowable Eccentricity / Eccentricity

  Warning: A performance ratio less than 1 was found. However, the
           bearing resistance was within an acceptable tolerance of
           the applied bearing pressure.

  The eccentricity is the distance from the center of the footing to
  the load resultant.  Positive towards toe; negative towards heel.
  The allowable eccentricity is the distance from the center of the
  footing to the edge of the kern.

         ************************************************************
         * Qult based on uniform properties over depth D (H1<D)    *
         ************************************************************
```

SPREAD FOOTING - SLIDING

Limit State	Load Case	Stage	Horizontal Force (kip)	Sliding Resistance (kip)	Performance Ratio
STR-I	Min	Tmp	22.73	39.58	1.741
STR-I	Min	Fin	33.63	48.90	1.454
STR-III	Min	Tmp	16.71	32.60	1.951
STR-III	Min	Fin	24.90	41.92	1.684
STR-V	Min	Tmp	21.87	38.58	1.764
STR-V	Min	Fin	31.63	47.30	1.495

SR 1 INTERCHANGE ABUTMENTS

FOOTING STABILITY (cont.)

SPREAD FOOTING - SLIDING (cont.)

Note: Only the Min Load Cases are checked for sliding.
Sliding resistance is based on a phi factor of 0.85

Performance Ratio = Sliding Resistance / Horizontal Force

SR 1 INTERCHANGE ABUTMENTS

FOOTING STABILITY (cont.)

SETTLEMENT SUMMARY

Elastic (in)	Consol (in)	Settlement Second (in)	Total (in)	Allow (in)	Perform Ratio	Temp Stage Settlement (in)
0.61	0.00	0.00	0.61	1.00	1.630	0.34

Notes:

Elastic settlement is based on:
effective width of 30.55 (ft) from SER-I Max Fin

Consolidation and Secondary settlement are based on:
effective width of 31.47 (ft) from CSS Max Fin

Temporary Stage settlement is based on:
effective width of 32.65 (ft) from SER-I Max Tmp

Uniform pressures (Vertical Force/Effective Width)
are used for settlement calculations.

Performance Ratio = Allowable Settlement / Total Settlement

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SR 1 INTERCHANGE ABUTMENTS

CONTROLLING FOOTING FORCES

TOE - WITH FOUNDATION PRESSURE

Limit State (Controlling)	Load Case Stage	Moment (kip-ft)		Limit State (Controlling)	Load Case Stage	Shear (kip)
STR-I	Max Fin	47.56T	(Strength)	STR-I	Max Fin	10.47
SER-I	Max Fin	33.56T	(Crack Control)			(Eff D)

Note: A "T" following the moment value indicates that the controlling moment for the bottom perpendicular reinforcement was found in the Toe. An "H" indicates the controlling moment was found in the Heel.

HEEL - WITH FOUNDATION PRESSURE

Limit State (Controlling)	Load Case Stage	Moment (kip-ft)		Limit State (Controlling)	Load Case Stage	Shear (kip)
STR-I	Min Fin	288.68H	(Strength)	STR-I	Min Fin	16.96
SER-I	Min Fin	168.48H	(Crack Control)			(Xdist)

Note: An "H" following the moment value indicates that the controlling moment for the top perpendicular reinforcement was found in the Heel. A "T" indicates the controlling moment was found in the Toe.

The Maximum shear in Heel is located at Xdist from back face of stem, where Xdist is (2.43) ft.

SR 1 INTERCHANGE ABUTMENTS

FOOTING FLEXURE

FLEXURAL STRENGTH

Location	Limit State (Controlling)	Load Case	Stage	Applied Moment (kip-ft)	Moment Resist (kip-ft)	Perform Ratio	Area Reqd (in^2)
Toe	STR-I	Max	Fin	47.56T	63.41	1.333	0.640
Heel	STR-I	Min	Fin	288.68H	288.68	1.000	2.986

Performance Ratio = Moment Resistance / Applied Moment

NOTE: A "T" following the applied moment indicates that the controlling moment is found in the Toe for the current location.
