Appendix B.

Concrete Strength and Elastic Modulus

Static Modulus of Elasticity of Rouge River Bridge Concrete.

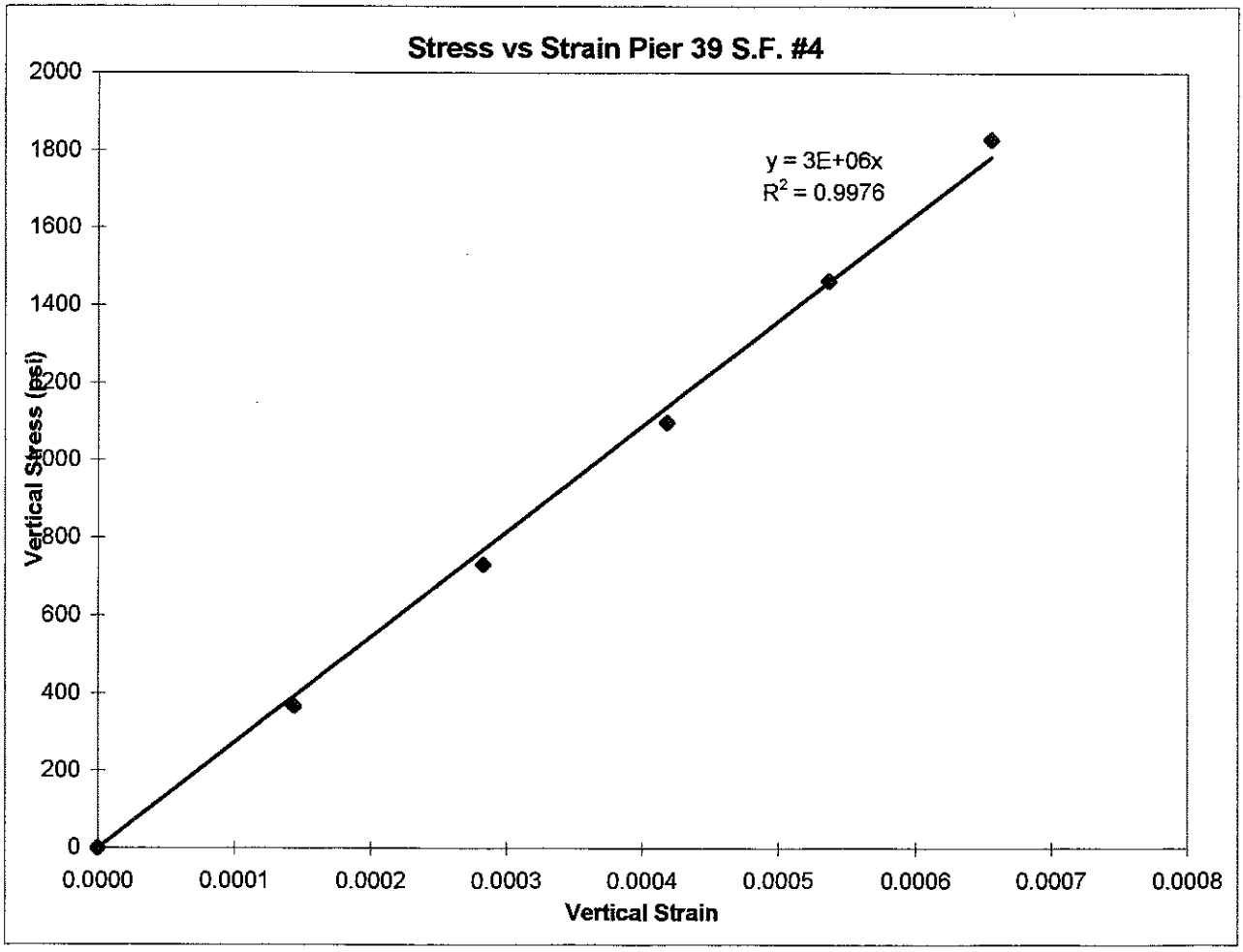
(Drilled Cores)

Specimen: **Pier 39 S.F. #4**

Diameter:	5.9 in	Corr.Factor:	0.980
Capped Length:	10.31 in	X-Section Area:	27.34 in2
l/d Ratio:	1.75		

Dist. between points of control: 6.1 in

Load	Vert.Gage(in)			Vert.Defl.	Vert.Strn.	Vert.Stress	E Static
lb	Trial 1	Trial 2	Average	dv (in)	(--)	psi	psi
0	0.0000	0.0000	0.0000	0.00000	0.00000	0.00	
10000	0.0017	0.0018	0.0018	0.00088	0.00014	365.77	2.55E+06
20000	0.0033	0.0036	0.0035	0.00173	0.00028	731.54	2.59E+06
30000	0.0049	0.0053	0.0051	0.00255	0.00042	1097.30	2.62E+06
40000	0.0064	0.0067	0.0066	0.00328	0.00054	1463.07	2.73E+06
50000	0.0078	0.0082	0.0080	0.00400	0.00066	1828.84	2.79E+06
Ult. Load (kip):		159.6			Average Elastic Mod:		2.66E+06
Ult. Strength (psi):		5838					
Corr Strength (psi)		5721					

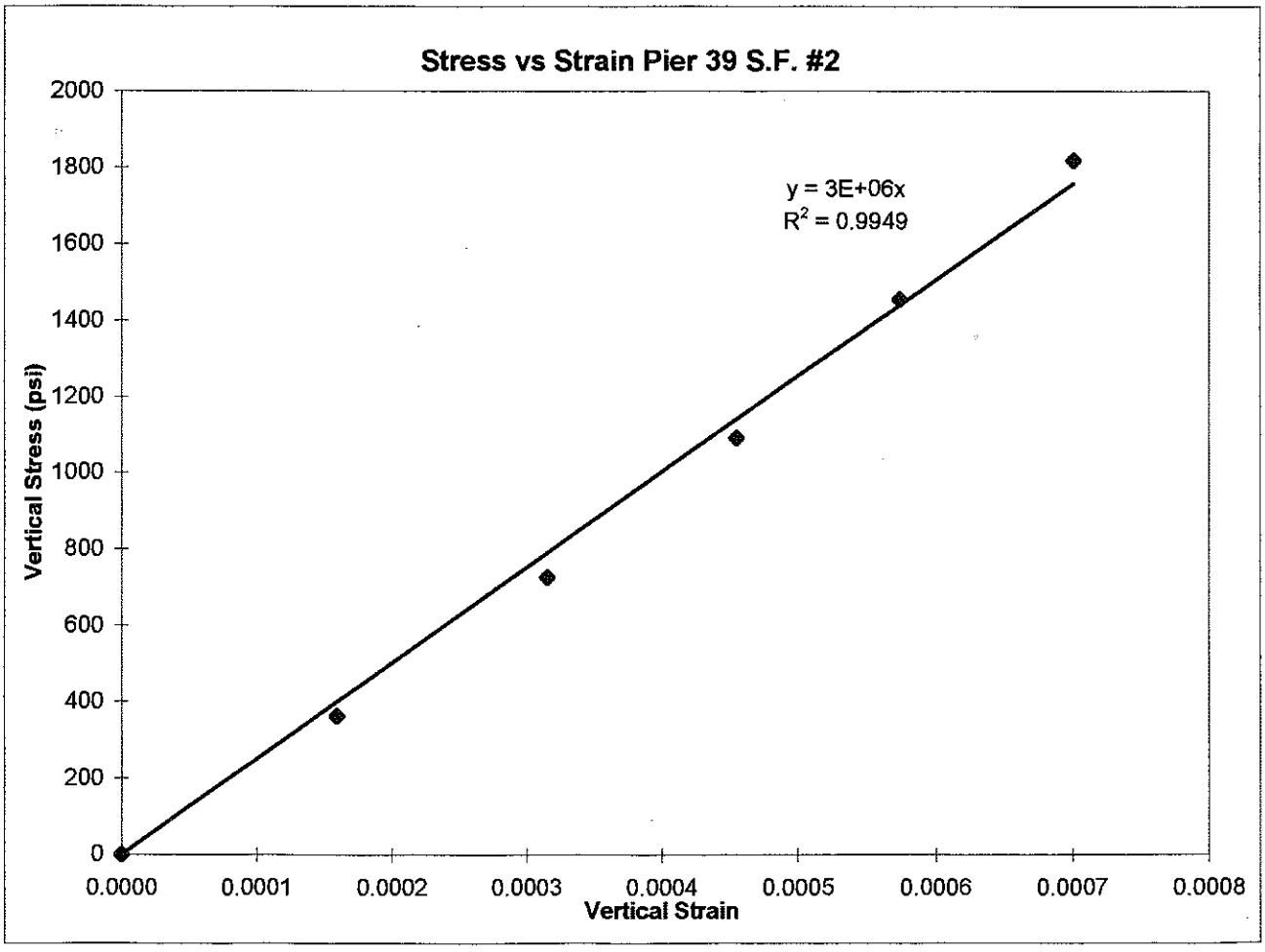


Static Modulus of Elasticity of Rouge River Bridge Concrete.

(Drilled Cores)
Specimen: **Pier 39 S.F. #2**

Diameter:	5.92 in	Corr.Factor:	0.990
Capped Length:	11 in	X-Section Area:	27.53 in2
l/d Ratio:	1.86		
Dist. between points of control:	6.1 in		

Load	Vert.Gage(in)			Vert.Defl.	Vert.Strn.	Vert.Stress	E Static
lb	Trial 1	Trial 2	Average	dv (in)	(--)	psi	psi
0	0.0000	0.0000	0.0000	0.00000	0.00000	0.00	
10000	0.0018	0.0021	0.0020	0.00098	0.00016	363.30	2.27E+06
20000	0.0039	0.0038	0.0039	0.00193	0.00032	726.60	2.30E+06
30000	0.0056	0.0055	0.0056	0.00278	0.00045	1089.90	2.40E+06
40000	0.0070	0.0070	0.0070	0.00350	0.00057	1453.20	2.53E+06
50000	0.0086	0.0085	0.0086	0.00428	0.00070	1816.51	2.59E+06
Ult. Load (kip):		141.5			Average Elastic Mod:		2.42E+06
Ult. Strength (psi):		5141					
Corr Strength (psi)		5089					



Static Modulus of Elasticity of Reference Slag Concrete.

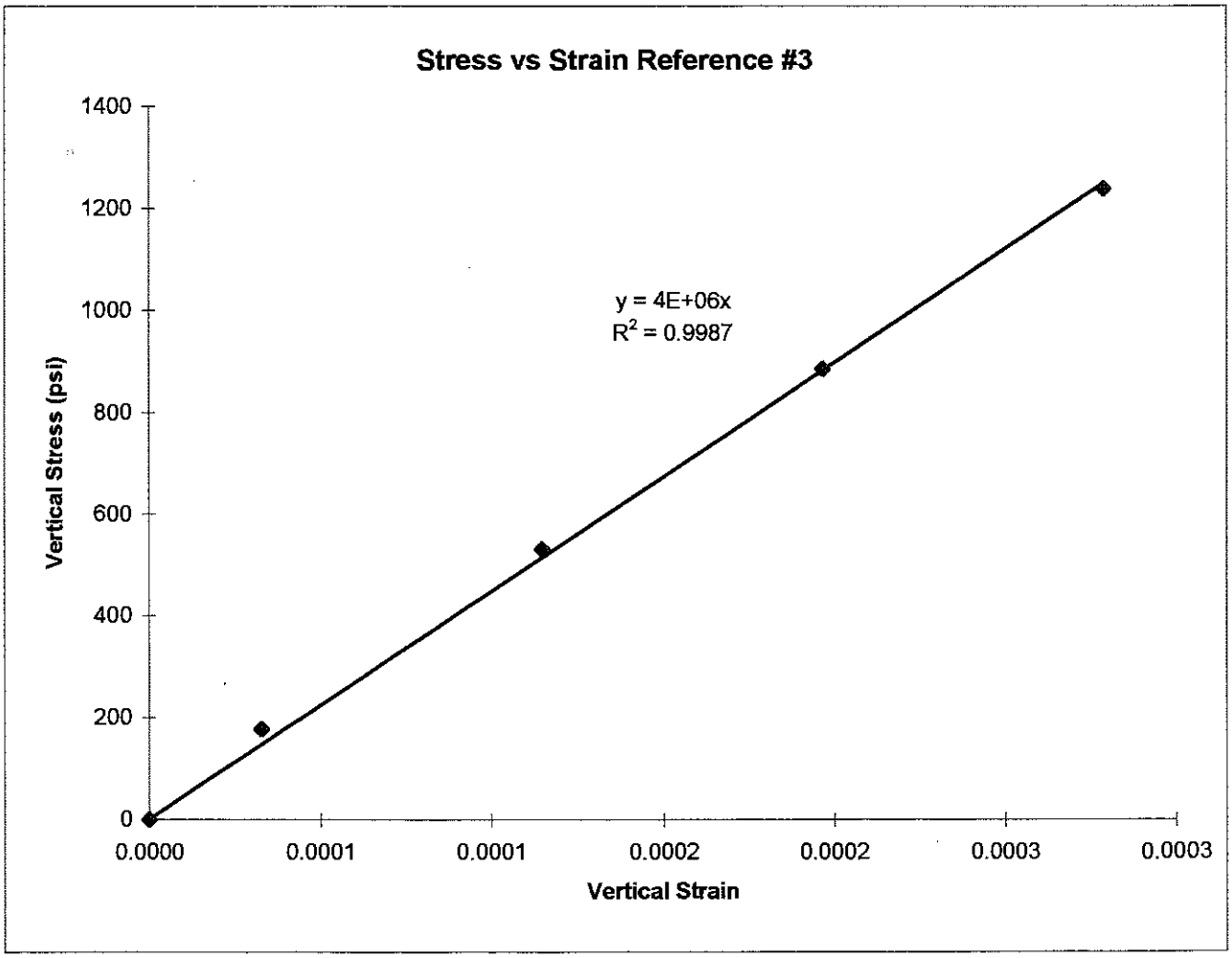
(Reference Batch Specimens - Levy Pit Slag Pit 82-22)

Specimen: **Reference #3**

Diameter:	6 in	Corr.Factor:	1.000
Capped Length:	12.2 in	X-Section Area:	28.27 in2
l/d Ratio:	2.03		

Dist. between points of control: 6.1 in

Load	Vert.Gage(in)			Vert.Defl.	Vert.Strn.	Vert.Stress	E Static
lb	Trial 1	Trial 2	Average	dv (in)	(--)	psi	psi
0	0.0000	0.0000	0.0000	0.00000	0.00000	0.00	
5000	0.0004	0.0004	0.0004	0.00020	0.00003	176.84	5.39E+06
15000	0.0014	0.0014	0.0014	0.00070	0.00011	530.52	4.62E+06
25000	0.0024	0.0024	0.0024	0.00120	0.00020	884.19	4.49E+06
35000	0.0034	0.0034	0.0034	0.00170	0.00028	1237.87	4.44E+06
Ult. Load (kip):		131.3			Average Elastic Mod:		4.74E+06
Ult. Strength (psi):		4644					
Corr Strength (psi)		4644					



Static Modulus of Elasticity of Reference Slag Concrete.

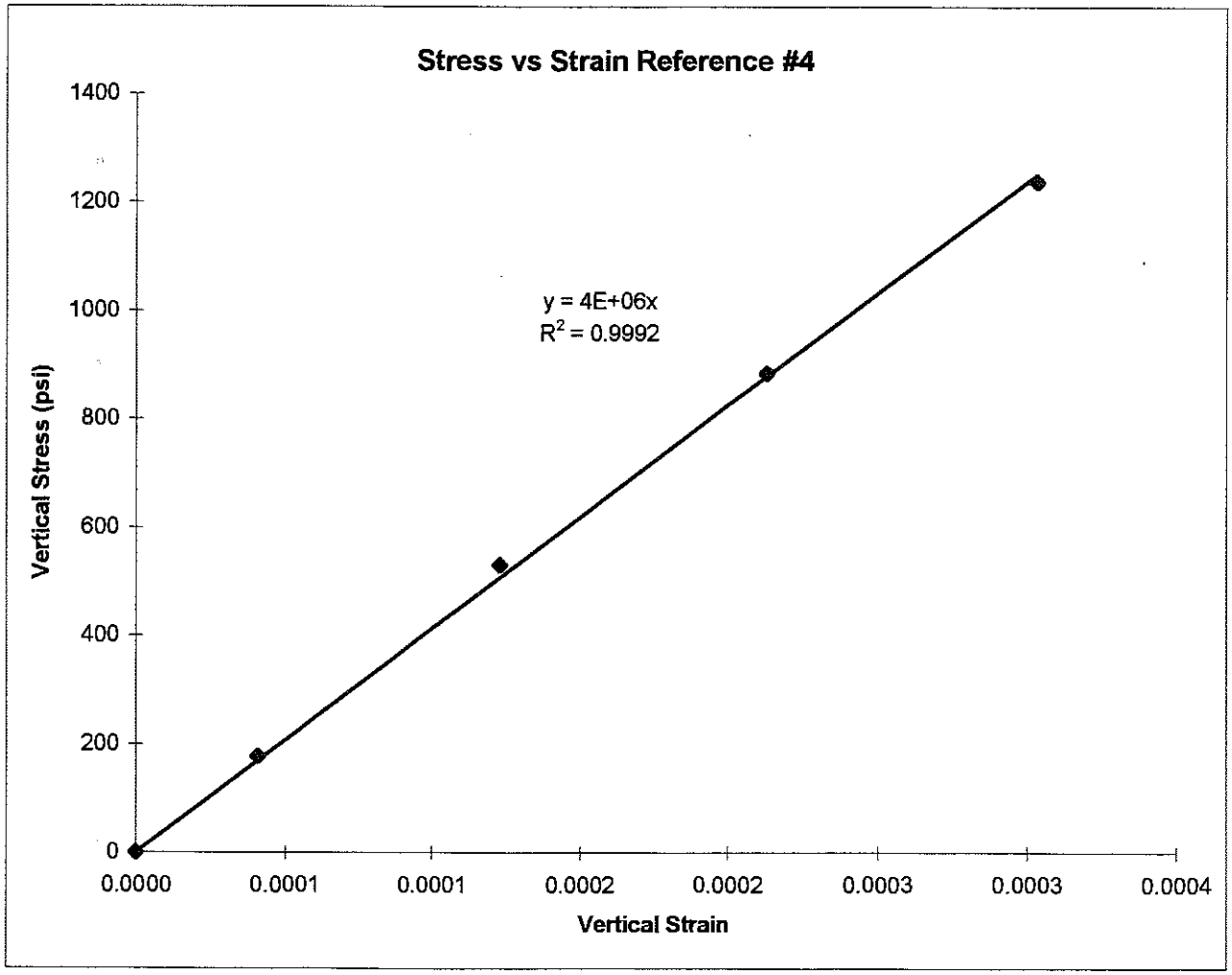
(Reference Batch Specimens - Levy Pit Slag Pit 82-22)

Specimen: **Reference #4**

Diameter:	6 in	Corr.Factor:	1.000
Capped Length:	12.2 in	X-Section Area:	28.27 in2
l/d Ratio:	2.03		

Dist. between points of control: 6.1 in

Load	Vert.Gage(in)			Vert.Defl.	Vert.Strn.	Vert.Stress	E Static
lb	Trial 1	Trial 2	Average	dv (in)	(--)	psi	psi
0	0.0000	0.0000	0.0000	0.00000	0.00000	0.00	
5000	0.0005	0.0005	0.0005	0.00025	0.00004	176.84	4.31E+06
15000	0.0015	0.0015	0.0015	0.00075	0.00012	530.52	4.31E+06
25000	0.0026	0.0026	0.0026	0.00130	0.00021	884.19	4.15E+06
35000	0.0037	0.0037	0.0037	0.00185	0.00030	1237.87	4.08E+06
Ult. Load (kip):		135.2			Average Elastic Mod:		4.22E+06
Ult. Strength (psi):		4782					
Corr Strength (psi)		4782					



Static Modulus of Elasticity of Reference Slag Concrete.

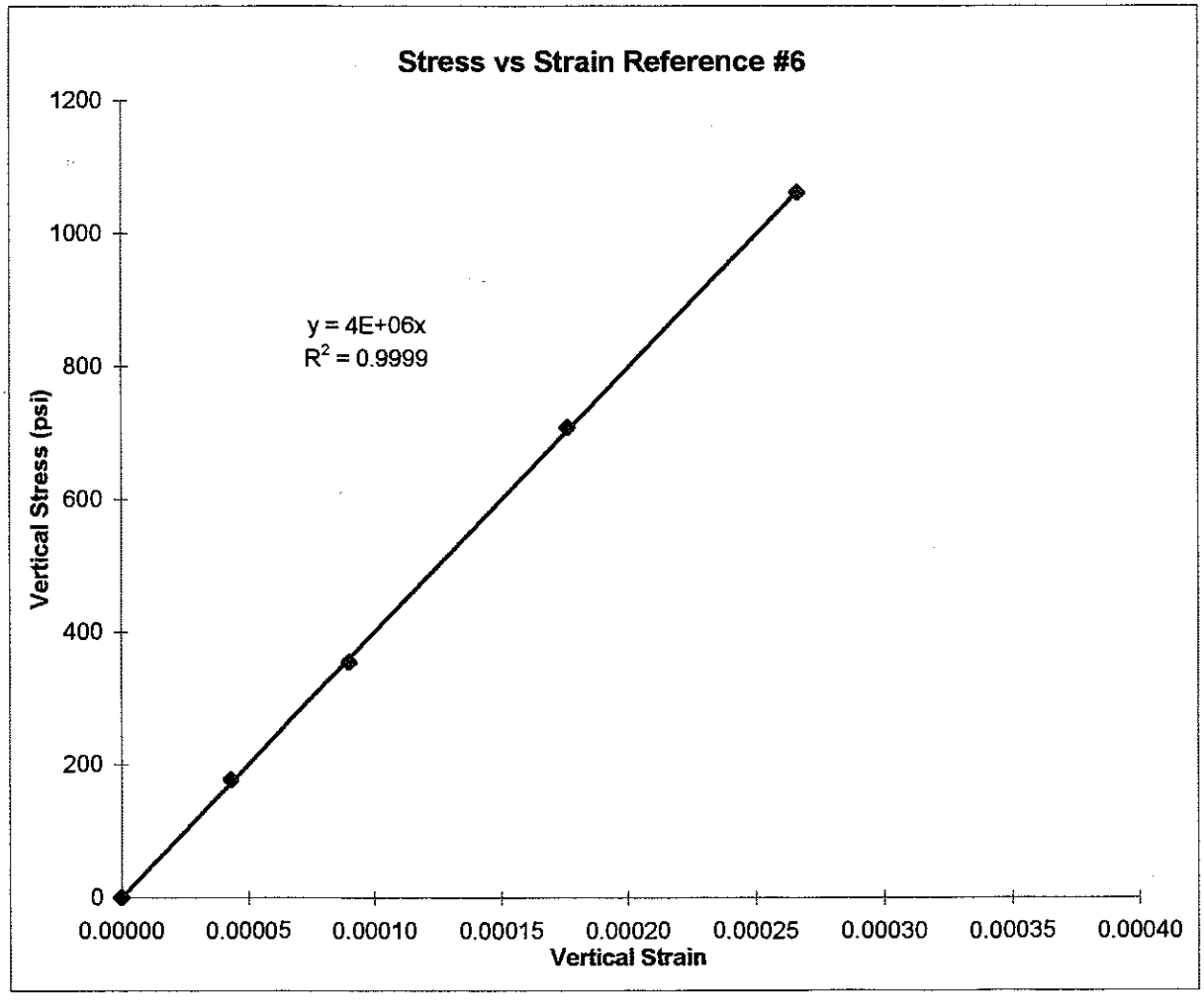
(Reference Batch Specimens - Levy Pit Slag Pit 82-22)

Specimen: **Reference #6**

Diameter:	6 in	Corr.Factor:	1.000
Capped Length:	12.2 in	X-Section Area:	28.27 in2
l/d Ratio:	2.03		

Dist. between points of control: 6.1 in

Load	Vert.Gage(in)			Vert.Defl.	Vert.Strn.	Vert.Stress	E Static
lb	Trial 1	Trial 2	Average	dv (in)	(--)	psi	psi
0	0.0000	0.0000	0.0000	0.00000	0.00000	0.00	
5000	0.0005	0.0006	0.0005	0.00026	0.00004	176.84	4.11E+06
10000	0.0011	0.0011	0.0011	0.00055	0.00009	353.68	3.92E+06
20000	0.0022	0.0021	0.0022	0.00108	0.00018	707.36	4.01E+06
30000	0.0032	0.0033	0.0033	0.00163	0.00027	1061.03	3.98E+06
Ult. Load (kip):		134.3			Average Elastic Mod:		4.01E+06
Ult. Strength (psi):		4750					
Corr Strength (psi)		4750					



Client: University of Michigan
Project: I-75 Bridge Over Rouge River, Detroit
Contact: Dr. Will Hansen
Submitter: R. Detwiler

CTL Project No.: 050860
CTL Project Mgr.: R. Detwiler
Technician: P. Brindise
Approved: W. Morrison
Date: July 16, 1996

Test Results of ASTM C 42-90 Standard Test Method for
Compressive Strength of Drilled Cores of Concrete

Core Identification	Pier 38, N.F. #4	Pier 38, N.F. #3		
Nominal Maximum Aggregate Size (in.)	1	1		
Concrete Age at Test (approximate years)	Not stated	Not stated		
Moisture Condition at Test	As received-dry	As received-dry		
Orientation of Core Axis in Structure	Not stated	Not stated		
Diameter 1, (in.)	3.91	3.91		
Diameter 2, (in.)	3.90	3.90		
Average Diameter (in.)	3.90	3.91		
Cross-Sectional Area (sq in.)	11.97	11.98		
Length Trimmed (in.)	7.6	7.6		
Length Capped (in.)	7.8	7.8		
Weight in Air (lb)	7.1	7.2		
Weight in Water (lb)	3.8	3.9		
Calculated Unit Weight (pcf)	135.5	136.2		
Loading Rate, psi/sec	35	35		
Maximum Load (lb)	99,300	104,000		
Uncorrected Compressive Strength (psi)	8,290	8,680		
Ratio of Capped Length to Diameter (L/D)	2.00	2.01		
Correction Factor (ASTM C42)	1.000	1.000		
Corrected Compressive Strength (psi)	**8,290**	**8,680**		
Fracture Pattern	cone and split	shear		
Notes:				

Appendix C.

Chloride Analysis

CTL Structural/Architectural Engineering, Consulting, & Materials Technology
5420 Old Orchard Road, Skokie, Illinois 60077-1030
708/965-7500 **800/522-2CTL** Fax: 708/965-6541

Client:	**University of Michigan**	CTL Project No:	**050860**
Project:	**Concrete Evaluation**	CTL Project Mgr.:	**Laura Powers-Couche**
	Piers 38 and 39	Analyst:	**Yea Yoon**
Contact:	**Dr. Will Hansen**	Approved:	
Submitter:	**Laura Powers-Couche, CTL**	Date Reported:	**8-Mar-96**
Date Rec'd:	**16-Feb-96**	Date Analyzed:	**6-Mar-96**

REPORT of CHLORIDE ANALYSIS

Sample Identification			Determined Water-Soluble Chloride
CTL ID	Client ID	Description	(wt% of sample)
918729	Pier 39 #3 NB 1 in.		0.015
919003	Pier 39 #3 NB 3 in.		0.007
918730	Pier 39 #3 NB 4 in.		0.007
918731	Pier 39 #3 NB 8 in.		0.005
918732	Pier 39 #3 SB 1 in.		0.023
919004	Pier 39 #3 SB 3 in.		0.005
918733	Pier 39 #3 SB 4 in.		0.006
918734	Pier 39 #3 SB 8 in.		0.003
918735	Pier 39 #5 NB 1 in.		0.018
919005	Pier 39 #5 NB 3 in.		0.003
918736	Pier 39 #5 NB 4 in.		0.007
918737	Pier 39 #5 NB 8 in.		0.003
918738	Pier 39 #5 SB 1 in.		0.006
919006	Pier 39 #5 SB 3 in.		0.006
918739	Pier 39 #5 SB 4 in.		0.006
918740	Pier 39 #5 SB 8 in		0.006

Notes:
1. This analysis represents specifically the samples submitted on a dry (105° C) basis.
2. This report may not be reproduced except in its entirety.
3. Analysis by potentiometric titration with silver nitrate. (ASTM C1218).