An "H" following the applied moment indicates that the controlling moment is found in the Heel for the current location

---

SR 1 INTERCHANGE ABUTMENTS

CRACK CONTROL - DESIGN

ABUTMENT BACKWALL 2.50 (ft) FROM TOP OF STRUCTURE

Back Face Vertical Reinforcement

Bar Size	Bar Spacing (in)	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Controlling Moment (kip-ft)	Controlling Axial (kip)	Status Codes
4	12.00	0.20	0.00	999.99	3.81	3.94	A C F
5	18.00	0.21	0.00	999.99	3.81	3.94	A C F
6	18.00	0.29	0.00	999.99	3.81	3.94	A C F
7	18.00	0.40	0.00	999.99	3.81	3.94	A C F
8	18.00	0.53	0.00	999.99	3.81	3.94	A C F
9	18.00	0.67	0.00	999.99	3.81	3.94	A C F
10	18.00	0.85	0.00	999.99	3.81	3.94	A C F
11	18.00	1.04	0.00	999.99	3.81	3.94	A C F

ABUTMENT BACKWALL AT SEAT LEVEL 5.00 (ft) FROM TOP OF STRUCTURE

Spread Ramp1.OUT

Back Face Vertical Reinforcement

Bar Size	Bar Spacing (in)	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Controlling Moment (kip-ft)	Controlling Axial (kip)	Status Codes	
4	12.00	0.20	0.00	999.99	6.18	4.68	A	F
5	18.00	0.21	0.00	999.99	6.18	4.68	A	F
6	18.00	0.29	0.00	999.99	6.18	4.68	A	F
7	18.00	0.40	0.00	999.99	6.18	4.68	A	F
8	18.00	0.53	0.00	999.99	6.18	4.68	A	F
9	18.00	0.67	0.00	999.99	6.18	4.68	A	F
10	18.00	0.85	0.00	999.99	6.18	4.68	A	F
11	18.00	1.04	0.00	999.99	6.18	4.68	A	F

STEM LOCATION A 10.00 (ft) FROM TOP OF STRUCTURE

Back Face Vertical Reinforcement

Bar Size	Bar Spacing (in)	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Controlling Moment (kip-ft)	Controlling Axial (kip)	Status Codes
4	9.00	0.27	0.00	999.99	13.54	13.91	F
5	12.00	0.31	0.00	999.99	13.54	13.91	F
6	18.00	0.29	0.00	999.99	13.54	13.91	F
7	18.00	0.40	0.00	999.99	13.54	13.91	F
8	18.00	0.53	0.00	999.99	13.54	13.91	F
9	18.00	0.67	0.00	999.99	13.54	13.91	F
10	18.00	0.85	0.00	999.99	13.54	13.91	F
11	18.00	1.04	0.00	999.99	13.54	13.91	F

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SR 1 INTERCHANGE ABUTMENTS

CRACK CONTROL - DESIGN (cont.)

STEM LOCATION B 15.00 (ft) FROM TOP OF STRUCTURE

Back Face Vertical Reinforcement

Bar Size	Bar Spacing (in)	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Controlling Moment (kip-ft)	Controlling Axial (kip)	Status Codes	
4	3.40	++ N/A	N/A	N/A	N/A	N/A	B	
5	5.27	++ N/A	N/A	N/A	N/A	N/A	B	
6	6.00	0.88	0.00	999.99	51.10	16.96		F
7	9.00	0.80	0.00	999.99	51.10	16.96		F
8	12.00	0.79	0.00	999.99	51.10	16.96		F
9	15.00	0.80	0.00	999.99	51.10	16.96		F
10	18.00	0.85	0.00	999.99	51.10	16.96		F
11	18.00	1.04	0.00	999.99	51.10	16.96		F

STEM LOCATION C 20.00 (ft) FROM TOP OF STRUCTURE

Back Face Vertical Reinforcement

Bar Size	Bar Spacing	Area/ Width	Actual Stress	Allow Spacing	Controlling Moment	Controlling Axial	Status Codes

	(in)	(in^2)	(ksi)	(in)	(kip-ft)	(kip)		
4	1.81	++ N/A	N/A	N/A	N/A	N/A	B	
5	2.80	++ N/A	N/A	N/A	N/A	N/A	B	
6	3.98	++ N/A	N/A	N/A	N/A	N/A	B	
7	5.43	++ N/A	N/A	N/A	N/A	N/A	B	
8	6.00	1.58	0.00	999.99	112.04	20.77		F
9	9.00	1.33	0.00	999.99	112.04	20.77		F
10	9.00	1.69	0.00	999.99	112.04	20.77		F
11	9.00	2.08	0.00	999.99	112.04	20.77		F

STEM LOCATION D 25.00 (ft) FROM TOP OF STRUCTURE

Back Face Vertical Reinforcement

Bar Size	Bar Spacing (in)	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Controlling Moment (kip-ft)	Axial (kip)	Status Codes	
4	1.52	++ N/A	N/A	N/A	N/A	N/A	B	
5	2.36	++ N/A	N/A	N/A	N/A	N/A	B	
6	3.35	++ N/A	N/A	N/A	N/A	N/A	B	
7	4.57	++ N/A	N/A	N/A	N/A	N/A	B	
8	6.00	1.58	0.00	999.99	202.86	25.35		F
9	6.00	2.00	0.00	999.99	202.86	25.35		F
10	6.00	2.54	0.00	999.99	202.86	25.35		EF
11	9.00	2.08	0.00	999.99	202.86	25.35		F

SR 1 INTERCHANGE ABUTMENTS

CRACK CONTROL - DESIGN (cont.)