CTL Structural/Architectural Engineering,
Testing and Materials Technology

5420 Old Orchard Road, Skokie, Illinois 60077-1030
847/ 965-7500 **800/ 522-2CTL** Fax: 847/ 965-6541

Client:	**University of Michigan**	CTL Project No:	**050860**
Project:	**Chloride Analysis**	CTL Project Mgr.:	**Rachel J. Detwiller**
	MDOT / University of Michigan	Analyst:	**M. Bharucha**
Contact:	**Dr. Will Hansen**	Approved:	
Submitter:	**Rachel J. Detwiller, CTL**	Date Reported:	**19-Jul-96**
Date Rec'd:	**11-Jul-96**	Date Analyzed:	**19-Jul-96**

REPORT of CHLORIDE ANALYSIS

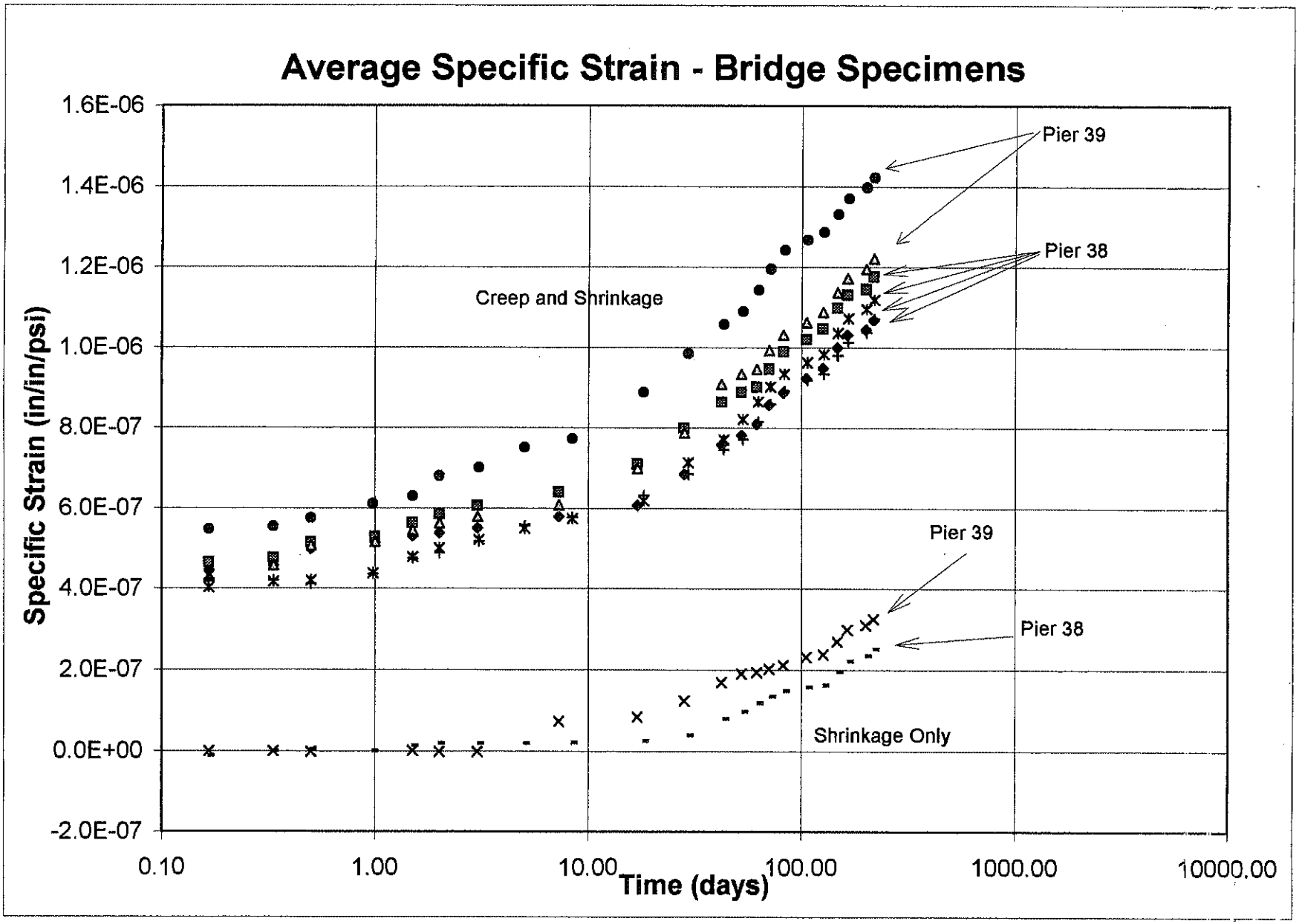
Sample Identification			Determined Water-Soluble Chloride
CTL ID	Client ID	Description	(wt% of sample)
920832	Pier 38 SF #2 1 in.		0.071
920833	Pier 38 SF #2 3 in.		0.072
920834	Pier 38 SF #2 4 in.		0.055
920835	Pier 38 SF #2 8 in.		0.066
920836	Pier 38 NF #1 1 in.		0.070
920837	Pier 38 NF #1 3 in.		0.063
920838	Pier 38 NF #1 4 in.		0.054
920839	Pier 38 NF #1 8 in.		0.042

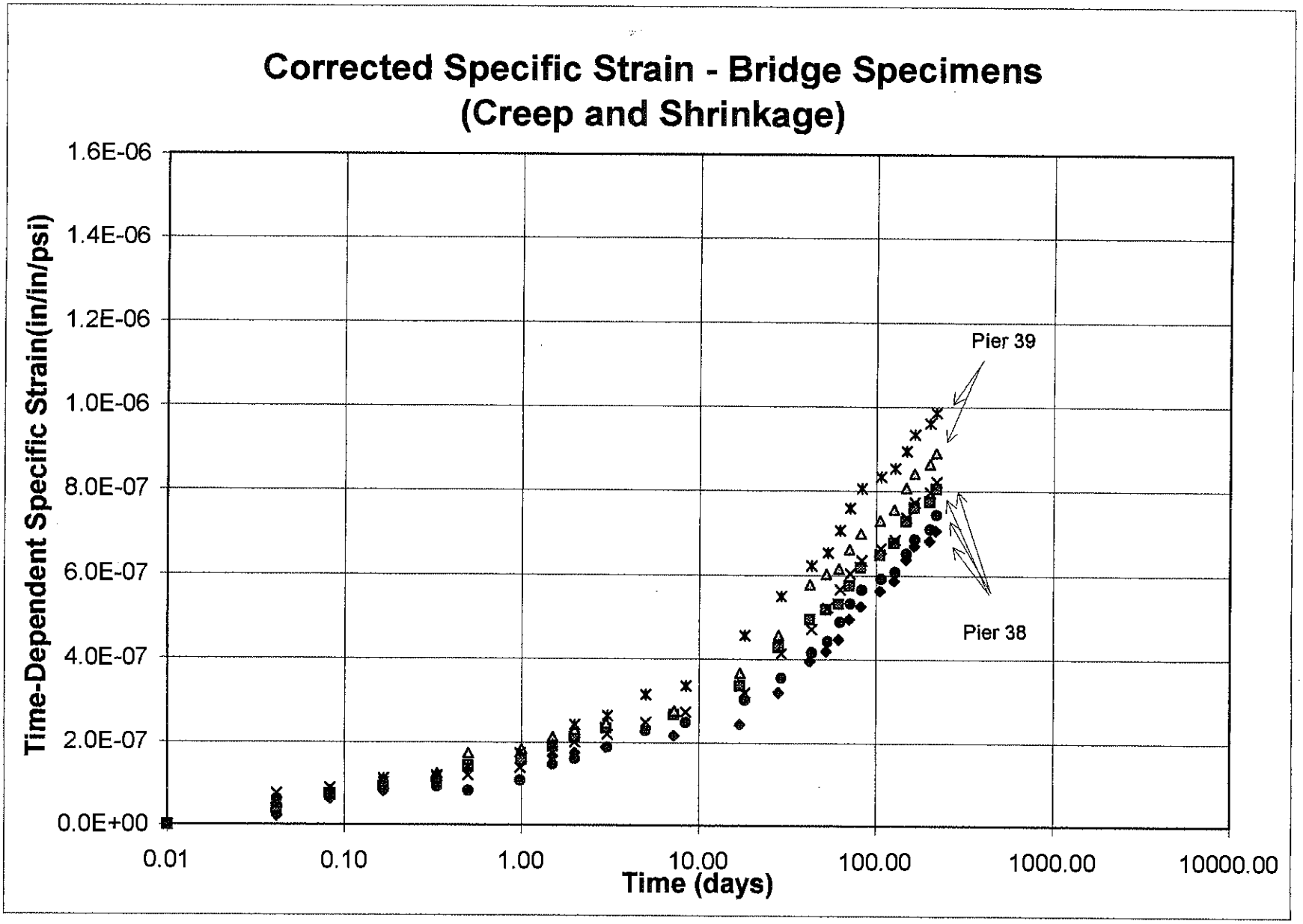
Notes:
1. This analysis represents specifically the samples submitted on a dry (105° C) basis.
2. This report may not be reproduced except in its entirety.
3. Analysis by potentiometric titration with silver nitrate. (ASTM C1218).

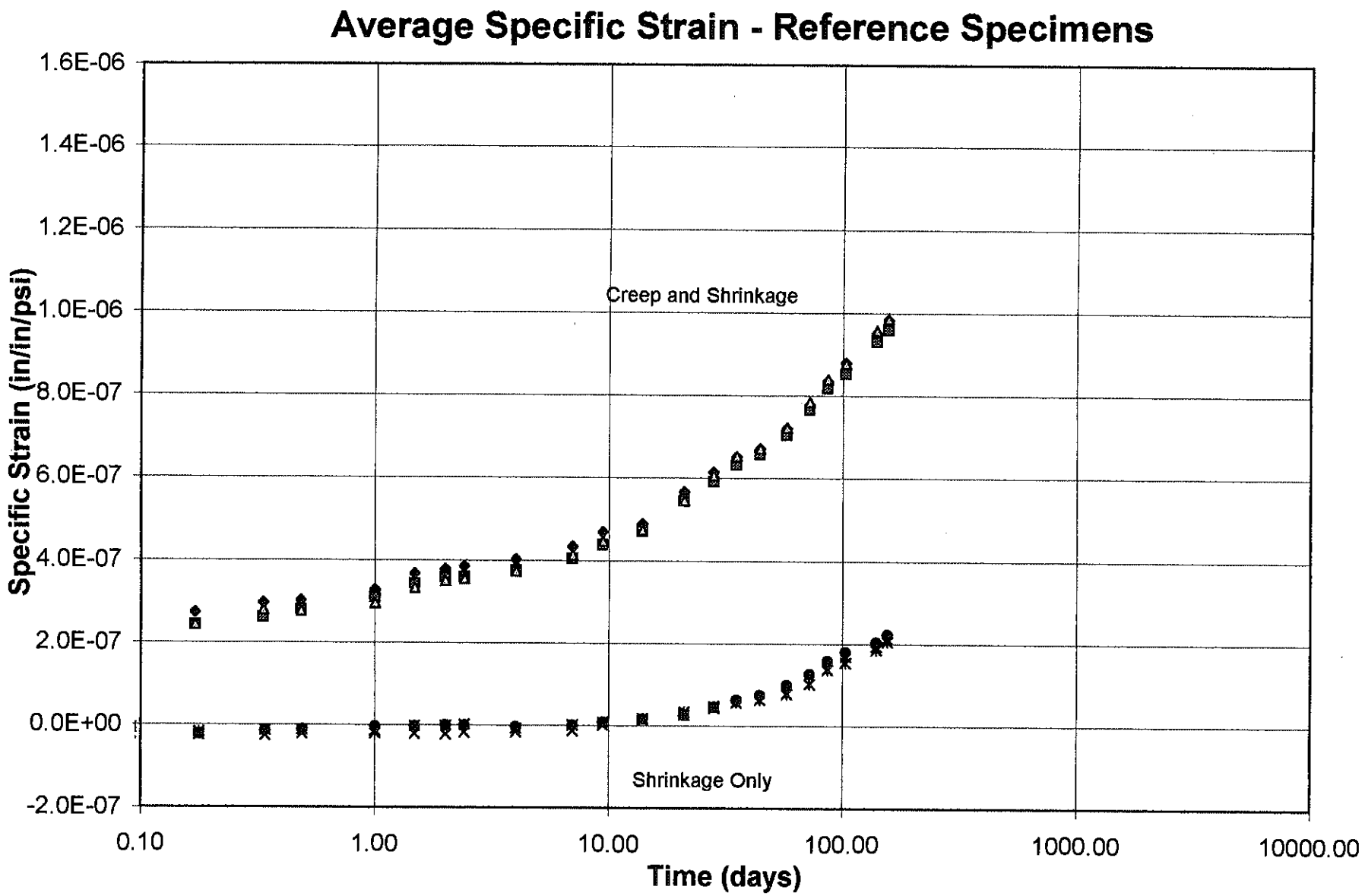
Appendix D.

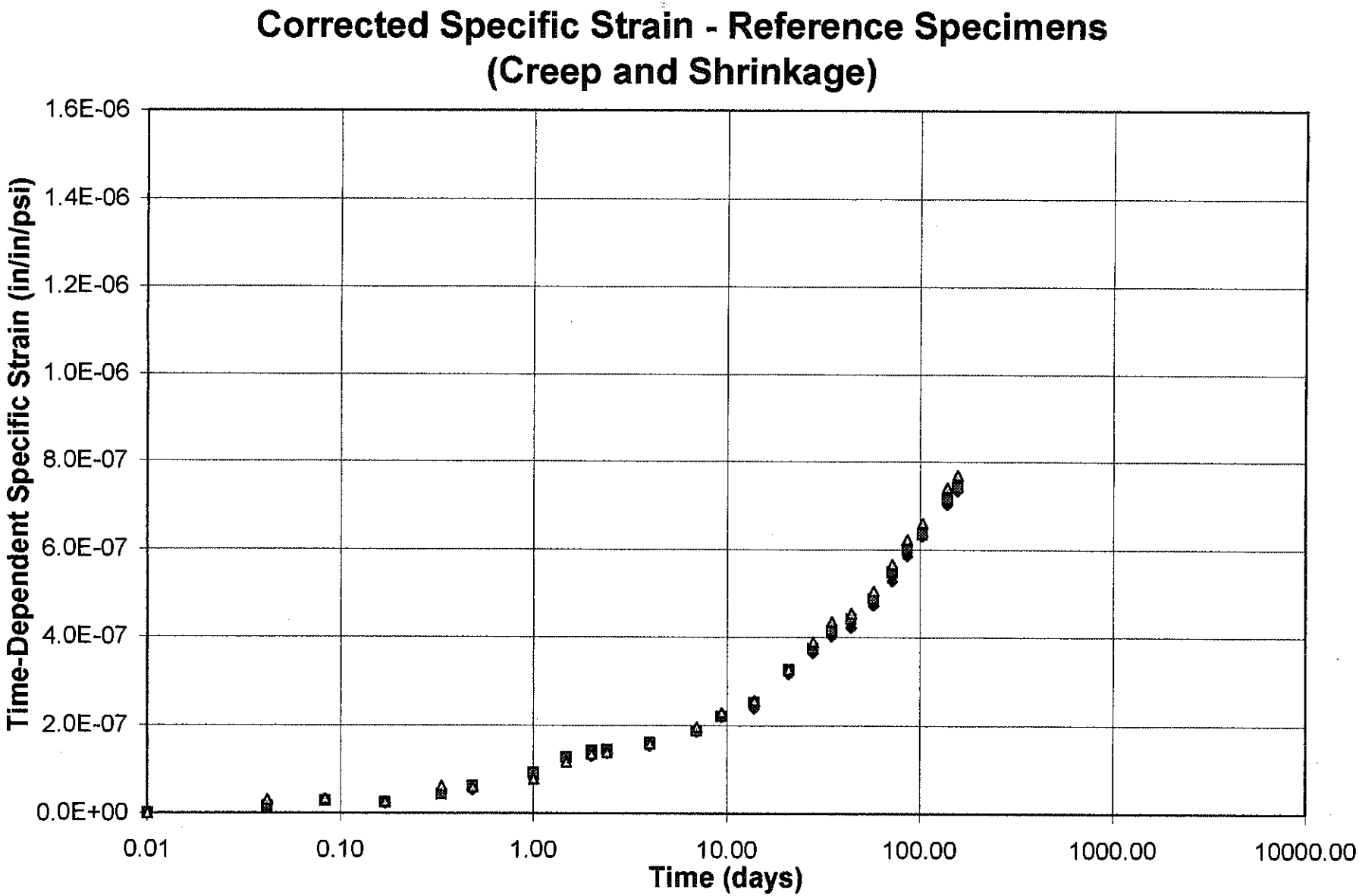
Creep Testing

The creep testing procedure is described on pages D47 and following.


Average Specific Strain - Bridge Specimens
1.6E-06
1.4E-06
1.2E-06
1.0E-06
8.0E-07
6.0E-07
4.0E-07
2.0E-07
0.0E+00
-2.0E-07
Specific Strain (in/in/psi)
0.10
1.00
10.00
100.00
1000.00
10000.00
Time (days)
Pier 39
Pier 38
Creep and Shrinkage
Pier 39
Pier 38
Shrinkage Only


Corrected Specific Strain - Bridge Specimens
(Creep and Shrinkage)
Time-Dependent Specific Strain(in/in/psi)
1.6E-06
1.4E-06
1.2E-06
1.0E-06
8.0E-07
6.0E-07
4.0E-07
2.0E-07
0.0E+00
0.01
0.10
1.00
10.00
100.00
1000.00
10000.00
Time (days)
Pier 39
Pier 38


Average Specific Strain - Reference Specimens
1.6E-06
1.4E-06
1.2E-06
1.0E-06
8.0E-07
6.0E-07
4.0E-07
2.0E-07
0.0E+00
-2.0E-07
Specific Strain (in/in/psi)
Creep and Shrinkage
Shrinkage Only
0.10
1.00
10.00
100.00
1000.00
10000.00
Time (days)


Corrected Specific Strain - Reference Specimens
(Creep and Shrinkage)
Time-Dependent Specific Strain (in/in/psi)
1.6E-06
1.4E-06
1.2E-06
1.0E-06
8.0E-07
6.0E-07
4.0E-07
2.0E-07
0.0E+00
0.01
0.10
1.00
10.00
100.00
1000.00
10000.00
Time (days)

			Initial		After Time Elapsed in Testiing (Test Time t)							Ultimate Values			
Specimen	Type	Test Time t (Days)	Initial Strain (in/in)	Specific Initial Strain (In/In/psi)	Shrinkage (In/In)	Specific Shrinkage (In/In/psi)	Creep+Shrinkage (in/In)	Specific Creep +Shrinkage (In/In/psi)	Creep (In/In)	Specific Creep (In/In/psi)	V-t	V-ult	Ult Creep Strain (in/in)	Ult Specific Creep Strn. (In/In/psi)	Ult Shrink Strain (In/In)
Pier 38 #1	Creep+Shrink	218	465.E-06	.328E-06			001.E-03	.744E-06							
Pier 38 #2	Creep+Shrink	218	513.E-06	.363E-06			997.E-06	.705E-06							
Pier 38 #3	Creep+Shrink	218	424.E-06	.300E-06			1166E-06	.821E-06							
Pier 38 #4	Creep+Shrink	218	526.E-06	.372E-06			1134E-06	.804E-06							
Avg Creep 38	Creep+Shrink		467.E-06	.341E-06			1088E-06	.769E-06							
#5 38	Shrink only	218			355.E-06	.251E-06									
Avg Shrink 38	Shrink only				355.E-06	.251E-06									
Avg. Pier 38									733.E-06	.518E-06	1.57	2.19	1022E-06	.722E-06	413E-06
Pier 39 #1	Creep+Shrink	218	616.E-06	.436E-06			1394E-06	.987E-06							
Pier 39 #3	Creep+Shrink	218	470.E-06	.332E-06			1260E-06	.890E-06							
Avg Creep 39	Creep+Shrink		543.E-06	.384E-06			1327E-06	.939E-06							
Pier 39 #5	Shrink only	218			460.E-06	.325E-06									
Avg Shrink 39	Shrink only				460.E-06	.325E-06									
Avg Pier 39									867.E-06	.614E-06	1.60	2.23	1208E-06	.854E-06	535E-06
Ref #1	Creep+Shrink	155	269.E-06	.217E-06			951.E-06	.769E-06							
Ref #5	Creep+Shrink	155	269.E-06	.217E-06			921.E-06	.742E-06							
Ref #7	Creep+Shrink	155	309.E-06	.250E-06			911.E-06	.734E-06							
Avg Creep REF	Creep+Shrink		282.E-06	.228E-06			928.E-06	.748E-06							
Ref #2	Shrink only	155			255.E-06	.206E-06									
Ref #8	Shrink only	155			276.E-06	.223E-06									
Ref #9	Shrink only	155			263.E-06	.212E-06									
Avg Shrink REF	Shrink only				265.E-06	.214E-06									
Avg Reference									663.E-06	.535E-06	2.35	3.49	985E-06	.796E-06	325E-06

SPECIMEN #1 38 A											
Date	Time	Load (kips)	Time (days)	A					Avg.	Diff.	Strain #1 38 A
				1	2	3	4	5			
2/22/96	9:30 AM	0	0.00	0.02735	0.02728	0.02723	0.02726	0.02734	0.02729	*****	*****
2/22/96	10:00 AM	40	0.01	0.02335	0.02320	0.02330	0.02325	0.02320	0.02326	0.00403	504E-06
2/22/96	11:00 AM	40	0.04	0.02240	0.02238	0.02235	0.02230	0.02239	0.02236	0.00493	616E-06
2/22/96	12:00 PM	40	0.08	0.02245	0.02251	0.02252	0.02240	0.02250	0.02248	0.00482	602E-06
2/22/96	2:00 PM	40	0.17	0.02236	0.02232	0.02235	0.02232	0.02233	0.02234	0.00496	620E-06
2/22/96	6:00 PM	40	0.33	0.02250	0.02254	0.02258	0.02259	0.02251	0.02254	0.00475	594E-06
2/22/96	10:00 PM	40	0.50	0.02261	0.02258	0.02258	0.02255	0.02250	0.02256	0.00473	591E-06
2/23/96	9:30 AM	40	0.98	0.02249	0.02245	0.02246	0.02248	0.02250	0.02248	0.00482	602E-06
2/23/96	10:00 PM	40	1.50	0.02193	0.02203	0.02195	0.02199	0.02200	0.02198	0.00531	664E-06
2/24/96	10:00 AM	40	2.00	0.02205	0.02199	0.02187	0.02198	0.02195	0.02197	0.00532	666E-06
2/25/96	11:30 AM	40	3.06	0.02179	0.02180	0.02180	0.02178	0.02182	0.02180	0.00549	687E-06
2/27/96	10:30 AM	40	5.02	0.02135	0.02140	0.02134	0.02135	0.02136	0.02136	0.00593	742E-06
3/1/96	7:35 PM	40	8.40	0.02126	0.02130	0.02121	0.02128	0.02122	0.02125	0.00604	755E-06
3/11/96	3:00 PM	40	18.21	0.02113	0.02118	0.02111	0.02120	0.02116	0.02116	0.00614	767E-06
3/22/96	4:45 PM	40	29.28	0.02061	0.02068	0.02068	0.02066	0.02069	0.02066	0.00663	829E-06
4/5/96	3:45 PM	40*	43.24	0.01971	0.01981	0.01975	0.01971	0.01966	0.01973	0.00756	946E-06
4/15/96	2:00 PM	40	53.17	0.01959	0.01965	0.01959	0.01965	0.01961	0.01962	0.00767	959E-06
4/24/96	9:10 PM	40	62.47	0.01905	0.01910	0.01908	0.01905	0.01910	0.01908	0.00822	1.03E-03
5/3/96	10:00 PM	40	71.50	0.01865	0.01861	0.01861	0.01862	0.01859	0.01862	0.00868	1.08E-03
5/15/96	1:45 PM	40	83.16	0.01828	0.01818	0.01828	0.01828	0.01831	0.01827	0.00903	1.13E-03
6/7/96	4:20 PM	40	106.26	0.01795	0.01791	0.01795	0.01792	0.01790	0.01793	0.00937	1.17E-03
6/28/96	2:50 PM	40	127.20	0.01769	0.01775	0.01781	0.01772	0.01772	0.01774	0.00955	1.19E-03
7/19/96	11:45 AM	40	148.07	0.01731	0.01725	0.01719	0.01721	0.01715	0.01722	0.01007	1.26E-03
8/5/96	11:10 AM	40	165.05	0.01690	0.01689	0.01687	0.01687	0.01687	0.01688	0.01041	1.30E-03
9/10/96	11:25 AM	40	201.06	0.01658	0.01655	0.01661	0.01660	0.01661	0.01659	0.01070	1.34E-03
9/27/96	2:10 PM	40	218.17	0.01621	0.01621	0.01620	0.01615	0.01618	0.01619	0.01110	1.39E-03