STEM CUTOFF LOCATION - SHOWN FOR EACH BAR CUTOFF

Back Face Vertical Reinforcement

Bar Size	Bar Spacing (in)	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Controlling Moment (kip-ft)	Axial (kip)	Status Codes	
4	3.05	++ N/A	N/A	N/A	N/A	N/A	B	
5	4.73	++ N/A	N/A	N/A	N/A	N/A	B	
6	6.71	++ N/A	N/A	N/A	N/A	N/A	B	
7	9.15	++ N/A	N/A	N/A	N/A	N/A	B	
8	12.00	0.79	0.00	999.99	59.35	17.47		F
9	12.00	1.00	0.00	999.99	79.95	18.76		F
10	12.00	1.27	0.00	999.99	106.45	20.42		F
11	18.00	1.04	0.00	999.99	83.88	19.01		F

FOOTING TOE

Bar Size	Bar Spacing (in)	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Control Moment (kip-ft)	Status Codes	
4	3.75	++ N/A	N/A	N/A	N/A	B	
5	5.81	++ N/A	N/A	N/A	N/A	B	
6	6.00	0.88	0.00	999.99	33.56		F
7	9.00	0.80	0.00	999.99	33.56		F
8	12.00	0.79	0.00	999.99	33.56		F

9	18.00	0.67	0.00	999.99	33.56	F
10	18.00	0.85	0.00	999.99	33.56	F
11	18.00	1.04	0.00	999.99	33.56	F

Note: Controlling moment was found in the toe

FOOTING HEEL

Bar Size	Bar Spacing (in)	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Control Moment (kip-ft)	Status Codes
4	0.80	++ N/A	N/A	N/A	N/A	B
5	1.25	++ N/A	N/A	N/A	N/A	B
6	1.77	++ N/A	N/A	N/A	N/A	B
7	2.41	++ N/A	N/A	N/A	N/A	B
8	3.17	++ N/A	N/A	N/A	N/A	B
9	4.02	++ N/A	N/A	N/A	N/A	B
10	5.10	++ N/A	N/A	N/A	N/A	B
11	6.00	3.12	26.01	9.59	168.48	

Note: Controlling moment was found in the heel

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SR 1 INTERCHANGE ABUTMENTS

CRACK CONTROL - DESIGN (cont.)

FOOTING HEEL (cont.)

Status Code Descriptions (Blank indicates an OK status)
A - min area & max spacing governed by shrinkage/temp requirements
B - spacing is less than minimum allowed, actual stress not computed
C - actual stress calculation did not converge
D - service load requirements result in an overreinforced section
E - spacing modified by development length ratio reduction
F - applied loads did not crack the cross section. Rebar tensile stress is set to 0.