SPECIMEN #1 38 B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain #1 38 B
				1	2	3	4	5			
2/22/96	9:30 AM	0	0.00	0.03086	0.03082	0.03092	0.03095	0.03098	0.03091	*****	*****
2/22/96	10:00 AM	40	0.01	0.02750	0.02745	0.02758	0.02747	0.02752	0.02750	0.00340	425E-06
2/22/96	11:00 AM	40	0.04	0.02693	0.02717	0.02700	0.02690	0.02697	0.02699	0.00391	489E-06
2/22/96	12:00 PM	40	0.08	0.02655	0.02670	0.02671	0.02664	0.02672	0.02666	0.00424	530E-06
2/22/96	2:00 PM	40	0.17	0.02636	0.02633	0.02620	0.02634	0.02628	0.02630	0.00460	576E-06
2/22/96	6:00 PM	40	0.33	0.02621	0.02606	0.02604	0.02618	0.02621	0.02614	0.00477	596E-06
2/22/96	10:00 PM	40	0.50	0.02643	0.02625	0.02620	0.02642	0.02640	0.02634	0.00457	571E-06
2/23/96	9:30 AM	40	0.98	0.02581	0.02595	0.02592	0.02581	0.02580	0.02586	0.00505	631E-06
2/23/96	10:00 PM	40	1.50	0.02552	0.02543	0.02544	0.02552	0.02545	0.02547	0.00543	679E-06
2/24/96	10:00 AM	40	2.00	0.02525	0.02521	0.02514	0.02511	0.02516	0.02517	0.00573	717E-06
2/25/96	11:30 AM	40	3.06	0.02470	0.02469	0.02472	0.02475	0.02470	0.02471	0.00619	774E-06
2/27/96	10:30 AM	40	5.02	0.02426	0.02423	0.02425	0.02422	0.02426	0.02424	0.00666	833E-06
3/1/96	7:35 PM	40	8.40	0.02390	0.02381	0.02389	0.02385	0.02391	0.02387	0.00703	879E-06
3/11/96	3:00 PM	40	18.21	0.02270	0.02280	0.02279	0.02274	0.02279	0.02276	0.00814	1.02E-03
3/22/96	4:45 PM	40	29.28	0.02196	0.02211	0.02209	0.02210	0.02202	0.02206	0.00885	1.11E-03
4/5/96	3:45 PM	40*	43.24	0.02159	0.02158	0.02165	0.02166	0.02162	0.02162	0.00929	1.16E-03
4/15/96	2:00 PM	40	53.17	0.02109	0.02118	0.02119	0.02119	0.02105	0.02114	0.00977	1.22E-03
4/24/96	9:10 PM	40	62.47	0.02069	0.02061	0.02065	0.02071	0.02060	0.02065	0.01025	1.28E-03
5/3/96	10:00 PM	40	71.50	0.02015	0.02010	0.02009	0.02010	0.02009	0.02011	0.01080	1.35E-03
5/15/96	1:45 PM	40	83.16	0.01975	0.01969	0.01969	0.01971	0.01969	0.01971	0.01120	1.40E-03
6/7/96	4:20 PM	40	106.26	0.01939	0.01945	0.01941	0.01949	0.01945	0.01944	0.01147	1.43E-03
6/28/96	2:50 PM	40	127.20	0.01925	0.01931	0.01922	0.01928	0.01931	0.01927	0.01163	1.45E-03
7/19/96	11:45 AM	40	148.07	0.01881	0.01881	0.01875	0.01881	0.01879	0.01879	0.01211	1.51E-03
8/5/96	11:10 AM	40	165.05	0.01832	0.01842	0.01840	0.01839	0.01838	0.01838	0.01252	1.57E-03
9/10/96	11:25 AM	40	201.06	0.01810	0.01811	0.01812	0.01811	0.01810	0.01811	0.01280	1.60E-03
9/27/96	2:10 PM	40	218.17	0.01775	0.01771	0.01775	0.01778	0.01771	0.01774	0.01317	1.65E-03

SPECIMEN #1 38				Avg Strain #1 38	Specific Strain #1 38	Corrected Spec Strain #1 38
Date	Time	Load (kips)	Time (days)			
2/22/96	9:30 AM	0	0.00			
2/22/96	10:00 AM	40	0.01	465E-06	.328E-06	.000E+00
2/22/96	11:00 AM	40	0.04	553E-06	.390E-06	.621E-07
2/22/96	12:00 PM	40	0.08	566E-06	.400E-06	.717E-07
2/22/96	2:00 PM	40	0.17	598E-06	.422E-06	.939E-07
2/22/96	6:00 PM	40	0.33	595E-06	.420E-06	.919E-07
2/22/96	10:00 PM	40	0.50	581E-06	.411E-06	.822E-07
2/23/96	9:30 AM	40	0.98	617E-06	.436E-06	.107E-06
2/23/96	10:00 PM	40	1.50	672E-06	.475E-06	.146E-06
2/24/96	10:00 AM	40	2.00	691E-06	.488E-06	.160E-06
2/25/96	11:30 AM	40	3.06	731E-06	.516E-06	.188E-06
2/27/96	10:30 AM	40	5.02	787E-06	.556E-06	.228E-06
3/1/96	7:35 PM	40	8.40	817E-06	.577E-06	.249E-06
3/11/96	3:00 PM	40	18.21	892E-06	.631E-06	.302E-06
3/22/96	4:45 PM	40	29.28	967E-06	.684E-06	.355E-06
4/5/96	3:45 PM	40*	43.24	1.05E-03	.744E-06	.416E-06
4/15/96	2:00 PM	40	53.17	1.09E-03	.770E-06	.442E-06
4/24/96	9:10 PM	40	62.47	1.15E-03	.816E-06	.487E-06
5/3/96	10:00 PM	40	71.50	1.22E-03	.860E-06	.532E-06
5/15/96	1:45 PM	40	83.16	1.26E-03	.893E-06	.565E-06
6/7/96	4:20 PM	40	106.26	1.30E-03	.920E-06	.592E-06
6/28/96	2:50 PM	40	127.20	1.32E-03	.936E-06	.607E-06
7/19/96	11:45 AM	40	148.07	1.39E-03	.980E-06	.651E-06
8/5/96	11:10 AM	40	165.05	1.43E-03	1.01E-06	.685E-06
9/10/96	11:25 AM	40	201.06	1.47E-03	1.04E-06	.710E-06
9/27/96	2:10 PM	40	218.17	1.52E-03	1.07E-06	.744E-06

SPECIMEN #2 38 A											
Date	Time	Load (kips)	Time (days)	A					Avg.	Diff.	Strain #2 38 A
				1	2	3	4	5			
2/23/96	12:00 PM	0	0.00	0.03030	0.03040	0.03050	0.03045	0.03042	0.03041	*****	*****
2/23/96	12:25 PM	20	0.00	0.02888	0.02881	0.02883	0.02875	0.02872	0.02880	*****	*****
2/23/96	12:45 PM	40	0.01	0.02615	0.02610	0.02625	0.02609	0.02618	0.02615	0.00426	533E-06
2/23/96	1:45 PM	40	0.04	0.02558	0.02566	0.02570	0.02580	0.02571	0.02569	0.00472	591E-06
2/23/96	2:45 PM	40	0.08	0.02523	0.02529	0.02519	0.02532	0.02531	0.02527	0.00515	643E-06
2/23/96	4:45 PM	40	0.17	0.02511	0.02513	0.02510	0.02513	0.02521	0.02514	0.00528	660E-06
2/23/96	8:45 PM	40	0.33	0.02485	0.02488	0.02483	0.02489	0.02486	0.02486	0.00555	694E-06
2/24/96	12:45 AM	40	0.50	0.02463	0.02461	0.02462	0.02451	0.02463	0.02460	0.00581	727E-06
2/24/96	12:45 PM	40	1.00	0.02436	0.02442	0.02438	0.02437	0.02439	0.02438	0.00603	754E-06
2/25/96	12:45 AM	40	1.50	0.02428	0.02423	0.02422	0.02426	0.02424	0.02425	0.00617	771E-06
2/25/96	12:45 PM	40	2.00	0.02430	0.02426	0.02415	0.02426	0.02427	0.02425	0.00617	771E-06
2/26/96	1:00 PM	40	3.01	0.02410	0.02412	0.02414	0.02413	0.02412	0.02412	0.00629	787E-06
3/1/96	7:05 PM	40	7.26	0.02384	0.02391	0.02391	0.02390	0.02388	0.02389	0.00653	816E-06
3/11/96	1:45 PM	40	17.04	0.02362	0.02360	0.02360	0.02360	0.02364	0.02361	0.00680	850E-06
3/22/96	5:15 PM	40	28.19	0.02275	0.02278	0.02275	0.02271	0.02270	0.02274	0.00768	960E-06
4/5/96	4:30 PM	40	42.16	0.02175	0.02162	0.02192	0.02178	0.02178	0.02177	0.00864	1.08E-03
4/15/96	4:15 PM	40	52.15	0.02145	0.02149	0.02139	0.02149	0.02142	0.02145	0.00897	1.12E-03
4/25/96	12:30 AM	40	61.49	0.02095	0.02095	0.02099	0.02105	0.02105	0.02100	0.00942	1.18E-03
5/3/96	10:30 PM	40	70.41	0.02045	0.02042	0.02055	0.02045	0.02050	0.02047	0.00994	1.24E-03
5/15/96	2:20 PM	40	82.07	0.02010	0.02005	0.02000	0.02008	0.02010	0.02007	0.01035	1.29E-03
6/7/96	5:40 PM	40	105.20	0.01968	0.01962	0.01961	0.01965	0.01960	0.01963	0.01078	1.35E-03
6/28/96	3:10 PM	40	126.10	0.01931	0.01935	0.01929	0.01931	0.01931	0.01931	0.01110	1.39E-03
7/19/96	12:45 PM	40	147.00	0.01898	0.01899	0.01895	0.01895	0.01892	0.01896	0.01146	1.43E-03
8/5/96	12:10 PM	40	163.98	0.01850	0.01849	0.01848	0.01842	0.01845	0.01847	0.01195	1.49E-03
9/10/96	11:50 AM	40	199.96	0.01820	0.01818	0.01819	0.01819	0.01821	0.01819	0.01222	1.53E-03
9/27/96	2:40 PM	40	217.08	0.01790	0.01795	0.01788	0.01791	0.01788	0.01790	0.01251	1.56E-03

SPECIMEN #2 38 B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain #2 38 B
				1	2	3	4	5			
2/23/96	12:00 PM	0	0.00	0.03000	0.03007	0.03001	0.03010	0.03006	0.03005	*****	*****
2/23/96	12:25 PM	20	0.00	0.02839	0.02821	0.02829	0.02819	0.02823	0.02826	*****	*****
2/23/96	12:45 PM	40	0.01	0.02611	0.02611	0.02618	0.02599	0.02610	0.02610	0.00395	494E-06
2/23/96	1:45 PM	40	0.04	0.02609	0.02600	0.02599	0.02617	0.02611	0.02607	0.00398	497E-06
2/23/96	2:45 PM	40	0.08	0.02550	0.02558	0.02561	0.02555	0.02557	0.02556	0.00449	561E-06
2/23/96	4:45 PM	40	0.17	0.02524	0.02522	0.02531	0.02529	0.02534	0.02528	0.00477	596E-06
2/23/96	8:45 PM	40	0.33	0.02515	0.02522	0.02533	0.02531	0.02527	0.02526	0.00479	599E-06
2/24/96	12:45 AM	40	0.50	0.02455	0.02450	0.02460	0.02461	0.02467	0.02459	0.00546	683E-06
2/24/96	12:45 PM	40	1.00	0.02450	0.02442	0.02442	0.02444	0.02437	0.02443	0.00562	702E-06
2/25/96	12:45 AM	40	1.50	0.02425	0.02420	0.02423	0.02421	0.02427	0.02423	0.00582	727E-06
2/25/96	12:45 PM	40	2.00	0.02408	0.02405	0.02400	0.02402	0.02408	0.02405	0.00600	750E-06
2/26/96	1:00 PM	40	3.01	0.02380	0.02389	0.02390	0.02388	0.02391	0.02388	0.00617	772E-06
3/1/96	7:05 PM	40	7.26	0.02351	0.02344	0.02343	0.02345	0.02349	0.02346	0.00658	823E-06
3/11/96	1:45 PM	40	17.04	0.02315	0.02306	0.02310	0.02312	0.02311	0.02311	0.00694	868E-06
3/22/96	5:15 PM	40	28.19	0.02223	0.02230	0.02221	0.02228	0.02225	0.02225	0.00779	974E-06
4/5/96	4:30 PM	40	42.16	0.02155	0.02155	0.02158	0.02148	0.02158	0.02155	0.00850	1.06E-03
4/15/96	4:15 PM	40	52.15	0.02135	0.02132	0.02129	0.02135	0.02132	0.02133	0.00872	1.09E-03
4/25/96	12:30 AM	40	61.49	0.02115	0.02118	0.02118	0.02115	0.02110	0.02115	0.00890	1.11E-03
5/3/96	10:30 PM	40	70.41	0.02055	0.02058	0.02050	0.02065	0.02058	0.02057	0.00948	1.18E-03
5/15/96	2:20 PM	40	82.07	0.02030	0.02029	0.02029	0.02030	0.02029	0.02029	0.00975	1.22E-03
6/7/96	5:40 PM	40	105.20	0.01985	0.01989	0.01989	0.01989	0.01991	0.01989	0.01016	1.27E-03
6/28/96	3:10 PM	40	126.10	0.01960	0.01965	0.01968	0.01969	0.01961	0.01965	0.01040	1.30E-03
7/19/96	12:45 PM	40	147.00	0.01888	0.01885	0.01880	0.01889	0.01888	0.01886	0.01119	1.40E-03
8/5/96	12:10 PM	40	163.98	0.01860	0.01865	0.01868	0.01865	0.01860	0.01864	0.01141	1.43E-03
9/10/96	11:50 AM	40	199.96	0.01869	0.01861	0.01861	0.01861	0.01860	0.01862	0.01142	1.43E-03
9/27/96	2:40 PM	40	217.08	0.01840	0.01839	0.01841	0.01835	0.01835	0.01838	0.01167	1.46E-03

SPECIMEN #2 38				Avg Strain #2 38	Specific Strain #2 38	Corrected Spec Strain #2 38
Date	Time	Load (kips)	Time (days)			
2/23/96	12:00 PM	0	0.00			
2/23/96	12:25 PM	20	0.00			
2/23/96	12:45 PM	40	0.01	513E-06	.363E-06	0.00E+00
2/23/96	1:45 PM	40	0.04	544E-06	.384E-06	.216E-07
2/23/96	2:45 PM	40	0.08	602E-06	.425E-06	.628E-07
2/23/96	4:45 PM	40	0.17	628E-06	.444E-06	.811E-07
2/23/96	8:45 PM	40	0.33	647E-06	.457E-06	.943E-07
2/24/96	12:45 AM	40	0.50	705E-06	.498E-06	.135E-06
2/24/96	12:45 PM	40	1.00	728E-06	.515E-06	.152E-06
2/25/96	12:45 AM	40	1.50	749E-06	.529E-06	.167E-06
2/25/96	12:45 PM	40	2.00	761E-06	.537E-06	.175E-06
2/26/96	1:00 PM	40	3.01	779E-06	.551E-06	.188E-06
3/1/96	7:05 PM	40	7.26	819E-06	.579E-06	.216E-06
3/11/96	1:45 PM	40	17.04	859E-06	.607E-06	.244E-06
3/22/96	5:15 PM	40	28.19	967E-06	.683E-06	.321E-06
4/5/96	4:30 PM	40	42.16	1.07E-03	.757E-06	.395E-06
4/15/96	4:15 PM	40	52.15	1.11E-03	.781E-06	.419E-06
4/25/96	12:30 AM	40	61.49	1.14E-03	.809E-06	.446E-06
5/3/96	10:30 PM	40	70.41	1.21E-03	.858E-06	.495E-06
5/15/96	2:20 PM	40	82.07	1.26E-03	.888E-06	.525E-06
6/7/96	5:40 PM	40	105.20	1.31E-03	.925E-06	.562E-06
6/28/96	3:10 PM	40	126.10	1.34E-03	.950E-06	.587E-06
7/19/96	12:45 PM	40	147.00	1.42E-03	1.00E-06	.638E-06
8/5/96	12:10 PM	40	163.98	1.46E-03	1.03E-06	.669E-06
9/10/96	11:50 AM	40	199.96	1.48E-03	1.04E-06	.682E-06
9/27/96	2:40 PM	40	217.08	1.51E-03	1.07E-06	.705E-06

SPECIMEN #3 38 A											
Date	Time	Load (kips)	Time (Days)	A					Avg.	Diff.	Strain #3 38 A
				1	2	3	4	5			
2/22/96	9:30 AM	0	0.00	0.02858	0.02866	0.02852	0.02847	0.02851	0.02855	*****	*****
2/22/96	10:00 AM	40	0.01	0.02542	0.02556	0.02540	0.02538	0.02551	0.02545	0.00309	387E-06
2/22/96	11:00 AM	40	0.04	0.02492	0.02505	0.02498	0.02501	0.02490	0.02497	0.00358	447E-06
2/22/96	12:00 PM	40	0.08	0.02481	0.02480	0.02483	0.02485	0.02479	0.02482	0.00373	467E-06
2/22/96	2:00 PM	40	0.17	0.02463	0.02463	0.02465	0.02456	0.02461	0.02462	0.00393	492E-06
2/22/96	6:00 PM	40	0.33	0.02429	0.02422	0.02423	0.02421	0.02414	0.02422	0.00433	541E-06
2/22/96	10:00 PM	40	0.50	0.02417	0.02413	0.02418	0.02416	0.02417	0.02416	0.00439	548E-06
2/23/96	9:30 AM	40	0.98	0.02410	0.02411	0.02403	0.02406	0.02409	0.02408	0.00447	559E-06
2/23/96	10:00 PM	40	1.50	0.02349	0.02358	0.02351	0.02352	0.02360	0.02354	0.00501	626E-06
2/24/96	10:00 AM	40	2.00	0.02330	0.02334	0.02332	0.02333	0.02332	0.02332	0.00523	653E-06
2/25/96	11:30 AM	40	3.06	0.02304	0.02309	0.02313	0.02315	0.02313	0.02311	0.00544	680E-06
2/27/96	10:30 AM	40	5.02	0.02297	0.02293	0.02296	0.02295	0.02299	0.02296	0.00559	699E-06
3/1/96	7:35 PM	40	8.40	0.02275	0.02278	0.02270	0.02269	0.02268	0.02272	0.00583	729E-06
3/11/96	3:00 PM	40	18.21	0.02209	0.02208	0.02206	0.02209	0.02209	0.02208	0.00647	808E-06
3/22/96	4:45 PM	40	29.28	0.02095	0.02097	0.02091	0.02098	0.02098	0.02096	0.00759	949E-06
4/5/96	3:45 PM	40*	43.24	0.03011	0.03028	0.03026	0.03018	0.03022	0.03021	0.00834	1.04E-03
4/15/96	2:00 PM	40	53.17	0.02931	0.02941	0.02935	0.02929	0.02945	0.02936	0.00919	1.15E-03
4/24/96	9:10 PM	40	62.47	0.02870	0.02869	0.02869	0.02865	0.02871	0.02869	0.00986	1.23E-03
5/3/96	10:00 PM	40	71.50	0.02831	0.02835	0.02831	0.02829	0.02829	0.02831	0.01024	1.28E-03
5/15/96	1:45 PM	40	83.16	0.02791	0.02795	0.02791	0.02798	0.02796	0.02794	0.01061	1.33E-03
6/7/96	4:20 PM	40	106.26	0.02761	0.02765	0.02761	0.02769	0.02761	0.02763	0.01091	1.36E-03
6/28/96	2:50 PM	40	127.20	0.02741	0.02740	0.02739	0.02739	0.02739	0.02740	0.01115	1.39E-03
7/19/96	11:45 AM	40	148.07	0.02685	0.02682	0.02685	0.02685	0.02682	0.02684	0.01171	1.46E-03
8/5/96	11:10 AM	40	165.05	0.02649	0.02645	0.02639	0.02641	0.02642	0.02643	0.01212	1.51E-03
9/10/96	11:25 AM	40	201.06	0.02611	0.02610	0.02612	0.02610	0.02609	0.02610	0.01244	1.56E-03
9/27/96	2:10 PM	40	218.17	0.02588	0.02590	0.02588	0.02588	0.02588	0.02588	0.01266	1.58E-03

SPECIMEN #3 38 B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain #3 38 B
				1	2	3	4	5			
2/22/96	9:30 AM	0	0.00	0.03131	0.03123	0.03134	0.03133	0.03133	0.03131	*****	*****
2/22/96	10:00 AM	40	0.01	0.02771	0.02769	0.02753	0.02759	0.02755	0.02761	0.00369	462E-06
2/22/96	11:00 AM	40	0.04	0.02637	0.02640	0.02638	0.02639	0.02635	0.02638	0.00493	616E-06
2/22/96	12:00 PM	40	0.08	0.02629	0.02618	0.02611	0.02624	0.02630	0.02622	0.00508	635E-06
2/22/96	2:00 PM	40	0.17	0.02622	0.02609	0.02618	0.02615	0.02603	0.02613	0.00517	647E-06
2/22/96	6:00 PM	40	0.33	0.02620	0.02624	0.02621	0.02619	0.02620	0.02621	0.00510	638E-06
2/22/96	10:00 PM	40	0.50	0.02619	0.02620	0.02620	0.02613	0.02621	0.02619	0.00512	640E-06
2/23/96	9:30 AM	40	0.98	0.02580	0.02590	0.02580	0.02598	0.02589	0.02587	0.00543	679E-06
2/23/96	10:00 PM	40	1.50	0.02552	0.02551	0.02549	0.02550	0.02548	0.02550	0.00581	726E-06
2/24/96	10:00 AM	40	2.00	0.02519	0.02520	0.02519	0.02524	0.02521	0.02521	0.00610	763E-06
2/25/96	11:30 AM	40	3.06	0.02498	0.02494	0.02492	0.02500	0.02497	0.02496	0.00635	793E-06
2/27/96	10:30 AM	40	5.02	0.02444	0.02448	0.02448	0.02445	0.02449	0.02447	0.00684	855E-06
3/1/96	7:35 PM	40	8.40	0.02411	0.02415	0.02413	0.02411	0.02416	0.02413	0.00718	897E-06
3/11/96	3:00 PM	40	18.21	0.02374	0.02378	0.02374	0.02373	0.02378	0.02375	0.00755	944E-06
3/22/96	4:45 PM	40	29.28	0.02271	0.02278	0.02280	0.02274	0.02277	0.02276	0.00855	1.07E-03
4/5/96	3:45 PM	40*	43.24	0.02222	0.02200	0.02240	0.02217	0.02227	0.02221	0.00910	1.14E-03
4/15/96	2:00 PM	40	53.17	0.02189	0.02189	0.02185	0.02199	0.02185	0.02189	0.00941	1.18E-03
4/24/96	9:10 PM	40	62.47	0.02155	0.02152	0.02158	0.02155	0.02158	0.02156	0.00975	1.22E-03
5/3/96	10:00 PM	40	71.50	0.02118	0.02108	0.02105	0.02105	0.02105	0.02108	0.01023	1.28E-03
5/15/96	1:45 PM	40	83.16	0.02078	0.02069	0.02075	0.02078	0.02075	0.02075	0.01056	1.32E-03
6/7/96	4:20 PM	40	106.26	0.02041	0.02039	0.02045	0.02039	0.02039	0.02041	0.01090	1.36E-03
6/28/96	2:50 PM	40	127.20	.0.02020	0.02021	0.02020	0.02021	0.02015	0.02019	0.01112	1.39E-03
7/19/96	11:45 AM	40	148.07	0.01955	0.01958	0.01952	0.01959	0.01955	0.01956	0.01175	1.47E-03
8/5/96	11:10 AM	40	165.05	0.01911	0.01912	0.01918	0.01910	0.01918	0.01914	0.01217	1.52E-03
9/10/96	11:25 AM	40	201.06	0.01895	0.01890	0.01900	0.01891	0.01895	0.01894	0.01237	1.55E-03
9/27/96	2:10 PM	40	218.17	0.01861	0.01860	0.01861	0.01859	0.01861	0.01860	0.01270	1.59E-03

SPECIMEN #3 38				Avg Strain #3 38	Specific Strain #3 38	Corrected Spec Strain #3 38
Date	Time	Load (kips)	Time (days)			
2/22/96	9:30 AM	0	0.00			
2/22/96	10:00 AM	40	0.01	424E-06	.300E-06	0.00E+00
2/22/96	11:00 AM	40	0.04	532E-06	.376E-06	.759E-07
2/22/96	12:00 PM	40	0.08	551E-06	.389E-06	.896E-07
2/22/96	2:00 PM	40	0.17	569E-06	.402E-06	.102E-06
2/22/96	6:00 PM	40	0.33	589E-06	.417E-06	.117E-06
2/22/96	10:00 PM	40	0.50	594E-06	.420E-06	.120E-06
2/23/96	9:30 AM	40	0.98	619E-06	.437E-06	.138E-06
2/23/96	10:00 PM	40	1.50	676E-06	.478E-06	.178E-06
2/24/96	10:00 AM	40	2.00	708E-06	.500E-06	.201E-06
2/25/96	11:30 AM	40	3.06	737E-06	.521E-06	.221E-06
2/27/96	10:30 AM	40	5.02	777E-06	.549E-06	.249E-06
3/1/96	7:35 PM	40	8.40	813E-06	.574E-06	.275E-06
3/11/96	3:00 PM	40	18.21	876E-06	.619E-06	.319E-06
3/22/96	4:45 PM	40	29.28	1.01E-03	.713E-06	.413E-06
4/5/96	3:45 PM	40*	43.24	1.09E-03	.770E-06	.470E-06
4/15/96	2:00 PM	40	53.17	1.16E-03	.822E-06	.522E-06
4/24/96	9:10 PM	40	62.47	1.23E-03	.866E-06	.566E-06
5/3/96	10:00 PM	40	71.50	1.28E-03	.904E-06	.604E-06
5/15/96	1:45 PM	40	83.16	1.32E-03	.935E-06	.635E-06
6/7/96	4:20 PM	40	106.26	1.36E-03	.964E-06	.664E-06
6/28/96	2:50 PM	40	127.20	1.39E-03	.984E-06	.684E-06
7/19/96	11:45 AM	40	148.07	1.47E-03	1.04E-06	.736E-06
8/5/96	11:10 AM	40	165.05	1.52E-03	1.07E-06	.773E-06
9/10/96	11:25 AM	40	201.06	1.55E-03	1.10E-06	.796E-06
9/27/96	2:10 PM	40	218.17	1.59E-03	1.12E-06	.821E-06

SPECIMEN #4 38 A											
Date	Time	Load (kips)	Time (days)	A					Avg.	Diff.	Strain #4 38 A
				1	2	3	4	5			
2/23/96	12:00 PM	0	0.00	0.02970	0.02961	0.02964	0.02952	0.02961	0.02962	*****	*****
2/23/96	12:25 PM	20	0.00	0.02861	0.02845	0.02842	0.02847	0.02840	0.02847	*****	*****
2/23/96	12:45 PM	40	0.01	0.02625	0.02620	0.02621	0.02621	0.02623	0.02622	0.00340	425E-06
2/23/96	1:45 PM	40	0.04	0.02612	0.02605	0.02603	0.02612	0.02595	0.02605	0.00357	446E-06
2/23/96	2:45 PM	40	0.08	0.02552	0.02553	0.02550	0.02565	0.02545	0.02553	0.00409	511E-06
2/23/96	4:45 PM	40	0.17	0.02543	0.02540	0.02539	0.02542	0.02542	0.02541	0.00420	526E-06
2/23/96	8:45 PM	40	0.33	0.02540	0.02532	0.02539	0.02542	0.02531	0.02537	0.00425	531E-06
2/24/96	12:45 AM	40	0.50	0.02480	0.02489	0.02481	0.02476	0.02478	0.02481	0.00481	601E-06
2/24/96	12:45 PM	40	1.00	0.02468	0.02466	0.02459	0.02464	0.02461	0.02464	0.00498	623E-06
2/25/96	12:45 AM	40	1.50	0.02422	0.02421	0.02422	0.02420	0.02421	0.02421	0.00540	676E-06
2/25/96	12:45 PM	40	2.00	0.02408	0.02412	0.02406	0.02407	0.02410	0.02409	0.00553	691E-06
2/26/96	1:00 PM	40	3.01	0.02398	0.02394	0.02395	0.02396	0.02394	0.02395	0.00566	708E-06
3/1/96	7:05 PM	40	7.26	0.02347	0.02346	0.02345	0.02347	0.02344	0.02346	0.00616	770E-06
3/11/96	1:45 PM	40	17.04	0.02288	0.02290	0.02291	0.02291	0.02290	0.02290	0.00672	840E-06
3/22/96	5:15 PM	40	28.19	0.02202	0.02201	0.02202	0.02200	0.02205	0.02202	0.00760	950E-06
4/5/96	4:30 PM	40	42.16	0.02105	0.02102	0.02112	0.02115	0.02108	0.02108	0.00853	1.07E-03
4/15/96	4:15 PM	40	52.15	0.02075	0.02079	0.02072	0.02078	0.02069	0.02075	0.00887	1.11E-03
4/25/96	12:30 AM	40	61.49	0.02065	0.02059	0.02059	0.02065	0.02058	0.02061	0.00900	1.13E-03
5/3/96	10:30 PM	40	70.41	0.02008	0.02005	0.02005	0.01995	0.01995	0.02002	0.00960	1.20E-03
5/15/96	2:20 PM	40	82.07	0.01960	0.01959	0.01960	0.01959	0.01958	0.01959	0.01002	1.25E-03
6/7/96	5:40 PM	40	105.20	0.01935	0.01930	0.01929	0.01935	0.01931	0.01932	0.01030	1.29E-03
6/28/96	3:10 PM	40	126.10	0.01910	0.01918	0.01910	0.01918	0.01915	0.01914	0.01047	1.31E-03
7/19/96	12:45 PM	40	147.00	0.01855	0.01865	0.01858	0.01850	0.01851	0.01856	0.01106	1.38E-03
8/5/96	12:10 PM	40	163.98	0.01829	0.01821	0.01821	0.01828	0.01828	0.01825	0.01136	1.42E-03
9/10/96	11:50 AM	40	199.96	0.01811	0.01810	0.01811	0.01812	0.01811	0.01811	0.01151	1.44E-03
9/27/96	2:40 PM	40	217.08	0.01771	0.01775	0.01771	0.01770	0.01772	0.01772	0.01190	1.49E-03

SPECIMEN #4 38 B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain #4 38 B
				1	2	3	4	5			
2/23/96	12:00 PM	0	0.00	0.02920	0.02922	0.02915	0.02919	0.02913	0.02918	*****	*****
2/23/96	12:25 PM	20	0.00	0.02791	0.02794	0.02786	0.02789	0.02782	0.02788	*****	*****
2/23/96	12:45 PM	40	0.01	0.02420	0.02412	0.02416	0.02413	0.02417	0.02416	0.00502	628E-06
2/23/96	1:45 PM	40	0.04	0.02347	0.02345	0.02350	0.02342	0.02347	0.02346	0.00572	714E-06
2/23/96	2:45 PM	40	0.08	0.02318	0.02311	0.02312	0.02325	0.02318	0.02317	0.00601	751E-06
2/23/96	4:45 PM	40	0.17	0.02285	0.02287	0.02289	0.02290	0.02288	0.02288	0.00630	788E-06
2/23/96	8:45 PM	40	0.33	0.02271	0.02268	0.02265	0.02263	0.02264	0.02266	0.00652	815E-06
2/24/96	12:45 AM	40	0.50	0.02231	0.02237	0.02239	0.02229	0.02231	0.02233	0.00684	856E-06
2/24/96	12:45 PM	40	1.00	0.02223	0.02225	0.02221	0.02218	0.02215	0.02220	0.00697	872E-06
2/25/96	12:45 AM	40	1.50	0.02180	0.02190	0.02185	0.02186	0.02190	0.02186	0.00732	915E-06
2/25/96	12:45 PM	40	2.00	0.02145	0.02148	0.02148	0.02147	0.02145	0.02147	0.00771	964E-06
2/26/96	1:00 PM	40	3.01	0.02111	0.02113	0.02115	0.02112	0.02111	0.02112	0.00805	1.01E-03
3/1/96	7:05 PM	40	7.26	0.02087	0.02089	0.02086	0.02087	0.02087	0.02087	0.00831	1.04E-03
3/11/96	1:45 PM	40	17.04	0.01988	0.01990	0.01981	0.01989	0.01984	0.01986	0.00931	1.16E-03
3/22/96	5:15 PM	40	28.19	0.01870	0.01869	0.01868	0.01870	0.01870	0.01869	0.01048	1.31E-03
4/5/96	4:30 PM	40	42.16	0.01821	0.01805	0.01812	0.01810	0.01819	0.01813	0.01104	1.38E-03
4/15/96	4:15 PM	40	52.15	0.01792	0.01789	0.01795	0.01787	0.01790	0.01791	0.01127	1.41E-03
4/25/96	12:30 AM	40	61.49	0.01775	0.01772	0.01775	0.01772	0.01778	0.01774	0.01143	1.43E-03
5/3/96	10:30 PM	40	70.41	0.01739	0.01731	0.01735	0.01728	0.01730	0.01733	0.01185	1.48E-03
5/15/96	2:20 PM	40	82.07	0.01680	0.01680	0.01675	0.01679	0.01681	0.01679	0.01239	1.55E-03
6/7/96	5:40 PM	40	105.20	0.01635	0.01645	0.01636	0.01639	0.01639	0.01639	0.01279	1.60E-03
6/28/96	3:10 PM	40	126.10	0.01591	0.01590	0.01589	0.01600	0.01600	0.01594	0.01324	1.65E-03
7/19/96	12:45 PM	40	147.00	0.01535	0.01538	0.01536	0.01535	0.01535	0.01536	0.01382	1.73E-03
8/5/96	12:10 PM	40	163.98	0.01492	0.01495	0.01489	0.01490	0.01491	0.01491	0.01426	1.78E-03
9/10/96	11:50 AM	40	199.96	0.01472	0.01471	0.01475	0.01472	0.01475	0.01473	0.01445	1.81E-03
9/27/96	2:40 PM	40	217.08	0.01445	0.01445	0.01448	0.01442	0.01445	0.01445	0.01473	1.84E-03

SPECIMEN #4 38				Avg Strain #4 38	Specific Strain #4 38	Corrected Spec Strain #4 38 B
Date	Time	Load (kips)	Time (days)			
2/23/96	12:00 PM	0	0.00			
2/23/96	12:25 PM	20	0.00			
2/23/96	12:45 PM	40	0.01	526E-06	.372E-06	.000E+00
2/23/96	1:45 PM	40	0.04	580E-06	.410E-06	.382E-07
2/23/96	2:45 PM	40	0.08	631E-06	.446E-06	.741E-07
2/23/96	4:45 PM	40	0.17	657E-06	.464E-06	.921E-07
2/23/96	8:45 PM	40	0.33	673E-06	.475E-06	.104E-06
2/24/96	12:45 AM	40	0.50	728E-06	.515E-06	.143E-06
2/24/96	12:45 PM	40	1.00	747E-06	.528E-06	.156E-06
2/25/96	12:45 AM	40	1.50	795E-06	.562E-06	.190E-06
2/25/96	12:45 PM	40	2.00	828E-06	.585E-06	.213E-06
2/26/96	1:00 PM	40	3.01	857E-06	.606E-06	.234E-06
3/1/96	7:05 PM	40	7.26	904E-06	.639E-06	.267E-06
3/11/96	1:45 PM	40	17.04	1.00E-03	.708E-06	.336E-06
3/22/96	5:15 PM	40	28.19	1.13E-03	.799E-06	.427E-06
4/5/96	4:30 PM	40	42.16	1.22E-03	.865E-06	.493E-06
4/15/96	4:15 PM	40	52.15	1.26E-03	.890E-06	.518E-06
4/25/96	12:30 AM	40	61.49	1.28E-03	.903E-06	.531E-06
5/3/96	10:30 PM	40	70.41	1.34E-03	.948E-06	.576E-06
5/15/96	2:20 PM	40	82.07	1.40E-03	.990E-06	.618E-06
6/7/96	5:40 PM	40	105.20	1.44E-03	.102E-05	.648E-06
6/28/96	3:10 PM	40	126.10	1.48E-03	.105E-05	.676E-06
7/19/96	12:45 PM	40	147.00	1.55E-03	.110E-05	.727E-06
8/5/96	12:10 PM	40	163.98	1.60E-03	.113E-05	.760E-06
9/10/96	11:50 AM	40	199.96	1.62E-03	1.15E-06	.775E-06
9/27/96	2:40 PM	40	217.08	1.66E-03	1.18E-06	.804E-06

SPECIMEN #5 38 A											
Date	Time	Load (kips)	Time (days)	A					Avg.	Diff.	Strain #5 38 A
				1	2	3	4	5			
2/22/96	9:30 AM	0	0.00	0.03180	0.03196	0.03185	0.03187	0.03185	0.03187	*****	*****
2/22/96	10:00 AM	0	0.01	0.03208	0.03190	0.03186	0.03193	0.03200	0.03195	-0.00009	-011E-06
2/22/96	11:00 AM	0	0.04	0.03192	0.03190	0.03197	0.03182	0.03191	0.03190	-0.00004	-005E-06
2/22/96	12:00 PM	0	0.08	0.03221	0.03213	0.03230	0.03219	0.03220	0.03221	-0.00034	-042E-06
2/22/96	2:00 PM	0	0.17	0.03206	0.03210	0.03200	0.03199	0.03202	0.03203	-0.00017	-021E-06
2/22/96	6:00 PM	0	0.33	0.03208	0.03219	0.03217	0.03195	0.03209	0.03210	-0.00023	-029E-06
2/22/96	10:00 PM	0	0.50	0.03170	0.03170	0.03182	0.03175	0.03181	0.03176	0.00011	014E-06
2/23/96	9:30 AM	0	0.98	0.03162	0.03171	0.03172	0.03160	0.03159	0.03165	0.00022	027E-06
2/23/96	10:00 PM	0	1.50	0.03154	0.03168	0.03169	0.03170	0.03168	0.03166	0.00021	026E-06
2/24/96	10:00 AM	0	2.00	0.03165	0.03169	0.03164	0.03170	0.03169	0.03167	0.00019	024E-06
2/25/96	11:30 AM	0	3.06	0.03175	0.03171	0.03170	0.03171	0.03165	0.03170	0.00016	020E-06
2/27/96	10:30 AM	0	5.02	0.03168	0.03170	0.03162	0.03173	0.03170	0.03169	0.00018	023E-06
3/1/96	7:35 PM	0	8.40	0.03167	0.03169	0.03169	0.03165	0.03168	0.03168	0.00019	024E-06
3/11/96	3:00 PM	0	18.21	0.03165	0.03168	0.03169	0.03162	0.03166	0.03166	0.00021	026E-06
3/22/96	4:45 PM	0	29.28	0.03161	0.03165	0.03163	0.03159	0.03150	0.03160	0.00027	034E-06
4/5/96	3:45 PM	0	43.24	0.03078	0.03077	0.03081	0.03071	0.03078	0.03077	0.00110	137E-06
4/15/96	2:00 PM	0	53.17	0.03069	0.03070	0.03069	0.03061	0.03070	0.03068	0.00119	149E-06
4/24/96	9:10 PM	0	62.47	0.03039	0.03045	0.03048	0.03045	0.03045	0.03044	0.00142	178E-06
5/3/96	10:00 PM	0	71.50	0.03025	0.03029	0.03029	0.03035	0.03029	0.03029	0.00157	197E-06
5/15/96	1:45 PM	0	83.16	0.03011	0.03005	0.03009	0.03010	0.03000	0.03007	0.00180	225E-06
6/7/96	4:20 PM	0	106.26	0.03000	0.02985	0.02991	0.02995	0.02990	0.02992	0.00194	243E-06
6/28/96	2:50 PM	0	127.20	0.02985	0.02990	0.02975	0.02980	0.02985	0.02983	0.00204	255E-06
7/19/96	11:45 AM	0	148.07	0.02955	0.02952	0.02945	0.02952	0.02955	0.02952	0.00235	294E-06
8/5/96	11:10 AM	0	165.05	0.02921	0.02919	0.02915	0.02915	0.02911	0.02916	0.00270	338E-06
9/10/96	11:25 AM	0	201.06	0.02905	0.02895	0.02901	0.02892	0.02890	0.02897	0.00290	363E-06
9/27/96	2:10 PM	0	218.17	0.02878	0.02881	0.02871	0.02869	0.02872	0.02874	0.00312	391E-06

SPECIMEN #5 38 B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain #5 38 B
				1	2	3	4	5			
2/22/96	9:30 AM	0	0.00	0.02958	0.02950	0.02948	0.02962	0.02964	0.02956	*****	*****
2/22/96	10:00 AM	0	0.01	0.02955	0.02961	0.02963	0.02964	0.02959	0.02960	-0.00004	-5.00E-06
2/22/96	11:00 AM	0	0.04	0.02963	0.02959	0.02965	0.02968	0.02960	0.02963	-0.00007	-8.25E-06
2/22/96	12:00 PM	0	0.08	0.02975	0.02965	0.02958	0.02961	0.02959	0.02964	-0.00007	-009E-06
2/22/96	2:00 PM	0	0.17	0.02971	0.02972	0.02960	0.02961	0.02970	0.02967	-0.00010	-013E-06
2/22/96	6:00 PM	0*	0.33	0.02669	0.02668	0.02660	0.02668	0.02651	0.02663	0.00023	029E-06
2/22/96	10:00 PM	0	0.50	0.02698	0.02689	0.02688	0.02685	0.02682	0.02688	-0.00002	-003E-06
2/23/96	9:30 AM	0	0.98	0.02704	0.02712	0.02707	0.02705	0.02708	0.02707	-0.00021	-026E-06
2/23/96	10:00 PM	0	1.50	0.02670	0.02682	0.02680	0.02682	0.02682	0.02679	0.00007	009E-06
2/24/96	10:00 AM	0	2.00	0.02664	0.02663	0.02665	0.02661	0.02665	0.02664	0.00023	029E-06
2/25/96	11:30 AM	0	3.06	0.02661	0.02662	0.02660	0.02658	0.02659	0.02660	0.00026	033E-06
2/27/96	10:30 AM	0	5.02	0.02660	0.02659	0.02665	0.02658	0.02668	0.02662	0.00024	031E-06
3/1/96	7:35 PM	0	8.40	0.02660	0.02652	0.02655	0.02656	0.02661	0.02657	0.00030	037E-06
3/11/96	3:00 PM	0	18.21	0.02650	0.02651	0.02659	0.02645	0.02648	0.02651	0.00036	045E-06
3/22/96	4:45 PM	0	29.28	0.02628	0.02623	0.02626	0.02624	0.02624	0.02625	0.00061	7.67E-05
4/5/96	3:45 PM	0	43.24	0.02610	0.02613	0.02612	0.02628	0.02625	0.02618	0.00069	086E-06
4/15/96	2:00 PM	0	53.17	0.02589	0.02590	0.02591	0.02581	0.02582	0.02587	0.00100	125E-06
4/24/96	9:10 PM	0	62.47	0.02559	0.02555	0.02559	0.02557	0.02580	0.02562	0.00124	156E-06
5/3/96	10:00 PM	0	71.50	0.02545	0.02541	0.02531	0.02545	0.02541	0.02541	0.00146	182E-06
5/15/96	1:45 PM	0	83.16	0.02529	0.02525	0.02529	0.02535	0.02539	0.02531	0.00155	194E-06
6/7/96	4:20 PM	0	106.26	0.02521	0.02530	0.02521	0.02525	0.02521	0.02524	0.00163	204E-06
6/28/96	2:50 PM	0	127.20	0.02531	0.02515	0.02518	0.02525	0.02522	0.02522	0.00164	205E-06
7/19/96	11:45 AM	0	148.07	0.02481	0.02484	0.02479	0.02475	0.02480	0.02480	0.00207	258E-06
8/5/96	11:10 AM	0	165.05	0.02455	0.02451	0.02458	0.02460	0.02458	0.02456	0.00230	288E-06
9/10/96	11:25 AM	0	201.06	0.02445	0.02450	0.02445	0.02448	0.02448	0.02447	0.00239	299E-06
9/27/96	2:10 PM	0	218.17	0.02430	0.02435	0.02430	0.02432	0.02428	0.02431	0.00255	319E-06

SPECIMEN #5 38				Avg Strain #5 38
Date	Time	Load (kips)	Time (days)	
2/22/96	9:30 AM	0	0.00	
2/22/96	10:00 AM	0	0.01	-008E-06
2/22/96	11:00 AM	0	0.04	-006E-06
2/22/96	12:00 PM	0	0.08	-026E-06
2/22/96	2:00 PM	0	0.17	-017E-06
2/22/96	6:00 PM	0*	0.33	125E-09
2/22/96	10:00 PM	0	0.50	006E-06
2/23/96	9:30 AM	0	0.98	625E-09
2/23/96	10:00 PM	0	1.50	018E-06
2/24/96	10:00 AM	0	2.00	026E-06
2/25/96	11:30 AM	0	3.06	027E-06
2/27/96	10:30 AM	0	5.02	027E-06
3/1/96	7:35 PM	0	8.40	030E-06
3/11/96	3:00 PM	0	18.21	035E-06
3/22/96	4:45 PM	0	29.28	055E-06
4/5/96	3:45 PM	0	43.24	112E-06
4/15/96	2:00 PM	0	53.17	137E-06
4/24/96	9:10 PM	0	62.47	167E-06
5/3/96	10:00 PM	0	71.50	189E-06
5/15/96	1:45 PM	0	83.16	209E-06
6/7/96	4:20 PM	0	106.26	223E-06
6/28/96	2:50 PM	0	127.20	230E-06
7/19/96	11:45 AM	0	148.07	276E-06
8/5/96	11:10 AM	0	165.05	313E-06
9/10/96	11:25 AM	0	201.06	331E-06
9/27/96	2:10 PM	0	218.17	355E-06

SPECIMEN #1 39 A											
Date	Time	Load (kips)	Time (days)	A					Avg.	Diff.	Strain #1 39 A
				1	2	3	4	5			
2/22/96	9:30 AM	0	0.00	0.02762	0.02752	0.02764	0.02752	0.02764	0.02759	*****	*****
2/22/96	10:00 AM	40	0.01	0.02113	0.02129	0.02130	0.02125	0.02124	0.02124	0.00635	793E-06
2/22/96	11:00 AM	40	0.04	0.02070	0.02061	0.02064	0.02068	0.02071	0.02067	0.00692	865E-06
2/22/96	12:00 PM	40	0.08	0.02048	0.02045	0.02044	0.02050	0.02046	0.02047	0.00712	890E-06
2/22/96	2:00 PM	40	0.17	0.02020	0.02005	0.02009	0.02013	0.02010	0.02011	0.00747	934E-06
2/22/96	6:00 PM	40	0.33	0.02003	0.02002	0.02000	0.01998	0.02002	0.02001	0.00758	947E-06
2/22/96	10:00 PM	40	0.50	0.01975	0.01981	0.01983	0.01980	0.01970	0.01978	0.00781	976E-06
2/23/96	9:30 AM	40	0.98	0.01935	0.01940	0.01939	0.01934	0.01941	0.01938	0.00821	1.03E-03
2/23/96	10:00 PM	40	1.50	0.01920	0.01920	0.01921	0.01920	0.01913	0.01919	0.00840	1.05E-03
2/24/96	10:00 AM	40	2.00	0.01861	0.01867	0.01868	0.01862	0.01861	0.01864	0.00895	1.12E-03
2/25/96	11:30 AM	40	3.06	0.01837	0.01832	0.01832	0.01833	0.01835	0.01834	0.00925	1.16E-03
2/27/96	10:30 AM	40	5.02	0.01783	0.01779	0.01786	0.01786	0.01781	0.01783	0.00976	1.22E-03
3/1/96	7:35 PM	40	8.40	0.01759	0.01756	0.01756	0.01755	0.01752	0.01756	0.01003	1.25E-03
3/11/96	3:00 PM	40	18.21	0.01624	0.01630	0.01628	0.01630	0.01631	0.01629	0.01130	1.41E-03
3/22/96	4:45 PM	40	29.28	0.01493	0.01500	0.01498	0.01498	0.01495	0.01497	0.01262	1.58E-03
4/5/96	3:45 PM	40*	43.24	0.01391	0.01398	0.01394	0.01400	0.01399	0.01396	0.01362	1.70E-03
4/15/96	2:00 PM	40	53.17	0.01361	0.01359	0.01365	0.01369	0.01370	0.01365	0.01394	1.74E-03
4/24/96	9:10 PM	40	62.47	0.01335	0.01339	0.01345	0.01339	0.01345	0.01341	0.01418	1.77E-03
5/3/96	10:00 PM	40	71.50	0.01278	0.01280	0.01281	0.01282	0.01281	0.01280	0.01478	1.85E-03
5/15/96	1:45 PM	40	83.16	0.01225	0.01221	0.01221	0.01225	0.01225	0.01223	0.01535	1.92E-03
6/7/96	4:20 PM	40	106.26	0.01200	0.01190	0.01200	0.01195	0.01200	0.01197	0.01562	1.95E-03
6/28/96	2:50 PM	40	127.20	0.01170	0.01178	0.01169	0.01178	0.01175	0.01174	0.01585	1.98E-03
7/19/96	11:45 AM	40	148.07	0.01119	0.01129	0.01122	0.01122	0.01125	0.01123	0.01635	2.04E-03
8/5/96	11:10 AM	40	165.05	0.01081	0.01071	0.01075	0.01065	0.01069	0.01072	0.01687	2.11E-03
9/10/96	11:25 AM	40	201.06	0.01045	0.01045	0.01055	0.01042	0.01045	0.01046	0.01712	2.14E-03
9/27/96	2:10 PM	40	218.17	0.01020	0.01018	0.01018	0.01015	0.01018	0.01018	0.01741	2.18E-03

SPECIMEN #1 39 B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain #1 39 B
				1	2	3	4	5			
2/22/96	9:30 AM	0	0.00	0.02500	0.02507	0.02509	0.02514	0.02502	0.02506	*****	*****
2/22/96	10:00 AM	40	0.01	0.02159	0.02144	0.02158	0.02160	0.02153	0.02155	0.00352	439E-06
2/22/96	11:00 AM	40	0.04	0.02095	0.02097	0.02089	0.02095	0.02099	0.02095	0.00411	514E-06
2/22/96	12:00 PM	40	0.08	0.02070	0.02075	0.02076	0.02065	0.02071	0.02071	0.00435	544E-06
2/22/96	2:00 PM	40	0.17	0.02005	0.02013	0.02018	0.02020	0.02019	0.02015	0.00491	614E-06
2/22/96	6:00 PM	40	0.33	0.02021	0.02016	0.01994	0.02011	0.02008	0.02010	0.00496	621E-06
2/22/96	10:00 PM	40	0.50	0.01975	0.01993	0.01988	0.01984	0.01990	0.01986	0.00520	651E-06
2/23/96	9:30 AM	40	0.98	0.01945	0.01950	0.01949	0.01946	0.01938	0.01946	0.00561	701E-06
2/23/96	10:00 PM	40	1.50	0.01928	0.01921	0.01922	0.01920	0.01913	0.01921	0.00586	732E-06
2/24/96	10:00 AM	40	2.00	0.01859	0.01866	0.01867	0.01861	0.01867	0.01864	0.00642	803E-06
2/25/96	11:30 AM	40	3.06	0.01851	0.01841	0.01845	0.01843	0.01847	0.01845	0.00661	826E-06
2/27/96	10:30 AM	40	5.02	0.01785	0.01782	0.01783	0.01782	0.01785	0.01783	0.00723	904E-06
3/1/96	7:35 PM	40	8.40	0.01762	0.01768	0.01764	0.01762	0.01761	0.01763	0.00743	929E-06
3/11/96	3:00 PM	40	18.21	0.01628	0.01621	0.01619	0.01621	0.01623	0.01622	0.00884	1.11E-03
3/22/96	4:45 PM	40	29.28	0.01533	0.01546	0.01542	0.01534	0.01541	0.01539	0.00967	1.21E-03
4/5/96	3:45 PM	40*	43.24	0.01480	0.01460	0.01478	0.01471	0.01479	0.01474	0.01033	1.29E-03
4/15/96	2:00 PM	40	53.17	0.01435	0.01439	0.01435	0.01429	0.01435	0.01435	0.01072	1.34E-03
4/24/96	9:10 PM	40	62.47	0.01331	0.01335	0.01335	0.01339	0.01345	0.01337	0.01169	1.46E-03
5/3/96	10:00 PM	40	71.50	0.01285	0.01275	0.01280	0.01280	0.01278	0.01280	0.01227	1.53E-03
5/15/96	1:45 PM	40	83.16	0.01235	0.01232	0.01232	0.01235	0.01231	0.01233	0.01273	1.59E-03
6/7/96	4:20 PM	40	106.26	0.01195	0.01199	0.01200	0.01195	0.01198	0.01197	0.01309	1.64E-03
6/28/96	2:50 PM	40	127.20	0.01178	0.01175	0.01169	0.01172	0.01175	0.01174	0.01333	1.67E-03
7/19/96	11:45 AM	40	148.07	0.01129	0.01128	0.01129	0.01131	0.01135	0.01130	0.01376	1.72E-03
8/5/96	11:10 AM	40	165.05	0.01095	0.01092	0.01090	0.01090	0.01091	0.01092	0.01415	1.77E-03
9/10/96	11:25 AM	40	201.06	0.01055	0.01052	0.01055	0.01055	0.01055	0.01054	0.01452	1.82E-03
9/27/96	2:10 PM	40	218.17	0.01030	0.01028	0.01025	0.01020	0.01028	0.01026	0.01480	1.85E-03

SPECIMEN #1 39				Avg Strain #1 39	Specific Strain #1 39	Corrected Spec Strain #1 39
Date	Time	Load (kips)	Time (days)			
2/22/96	9:30 AM	0	0.00			
2/22/96	10:00 AM	40	0.01	616E-06	.436E-06	.000E+00
2/22/96	11:00 AM	40	0.04	690E-06	.487E-06	.518E-07
2/22/96	12:00 PM	40	0.08	717E-06	.507E-06	.711E-07
2/22/96	2:00 PM	40	0.17	774E-06	.547E-06	.112E-06
2/22/96	6:00 PM	40	0.33	784E-06	.554E-06	.118E-06
2/22/96	10:00 PM	40	0.50	813E-06	.575E-06	.139E-06
2/23/96	9:30 AM	40	0.98	864E-06	.610E-06	.175E-06
2/23/96	10:00 PM	40	1.50	891E-06	.630E-06	.194E-06
2/24/96	10:00 AM	40	2.00	961E-06	.679E-06	.243E-06
2/25/96	11:30 AM	40	3.06	991E-06	.701E-06	.265E-06
2/27/96	10:30 AM	40	5.02	1.06E-03	.750E-06	.315E-06
3/1/96	7:35 PM	40	8.40	1.09E-03	.771E-06	.336E-06
3/11/96	3:00 PM	40	18.21	1.26E-03	.890E-06	.454E-06
3/22/96	4:45 PM	40	29.28	1.39E-03	.985E-06	.549E-06
4/5/96	3:45 PM	40*	43.24	1.50E-03	1.06E-06	.622E-06
4/15/96	2:00 PM	40	53.17	1.54E-03	1.09E-06	.654E-06
4/24/96	9:10 PM	40	62.47	1.62E-03	1.14E-06	.707E-06
5/3/96	10:00 PM	40	71.50	1.69E-03	1.19E-06	.759E-06
5/15/96	1:45 PM	40	83.16	1.76E-03	1.24E-06	.805E-06
6/7/96	4:20 PM	40	106.26	1.79E-03	1.27E-06	.832E-06
6/28/96	2:50 PM	40	127.20	1.82E-03	1.29E-06	.853E-06
7/19/96	11:45 AM	40	148.07	1.88E-03	1.33E-06	.895E-06
8/5/96	11:10 AM	40	165.05	1.94E-03	1.37E-06	.934E-06
9/10/96	11:25 AM	40	201.06	1.98E-03	1.40E-06	.962E-06
9/27/96	2:10 PM	40	218.17	2.01E-03	1.42E-06	.987E-06