++ - Design spacing is less than minimum spacing. Bar size is not applicable

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SR 1 INTERCHANGE ABUTMENTS

REINFORCEMENT SUMMARY - DESIGN

BACKWALL

Spread Ramp1.OUT

Bar Size	Backwall 2.50 (ft) from top of structure Strength (in)	Backwall 2.50 (ft) from top of structure Crack Control (in)	Seat 5.00 (ft) from top of structure Strength (in)	Seat 5.00 (ft) from top of structure Crack Control (in)
4	18.00	12.00	12.00	12.00
5	30.00	18.00	18.00	18.00
6	42.00	18.00	27.00	18.00
7	60.00	18.00	36.00	18.00
8	78.00	18.00	48.00	18.00
9	99.00	18.00	63.00	18.00
10	126.00	18.00	78.00	18.00
11	156.00	18.00	96.00	18.00

STEM

Bar Size	Location A 10.00 (ft) Streng (in)	Location A 10.00 (ft) Crack Control (in)	Location B 15.00 (ft) Streng (in)	Location B 15.00 (ft) Crack Control (in)	Location C 20.00 (ft) Streng (in)	Location C 20.00 (ft) Crack Control (in)	Location D 25.00 (ft) Streng (in)	Location D 25.00 (ft) Crack Control (in)
4	9.00	9.00	3.40 ++	3.40	1.81 ++	1.81	1.52 ++	1.52
5	12.00	12.00	5.27 ++	5.27	2.80 ++	2.80	2.36 ++	2.36
6	18.00	18.00	6.00	6.00	3.98 ++	3.98	3.35 ++	3.35
7	27.00	18.00	9.00	9.00	5.43 ++	5.43	4.57 ++	4.57
8	33.00	18.00	12.00	12.00	6.00	6.00	6.00	6.00
9	45.00	18.00	15.00	15.00	9.00	9.00	6.00	6.00
10	57.00	18.00	21.00	18.00	9.00	9.00	9.00	6.00
11	69.00	18.00	24.00	18.00	12.00	9.00	9.00	9.00

++ - Design Spacing is less than the minimum spacing. Bar size is not applicable.

FOOTING

Bar Size	Footing Toe Strength (in)	Footing Toe Crack Control (in)	Footing Heel Strength (in)	Footing Heel Crack Control (in)
4	3.75	++ 3.75	0.80	++ 0.80
5	5.81	++ 5.81	1.25	++ 1.25
6	6.00	6.00	1.77	++ 1.77
7	9.00	9.00	2.41	++ 2.41
8	12.00	12.00	3.17	++ 3.17
9	18.00	18.00	4.02	++ 4.02
10	21.00	18.00	5.10	++ 5.10
11	27.00	18.00	6.00	6.00

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SR 1 INTERCHANGE ABUTMENTS

REINFORCEMENT SUMMARY - DESIGN (cont.)

FOOTING (cont.)

++ - Design Spacing is less than the minimum spacing. Bar size is not

applicable.

SR 1 INTERCHANGE ABUTMENTS

SHEAR RESULTS

BACKWALL AND STEM

Location	Dist from Struc Top (ft)	Limit State	Load Case Stage (Controlling)		Applied Shear (kip)	Shear Resist (kip)	Perform Ratio
Backwall	2.50	STR-I	Max	Fin	0.87	28.68	33.063
Seat	5.00	STR-I	Max	Fin	2.14	28.62	13.367
Stem A	10.00	STR-I	Max	Fin	7.29	46.73	6.409
Stem B	15.00	STR-I	Max	Fin	12.69	54.46	4.293
Stem C	20.00	STR-I	Max	Fin	19.71	62.03	3.148
Stem D	25.00	STR-I	Max	Fin	28.35	69.94	2.467

STEM CUTOFF LOCATIONS

Bar Size	Dist from Struc Top (ft)	Limit State	Load Case Stage (Controlling)		Applied Shear (kip)	Shear Resist (kip)	Perform Ratio
4	10.90	STR-I	Min	Fin	8.27	49.17	5.949
5	10.90	STR-I	Min	Fin	8.27	49.17	5.949
6	15.65	STR-I	Max	Fin	13.60	56.89	4.182
7	15.65	STR-I	Max	Fin	13.60	56.89	4.182
8	15.68	STR-I	Max	Fin	13.64	56.93	4.175
9	17.37	STR-I	Max	Fin	16.01	59.49	3.716
10	19.54	STR-I	Max	Fin	19.06	62.78	3.293
11	17.69	STR-I	Max	Fin	16.46	59.97	3.643

Note: Shear resistance is based on a phi factor of 0.90

FOOTING

Location	Limit State	Load Case Stage (Controlling)		Applied Shear (kip)	Shear Resist (kip)	Perform Ratio
Toe	STR-I	Max	Fin	10.47	33.74	3.223
Heel	STR-I	Min	Fin	16.96	32.92	1.941

Note: Shear resistance is based on a phi factor of 0.90

Performance Ratio = Shear Resistance / Applied Shear

SR 1 INTERCHANGE ABUTMENTS

Spread Ramp1.OUT
REINFORCEMENT DESIGN DETAILS

ABUTMENT BACKWALL AT SEAT LEVEL

Bar Size	Bar Spacing (in)	Develop Length (in)	Area Prov (in^2)	Status Codes
4 *	12.0	12.0	0.200	
5	18.0	12.0	0.207	
6	18.0	12.0	0.293	
7	18.0	12.0	0.400	
8	18.0	12.0	0.527	
9	18.0	12.0	0.667	
10	18.0	12.0	0.847	
11	18.0	12.0	1.040	

Area Reqd = 0.189 (in^2)

* Indicates bar size and spacing with the least area of steel per unit width of the structure in the backwall.