SPECIMEN #3 39 A											
Date	Time	Load (kips)	Time (days)	A					Avg.	Diff.	Strain #3 39 A
				1	2	3	4	5			
2/23/96	12:00 PM	0	0.00	0.02361	0.02371	0.02378	0.02369	0.02370	0.02370	*****	*****
2/23/96	12:25 PM	20	0.00	0.02248	0.02231	0.02229	0.02230	0.02235	0.02235	*****	*****
2/23/96	12:45 PM	40	0.01	0.02128	0.02113	0.02124	0.02122	0.02115	0.02120	0.00249	312E-06
2/23/96	1:45 PM	40	0.04	0.02021	0.02032	0.02026	0.02029	0.02026	0.02027	0.00343	429E-06
2/23/96	2:45 PM	40	0.08	0.01977	0.01980	0.01972	0.01986	0.01976	0.01978	0.00392	490E-06
2/23/96	4:45 PM	40	0.17	0.01980	0.01981	0.01983	0.01986	0.01990	0.01984	0.00386	482E-06
2/23/96	8:45 PM	40	0.33	0.01952	0.01962	0.01953	0.01964	0.01957	0.01958	0.00412	515E-06
2/24/96	12:45 AM	40	0.50	0.01898	0.01901	0.01890	0.01888	0.01894	0.01894	0.00476	595E-06
2/24/96	12:45 PM	40	1.00	0.01890	0.01891	0.01876	0.01889	0.01885	0.01886	0.00484	605E-06
2/25/96	12:45 AM	40	1.50	0.01862	0.01867	0.01861	0.01861	0.01864	0.01863	0.00507	634E-06
2/25/96	12:45 PM	40	2.00	0.01860	0.01861	0.01857	0.01857	0.01855	0.01858	0.00512	640E-06
2/26/96	1:00 PM	40	3.01	0.01853	0.01851	0.01855	0.01857	0.01856	0.01854	0.00515	644E-06
3/1/96	7:05 PM	40	7.26	0.01822	0.01815	0.01819	0.01813	0.01812	0.01816	0.00554	692E-06
3/11/96	1:45 PM	40	17.04	0.01772	0.01780	0.01768	0.01765	0.01767	0.01770	0.00599	749E-06
3/22/96	5:15 PM	40	28.19	0.01680	0.01688	0.01681	0.01682	0.01685	0.01683	0.00687	858E-06
4/5/96	4:30 PM	40	42.16	0.01568	0.01568	0.01562	0.01569	0.01562	0.01566	0.00804	1.01E-03
4/15/96	4:15 PM	40	52.15	0.01540	0.01545	0.01542	0.01549	0.01545	0.01544	0.00826	1.03E-03
4/25/96	12:30 AM	40	61.49	0.01531	0.01535	0.01535	0.01530	0.01531	0.01532	0.00837	1.05E-03
5/3/96	10:30 PM	40	70.41	0.01480	0.01485	0.01480	0.01479	0.01488	0.01482	0.00887	1.11E-03
5/15/96	2:20 PM	40	82.07	0.01449	0.01445	0.01441	0.01445	0.01442	0.01444	0.00925	1.16E-03
6/7/96	5:40 PM	40	105.20	0.01419	0.01425	0.01429	0.01419	0.01425	0.01423	0.00946	1.18E-03
6/28/96	3:10 PM	40	126.10	0.01415	0.01411	0.01409	0.01390	0.01395	0.01404	0.00966	1.21E-03
7/19/96	12:45 PM	40	147.00	0.01365	0.01359	0.01360	0.01355	0.01361	0.01360	0.01010	1.26E-03
8/5/96	12:10 PM	40	163.98	0.01325	0.01329	0.01319	0.01319	0.01321	0.01323	0.01047	1.31E-03
9/10/96	11:50 AM	40	199.96	0.01301	0.01300	0.01300	0.01305	0.01302	0.01302	0.01068	1.34E-03
9/27/96	2:40 PM	40	217.08	0.01278	0.01282	0.01278	0.01281	0.01278	0.01279	0.01090	1.36E-03

SPECIMEN #3 39 B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain #3 39 B
				1	2	3	4	5			
2/23/96	12:00 PM	0	0.00	0.03448	0.03449	0.03458	0.03451	0.03444	0.03450	*****	*****
2/23/96	12:25 PM	20	0.00	0.03228	0.03230	0.03231	0.03225	0.03218	0.03226	*****	*****
2/23/96	12:45 PM	40	0.01	0.02950	0.02941	0.02951	0.02948	0.02950	0.02948	0.00502	628E-06
2/23/96	1:45 PM	40	0.04	0.02923	0.02917	0.02920	0.02921	0.02921	0.02920	0.00530	662E-06
2/23/96	2:45 PM	40	0.08	0.02905	0.02910	0.02903	0.02907	0.02908	0.02907	0.00543	679E-06
2/23/96	4:45 PM	40	0.17	0.02868	0.02870	0.02865	0.02868	0.02858	0.02866	0.00584	730E-06
2/23/96	8:45 PM	40	0.33	0.02832	0.02831	0.02829	0.02826	0.02831	0.02830	0.00620	775E-06
2/24/96	12:45 AM	40	0.50	0.02781	0.02781	0.02780	0.02778	0.02783	0.02781	0.00669	837E-06
2/24/96	12:45 PM	40	1.00	0.02768	0.02762	0.02769	0.02763	0.02768	0.02766	0.00684	855E-06
2/25/96	12:45 AM	40	1.50	0.02718	0.02728	0.02723	0.02724	0.02723	0.02723	0.00727	909E-06
2/25/96	12:45 PM	40	2.00	0.02682	0.02691	0.02690	0.02688	0.02690	0.02688	0.00762	952E-06
2/26/96	1:00 PM	40	3.01	0.02650	0.02655	0.02656	0.02659	0.02653	0.02655	0.00795	994E-06
3/1/96	7:05 PM	40	7.26	0.02628	0.02627	0.02628	0.02625	0.02620	0.02626	0.00824	1.03E-03
3/11/96	1:45 PM	40	17.04	0.02470	0.02471	0.02468	0.02467	0.02469	0.02469	0.00981	1.23E-03
3/22/96	5:15 PM	40	28.19	0.02357	0.02350	0.02351	0.02358	0.02357	0.02355	0.01095	1.37E-03
4/5/96	4:30 PM	40	42.16	0.02199	0.02185	0.02199	0.02190	0.02199	0.02194	0.01256	1.57E-03
4/15/96	4:15 PM	40	52.15	0.02165	0.02155	0.02162	0.02155	0.02160	0.02159	0.01291	1.61E-03
4/25/96	12:30 AM	40	61.49	0.02140	0.02145	0.02139	0.02145	0.02148	0.02143	0.01307	1.63E-03
5/3/96	10:30 PM	40	70.41	0.02090	0.02089	0.02090	0.02085	0.02089	0.02089	0.01361	1.70E-03
5/15/96	2:20 PM	40	82.07	0.02045	0.02040	0.02045	0.02035	0.02039	0.02041	0.01409	1.76E-03
6/7/96	5:40 PM	40	105.20	0.01995	0.01991	0.01990	0.01991	0.01995	0.01992	0.01458	1.82E-03
6/28/96	3:10 PM	40	126.10	0.01955	0.01950	0.01950	0.01952	0.01951	0.01952	0.01498	1.87E-03
7/19/96	12:45 PM	40	147.00	0.01880	0.01885	0.01885	0.01885	0.01881	0.01883	0.01567	1.96E-03
8/5/96	12:10 PM	40	163.98	0.01842	0.01845	0.01842	0.01841	0.01841	0.01842	0.01608	2.01E-03
9/10/96	11:50 AM	40	199.96	0.01812	0.01811	0.01815	0.01810	0.01815	0.01813	0.01637	2.05E-03
9/27/96	2:40 PM	40	217.08	0.01775	0.01781	0.01775	0.01772	0.01772	0.01775	0.01675	2.09E-03

SPECIMEN #3 39				Avg Strain #3 39	Specific Strain #3 39	Corrected Spec Stain #3 39
Date	Time	Load (kips)	Time (days)			
2/23/96	12:00 PM	0	0.00			
2/23/96	12:25 PM	20	0.00			
2/23/96	12:45 PM	40	0.01	470E-06	.332E-06	.000E+00
2/23/96	1:45 PM	40	0.04	545E-06	.385E-06	.535E-07
2/23/96	2:45 PM	40	0.08	584E-06	.413E-06	.811E-07
2/23/96	4:45 PM	40	0.17	606E-06	.428E-06	.966E-07
2/23/96	8:45 PM	40	0.33	645E-06	.456E-06	.124E-06
2/24/96	12:45 AM	40	0.50	716E-06	.506E-06	.174E-06
2/24/96	12:45 PM	40	1.00	730E-06	.516E-06	.184E-06
2/25/96	12:45 AM	40	1.50	771E-06	.545E-06	.213E-06
2/25/96	12:45 PM	40	2.00	796E-06	.563E-06	.231E-06
2/26/96	1:00 PM	40	3.01	819E-06	.579E-06	.247E-06
3/1/96	7:05 PM	40	7.26	861E-06	.609E-06	.277E-06
3/11/96	1:45 PM	40	17.04	988E-06	.698E-06	.366E-06
3/22/96	5:15 PM	40	28.19	1.11E-03	.787E-06	.455E-06
4/5/96	4:30 PM	40	42.16	1.29E-03	.910E-06	.578E-06
4/15/96	4:15 PM	40	52.15	1.32E-03	.935E-06	.603E-06
4/25/96	12:30 AM	40	61.49	1.34E-03	.947E-06	.615E-06
5/3/96	10:30 PM	40	70.41	1.41E-03	.993E-06	.661E-06
5/15/96	2:20 PM	40	82.07	1.46E-03	.103E-05	.699E-06
6/7/96	5:40 PM	40	105.20	1.50E-03	.106E-05	.730E-06
6/28/96	3:10 PM	40	126.10	1.54E-03	.109E-05	.757E-06
7/19/96	12:45 PM	40	147.00	1.61E-03	.114E-05	.806E-06
8/5/96	12:10 PM	40	163.98	1.66E-03	.117E-05	.841E-06
9/10/96	11:50 AM	40	199.96	1.69E-03	1.20E-06	.863E-06
9/27/96	2:40 PM	40	217.08	1.73E-03	1.22E-06	.890E-06

SPECIMEN #5 39 A											
Date	Time	Load (kips)	Time (days)	A					Avg.	Diff.	Strain #5 39 A
				1	2	3	4	5			
2/23/96	12:00 PM	0	0.00	0.03086	0.03080	0.03069	0.03080	0.03086	0.03080	*****	*****
2/23/96	12:25 PM	0	0.00	0.03086	0.03080	0.03069	0.03080	0.03086	0.03080	*****	*****
2/23/96	12:45 PM	0	0.01	0.03086	0.03080	0.03069	0.03080	0.03086	0.03080	0.00000	0.00E+00
2/23/96	1:45 PM	0	0.04	0.03113	0.03110	0.03112	0.03102	0.03112	0.03110	-0.00030	-037E-06
2/23/96	2:45 PM	0	0.08	0.03089	0.03098	0.03081	0.03080	0.03097	0.03089	-0.00009	-011E-06
2/23/96	4:45 PM	0	0.17	0.03078	0.03082	0.03072	0.03086	0.03085	0.03081	0.00000	-500E-09
2/23/96	8:45 PM	0	0.33	0.03079	0.03082	0.03086	0.03080	0.03079	0.03081	-0.00001	-001E-06
2/24/96	12:45 AM	0	0.50	0.03080	0.03083	0.03086	0.03085	0.03082	0.03083	-0.00003	-004E-06
2/24/96	12:45 PM	0	1.00	0.03078	0.03080	0.03075	0.03082	0.03077	0.03078	0.00002	002E-06
2/25/96	12:45 AM	0	1.50	0.03081	0.03080	0.03090	0.03087	0.03082	0.03084	-0.00004	-005E-06
2/25/96	12:45 PM	0	2.00	0.03089	0.03080	0.03087	0.03088	0.03081	0.03085	-0.00005	-006E-06
2/26/96	1:00 PM	0	3.01	0.03076	0.03080	0.03071	0.03080	0.03081	0.03078	0.00003	003E-06
3/1/96	7:05 PM	0	7.26	0.02920	0.02910	0.02913	0.02911	0.02912	0.02913	0.00167	209E-06
3/11/96	1:45 PM	0	17.04	0.02885	0.02879	0.02882	0.02887	0.02890	0.02885	0.00196	245E-06
3/22/96	5:15 PM	0	28.19	0.02811	0.02818	0.02819	0.02815	0.02816	0.02816	0.00264	331E-06
4/5/96	4:30 PM	0	42.16	0.02768	0.02760	0.02762	0.02765	0.02759	0.02763	0.00317	397E-06
4/15/96	4:15 PM	0	52.15	0.02745	0.02745	0.02749	0.02740	0.02742	0.02744	0.00336	420E-06
4/25/96	12:30 AM	0	61.49	0.02745	0.02740	0.02742	0.02745	0.02742	0.02743	0.00337	422E-06
5/3/96	10:30 PM	0	70.41	0.02741	0.02739	0.02741	0.02739	0.02739	0.02740	0.00340	426E-06
5/15/96	2:20 PM	0	82.07	0.02729	0.02725	0.02729	0.02731	0.02729	0.02729	0.00352	440E-06
6/7/96	5:40 PM	0	105.20	0.02705	0.02702	0.02709	0.02705	0.02710	0.02706	0.00374	468E-06
6/28/96	3:10 PM	0	126.10	0.02691	0.02695	0.02685	0.02685	0.02690	0.02689	0.00391	489E-06
7/19/96	12:45 PM	0	147.00	0.02655	0.02661	0.02651	0.02655	0.02661	0.02657	0.00424	530E-06
8/5/96	12:10 PM	0	163.98	0.02621	0.02629	0.02625	0.02619	0.02611	0.02621	0.00459	574E-06
9/10/96	11:50 AM	0	199.96	0.02610	0.02609	0.02605	0.02605	0.02605	0.02607	0.00473	592E-06
9/27/96	2:40 PM	0	217.08	0.02585	0.02588	0.02580	0.02588	0.02578	0.02584	0.00496	621E-06

SPECIMEN #5 39 B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain #5 39 B
				1	2	3	4	5			
2/23/96	12:00 PM	0	0.00							*****	*****
2/23/96	12:25 PM	0	0.00							*****	*****
2/23/96	12:45 PM	0	0.01							0.00000	0.00E+00
2/23/96	1:45 PM	0	0.04	0.03227	0.03231	0.03232	0.03236	0.03230	0.03231	-0.03231	-4.04E-03
2/23/96	2:45 PM	0	0.08	Stud Loose!						0.00000	0.00E+00
2/23/96	4:45 PM	0	0.17							0.00000	0.00E+00
2/23/96	8:45 PM	0	0.33							0.00000	0.00E+00
2/24/96	12:45 AM	0	0.50							0.00000	0.00E+00
2/24/96	12:45 PM	0	1.00	0.02712	0.02716	0.02720	0.02714	0.02721	0.02717	-0.02717	-3.40E-03
2/25/96	12:45 AM	0	1.50	0.02698	0.02713	0.02710	0.02717	0.02711	0.02710	0.00007	009E-06
2/25/96	12:45 PM	0	2.00	0.02719	0.02720	0.02709	0.02715	0.02715	0.02716	0.00001	001E-06
2/26/96	1:00 PM	0	3.01	0.02715	0.02720	0.02722	0.02728	0.02728	0.02723	-0.00006	-007E-06
3/1/96	7:05 PM	0	7.26	0.02712	0.02720	0.02725	0.02713	0.02722	0.02718	-0.00002	-002E-06
3/11/96	1:45 PM	0	17.04	0.02723	0.02719	0.02729	0.02726	0.02721	0.02724	-0.00007	-009E-06
3/22/96	5:15 PM	0	28.19	0.02700	0.02705	0.02698	0.02700	0.02700	0.02701	0.00016	020E-06
4/5/96	4:30 PM	0	42.16	0.02658	0.02651	0.02650	0.02650	0.02648	0.02651	0.00065	082E-06
4/15/96	4:15 PM	0	52.15	0.02625	0.02629	0.02625	0.02615	0.02615	0.02622	0.00095	119E-06
4/25/96	12:30 AM	0	61.49	0.02615	0.02619	0.02612	0.02612	0.02615	0.02615	0.00102	128E-06
5/3/96	10:30 PM	0	70.41	0.02599	0.02600	0.02601	0.02600	0.02595	0.02599	0.00118	147E-06
5/15/96	2:20 PM	0	82.07	0.02585	0.02595	0.02590	0.02589	0.02581	0.02588	0.00129	161E-06
6/7/96	5:40 PM	0	105.20	0.02572	0.02565	0.02571	0.02561	0.02565	0.02567	0.00150	187E-06
6/28/96	3:10 PM	0	126.10	0.02570	0.02569	0.02569	0.02572	0.02571	0.02570	0.00146	183E-06
7/19/96	12:45 PM	0	147.00	0.02530	0.02531	0.02530	0.02525	0.02535	0.02530	0.00186	233E-06
8/5/96	12:10 PM	0	163.98	0.02505	0.02498	0.02501	0.02502	0.02495	0.02500	0.00216	271E-06
9/10/96	11:50 AM	0	199.96	0.02491	0.02490	0.02491	0.02490	0.02485	0.02489	0.00227	284E-06
9/27/96	2:40 PM	0	217.08	0.02475	0.02472	0.02478	0.02478	0.02481	0.02477	0.00240	300E-06

SPECIMEN #5 39				Avg Strain #5 39
Date	Time	Load (kips)	Time (days)	
2/23/96	12:00 PM	0	0.00	
2/23/96	12:25 PM	0	0.00	
2/23/96	12:45 PM	0	0.01	0.00E+00
2/23/96	1:45 PM	0	0.04	-2.04E-03
2/23/96	2:45 PM	0	0.08	-5.50E-06
2/23/96	4:45 PM	0	0.17	-2.50E-07
2/23/96	8:45 PM	0	0.33	-6.25E-07
2/24/96	12:45 AM	0	0.50	-1.88E-06
2/24/96	12:45 PM	0	1.00	-1.70E-03
2/25/96	12:45 AM	0	1.50	002E-06
2/25/96	12:45 PM	0	2.00	-002E-06
2/26/96	1:00 PM	0	3.01	-002E-06
3/1/96	7:05 PM	0	7.26	103E-06
3/11/96	1:45 PM	0	17.04	118E-06
3/22/96	5:15 PM	0	28.19	175E-06
4/5/96	4:30 PM	0	42.16	239E-06
4/15/96	4:15 PM	0	52.15	269E-06
4/25/96	12:30 AM	0	61.49	275E-06
5/3/96	10:30 PM	0	70.41	286E-06
5/15/96	2:20 PM	0	82.07	300E-06
6/7/96	5:40 PM	0	105.20	327E-06
6/28/96	3:10 PM	0	126.10	336E-06
7/19/96	12:45 PM	0	147.00	381E-06
8/5/96	12:10 PM	0	163.98	422E-06
9/10/96	11:50 AM	0	199.96	438E-06
9/27/96	2:40 PM	0	217.08	460E-06

REFERENCE SPECIMEN #1 - LOADED - A											
Date	Time	Load (kips)	Time (days)	A					Avg.	Diff.	Strain Ref #1-A
				1	2	3	4	5			
4/24/96	1:50 PM	0	0.00	0.02475	0.02478	0.02475	0.02468	0.02478	0.02475	*****	*****
4/24/96	2:10 PM	35	0.01	0.02235	0.02232	0.02235	0.02235	0.02235	0.02234	0.00240	301E-06
4/24/96	3:10 PM	35	0.04	0.02225	0.02228	0.02225	0.02228	0.02229	0.02227	0.00248	310E-06
4/24/96	4:10 PM	35	0.08	0.02229	0.02225	0.02231	0.02225	0.02231	0.02228	0.00247	308E-06
4/24/96	6:15 PM	35	0.17	0.02238	0.02235	0.02238	0.02231	0.02230	0.02234	0.00240	301E-06
4/24/96	10:10 PM	35	0.33	0.02195	0.02191	0.02198	0.02192	0.02198	0.02195	0.00280	350E-06
4/25/96	1:45 AM	35	0.48	0.02195	0.02190	0.02199	0.02198	0.02198	0.02196	0.00279	349E-06
4/25/96	2:10 PM	35	1.00	0.02185	0.02189	0.02190	0.02191	0.02185	0.02188	0.00287	359E-06
4/26/96	1:40 AM	35	1.48	0.02150	0.02145	0.02148	0.02148	0.02151	0.02148	0.00326	408E-06
4/26/96	2:10 PM	35	2.00	0.02135	0.02131	0.02129	0.02131	0.02125	0.02130	0.00345	431E-06
4/27/96	12:00 AM	35	2.41	0.02125	0.02129	0.02125	0.02131	0.02121	0.02126	0.00349	436E-06
4/28/96	2:10 PM	35	4.00	0.02100	0.02105	0.02111	0.02105	0.02111	0.02106	0.00368	461E-06
5/1/96	2:10 PM	35	7.00	0.02048	0.02045	0.02048	0.02041	0.02045	0.02045	0.00429	537E-06
5/4/96	12:10 AM	35	9.42	0.02010	0.02008	0.02008	0.02005	0.02011	0.02008	0.00466	583E-06
5/8/96	12:10 PM	35	13.92	0.01980	0.01975	0.01970	0.01970	0.01969	0.01973	0.00502	628E-06
5/15/96	12:40 PM	35	20.94	0.01895	0.01889	0.01889	0.01885	0.01888	0.01889	0.00586	732E-06
5/22/96	3:00 PM	35	28.03	0.01821	0.01819	0.01821	0.01820	0.01825	0.01821	0.00654	817E-06
5/29/96	1:45 PM	35	34.98	0.01775	0.01771	0.01769	0.01771	0.01772	0.01772	0.00703	879E-06
6/7/96	3:10 PM	35	44.04	0.01755	0.01756	0.01758	0.01752	0.01755	0.01755	0.00720	900E-06
6/21/96	12:30 AM	35	57.43	0.01715	0.01712	0.01710	0.01705	0.01712	0.01711	0.00764	955E-06
7/5/96	10:45 AM	35	71.86	0.01651	0.01655	0.01661	0.01652	0.01658	0.01655	0.00819	1.02E-03
7/19/96	11:00 AM	35	85.87	0.01595	0.01595	0.01592	0.01591	0.01595	0.01594	0.00881	1.10E-03
8/5/96	9:50 AM	35	102.82	0.01565	0.01559	0.01561	0.01559	0.01551	0.01559	0.00916	1.14E-03
9/10/96	10:10 AM	35	138.83	0.01481	0.01475	0.01481	0.01478	0.01475	0.01478	0.00997	1.25E-03
9/27/96	1:10 PM	35	155.96	0.01448	0.01449	0.01445	0.01448	0.01450	0.01448	0.01027	1.28E-03

REFERENCE SPECIMEN #1 - LOADED - B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain Ref #1-B
				1	2	3	4	5			
4/24/96	1:50 PM	0	0.00	0.02635	0.02630	0.02635	0.02632	0.02640	0.02634	*****	*****
4/24/96	2:10 PM	35	0.01	0.02445	0.02445	0.02441	0.02449	0.02442	0.02444	0.00190	238E-06
4/24/96	3:10 PM	35	0.04	0.02390	0.02389	0.02395	0.02385	0.02389	0.02390	0.00245	306E-06
4/24/96	4:10 PM	35	0.08	0.02382	0.02389	0.02385	0.02390	0.02382	0.02386	0.00249	311E-06
4/24/96	6:15 PM	35	0.17	0.02389	0.02395	0.02399	0.02391	0.02389	0.02393	0.00242	302E-06
4/24/96	10:10 PM	35	0.33	0.02361	0.02359	0.02359	0.02362	0.02365	0.02361	0.00273	342E-06
4/25/96	1:45 AM	35	0.48	0.02365	0.02365	0.02368	0.02368	0.02361	0.02365	0.00269	336E-06
4/25/96	2:10 PM	35	1.00	0.02335	0.02341	0.02333	0.02336	0.02340	0.02337	0.00297	372E-06
4/26/96	1:40 AM	35	1.48	0.02299	0.02295	0.02300	0.02305	0.02306	0.02301	0.00333	417E-06
4/26/96	2:10 PM	35	2.00	0.02285	0.02289	0.02282	0.02281	0.02289	0.02285	0.00349	437E-06
4/27/96	12:00 AM	35	2.41	0.02281	0.02275	0.02278	0.02281	0.02280	0.02279	0.00355	444E-06
4/28/96	2:10 PM	35	4.00	0.02261	0.02265	0.02259	0.02260	0.02265	0.02262	0.00372	466E-06
5/1/96	2:10 PM	35	7.00	0.02250	0.02245	0.02248	0.02245	0.02240	0.02246	0.00389	486E-06
5/4/96	12:10 AM	35	9.42	0.02219	0.02215	0.02221	0.02211	0.02215	0.02216	0.00418	523E-06
5/8/96	12:10 PM	35	13.92	0.02195	0.02205	0.02202	0.02195	0.02191	0.02198	0.00437	546E-06
5/15/96	12:40 PM	35	20.94	0.02141	0.02142	0.02139	0.02141	0.02140	0.02141	0.00494	617E-06
5/22/96	3:00 PM	35	28.03	0.02089	0.02085	0.02089	0.02091	0.02082	0.02087	0.00547	684E-06
5/29/96	1:45 PM	35	34.98	0.02045	0.02045	0.02049	0.02042	0.02039	0.02044	0.00590	738E-06
6/7/96	3:10 PM	35	44.04	0.02025	0.02021	0.02025	0.02021	0.02026	0.02024	0.00611	764E-06
6/21/96	12:30 AM	35	57.43	0.01969	0.01970	0.01971	0.01965	0.01964	0.01968	0.00667	833E-06
7/5/96	10:45 AM	35	71.86	0.01905	0.01901	0.01899	0.01900	0.01898	0.01901	0.00734	917E-06
7/19/96	11:00 AM	35	85.87	0.01851	0.01852	0.01851	0.01855	0.01852	0.01852	0.00782	978E-06
8/5/96	9:50 AM	35	102.82	0.01818	0.01815	0.01811	0.01811	0.01809	0.01813	0.00822	1.03E-03
9/10/96	10:10 AM	35	138.83	0.01732	0.01731	0.01735	0.01731	0.01735	0.01733	0.00902	1.13E-03
9/27/96	1:10 PM	35	155.96	0.01708	0.01705	0.01708	0.01705	0.01711	0.01707	0.00927	1.16E-03

REF SPECIMEN #1 - LOADED				Avg Strain Ref #1	Specific Strain Ref #1	Corrected Spec Strain Ref #1
Date	Time	Load (kips)	Time (days)			
4/24/96	1:50 PM	0	0.00			
4/24/96	2:10 PM	35	0.01	269E-06	.217E-06	.000E+00
4/24/96	3:10 PM	35	0.04	308E-06	.249E-06	.314E-07
4/24/96	4:10 PM	35	0.08	310E-06	.250E-06	.328E-07
4/24/96	6:15 PM	35	0.17	301E-06	.243E-06	.261E-07
4/24/96	10:10 PM	35	0.33	346E-06	.279E-06	.620E-07
4/25/96	1:45 AM	35	0.48	342E-06	.277E-06	.593E-07
4/25/96	2:10 PM	35	1.00	365E-06	.295E-06	.776E-07
4/26/96	1:40 AM	35	1.48	412E-06	.333E-06	.116E-06
4/26/96	2:10 PM	35	2.00	434E-06	.350E-06	.133E-06
4/27/96	12:00 AM	35	2.41	440E-06	.355E-06	.138E-06
4/28/96	2:10 PM	35	4.00	463E-06	.374E-06	.157E-06
5/1/96	2:10 PM	35	7.00	511E-06	.413E-06	.196E-06
5/4/96	12:10 AM	35	9.42	553E-06	.447E-06	.229E-06
5/8/96	12:10 PM	35	13.92	587E-06	.474E-06	.257E-06
5/15/96	12:40 PM	35	20.94	675E-06	.545E-06	.328E-06
5/22/96	3:00 PM	35	28.03	751E-06	.606E-06	.389E-06
5/29/96	1:45 PM	35	34.98	809E-06	.653E-06	.436E-06
6/7/96	3:10 PM	35	44.04	832E-06	.672E-06	.454E-06
6/21/96	12:30 AM	35	57.43	894E-06	.722E-06	.505E-06
7/5/96	10:45 AM	35	71.86	971E-06	.784E-06	.567E-06
7/19/96	11:00 AM	35	85.87	1.04E-03	.840E-06	.622E-06
8/5/96	9:50 AM	35	102.82	1.09E-03	.877E-06	.660E-06
9/10/96	10:10 AM	35	138.83	1.19E-03	9.58E-07	7.41E-07
9/27/96	1:10 PM	35	155.96	1.22E-03	9.86E-07	7.69E-07

REFERENCE SPECIMEN #5 - LOADED - A											
Date	Time	Load (kips)	Time (days)	A					Avg.	Diff.	Strain Ref #5-A
				1	2	3	4	5			
4/24/96	1:50 PM	0	0.00	0.02785	0.02781	0.02789	0.02780	0.02779	0.02783	*****	*****
4/24/96	2:10 PM	35	0.01	0.02550	0.02555	0.02558	0.02555	0.02558	0.02555	0.00228	285E-06
4/24/96	3:10 PM	35	0.04	0.02559	0.02561	0.02555	0.02552	0.02552	0.02556	0.00227	284E-06
4/24/96	4:10 PM	35	0.08	0.02539	0.02541	0.02545	0.02539	0.02539	0.02541	0.00242	303E-06
4/24/96	6:15 PM	35	0.17	0.02541	0.02548	0.02541	0.02545	0.02545	0.02544	0.00239	299E-06
4/24/96	10:10 PM	35	0.33	0.02515	0.02519	0.02515	0.02515	0.02512	0.02515	0.00268	335E-06
4/25/96	1:45 AM	35	0.48	0.02492	0.02495	0.02501	0.02499	0.02500	0.02497	0.00285	357E-06
4/25/96	2:10 PM	35	1.00	0.02480	0.02475	0.02478	0.02475	0.02478	0.02477	0.00306	382E-06
4/26/96	1:40 AM	35	1.48	0.02438	0.02435	0.02438	0.02441	0.02438	0.02438	0.00345	431E-06
4/26/96	2:10 PM	35	2.00	0.02418	0.02415	0.02415	0.02415	0.02412	0.02415	0.00368	460E-06
4/27/96	12:00 AM	35	2.41	0.02409	0.02415	0.02418	0.02405	0.02411	0.02412	0.00371	464E-06
4/28/96	2:10 PM	35	4.00	0.02395	0.02398	0.02390	0.02391	0.02394	0.02394	0.00389	487E-06
5/1/96	2:10 PM	35	7.00	0.02350	0.02351	0.02345	0.02351	0.02349	0.02349	0.00434	542E-06
5/4/96	12:10 AM	35	9.42	0.02309	0.02310	0.02311	0.02309	0.02305	0.02309	0.00474	593E-06
5/8/96	12:10 PM	35	13.92	0.02275	0.02270	0.02271	0.02271	0.02275	0.02272	0.00510	638E-06
5/15/96	12:40 PM	35	20.94	0.02195	0.02198	0.02191	0.02195	0.02192	0.02194	0.00589	736E-06
5/22/96	3:00 PM	35	28.03	0.02155	0.02150	0.02158	0.02150	0.02151	0.02153	0.00630	788E-06
5/29/96	1:45 PM	35	34.98	0.02115	0.02111	0.02111	0.02110	0.02109	0.02111	0.00672	840E-06
6/7/96	3:10 PM	35	44.04	0.02095	0.02095	0.02089	0.02096	0.02086	0.02092	0.00691	863E-06
6/21/96	12:30 AM	35	57.43	0.02052	0.02050	0.02051	0.02049	0.02049	0.02050	0.00733	916E-06
7/5/96	10:45 AM	35	71.86	0.01990	0.01995	0.01989	0.01999	0.01989	0.01992	0.00790	988E-06
7/19/96	11:00 AM	35	85.87	0.01948	0.01942	0.01945	0.01948	0.01945	0.01946	0.00837	1.05E-03
8/5/96	9:50 AM	35	102.82	0.01921	0.01925	0.01922	0.01920	0.01920	0.01922	0.00861	1.08E-03
9/10/96	10:10 AM	35	138.83	0.01848	0.01841	0.01842	0.01841	0.01839	0.01842	0.00941	1.18E-03
9/27/96	1:10 PM	35	155.96	0.01810	0.01813	0.01815	0.01809	0.01811	0.01812	0.00971	1.21E-03

REFERENCE SPECIMEN #5 - LOADED - B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain Ref #5-B
				1	2	3	4	5			
4/24/96	1:50 PM	0	0.00	0.02559	0.02561	0.02558	0.02555	0.02558	0.02558	*****	*****
4/24/96	2:10 PM	35	0.01	0.02351	0.02352	0.02355	0.02359	0.02359	0.02355	0.00203	254E-06
4/24/96	3:10 PM	35	0.04	0.02329	0.02328	0.02325	0.02319	0.02321	0.02324	0.00234	292E-06
4/24/96	4:10 PM	35	0.08	0.02318	0.02319	0.02312	0.02315	0.02312	0.02315	0.00243	304E-06
4/24/96	6:15 PM	35	0.17	0.02315	0.02321	0.02320	0.02320	0.02312	0.02318	0.00241	301E-06
4/24/96	10:10 PM	35	0.33	0.02309	0.02311	0.02308	0.02310	0.02309	0.02309	0.00249	311E-06
4/25/96	1:45 AM	35	0.48	0.02291	0.02291	0.02295	0.02295	0.02290	0.02292	0.00266	332E-06
4/25/96	2:10 PM	35	1.00	0.02252	0.02251	0.02255	0.02250	0.02251	0.02252	0.00306	383E-06
4/26/96	1:40 AM	35	1.48	0.02225	0.02221	0.02221	0.02228	0.02225	0.02224	0.00334	418E-06
4/26/96	2:10 PM	35	2.00	0.02215	0.02219	0.02215	0.02215	0.02219	0.02217	0.00342	427E-06
4/27/96	12:00 AM	35	2.41	0.02215	0.02215	0.02211	0.02218	0.02220	0.02216	0.00342	428E-06
4/28/96	2:10 PM	35	4.00	0.02208	0.02200	0.02201	0.02205	0.02201	0.02203	0.00355	444E-06
5/1/96	2:10 PM	35	7.00	0.02198	0.02185	0.02191	0.02195	0.02191	0.02192	0.00366	458E-06
5/4/96	12:10 AM	35	9.42	0.02165	0.02169	0.02165	0.02158	0.02169	0.02165	0.00393	491E-06
5/8/96	12:10 PM	35	13.92	0.02135	0.02145	0.02138	0.02135	0.02140	0.02139	0.00420	525E-06
5/15/96	12:40 PM	35	20.94	0.02075	0.02069	0.02071	0.02069	0.02068	0.02070	0.00488	610E-06
5/22/96	3:00 PM	35	28.03	0.02025	0.02015	0.02019	0.02018	0.02015	0.02018	0.00540	675E-06
5/29/96	1:45 PM	35	34.98	0.01979	0.01975	0.01975	0.01978	0.01980	0.01977	0.00581	726E-06
6/7/96	3:10 PM	35	44.04	0.01945	0.01945	0.01951	0.01942	0.01942	0.01945	0.00613	767E-06
6/21/96	12:30 AM	35	57.43	0.01895	0.01889	0.01898	0.01899	0.01892	0.01895	0.00664	830E-06
7/5/96	10:45 AM	35	71.86	0.01831	0.01839	0.01835	0.01829	0.01829	0.01833	0.00726	907E-06
7/19/96	11:00 AM	35	85.87	0.01775	0.01781	0.01772	0.01772	0.01781	0.01776	0.00782	978E-06
8/5/96	9:50 AM	35	102.82	0.01735	0.01730	0.01731	0.01730	0.01730	0.01731	0.00827	1.03E-03
9/10/96	10:10 AM	35	138.83	0.01650	0.01651	0.01655	0.01658	0.01658	0.01654	0.00904	1.13E-03
9/27/96	1:10 PM	35	155.96	0.01632	0.01628	0.01625	0.01630	0.01629	0.01629	0.00929	1.16E-03

REF SPECIMEN #5 - LOADED				Avg Strain Ref #5	Specific Strain Ref #5	Corrected Spec Strain Ref #5
Date	Time	Load (kips)	Time (days)			
4/24/96	1:50 PM	0	0.00			
4/24/96	2:10 PM	35	0.01	269.1E-06	.217E-06	.000E+00
4/24/96	3:10 PM	35	0.04	288.0E-06	.233E-06	.152E-07
4/24/96	4:10 PM	35	0.08	303.3E-06	.245E-06	.276E-07
4/24/96	6:15 PM	35	0.17	299.6E-06	.242E-06	.246E-07
4/24/96	10:10 PM	35	0.33	322.8E-06	.261E-06	.433E-07
4/25/96	1:45 AM	35	0.48	344.5E-06	.278E-06	.609E-07
4/25/96	2:10 PM	35	1.00	382.5E-06	.309E-06	.916E-07
4/26/96	1:40 AM	35	1.48	424.4E-06	.343E-06	.125E-06
4/26/96	2:10 PM	35	2.00	443.4E-06	.358E-06	.141E-06
4/27/96	12:00 AM	35	2.41	446.0E-06	.360E-06	.143E-06
4/28/96	2:10 PM	35	4.00	465.3E-06	.376E-06	.158E-06
5/1/96	2:10 PM	35	7.00	499.9E-06	.404E-06	.186E-06
5/4/96	12:10 AM	35	9.42	541.9E-06	.438E-06	.220E-06
5/8/96	12:10 PM	35	13.92	581.3E-06	.469E-06	.252E-06
5/15/96	12:40 PM	35	20.94	672.8E-06	.543E-06	.326E-06
5/22/96	3:00 PM	35	28.03	731.1E-06	.591E-06	.373E-06
5/29/96	1:45 PM	35	34.98	782.8E-06	.632E-06	.415E-06
6/7/96	3:10 PM	35	44.04	814.9E-06	.658E-06	.441E-06
6/21/96	12:30 AM	35	57.43	872.6E-06	.705E-06	.487E-06
7/5/96	10:45 AM	35	71.86	947.5E-06	.765E-06	.548E-06
7/19/96	11:00 AM	35	85.87	1.01E-03	.817E-06	.600E-06
8/5/96	9:50 AM	35	102.82	1.06E-03	.852E-06	.635E-06
9/10/96	10:10 AM	35	138.83	1.15E-03	9.31E-07	7.14E-07
9/27/96	1:10 PM	35	155.96	1.19E-03	9.59E-07	7.42E-07

REFERENCE SPECIMEN #7 - LOADED - A											
Date	Time	Load (kips)	Time (Days)	A					Avg.	Diff.	Strain Ref #7-A
				1	2	3	4	5			
4/24/96	1:50 PM	0	0.00	0.02908	0.02905	0.02907	0.02909	0.02911	0.02908	*****	*****
4/24/96	2:10 PM	35	0.01	0.02690	0.02685	0.02685	0.02680	0.02682	0.02684	0.002236	280E-06
4/24/96	3:10 PM	35	0.04	0.02650	0.02652	0.02652	0.02651	0.02655	0.02652	0.00256	320E-06
4/24/96	4:10 PM	35	0.08	0.02648	0.02645	0.02642	0.02648	0.02645	0.02646	0.002624	328E-06
4/24/96	6:15 PM	35	0.17	0.02659	0.02655	0.02658	0.02658	0.02652	0.02656	0.002516	315E-06
4/24/96	10:10 PM	35	0.33	0.02632	0.02631	0.02631	0.02630	0.02635	0.02632	0.002762	345E-06
4/25/96	1:45 AM	35	0.48	0.02622	0.02621	0.02625	0.02621	0.02620	0.02622	0.002862	358E-06
4/25/96	2:10 PM	35	1.00	0.02605	0.02601	0.02605	0.02605	0.02609	0.02605	0.00303	379E-06
4/26/96	1:40 AM	35	1.48	0.02558	0.02561	0.02565	0.02564	0.02560	0.02562	0.003464	433E-06
4/26/96	2:10 PM	35	2.00	0.02549	0.02550	0.02549	0.02551	0.02555	0.02551	0.003572	447E-06
4/27/96	12:00 AM	35	2.41	0.02545	0.02549	0.02549	0.02542	0.02541	0.02545	0.003628	454E-06
4/28/96	2:10 PM	35	4.00	0.02531	0.02525	0.02535	0.02529	0.02530	0.02530	0.00378	473E-06
5/1/96	2:10 PM	35	7.00	0.02495	0.02500	0.02505	0.02495	0.02498	0.02499	0.004094	512E-06
5/4/96	12:10 AM	35	9.42	0.02465	0.02460	0.02465	0.02460	0.02465	0.02463	0.00445	556E-06
5/8/96	12:10 PM	35	13.92	0.02440	0.02439	0.02435	0.02439	0.02439	0.02438	0.004696	587E-06
5/15/96	12:40 PM	35	20.94	0.02345	0.02340	0.02341	0.02335	0.02335	0.02339	0.005688	711E-06
5/22/96	3:00 PM	35	28.03	0.02280	0.02279	0.02275	0.02279	0.02275	0.02278	0.006304	788E-06
5/29/96	1:45 PM	35	34.98	0.02232	0.02239	0.02240	0.02233	0.02238	0.02236	0.006716	840E-06
6/7/96	3:10 PM	35	44.04	0.02225	0.02221	0.02225	0.02220	0.02221	0.02222	0.006856	857E-06
6/21/96	12:30 AM	35	57.43	0.02172	0.02175	0.02171	0.02172	0.02175	0.02173	0.00735	919E-06
7/5/96	10:45 AM	35	71.86	0.02135	0.02129	0.02130	0.02129	0.02131	0.02131	0.007772	972E-06
7/19/96	11:00 AM	35	85.87	0.02085	0.02081	0.02082	0.02085	0.02081	0.02083	0.008252	1.03E-03
8/5/96	9:50 AM	35	102.82	0.02059	0.02060	0.02060	0.02059	0.02060	0.02060	0.008484	1.06E-03
9/10/96	10:10 AM	35	138.83	0.02001	0.01998	0.01995	0.01996	0.01989	0.01996	0.009122	1.14E-03
9/27/96	1:10 PM	35	155.96	0.01968	0.01969	0.01970	0.01958	0.01961	0.01965	0.009428	1.18E-03

REFERENCE SPECIMEN #7 - LOADED - B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain Ref #7-B
				1	2	3	4	5			
4/24/96	1:50 PM	0	0.00	0.02769	0.02769	0.02765	0.02771	0.02770	0.02769	*****	*****
4/24/96	2:10 PM	35	0.01	0.02499	0.02500	0.02495	0.02501	0.02495	0.02498	0.00271	338E-06
4/24/96	3:10 PM	35	0.04	0.02481	0.02475	0.02485	0.02480	0.02480	0.02480	0.00289	361E-06
4/24/96	4:10 PM	35	0.08	0.02479	0.02475	0.02471	0.02469	0.02478	0.02474	0.00294	368E-06
4/24/96	6:15 PM	35	0.17	0.02478	0.02480	0.02481	0.02482	0.02481	0.02480	0.00288	361E-06
4/24/96	10:10 PM	35	0.33	0.02465	0.02455	0.02459	0.02454	0.02455	0.02458	0.00311	389E-06
4/25/96	1:45 AM	35	0.48	0.02458	0.02458	0.02455	0.02454	0.02455	0.02456	0.00313	391E-06
4/25/96	2:10 PM	35	1.00	0.02425	0.02421	0.02419	0.02425	0.02425	0.02423	0.00346	432E-06
4/26/96	1:40 AM	35	1.48	0.02389	0.02385	0.02385	0.02385	0.02389	0.02387	0.00382	478E-06
4/26/96	2:10 PM	35	2.00	0.02371	0.02375	0.02378	0.02375	0.02378	0.02375	0.00393	492E-06
4/27/96	12:00 AM	35	2.41	0.02368	0.02365	0.02368	0.02369	0.02371	0.02368	0.00401	501E-06
4/28/96	2:10 PM	35	4.00	0.02351	0.02349	0.02350	0.02351	0.02351	0.02350	0.00418	523E-06
5/1/96	2:10 PM	35	7.00	0.02315	0.02320	0.02315	0.02320	0.02329	0.02320	0.00449	561E-06
5/4/96	12:10 AM	35	9.42	0.02285	0.02285	0.02280	0.02285	0.02289	0.02285	0.00484	605E-06
5/8/96	12:10 PM	35	13.92	0.02269	0.02270	0.02270	0.02271	0.02269	0.02270	0.00499	624E-06
5/15/96	12:40 PM	35	20.94	0.02219	0.02215	0.02211	0.02215	0.02216	0.02215	0.00554	692E-06
5/22/96	3:00 PM	35	28.03	0.02181	0.02185	0.02181	0.02185	0.02182	0.02183	0.00586	732E-06
5/29/96	1:45 PM	35	34.98	0.02152	0.02149	0.02145	0.02151	0.02145	0.02148	0.00620	776E-06
6/7/96	3:10 PM	35	44.04	0.02125	0.02128	0.02121	0.02125	0.02122	0.02124	0.00645	806E-06
6/21/96	12:30 AM	35	57.43	0.02078	0.02075	0.02081	0.02071	0.02075	0.02076	0.00693	866E-06
7/5/96	10:45 AM	35	71.86	0.02010	0.02011	0.02015	0.02000	0.01995	0.02006	0.00763	953E-06
7/19/96	11:00 AM	35	85.87	0.01941	0.01939	0.01939	0.01941	0.01939	0.01940	0.00829	1.04E-03
8/5/96	9:50 AM	35	102.82	0.01879	0.01878	0.01875	0.01871	0.01870	0.01875	0.00894	1.12E-03
9/10/96	10:10 AM	35	138.83	0.01795	0.01790	0.01791	0.01791	0.01801	0.01794	0.00975	1.22E-03
9/27/96	1:10 PM	35	155.96	0.01765	0.01762	0.01762	0.01761	0.01762	0.01762	0.01006	1.26E-03

REF SPECIMEN #7 - LOADED				Avg Strain Ref #7	Specific Strain Ref #7	Corrected Spec Strain Ref #7
Date	Time	Load (kips)	Time (days)			
4/24/96	1:50 PM	0	0.00			
4/24/96	2:10 PM	35	0.01	309E-06	.250E-06	.000E+00
4/24/96	3:10 PM	35	0.04	340E-06	.275E-06	.253E-07
4/24/96	4:10 PM	35	0.08	348E-06	.281E-06	.315E-07
4/24/96	6:15 PM	35	0.17	338E-06	.273E-06	.230E-07
4/24/96	10:10 PM	35	0.33	367E-06	.297E-06	.469E-07
4/25/96	1:45 AM	35	0.48	374E-06	.302E-06	.528E-07
4/25/96	2:10 PM	35	1.00	406E-06	.328E-06	.779E-07
4/26/96	1:40 AM	35	1.48	455E-06	.368E-06	.118E-06
4/26/96	2:10 PM	35	2.00	469E-06	.379E-06	.129E-06
4/27/96	12:00 AM	35	2.41	477E-06	.385E-06	.136E-06
4/28/96	2:10 PM	35	4.00	498E-06	.402E-06	.152E-06
5/1/96	2:10 PM	35	7.00	537E-06	.433E-06	.184E-06
5/4/96	12:10 AM	35	9.42	581E-06	.469E-06	.219E-06
5/8/96	12:10 PM	35	13.92	605E-06	.489E-06	.239E-06
5/15/96	12:40 PM	35	20.94	702E-06	.567E-06	.317E-06
5/22/96	3:00 PM	35	28.03	760E-06	.614E-06	.364E-06
5/29/96	1:45 PM	35	34.98	808E-06	.652E-06	.403E-06
6/7/96	3:10 PM	35	44.04	831E-06	.672E-06	.422E-06
6/21/96	12:30 AM	35	57.43	892E-06	.721E-06	.471E-06
7/5/96	10:45 AM	35	71.86	962E-06	.777E-06	.528E-06
7/19/96	11:00 AM	35	85.87	1.03E-03	.835E-06	.585E-06
8/5/96	9:50 AM	35	102.82	1.09E-03	.880E-06	.630E-06
9/10/96	10:10 AM	35	138.83	1.18E-03	9.53E-07	7.03E-07
9/27/96	1:10 PM	35	155.96	1.22E-03	9.84E-07	7.34E-07

REFERENCE SPECIMEN #2 - UNLOADED - A											
Date	Time	Load (kips)	Time (days)	A					Avg.	Diff.	Strain #2-UL-A
				1	2	3	4	5			
4/24/96	10:15 AM	0	0.00	0.03018	0.03020	0.03018	0.03019	0.03021	0.03019	*****	*****
4/24/96	2:30 PM	0	0.01	0.03009	0.03009	0.03015	0.03009	0.03010	0.03010	0.00009	011E-06
4/24/96	3:35 PM	0	0.05	0.03015	0.03019	0.03121	0.03021	0.03021	0.03039	-0.00020	-025E-06
4/24/96	4:40 PM	0	0.09	0.03019	0.03020	0.03025	0.03021	0.03021	0.03021	-0.00002	-003E-06
4/24/96	6:45 PM	0	0.18	0.03028	0.03020	0.03025	0.03034	0.03032	0.03028	-0.00009	-011E-06
4/24/96	10:40 PM	0	0.34	0.03015	0.03019	0.03019	0.03020	0.03019	0.03018	0.00001	001E-06
4/25/96	2:15 AM	0	0.49	0.03031	0.03019	0.03031	0.03019	0.03025	0.03025	-0.00006	-007E-06
4/25/96	2:30 PM	0	1.00	0.03035	0.03032	0.03035	0.03038	0.03038	0.03036	-0.00016	-021E-06
4/26/96	2:00 AM	0	1.48	0.03015	0.03021	0.03025	0.03019	0.03021	0.03020	-0.00001	-001E-06
4/26/96	2:40 PM	0	2.01	0.03019	0.03020	0.03021	0.03015	0.03018	0.03019	0.00001	750E-09
4/27/96	12:20 AM	0	2.41	0.03019	0.03021	0.03015	0.03009	0.03008	0.03014	0.00005	006E-06
4/28/96	2:30 PM	0	4.00	0.03025	0.03021	0.03025	0.03019	0.03015	0.03021	-0.00002	-002E-06
5/1/96	2:40 PM	0	7.01	0.03015	0.03019	0.03019	0.03011	0.03008	0.03014	0.00005	006E-06
5/4/96	12:35 AM	0	9.42	0.03008	0.03010	0.03010	0.03010	0.03011	0.03010	0.00009	012E-06
5/8/96	12:35 PM	0	13.92	0.02998	0.02995	0.03005	0.03005	0.03002	0.03001	0.00018	023E-06
5/15/96	1:05 PM	0	20.94	0.02985	0.02989	0.02985	0.02979	0.02989	0.02985	0.00034	042E-06
5/22/96	3:40 PM	0	28.05	0.02969	0.02969	0.02971	0.02971	0.02970	0.02970	0.00049	061E-06
5/29/96	2:10 PM	0	34.99	0.02959	0.02961	0.02961	0.02955	0.02958	0.02959	0.00060	076E-06
6/7/96	3:45 PM	0	44.05	0.02955	0.02959	0.02951	0.02955	0.02949	0.02954	0.00065	082E-06
6/21/96	1:00 AM	0	57.44	0.02940	0.02945	0.02942	0.02945	0.02947	0.02944	0.00075	094E-06
7/5/96	11:15 AM	0	71.86	0.02919	0.02915	0.02925	0.02921	0.02929	0.02922	0.00097	122E-06
7/19/96	11:20 AM	0	85.87	0.02885	0.02872	0.02878	0.02882	0.02882	0.02880	0.00139	174E-06
8/5/96	10:29 AM	0	102.83	0.02865	0.02861	0.02865	0.02865	0.02861	0.02863	0.00156	195E-06
9/10/96	10:35 AM	0	138.84	0.02831	0.02838	0.02832	0.02829	0.02832	0.02832	0.00187	234E-06
9/27/96	1:40 AM	0	155.47	0.02825	0.02819	0.02815	0.02821	0.02821	0.02820	0.00199	249E-06

REFERENCE SPECIMEN #2 - UNLOADED - B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain #2-UL-B
				1	2	3	4	5			
4/24/96	10:15 AM	0	0.00	0.03155	0.03145	0.03150	0.03145	0.03148	0.03149	*****	*****
4/24/96	2:30 PM	0	0.01	0.03141	0.03139	0.03145	0.03142	0.03140	0.03141	0.00007	009E-06
4/24/96	3:35 PM	0	0.05	0.03150	0.03155	0.03152	0.03158	0.03155	0.03154	-0.00005	-007E-06
4/24/96	4:40 PM	0	0.09	0.03161	0.03165	0.03159	0.03161	0.03165	0.03162	-0.00014	-017E-06
4/24/96	6:45 PM	0	0.18	0.03175	0.03178	0.03172	0.03172	0.03178	0.03175	-0.00026	-033E-06
4/24/96	10:40 PM	0	0.34	0.03175	0.03178	0.03175	0.03176	0.03175	0.03176	-0.00027	-034E-06
4/25/96	2:15 AM	0	0.49	0.03170	0.03168	0.03162	0.03165	0.03169	0.03167	-0.00018	-023E-06
4/25/96	2:30 PM	0	1.00	0.03158	0.03165	0.03161	0.03165	0.03160	0.03162	-0.00013	-017E-06
4/26/96	2:00 AM	0	1.48	0.03155	0.03155	0.03151	0.03158	0.03151	0.03154	-0.00005	-007E-06
4/26/96	2:40 PM	0	2.01	0.03151	0.03159	0.03149	0.03149	0.03150	0.03152	-0.00003	-004E-06
4/27/96	12:20 AM	0	2.41	0.03159	0.03150	0.03149	0.03155	0.03149	0.03152	-0.00004	-005E-06
4/28/96	2:30 PM	0	4.00	0.03159	0.03160	0.03165	0.03159	0.03161	0.03161	-0.00012	-015E-06
5/1/96	2:40 PM	0	7.01	0.03151	0.03145	0.03159	0.03152	0.03151	0.03152	-0.00003	-004E-06
5/4/96	12:35 AM	0	9.42	0.03141	0.03145	0.03149	0.03139	0.03141	0.03143	0.00006	007E-06
5/8/96	12:35 PM	0	13.92	0.03129	0.03129	0.03130	0.03139	0.03135	0.03132	0.00016	020E-06
5/15/96	1:05 PM	0	20.94	0.03119	0.03115	0.03111	0.03115	0.03115	0.03115	0.00034	042E-06
5/22/96	3:40 PM	0	28.05	0.03100	0.03105	0.03105	0.03101	0.03105	0.03103	0.00045	057E-06
5/29/96	2:10 PM	0	34.99	0.03095	0.03098	0.03095	0.03092	0.03095	0.03095	0.00054	067E-06
6/7/96	3:45 PM	0	44.05	0.03089	0.03091	0.03085	0.03085	0.03091	0.03088	0.00060	076E-06
6/21/96	1:00 AM	0	57.44	0.03065	0.03068	0.03072	0.03065	0.03071	0.03068	0.00080	101E-06
7/5/96	11:15 AM	0	71.86	0.03045	0.03039	0.03040	0.03045	0.03045	0.03043	0.00106	132E-06
7/19/96	11:20 AM	0	85.87	0.03024	0.03021	0.03020	0.03015	0.03018	0.03020	0.00129	161E-06
8/5/96	10:29 AM	0	102.83	0.03001	0.02999	0.03000	0.02995	0.03002	0.02999	0.00149	187E-06
9/10/96	10:35 AM	0	138.84	0.02968	0.02971	0.02965	0.02965	0.02969	0.02968	0.00181	226E-06
9/27/96	1:40 AM	0	155.47	0.02945	0.02938	0.02935	0.02939	0.02941	0.02940	0.00209	261E-06