Status Code Descriptions
A - Development length exceeds stem height
B - Development length exceeds backwall height

FOOTING TOE (BOTTOM)

Bar Size	Bar Spacing (in)	Develop Length (in)	Bar Type	Area Prov (in^2)
4	3.8 ++	N/A	S	N/A
5	5.8 ++	N/A	S	N/A
6	6.0	12.0	S	0.880
7	9.0	16.0	S	0.800
8	12.0	21.4	S	0.790
9 *	18.0	32.1	S	0.667
10	18.0	32.1	S	0.847
11	18.0	32.1	S	1.040

Area Reqd = 0.640 (in^2)
Actual Length = 45.0 (in)

FOOTING HEEL (TOP)

Bar Size	Bar Spacing (in)	Develop Length (in)	Bar Type	Area Prov (in^2)
4	0.8 ++	N/A	S	N/A
5	1.2 ++	N/A	S	N/A
6	1.8 ++	N/A	S	N/A
7	2.4 ++	N/A	S	N/A
8	3.2 ++	N/A	S	N/A
9	4.0 ++	N/A	S	N/A
10	5.1 ++	N/A	S	N/A
11 *	6.0	69.8	S	3.120

Area Reqd = 2.986 (in^2)
Actual Length = 290.0 (in)

++ - Design Spacing is less than the minimum spacing. Bar size is not applicable.

* Indicates bar size and spacing with the least area of steel per unit width of the structure in the footing.

Bar Type Description
S - Straight Bar
H - Hooked Bar

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SR 1 INTERCHANGE ABUTMENTS

REINFORCEMENT DESIGN DETAILS (cont.)

STEM Location D

Bar Size	Bar Space (in)	Bar Lap Length (in)	Hooked Bar Develop Length (in)	Straight Bar Develop Length (in)	Area Prov (in^2)	Weight with Cutoffs (lbs)	Weight without Cutoffs (lbs)	Status Codes
4	1.5	++ N/A	N/A	N/A	N/A	N/A	N/A	
5	2.4	++ N/A	N/A	N/A	N/A	N/A	N/A	
6	3.4	++ N/A	N/A	N/A	N/A	N/A	N/A	
7	4.6	++ N/A	N/A	N/A	N/A	N/A	N/A	
8 *+	6.0	67.0	24.3	39.4	1.580	88.68	107.53	
9	6.0	67.0	21.6	39.4	2.000	107.12	136.11	
10	6.0	67.0	19.2	39.4	2.540	127.64	172.86	
11	9.0	100.6	26.0	59.2	2.080	110.38	141.56	

Area Reqd = 1.574 (in^2)
Actual Length in Footing = 28.0 (in)

Bar Size	Bar Space (in)	Theoret Cutoff (in)	Extension Length (in)	Code	Physical Cutoff (in)	Status Codes
4	1.5	++ N/A	N/A		N/A	
5	2.4	++ N/A	N/A		N/A	
6	3.4	++ N/A	N/A		N/A	
7	4.6	++ N/A	N/A		N/A	
8 *+	6.0	111.9	44.0	A	155.9	
9	6.0	91.6	46.2	A	137.7	
10	6.0	65.5	48.9	A	114.4	
11	9.0	87.7	46.6	A	134.3	

Status Code Descriptions
- A - Cutoff location controlled by strength check at cutoff
- B - Cutoff location controlled by service load check at cutoff
- C - Bars could not be cut off because the resulting bar spacing would be greater than the maximum allowable bar spacing.
- D - Physical cutoff is at the top of wall/stem because the calculated value is within 2 feet of the top of wall/stem
- E - Physical cutoff is at top of wall/stem because the calculated value is above the actual top of wall/stem.