REF SPECIMEN #2-UNLOADED				Avg Strain #2-UL
Date	Time	Load (kips)	Time (days)	
4/24/96	10:15 AM	0	0.00	
4/24/96	2:30 PM	0	0.01	010E-06
4/24/96	3:35 PM	0	0.05	-016E-06
4/24/96	4:40 PM	0	0.09	-010E-06
4/24/96	6:45 PM	0	0.18	-022E-06
4/24/96	10:40 PM	0	0.34	-016E-06
4/25/96	2:15 AM	0	0.49	-015E-06
4/25/96	2:30 PM	0	1.00	-019E-06
4/26/96	2:00 AM	0	1.48	-004E-06
4/26/96	2:40 PM	0	2.01	-002E-06
4/27/96	12:20 AM	0	2.41	625E-09
4/28/96	2:30 PM	0	4.00	-009E-06
5/1/96	2:40 PM	0	7.01	001E-06
5/4/96	12:35 AM	0	9.42	009E-06
5/8/96	12:35 PM	0	13.92	022E-06
5/15/96	1:05 PM	0	20.94	042E-06
5/22/96	3:40 PM	0	28.05	059E-06
5/29/96	2:10 PM	0	34.99	071E-06
6/7/96	3:45 PM	0	44.05	079E-06
6/21/96	1:00 AM	0	57.44	097E-06
7/5/96	11:15 AM	0	71.86	127E-06
7/19/96	11:20 AM	0	85.87	168E-06
8/5/96	10:29 AM	0	102.83	191E-06
9/10/96	10:35 AM	0	138.84	230E-06
9/27/96	1:40 AM	0	155.47	255E-06

REFERENCE SPECIMEN #8 - UNLOADED - A											
Date	Time	Load (kips)	Time (days)	A					Avg.	Diff.	Strain #8-UL-A
				1	2	3	4	5			
4/24/96	10:15 AM	0	0.00	0.02940	0.02948	0.02942	0.02949	0.02942	0.02944	*****	*****
4/24/96	2:30 PM	0	0.01	0.02939	0.02941	0.02939	0.02945	0.02941	0.02941	0.00003	004E-06
4/24/96	3:35 PM	0	0.05	0.02961	0.02965	0.02965	0.02965	0.02959	0.02963	-0.00019	-023E-06
4/24/96	4:40 PM	0	0.09	0.02960	0.02961	0.02961	0.02965	0.02965	0.02962	-0.00018	-023E-06
4/24/96	6:45 PM	0	0.18	0.02965	0.02971	0.02970	0.02971	0.02975	0.02970	-0.00026	-033E-06
4/24/96	10:40 PM	0	0.34	0.02955	0.02949	0.02951	0.02958	0.02958	0.02954	-0.00010	-012E-06
4/25/96	2:15 AM	0	0.49	0.02950	0.02955	0.02950	0.02958	0.02949	0.02952	-0.00008	-010E-06
4/25/96	2:30 PM	0	1.00	0.02955	0.02950	0.02955	0.02958	0.02958	0.02955	-0.00011	-014E-06
4/26/96	2:00 AM	0	1.48	0.02945	0.02945	0.02941	0.02951	0.02950	0.02946	-0.00002	-003E-06
4/26/96	2:40 PM	0	2.01	0.02948	0.02950	0.02949	0.02950	0.02945	0.02948	-0.00004	-005E-06
4/27/96	12:20 AM	0	2.41	0.02945	0.02939	0.02945	0.02939	0.02940	0.02942	0.00003	003E-06
4/28/96	2:30 PM	0	4.00	0.02942	0.02945	0.02950	0.02951	0.02942	0.02946	-0.00002	-002E-06
5/1/96	2:40 PM	0	7.01	0.02948	0.02942	0.02951	0.02942	0.02945	0.02946	-0.00001	-002E-06
5/4/96	12:35 AM	0	9.42	0.02945	0.02939	0.02941	0.02941	0.02939	0.02941	0.00003	004E-06
5/8/96	12:35 PM	0	13.92	0.02935	0.02938	0.02931	0.02941	0.02939	0.02937	0.00007	009E-06
5/15/96	1:05 PM	0	20.94	0.02930	0.02935	0.02925	0.02919	0.02920	0.02926	0.00018	023E-06
5/22/96	3:40 PM	0	28.05	0.02905	0.02909	0.02910	0.02905	0.02909	0.02908	0.00037	046E-06
5/29/96	2:10 PM	0	34.99	0.02885	0.02885	0.02884	0.02891	0.02890	0.02887	0.00057	072E-06
6/7/96	3:45 PM	0	44.05	0.02878	0.02872	0.02875	0.02872	0.02875	0.02874	0.00070	087E-06
6/21/96	1:00 AM	0	57.44	0.02850	0.02845	0.02848	0.02851	0.02850	0.02849	0.00095	119E-06
7/5/96	11:15 AM	0	71.86	0.02825	0.02821	0.02819	0.02821	0.02818	0.02821	0.00123	154E-06
7/19/96	11:20 AM	0	85.87	0.02785	0.02775	0.02778	0.02778	0.02779	0.02779	0.00165	207E-06
8/5/96	10:29 AM	0	102.83	0.02765	0.02762	0.02765	0.02759	0.02759	0.02762	0.00182	228E-06
9/10/96	10:35 AM	0	138.84	0.02730	0.02725	0.02731	0.02730	0.02726	0.02728	0.00216	270E-06
9/27/96	1:40 AM	0	155.47	0.02710	0.02709	0.02710	0.02711	0.02709	0.02710	0.00234	293E-06

REFERENCE SPECIMEN #8 - UNLOADED - B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain #8-UL-B
				1	2	3	4	5			
4/24/96	10:15 AM	0	0.00	0.02280	0.02275	0.02275	0.02270	0.02272	0.02274	*****	*****
4/24/96	2:30 PM	0	0.01	0.02255	0.02259	0.02252	0.02253	0.02255	0.02255	0.00020	025E-06
4/24/96	3:35 PM	0	0.05	0.02265	0.02275	0.02269	0.02271	0.02269	0.02270	0.00005	006E-06
4/24/96	4:40 PM	0	0.09	0.02275	0.02275	0.02268	0.02269	0.02269	0.02271	0.00003	004E-06
4/24/96	6:45 PM	0	0.18	0.02295	0.02299	0.02295	0.02299	0.02289	0.02295	-0.00021	-026E-06
4/24/96	10:40 PM	0	0.34	0.02295	0.02295	0.02301	0.02295	0.02298	0.02297	-0.00022	-028E-06
4/25/96	2:15 AM	0	0.49	0.02290	0.02289	0.02289	0.02295	0.02290	0.02291	-0.00016	-020E-06
4/25/96	2:30 PM	0	1.00	0.02280	0.02275	0.02272	0.02275	0.02272	0.02275	0.00000	-500E-09
4/26/96	2:00 AM	0	1.48	0.02275	0.02281	0.02280	0.02281	0.02281	0.02280	-0.00005	-007E-06
4/26/96	2:40 PM	0	2.01	0.02275	0.02271	0.02279	0.02279	0.02269	0.02275	0.00000	-250E-09
4/27/96	12:20 AM	0	2.41	0.02279	0.02280	0.02279	0.02279	0.02279	0.02279	-0.00005	-006E-06
4/28/96	2:30 PM	0	4.00	0.02281	0.02278	0.02285	0.02289	0.02284	0.02283	-0.00009	-011E-06
5/1/96	2:40 PM	0	7.01	0.02275	0.02281	0.02272	0.02269	0.02278	0.02275	-0.00001	-750E-09
5/4/96	12:35 AM	0	9.42	0.02269	0.02265	0.02262	0.02259	0.02260	0.02263	0.00011	014E-06
5/8/96	12:35 PM	0	13.92	0.02259	0.02255	0.02251	0.02250	0.02251	0.02253	0.00021	026E-06
5/15/96	1:05 PM	0	20.94	0.02245	0.02250	0.02245	0.02245	0.02239	0.02245	0.00030	037E-06
5/22/96	3:40 PM	0	28.05	0.02220	0.02225	0.02221	0.02221	0.02225	0.02222	0.00052	065E-06
5/29/96	2:10 PM	0	34.99	0.02205	0.02211	0.02210	0.02205	0.02204	0.02207	0.00067	084E-06
6/7/96	3:45 PM	0	44.05	0.02195	0.02195	0.02200	0.02199	0.02195	0.02197	0.00078	097E-06
6/21/96	1:00 AM	0	57.44	0.02169	0.02175	0.02171	0.02175	0.02179	0.02174	0.00101	126E-06
7/5/96	11:15 AM	0	71.86	0.02145	0.02141	0.02155	0.02145	0.02151	0.02147	0.00127	159E-06
7/19/96	11:20 AM	0	85.87	0.02128	0.02125	0.02122	0.02122	0.02125	0.02124	0.00150	188E-06
8/5/96	10:29 AM	0	102.83	0.02101	0.02105	0.02100	0.02095	0.02102	0.02101	0.00174	217E-06
9/10/96	10:35 AM	0	138.84	0.02085	0.02081	0.02084	0.02091	0.02088	0.02086	0.00189	236E-06
9/27/96	1:40 AM	0	155.47	0.02068	0.02075	0.02065	0.02068	0.02062	0.02068	0.00207	259E-06

REF SPECIMEN #8-UNLOADED				Avg Strain #8-UL
Date	Time	Load (kips)	Time (days)	
4/24/96	10:15 AM	0	0.00	
4/24/96	2:30 PM	0	0.01	014E-06
4/24/96	3:35 PM	0	0.05	-009E-06
4/24/96	4:40 PM	0	0.09	-009E-06
4/24/96	6:45 PM	0	0.18	-029E-06
4/24/96	10:40 PM	0	0.34	-020E-06
4/25/96	2:15 AM	0	0.49	-015E-06
4/25/96	2:30 PM	0	1.00	-007E-06
4/26/96	2:00 AM	0	1.48	-005E-06
4/26/96	2:40 PM	0	2.01	-003E-06
4/27/96	12:20 AM	0	2.41	-001E-06
4/28/96	2:30 PM	0	4.00	-007E-06
5/1/96	2:40 PM	0	7.01	-001E-06
5/4/96	12:35 AM	0	9.42	009E-06
5/8/96	12:35 PM	0	13.92	018E-06
5/15/96	1:05 PM	0	20.94	030E-06
5/22/96	3:40 PM	0	28.05	055E-06
5/29/96	2:10 PM	0	34.99	078E-06
6/7/96	3:45 PM	0	44.05	092E-06
6/21/96	1:00 AM	0	57.44	123E-06
7/5/96	11:15 AM	0	71.86	157E-06
7/19/96	11:20 AM	0	85.87	197E-06
8/5/96	10:29 AM	0	102.83	223E-06
9/10/96	10:35 AM	0	138.84	253E-06
9/27/96	1:40 AM	0	155.47	276E-06

REFERENCE SPECIMEN #9 - UNLOADED - A											
Date	Time	Load (kips)	Time (days)	A							Strain #9-UL-A
				1	2	3	4	5	Avg.	Diff.	
4/24/96	10:15 AM	0	0.00	0.02420	0.02421	0.02418	0.02414	0.02415	0.02418	*****	*****
4/24/96	2:30 PM	0	0.01	0.02415	0.02409	0.02409	0.02411	0.02411	0.02411	0.00007	008E-06
4/24/96	3:35 PM	0	0.05	0.02419	0.02420	0.02411	0.02421	0.02420	0.02418	-0.00001	-750E-09
4/24/96	4:40 PM	0	0.09	0.02449	0.02450	0.02450	0.02449	0.02448	0.02449	-0.00032	-040E-06
4/24/96	6:45 PM	0	0.18	0.02470	0.02465	0.02458	0.02471	0.02465	0.02466	-0.00048	-060E-06
4/24/96	10:40 PM	0	0.34	0.02449	0.02451	0.02448	0.02448	0.02451	0.02449	-0.00032	-040E-06
4/25/96	2:15 AM	0	0.49	0.02445	0.02445	0.02448	0.02452	0.02448	0.02448	-0.00030	-038E-06
4/25/96	2:30 PM	0	1.00	0.02441	0.02445	0.02440	0.02448	0.02448	0.02444	-0.00027	-034E-06
4/26/96	2:00 AM	0	1.48	0.02445	0.02445	0.02448	0.02448	0.02445	0.02446	-0.00029	-036E-06
4/26/96	2:40 PM	0	2.01	0.02449	0.02450	0.02445	0.02450	0.02449	0.02449	-0.00031	-039E-06
4/27/96	12:20 AM	0	2.41	0.02439	0.02445	0.02442	0.02448	0.02441	0.02443	-0.00025	-032E-06
4/28/96	2:30 PM	0	4.00	0.02435	0.02439	0.02445	0.02435	0.02441	0.02439	-0.00021	-027E-06
5/1/96	2:40 PM	0	7.01	0.02445	0.02441	0.02445	0.02435	0.02445	0.02442	-0.00025	-031E-06
5/4/96	12:35 AM	0	9.42	0.02419	0.02425	0.02420	0.02425	0.02419	0.02422	-0.00004	-005E-06
5/8/96	12:35 PM	0	13.92	0.02411	0.02405	0.02400	0.02405	0.02401	0.02404	0.00013	016E-06
5/15/96	1:05 PM	0	20.94	0.02400	0.02395	0.02395	0.02389	0.02389	0.02394	0.00024	030E-06
5/22/96	3:40 PM	0	28.05	0.02390	0.02375	0.02371	0.02379	0.02370	0.02377	0.00041	051E-06
5/29/96	2:10 PM	0	34.99	0.02365	0.02370	0.02369	0.02375	0.02368	0.02369	0.00048	060E-06
6/7/96	3:45 PM	0	44.05	0.02361	0.02355	0.02359	0.02359	0.02361	0.02359	0.00059	073E-06
6/21/96	1:00 AM	0	57.44	0.02345	0.02349	0.02350	0.02349	0.02342	0.02347	0.00071	088E-06
7/5/96	11:15 AM	0	71.86	0.02321	0.02325	0.02328	0.02325	0.02321	0.02324	0.00094	117E-06
7/19/96	11:20 AM	0	85.87	0.02295	0.02292	0.02292	0.02291	0.02292	0.02292	0.00125	157E-06
8/5/96	10:29 AM	0	102.83	0.02241	0.02235	0.02239	0.02241	0.02240	0.02239	0.00178	223E-06
9/10/96	10:35 AM	0	138.84	0.02221	0.02219	0.02215	0.02218	0.02215	0.02218	0.00200	250E-06
9/27/96	1:40 AM	0	155.47	0.02205	0.02209	0.02205	0.02209	0.02201	0.02206	0.00212	265E-06

REFERENCE SPECIMEN #9 - UNLOADED - B											
Date	Time	Load (kips)	Time (days)	B					Avg.	Diff.	Strain #9-UL-B
				1	2	3	4	5			
4/24/96	10:15 AM	0	0.00	0.02860	0.02858	0.02860	0.02862	0.02858	0.02860	*****	*****
4/24/96	2:30 PM	0	0.01	0.02849	0.02840	0.02843	0.02841	0.02845	0.02844	0.00016	020E-06
4/24/96	3:35 PM	0	0.05	0.02865	0.02859	0.02860	0.02861	0.02865	0.02862	-0.00002	-003E-06
4/24/96	4:40 PM	0	0.09	0.02872	0.02875	0.02875	0.02870	0.02871	0.02873	-0.00013	-016E-06
4/24/96	6:45 PM	0	0.18	0.02885	0.02878	0.02790	0.02880	0.02879	0.02862	-0.00003	-004E-06
4/24/96	10:40 PM	0	0.34	0.02875	0.02881	..02879	0.02885	0.02878	0.02880	-0.00020	-025E-06
4/25/96	2:15 AM	0	0.49	0.02875	0.02872	0.02872	0.02871	0.02871	0.02872	-0.00013	-016E-06
4/25/96	2:30 PM	0	1.00	0.02875	0.02872	0.02868	0.02870	0.02878	0.02873	-0.00013	-016E-06
4/26/96	2:00 AM	0	1.48	0.02870	0.02872	0.02875	0.02875	0.02875	0.02873	-0.00014	-017E-06
4/26/96	2:40 PM	0	2.01	0.02875	0.02872	0.02875	0.02872	0.02875	0.02874	-0.00014	-018E-06
4/27/96	12:20 AM	0	2.41	0.02875	0.02870	0.02869	0.02871	0.02865	0.02870	-0.00010	-013E-06
4/28/96	2:30 PM	0	4.00	0.02869	0.02871	0.02870	0.02871	0.02875	0.02871	-0.00012	-014E-06
5/1/96	2:40 PM	0	7.01	0.02860	0.02859	0.02859	0.02861	0.02865	0.02861	-0.00001	-002E-06
5/4/96	12:35 AM	0	9.42	0.02858	0.02851	0.02855	0.02855	0.02850	0.02854	0.00006	007E-06
5/8/96	12:35 PM	0	13.92	0.02845	0.02848	0.02850	0.02851	0.02852	0.02849	0.00010	013E-06
5/15/96	1:05 PM	0	20.94	0.02835	0.02830	0.02829	0.02831	0.02830	0.02831	0.00029	036E-06
5/22/96	3:40 PM	0	28.05	0.02810	0.02820	0.02815	0.02815	0.02819	0.02816	0.00044	055E-06
5/29/96	2:10 PM	0	34.99	0.02799	0.02795	0.02792	0.02795	0.02799	0.02796	0.00064	079E-06
6/7/96	3:45 PM	0	44.05	0.02791	0.02795	0.02789	0.02791	0.02791	0.02791	0.00068	085E-06
6/21/96	1:00 AM	0	57.44	0.02775	0.02771	0.02771	0.02778	0.02771	0.02773	0.00086	108E-06
7/5/96	11:15 AM	0	71.86	0.02745	0.02748	0.02751	0.02749	0.02751	0.02749	0.00111	139E-06
7/19/96	11:20 AM	0	85.87	0.02720	0.02712	0.02715	0.02711	0.02712	0.02714	0.00146	182E-06
8/5/96	10:29 AM	0	102.83	0.02700	0.02695	0.02701	0.02699	0.02710	0.02701	0.00159	198E-06
9/10/96	10:35 AM	0	138.84	0.02670	0.02675	0.02678	0.02671	0.02678	0.02674	0.00185	232E-06
9/27/96	1:40 AM	0	155.47	0.02649	0.02650	0.02655	0.02649	0.02649	0.02650	0.00209	262E-06

REF SPECIMEN #9-UNLOADED				Avg Strain #9-UL
Date	Time	Load (kips)	Time (days)	
4/24/96	10:15 AM	0	0.00	
4/24/96	2:30 PM	0	0.01	014E-06
4/24/96	3:35 PM	0	0.05	-002E-06
4/24/96	4:40 PM	0	0.09	-028E-06
4/24/96	6:45 PM	0	0.18	-032E-06
4/24/96	10:40 PM	0	0.34	-032E-06
4/25/96	2:15 AM	0	0.49	-027E-06
4/25/96	2:30 PM	0	1.00	-025E-06
4/26/96	2:00 AM	0	1.48	-027E-06
4/26/96	2:40 PM	0	2.01	-028E-06
4/27/96	12:20 AM	0	2.41	-022E-06
4/28/96	2:30 PM	0	4.00	-021E-06
5/1/96	2:40 PM	0	7.01	-016E-06
5/4/96	12:35 AM	0	9.42	001E-06
5/8/96	12:35 PM	0	13.92	015E-06
5/15/96	1:05 PM	0	20.94	033E-06
5/22/96	3:40 PM	0	28.05	053E-06
5/29/96	2:10 PM	0	34.99	070E-06
6/7/96	3:45 PM	0	44.05	079E-06
6/21/96	1:00 AM	0	57.44	098E-06
7/5/96	11:15 AM	0	71.86	128E-06
7/19/96	11:20 AM	0	85.87	169E-06
8/5/96	10:29 AM	0	102.83	211E-06
9/10/96	10:35 AM	0	138.84	241E-06
9/27/96	1:40 AM	0	155.47	263E-06

1. GENERAL

To facilitate the investigation of creep characteristics in accordance with ASTM C512 and other specifications, Soiltest has designed the CT-180 Concrete Creep Tester for subjecting three standard 6 in. diameter cylinders to the necessary sustained compressive force. The unit consists of a simple loading frame, spring operated to maintain the applied force despite dimensional changes in the specimens, and a hydraulic ram and hand pump for the initial application of the desired load.

With the apparatus assembled as shown in the enclosed drawing and the lower ram bearing plate resting freely upon the specimen stack, unrestrained by the (loosened) nuts below the plate, the required load is applied with the hand pump, thus compressing the heavy springs in the lower portion of the frame. By tightening the nuts both above and below the plate, the force in the compressed springs will now be maintained by the reacting tension in the supporting tie rods of the stressed frame.

The loading frame is 78 in. high and 14 in. in diameter at the base. Its daylight opening is adjustable from approximately 39 in. to 44-3/4 in. All plates are 1 in. thick. The bearing blocks are 6 in. in diameter, and their surfaces are plane within .001 in. To insure proper leveling, the lower bearing block is seated on a 1-1/4 in. diameter ball. The 6 in. diameter springs are coiled from 1-1/2 in. diameter bars and will compress 1-3/4 in. at approximately 25,400 lb. each, or 76,200 lb. total. All parts are plated for protection.

The single acting cylinder has a 3 in. bore and stroke, and is spring returned. It is activated by a 10,000 PSI hand pump which displaces 0.294 cubic in. per stroke, and is set at the maximum load by an internal adjustable relief valve. The reservoir has an 80 cu. in. capacity.

Calibrated with U.S. Bureau of Standards certified proving rings, the 8-1/2 in. diameter, 60,000 lb. gauge is accurate to within 1 percent of the indicated load from 10 percent to full capacity. Recalibration may be effected without removing the movement from its case as the linkage and zero adjusting screw are easily accessible through ports located at the side and back of the gauge. The linkage has a micro-adjusting screw for delicate calibration changes. The gauge may be conveniently bled through a port located on the rear of the gauge. A six ft. flexible hose, equipped with quick disconnects is provided for coupling the pump and gauge to the cylinder.

2. SPECIMEN PREPARATION

In general, nine specimens are required for testing purposes, three each for compressive strength, and creep deformation, and three for controls to indicate deformations due to causes other than loading. The cylinders are fabricated from standard molds modified for the attachment of the necessary strain gauge studs and inserts.

In addition to the specimens, dummy cylinders 3 in. long are required between the specimens and bearing plates to prevent unnatural stress distributions at the specimens ends. Consult ASTM 512 for dimensional details of the specimens, curing and storage instructions.

3. STRAIN MEASUREMENT

The longitudinal strain in the specimen should be measured to the nearest 10 microin. (0.000010 in.) per in. The prime requirement of the strain-measuring device is that it shall be capable of measuring strains for at least one year without change in calibration. Systems in which the varying strains are

compared with a constant length standard bar are considered most reliable. See Section 6, Accessories.

4. PROCEDURE

Immediately before loading the creep specimens, determine the compressive strength of the strength specimens.

With the ram removed from the frame, adjust the ram plates to their approximate positions and stack the specimens, dummy cylinders and bearing blocks in their respective positions within the frame. Drop the lower ram bearing plate to the stack and tighten the nuts above the plates to hold the stack securely. Adjust the stack into proper alignment to prevent eccentric loading. The ram may now be placed between the bearing plates and, with the nuts beneath the lower bearing plate loosened 1 in. or so from the plate, the load may now be applied. Load the specimens at a intensity of not more than 40 percent of the compressive strength at the age of loading.

Take strain readings immediately before and after loading, 6 hours later, then daily for one week, weekly for one month, and monthly until the end of one year. Strain readings on the control specimens should be observed on the same schedule. After the load has been applied, tighten the nuts above the lower ram bearing plate. The ram may now be removed for loading other frames, if desired.

5. CALCULATIONS

Calculate the total strain per PSI (or kilopascals) at any time as the difference between the average strain values of the loaded and control specimens divided by the average stress to determine creep strain per PSI (or Kilopascals) for any age, subtract from the total strain per PSI (or

Kilopascals) at that age the strain per PSI (or kilopascals) immediately after loading. If desired, plot total strains per PSI (or kilopascals) on semilog coordinate paper, on which the logarithmic axis represents time, to determine the constants 1/E and F(K) for the following equation:

$$e = (1/E) + F(K) \log_e (t+1)$$

where:

e = total strain per PSI (or kP_a),

E = instantaneous modulus of elasticity, in PSI (or kP_a),

F(K) = creep rate, calculated as the slope of a straight line representing the creep curve on the semilog plot, and

t = time after loading, in days.

The quantity 1/E is the initial elastic strain per PSI (or kilopascals) and is determined from the strain readings taken immediately before and after loading the specimen.

If loading is not accomplished expeditiously, some creep may occur before the after loading strain is observed, in which event extrapolation to zero time by the method of least squares may be used to determine this quantity. It should not be implied from the use of the logarithmic expression that the creep strain time relationship is necessarily an exact logarithmic function; however, for the period of one year, the expression approximates normal creep behavior with sufficient accuracy to make possible the calculation of parameters that are useful for the purpose of comparing concretes.

6. ACCESSORIES

Soiltest manufactures an extensive variety of equipment for fabricating the necessary specimens. Attention is called to the concrete section in our latest catalog.

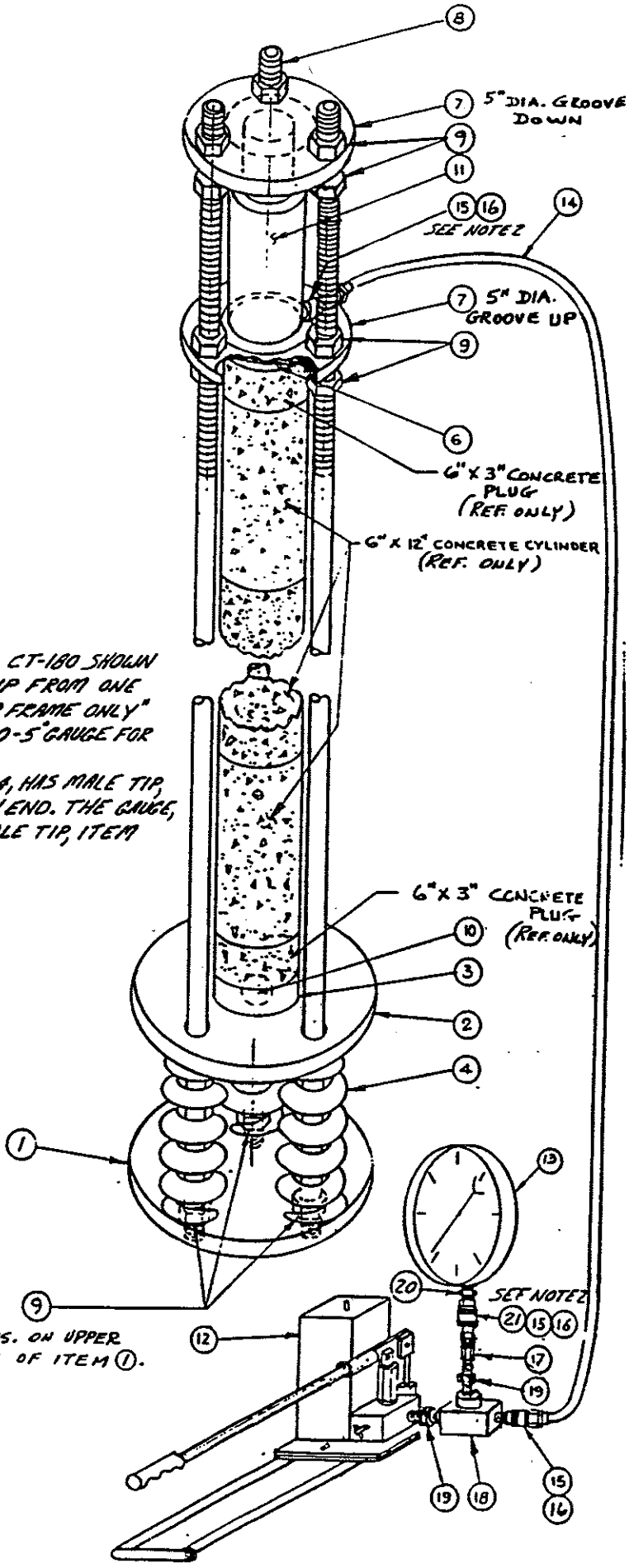
The CT-171 Multi-Position Strain Gauge is ideally suited to the requirements mentioned in Section 3, Strain Measurement. It will measure relative displacement between gauge points of 2, 4, 6, 8, or 10 in. It is equipped with a dial indicator of 0.2 in. range graduated in 0.0001 in. divisions (the equivalent of 10 microin. over a gauge length of 10 in. on creep specimens). The unit is provided with eight brass inserts, two reusable contact seats which screw into the inserts, and two contact points which mount on the strain gauge.