- F - Could not develop the bar into the footing due to insufficient footing thickness
- G - Development length exceeds stem height
- * - Indicates bar size and spacing with the least weight of steel per unit width of the structure at the base of stem when bars are NOT cutoff
- + - Indicates bar size and spacing with the least weight per unit width of the structure for the whole height of the stem when bars are both cutoff and full height
- **- Indicates area required was governed by the minimum temperature and shrinkage reinforcement criteria
- ++ - Design Spacing is less than the minimum spacing. Bar size is not

applicable.

Extension Length Code
A - Effective Depth Controlled
B - Fifteen Bar Diameters Controlled
C - 12 inch Minimum Controlled

Note: The theoretical cutoff point is where every other bar is no longer required in the stem.

Note: Stem Bars at Location D are always epoxy coated as per DM4-2000 Section 5.4.3.6P

SR 1 INTERCHANGE ABUTMENTS

OPTIMUM DESIGN DETAILS

ABUTMENT BACKWALL AT SEAT LEVEL

Bar Size	Bar Spacing (in)	Develop Length (in)	Status Codes
4	12.0	12.0	

Status Code Descriptions
A - Development length exceeds stem height
B - Development exceeds backwall height

FOOTING TOE (BOTTOM)				FOOTING HEEL (TOP)			
Bar Size	Bar Spacing (in)	Develop Length (in)	Bar Type	Bar Size	Bar Spacing (in)	Develop Length (in)	Bar Type
9	18.0	32.1	S	11	6.0	69.8	S

Bar Type Description
S - Straight Bar
H - Hooked Bar

STEM Location D

Bar Size	Bar Space (in)	Bar Lap Length (in)	Hooked Bar Develop Length (in)	Straight Bar Develop Length (in)	Weight with Cutoffs (lbs)	Weight without Cutoffs (lbs)	Status Codes
8 *+	6.0	67.0	24.3	39.4	88.68	107.53	

Bar Size	Bar Space (in)	Theoret Cutoff (in)	Extension Length (in)	Physical Cutoff (in)	Status Codes
8 *+	6.0	111.9	44.0	155.9	

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OPTIMUM DESIGN DETAILS (cont.)

Status Code Descriptions
- A - Cutoff location controlled by strength check at cutoff
- B - Cutoff location controlled by service load check at cutoff
- C - Bars could not be cut off because the resulting bar spacing would be greater than the maximum allowable bar spacing.
- D - Physical cutoff is at the top of wall/stem because the calculated value is within 2 feet of the top of wall/stem
- E - Physical cutoff is at top of wall/stem because the calculated value is above the actual top of wall/stem.
- F - Could not develop the bar into the footing due to insufficient footing thickness
- G - Development length exceeds stem height
- * - Indicates bar size and spacing with the least weight of steel per unit width of the structure at the base of stem when bars are NOT cutoff
- + - Indicates bar size and spacing with the least weight per unit width of the structure for the whole height of the stem when bars are both cutoff and full height

Note: The theoretical cutoff point is where every other bar is no longer required in the stem.

Note: Stem Bars at Location D are always epoxy coated as per DM4-2000 Section 5.4.3.6P

SR 1 INTERCHANGE ABUTMENTS

SUMMARY - SPECIFICATION CHECKS

SPECIFICATION CHECK WARNINGS

For the live loadings input by the user, the program did not encounter any specification check warnings for any of the applicable limit states. It should be noted that the program does not perform the specification checking corresponding to commands that have not been input by the user.

THE FOLLOWING TABLES HAVE SPEC CHECK WARNINGS PAGE NO.

FOOTING STABILITY
SPREAD FOOTING - BEARING RESISTANCE..... 17 ok
MOMENT AXIAL INTERACTION*
STEM LOCATION D 25.00 (ft) FROM TOP OF STRUCTURE*

Spread Ramp1.OUT

* - An asterisk indicates the table was not printed

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Input File: Spread Ramp1.dat 01/06/2009 12:06:02

SR 1 INTERCHANGE ABUTMENTS

SUMMARY - SPECIFICATION CHECKS (cont.)

SPECIFICATION CHECK ERRORS

For the live loadings input by the user, the program encountered one or more specification check failures. The following is a list of output table headings for which failures have occurred. It should be noted that the program does not perform specification checking corresponding to commands that have not been input by the user.

THE FOLLOWING TABLES HAVE SPEC CHECK ERRORS	PAGE NO.

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