Accessory items which may be obtained include the CT-176 Punch Bar, used to establish the gauge distances for locating the contact points in the specimen, and the CT-175 invar Master Bar. This bar has a mean coefficient of thermal expansion of 0.5 x 10^{-6} in/in/°F for the range of 0-350°F. Over a 10 in. gauge length, a 10° temperature difference would change the master bar setting only 0.00005, of less than one dial indicator division.

Inquiries for quantity lots of either the standard or custom frames to your individual specifications will be given special consideration.

ADDITION

CT-180 Assembly Drawing



NOTE:

1. THE COMPLETE CT-180 SHOWN MAY BE MADE UP FROM ONE CT-180Y, "CREEP FRAME ONLY" PLUS ONE CT-180-5" GAUGE FOR CT-180."
2. THE HOSE, ITEM 14, HAS MALE TIP, ITEM 16, ON EACH END. THE GAUGE, ITEM 13 HAS MALE TIP, ITEM 16, ATTACHED.

Appendix E.

Potential for Future ASR Expansion

Interim Interpretation of MiDOT Core Expansions

Based on the 5 month expansion of the MiDOT pier cap cores, the following interim conclusions are drawn:

1. The cores are nearing equilibrium with their storage environment, based on their uptake of moisture. Experience dictates that all conclusions at this time are speculative.

2. Testing should continue for at least the originally specified 12 month period.

3. Potentially reactive aggregate is available for further reaction if sufficient alkali is present.

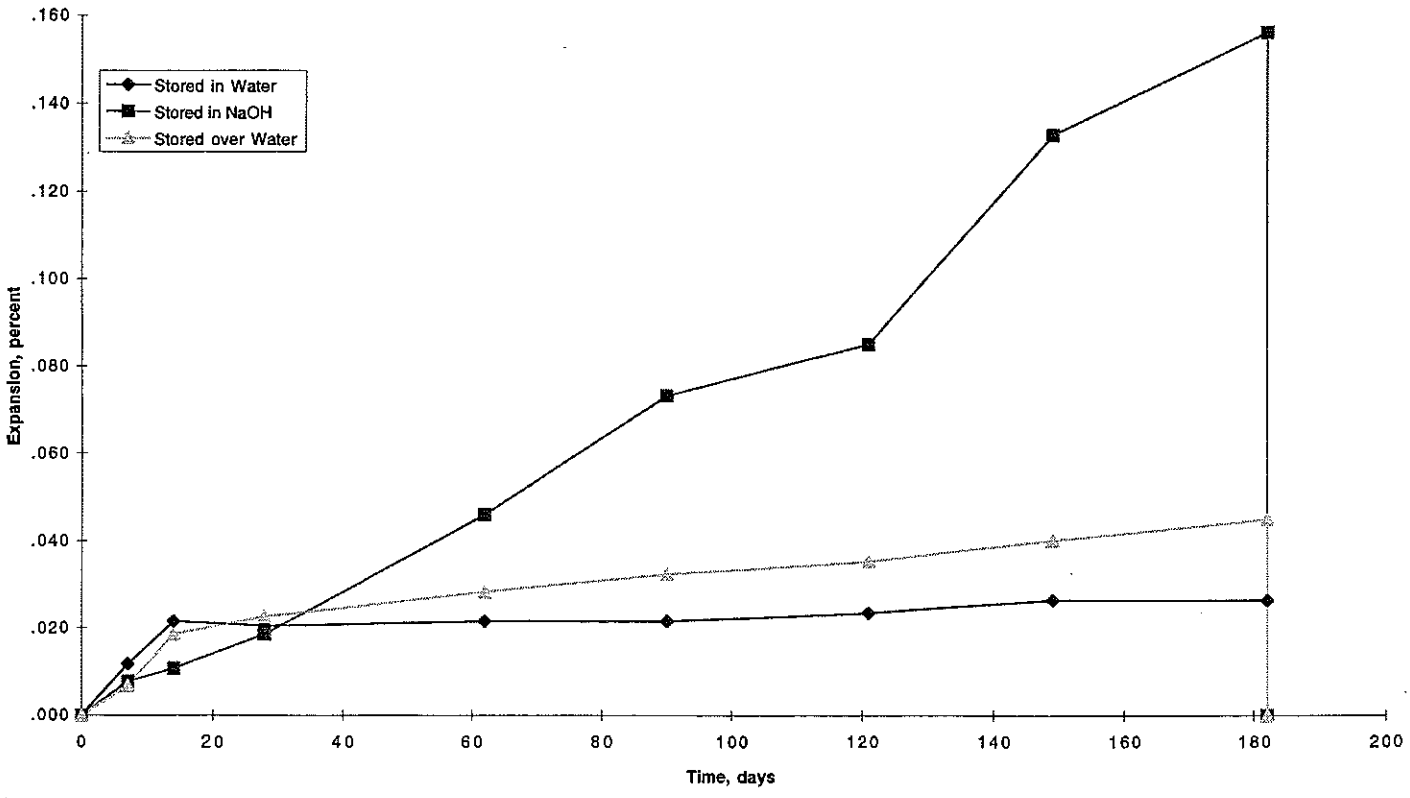
4. There appears to be small potential for further in the concrete pier cap provided that adequate moisture is available.

In summary, the cores are not yet at equilibrium with their storage environment. Therefore, conclusions at this point are speculate, and may not be representative of the final test results. Based on data obtained to date, the ASR reaction appears to have exhausted its moisture and alkali supply. Potentially reactive aggregate is available for further reaction if sufficient alkalis become available.

John Gajda
Materials Engineer
7-19-96

	In Water		In NaOH		Over Water	
Date	Length	Weight	Length	Weight	Length	Weight
2/21/96	.2107	4130	.1101	4137	.1821	4146
2/28/96	.2119	4148	.1109	4154	.1828	4144
3/6/96	.2129	4155	.1112	4162	.1840	4151
3/20/96	.2128	4161	.1120	4170	.1844	4163
4/23/96	.2129	4166	.1148	4181	.1850	4172
5/21/96	.2129	4169	.1176	4185	.1854	4174
6/21/96	.2131	4171	.1188	4188	.1857	4175
7/19/96	.2134	4171	.1237	4192	.1862	4177
8/21/96	.2134	4174	.1261	4196	.1867	4180
11/21/96						
2/21/97						

	In Water		In NaOH		Over Water	
Elapsed Days	% Length Change	Weight Change	% Length Change	Weight Change	% Length Change	Weight Change
0	.000		.000		.000	
7	.012	18	.008	17	.007	-2
14	.021	7	.011	8	.019	7
28	.021	6	.019	8	.022	12
62	.021	5	.046	11	.028	9
90	.021	3	.073	4	.032	2
121	.023	2	.085	3	.035	1
149	.026	0	.133	4	.040	2
182	.026	3	.156	4	.045	3
182						
182						



CTL

Alkali-Silica Reactivity Testing

The objective of this test is to determine if there is any potential for alkali-silica reactivity (ASR) in concrete and to determine future maximum expansions. This test is usually performed on concrete that already exhibits ASR.

This ASR test consists of the determination of relative weight and length changes of "companion" samples cut from concrete cores when immersed in 1M NaOH solution (40 grams NaOH/liter of water), in water, and over water in a sealed container, all at 100°F. These weight and length changes are interpreted to indicate the potential for possible or further alkali-silica reactivity. Companion samples for testing are adjacent cores Core samples are fitted at each end with gauge points. Their weights and lengths are measured and one sample is immersed in the NaOH solution, another in water, and a third over water in a sealed container. Immersion in water is used to determine length and weight change caused by rewetting of partially dried concrete. Moisture equilibrium is identified when the samples reach constant weight ± 2 grams. This point is taken as a reference when assessing the potential for expansion from additional alkali-silica reactivity in the companion samples. Immersion of samples in NaOH solution is intended to force any potential expansive alkali-silica reactivity. Differences in expansion between cores stored in NaOH solution and in water can indicate the presence of potentially reactive aggregates. Comparison of the expansion of the cores stored over water with those stored in water can indicate the presence of sufficient alkali to sustain expansive ASR. Expansion of the samples stored in water, after weight equilibrium is reached, indicates swelling of existing alkali-silica gel. In order to establish meaningful trends, time duration of these tests is, at a minimum, six to nine months. It is suggested by CTL that testing be continued to 1 year.

Appendix F.

Historical Record

Date: August 9, 1977

To: K.A. Allemeir - Engineer of Testing Research

T.R. Wiseman - Engineer of Maintenance

From: M.G. Brown and D.J. Kanellitsas

Subject: Cracking in Pier Girders of I-75 - Rouge River Bridge

Research Project 77 TI-416

The following is a summary of a field inspection of the subject piers made by D.J. Kanellitsas and M.G. Brown on July 19, 1977. This was as per verbal request of G.J. McCarthy subsequent to an article in the July 17th Detroit News by J.F. Nehman. This article contained a picture of the south face of northbound pier 38, which is the south river pier. Our detailed inspection concerned the four largest piers at the river, nos. 37 to 40, and also those adjacently to these four.

Mr. McCarthy's remark in the article that the cracking in the pier caps is "source disintegration only" and "not load related" is correct. We believe the cracks to be nothing more than the common shrinkage and temperature related cracks associated with hot weather curing conditions and massive volumes of concrete generating great amounts of heat while curing. The largest piers, nos. 38 and 39 had girder sections 8.5 ft wide and 9 ft to 12 ft deep. Piers 37 and 40 had girders of the same depth, but 7 ft wide. This is evidenced by the random pattern of the cracking (map cracking) very typical of this type of concrete behavior, as opposed to the very definite pattern of cracks which would be caused by stress, whether shear or tensile. The fact that these cracks appear only in the largest piers is not evidence that they are stress cracks, as the newspaper article hints, but rather substantiates our position that they are due to massive concrete pours and hot weather.

A search of the project records furnished additional information which adds support to the hot weather - thermal cracking theory. The eight pier girder pours for nos. 37 to 40 were placed in hot weather form May 7 to July 29, 1965. In addition, a 7.5 sack cement per cubic yard mix was used " to obtain 70 % design strength earlier." This rich mix would have greatly increased thermal buildup and resultant surface cracking. In contrast, all pier girder pours other than the above, used the normal 6 sack of cement per cubic yard.

Shrinkage cracks on pier columns and caps usually are no more than 2" to 3" deep, remain in this condition for a long time, perhaps 20 to 30 years. Eventually if the concrete is not protected, and under wet conditions with many freeze-thaw cycles may occur. At that time we proceed with repairs. In this particular case there is no cause for alarm because:

1. The previously leaking expansion joints over piers 37 to 40 have been replaced with new joints that are relatively leakproof.

2. With the aid of "snooper," the tops of the pier caps and all the bearing rockers were inspected. No cracks were found, and the top of the piers is very sound. Therefore, the leaching of the cracks seen from below is due to water entering the top and exiting from the bottom after traveling through the pier cap. It is rather the result of water seeping through the crack itself, when water ran down the side of the pier through leaking expansion joints, or in some cases, from the overflowing downspouts on the ?? of ?? girder.

3. In order to provide added protection, now that the deck has been resurfaced, and new expansion joints have been installed, we proposed to let a contract whereby some of the most prominent cracks will be pressure grouted, and the entire cap will be sealed with protective coating.

4. D.J. Kanellitsas recalled that when these particular piers were designed (at that time he worked on drawing plans for the caisson foundation), it was not the stresses, but rather the geometry or aesthetics that controlled the size of the piers, and therefore, they were greatly over designed.

The newspaper's contention that the Department was unaware of the existence of cracks is inaccurate. Our inspection reports dated back to 1969 mentions these particular cracks in piers 37 to 40.

Neither of the "two possible causes" for the cracking offered by Dr. Almeida exists. There is no evidence of honeycomb, nor flow of water through the pier cap as explained previously. He should also be aware of the Department's annual, systematic bridge inspection program which surpasses even Federal requirements.

Finally, the newspaper write-up mentions cracks through the 8 1/2" deck. The existence of these has been for some time and usually occurs in the longer continuos spans such as the three at the river. That problem, or course, has been taken care of recently complete latex concrete overlay on the southbound spans in 1975 and the northbound this year.

FG 77 TI-41

OFFICE MEMORANDUM

Roll 121
Start @ 145

[illegible] 1977

[illegible] K. A. Allemeier - Engineer of Testing & [illegible]
[illegible] Wiseman - Engineer [illegible]

[illegible] D. J. Kanellitsas

[illegible] 12 Pages [illegible] 301 of 82(94)

[illegible] inspection of the subject piers made by D. J. [illegible] 19, 1977. This was as per verbal request of [illegible] in the July 17th Detroit News by J. F. [illegible] article [illegible] picture of the south face of northbound pier 38, [illegible] river pier. Our detailed inspection concerned the four largest [illegible] river, nos. 37 to 40, and also those adjacent to these four.

[illegible]'s remark in the article that the cracking in the pier caps is "[illegible] [illegible] only" and "not load related" is correct. We believe the cracks to be [illegible] common shrinkage and temperature relat[illegible] [illegible] associated [illegible] [illegible] girder [illegible] [illegible] of the same depth, [illegible] pot[illegible] [illegible] cracking [illegible] crack[illegible] [illegible] concrete [illegible] as opposed [illegible] the very [illegible] [illegible] caused by [illegible], whether shear or tensile. The fact that [illegible] appear only in the largest piers is not evidence that they are stress cracks, [illegible] article [illegible] substantiates our position that they are due [illegible] pours and [illegible].

[illegible] project [illegible] additional information which adds support to [illegible] thermal cracking theory. The eight pier girder pours for nos. 37 to [illegible] in hot weather from May 7 to July 29, 1965. In addition, a 7.5 sack [illegible] obtain 70% design strength earlier." This [illegible] thermal buildup and resultant surface cracking. [illegible] than the above, used the normal 6 sacks of [illegible]

[illegible] on pier [illegible] usually are no more than 2" to 3" [illegible] perhaps 20 to 30 years. Eventually, if the [illegible] [illegible] [illegible] At that time [illegible] with repairs. In this particular case [illegible] for [illegible]

3. The previously leaking expansion joints over piers 37 and 40 have [illegible] with new joints that are relatively leakproof.

[illegible], the tops of the pier caps and all the bearing rockers were inspected. No cracks of any [illegible] were found, and the top of the piers is very sound. Therefore, the leaching of the cracks seen from below is not due to water entering the top and exiting from the bottom after travelling through the pier [illegible] of water seeping through the crack itself, [illegible] through a leaking [illegible] joint, or in some cases, [illegible] downspouts on [illegible] girder.

[illegible] added protection, now that the deck has been resurfaced, and [illegible] joints installed, we propose to let a contract whereby some of the [illegible] cracks will be pressure grouted, and the entire pier cap will be [illegible] a protective coating.

4. D. J. Kanellitsas recalled that when these particular piers were designed (at that time he worked on drawing the plans for the caisson foundations), it was not the stresses, but rather the geometry or aesthetics that controlled the size of these piers, and, therefore, they are greatly overdesigned.

The newspaper's contention that the Department was unaware of the existence of cracks is inaccurate. [illegible] inspection reports [illegible] to 1969 mentions these particular [illegible]

[illegible] the cracking offered by [illegible] of water through the pier cap as explained previously. He should also be made aware of the Department's annual, systematic bridge inspection program which surpasses even Federal requirements.

Finally, the newspaper write-up mentions cracks through the 8-1/2" deck. The existance of these has been known for some time and usually occurs in the longer continuous spans such as the three at the river. That problem, of course, has been taken care of by recently completed latex concrete overlay on the southbound spans in 1975 and the northbound this year.

M. G. Brown
Acting Supervising Engineer
Materials Research Unit-Research Laboratory

[illegible]
mc J. P. [illegible]
G. J. McCarthy
M. N. Clyde
W. J. McCreery
H. B. LaFrance
L. T. Oehler

THIS COPY FOR

D. J. Kanellitsas
Assistant Engineer of Structures Maintenance

1181-160

MICHIGAN STATE HIGHWAY DEPARTMENT
BUREAU OF TESTING AND RESEARCH

BRIDGE CONCRETE PROPORTIONING

PROJ. NO. _____
ROUTE _____ CROSSING Au Sable River
CONTRACTOR R. C. Bailey & Co. (Sutton-Kelly Co.)
REPORT NO 59 DATE 5-21-65

Name and Location of Concrete Proportioning Plant Conrad Brown Co. - Miller Rd. Plant
Source of Cement Peerless Type II Silo # _____ Car # _____ Truck # _____
Source of Aggregate: Fine Amer. Agg. Green Oak Sand CA 6 E.C. Jerry-Trenton 6B _____
Plan Volume of Pour 236.0 Cu. Yds. Grade A (Air) Chart No. 5CV-177(.06) Consistency: ☐ Medium
5CV-177(Remodified) ☐ Dry

PROPORTIONS

Time of Test	Wt. per cu. ft (Bone Dry) Coarse Aggregate, Lbs.	Quantities per sack of Cement from chart: Sand, Pounds	Coarse Aggregate, Pounds	Water, Pounds	Moisture Percent: Sand	Coarse Aggregate	Total Computed Mix: Cement, Sacks	Sand, Pounds	Coarse Aggregate, Pounds	Water, Pounds	Computed Water to be added at mixer, gallons	Actual water added at Mixer, gallons	Relative Water Content	Slump - Inches	Estimated sacks of cement per cu. yd. of concrete
7:30 A	74	183.0	286.0	73.6	4.8	2.9	7.5	1291	1436	302.8	36.3	32.0	1.25	4	7.5
10:00 A	74	183.0	286.0	73.6	4.8	2.9	7.5	1292	1437	302.8	36.3	32.0	1.25	3½	7.5
														3	

Weather: A.M. Clear, Cool
P.M. Clear, Hot
Pour Slab #3 of Bridge, Course 2 of 2
Time, from 7:30 A to 7:00 P
Number of Test Beams 3 Series 5-1-65
Date water gauge checked 5/20/65 Result OK
Date batch scale checked 5/9/65 Result OK
Auto. Controls checked 4/17/65 Result OK

(A) Plan Volume of Pour 236.0 cyds
(B) Actual Quantity Placed by Batch Count 238.0 cyds
(C) Difference between A & B 2.0 cyds*
(D) Overrun or Underrun (C ÷ A) 0.8%
(E) Total Concrete Batched 240.0 cyds
(F) Excess (E minus B) 2.0 cyds*
(G) Total Cement Batched 450.0 bbls
*Explain under Remarks

RECEIVED
JUN 1 1965
BY

By _____
FIELD TEST & INV.

TEMPERATURES

Time	Atmosphere	Water	Fine Aggregate	Coarse Aggregate	Concrete	Housing	Air Content %
7:30 A		56°	62°	60°			
					70°		7.1 Chace
11:00 A					75°		6.7 Rollameter
7:00 P					76°		6.9 Rollameter
					78°		

REMARKS Due to the wide variation in the aggregate moisture tests, the plant moisture meters were used as a guide only. Concrete to be cured by ponding. Forms on side and top rolled with burlap. Wooden separators used. Type AEA-5 admixture was used to obtain

Prepared by _____ Checked by _____

F7

One gallon of water is equivalent to 8.33 pounds.
Reports are to be filled out completely and mailed not later than the day following the pour.
Original to District Materials Supervisor, Copy to Br. Constr. Engr., Copy to Dist. Br. Engr., Retain one copy.

1151-169

Form 1000
Rev. 12/60

MICHIGAN STATE HIGHWAY DEPARTMENT
OFFICE OF TESTING AND RESEARCH
Lansing, Michigan

Project: [illegible]
F. A. No. I-75-1(64)43 Part I
Series No. G-195 (7 day)
Date: May 28, 1965

REPORT ON MODULUS OF RUPTURE

Chart No. 65NV-177 (Modified)
Date Molded May 21, 1965
Station No.
Time of Day 6:00 PM
Temperature 65 degrees F.
Grade of Concrete A(6AA)

Concrete used in Pours D & E, Girder, Pr. 38 NB
Cement Factor 7.5 Sacks per cu. yd.
Slump in 3
Curing Method of Structure Forms Left in place and curing compo
Curing Method of Beam Placed under wetted sand
Consistency

Source of Cement Peerless Type II
Fine Aggregate Amer. Agg. Co. - Green Oaks
Coarse Aggregate E.C.Levy - Trenton [illegible] (6AA)
Coarse Aggregate (6AA)

DATE OF TESTS
Beam A May 25, 1965
Beam B May 28, 1965
Beam C
Beam D

MACHINE NO. 31

JACK NO. 327142

Beam	Test No.	Load Applied Pounds	Modulus of Rupture, Lbs. per sq. in.	Average	Length of Beam Broken Off, In.	Average Temperature	Breadth of Beam	Depth of Beam	FACTOR
A	1	2225	726	727	12 3/4	60°	6	6 1/16"	0.3265
7-days	2	2250	727		13	60°	6 1/16"	6 1/16"	0.3232
B	1	2100	693	718	12	60°	6 1/16"	6"	0.3299
7-days	2	2300	743		11½	60°	6 1/16"	6 1/16"	0.3232
C	1								
14-days	2								
D	1								
14-days	2								
C	1								
28-days	2								
D	1								
28-days	2								

RECEIVED
JUN 8 1965
FIELD TESTING DIV.
DISTRICT 10

REMARKS

Molded by J. Kelsch
Mix Inspector

Tested by T. Ledger
Proportioning Plant Inspector

Reported by [signature]
Project Engineer Jose J. Sanchez

Report 7-day test results on 14-day or 28-day reports.
Copies: Original to District Materials Supervisor
District Engineer. (On Bridge Construction This Copy to District Bridge Engineer).
Construction Engineer. (On Road Construction).
Bridge Engineer. (On Bridge Construction).
Retain one copy for Project Engineer's file.

NOTE:
Reports to be filled out completely and mailed not later than one day following the test.

F8

Form 1758
Rev. 12/60

181-469

I-75 over Huron

MICHIGAN STATE HIGHWAY DEPARTMENT
OFFICE OF TESTING AND RESEARCH
Lansing, Michigan

Project II 801 of 63

P. A. No. I-75-I(64)43 Part I

Series No. C-195 (4 day)

Date May 25, 1965

REPORT ON MODULUS OF RUPTURE

Chart No. 6SW-177 Modified

Date Marked Rec. May 21, 1965

Station No.

Time of Day Given PM

Temperature 65 degrees F.

Grade of Concrete A(6AA) High Early

Concrete used in Piers D & E, Girder, near 38 Ft.

Cement Factor 7.5 Sacks per cu. yd.

Slump in. 3

Curing Method of Structure Forms in place & curing mat

Curing Method of Beam Placed under wetted sand

Consistency

Source of Cement Peerless Type II

Fine Aggregate A.B.C. Mfg. Co. - Grand Calm

Coarse Aggregate B. C. Levy - Trenton (6AA)

Coarse Aggregate (10A)

DATE OF TESTS

Beam A May 25, 1965

Beam B

Beam C

Beam D

MACHINE NO. 163 JACK NO. 327-53

Beam	Test No.	Load Applied Pounds	Modulus of Rupture, Lbs. per sq. in.	Average	Length of Beam Broken Out, In.	Average Temperature	Breadth of Beam	Depth of Beam	FACTOR
A 4 days	1	2225	726	727	12 3/4	60°	6"	6 1/16"	0.3265
	2	2250	727		13	60°	6 1/16"	6 1/16"	0.3232
B 7 days	1								
	2								
C 14 days	1								
	2								
D 21 days	1								
	2								
28 days	1								
	2								

RECEIVED
MAY 27 1965
By
FIELD TESTING DIV.
DISTRICT 19

REMARKS Tested at 4 days for the purpose of determining percentage of designed strength.

Tested by T. Nelson
Mat Inspector

Tested by T. Nedder
Proportioning Plant Inspector

Reported by
Project Engineer

Forward 7-day test results on 14-day or 28-day reports.

Copies: Original to District Materials Supervisor
1 - Engineer of Bridge Construction This Copy
1 - District Bridge Engineer

NOTE:

Form 1081
(Rev. 3/58)

184-168

I-75 over Grand River

MICHIGAN STATE HIGHWAY DEPARTMENT
OFFICE OF TESTING AND RESEARCH
Lansing, Michigan

Project III 82(1 of 82)96, Gr.
F. A. No. I-75-1(6)83 Part 3
Series No. C-196 (28 day)
Date June 18, 1965

REPORT ON MODULUS OF RUPTURE

Chart No. 6-28-17 Mod.
Date Molded May 21, 1965
Station No.
Time of Day 6:00 PM
Temperature 65 Degrees F.
Grade of Concrete A(6AA)

Concrete used in Girder, Fr. 38 NB, Years '64 & '65
Cement Factor 7.5 Sacks per cu. yd.
Slump in 3
Curing Method of Structure Forms left in place & curing.
Placed in sand & wetted

RECEIVED
JUN 25 1965
By
FIELD TESTING DIV.
DISTRICT 10

Source of Cement Peerless Type II
Fine Aggregate Amer. Agg. Green Oaks
Coarse Aggregate B.C.Lev. - Trenton (6AA)
Coarse Aggregate (6AA)

DATE OF TESTS
Beam A May 25, 1965
Beam B May 28, 1965
Beam C June 18, 1965
Beam D

MACHINE NO. 31
JACK NO. 327:42

Beam	Test No.	Load Applied Pounds	Modulus of Rupture, lbs. per sq. in.	Average	Length of Beam Broken, Ctr. to Ctr. In.	Average Temperature	Breadth of Beam	Depth of Beam	FACTOR
A	1	2225	726	727	12 3/4	60°	6"	6 1/16"	0.3265
7-days	2	2250	727		13	60°	6 1/16"	6 1/16"	0.3232
B	1	2100	693	715	12	60°	6 1/16"	6"	0.3299
7-days	2	2300	743		11½	60°	6 1/16"	6 1/16"	0.3232
C	1								
14-days	2								
D	1								
14-days	2								
C	1	2650	867	836	12	66°	6 1/8"	6 1/16"	0.3198
28-days	2	2550	824		13	66°	6 1/16"	6 1/16"	0.3232
D	1								
28-days	2								

REMARKS 7 day and 7 day Rupture Reports on this beam erroneously marked C-195; should have been marked C-196.

Molded by J. Kelsch
Mix Inspector

Tested by L. Minier
Preconstruction Plant Inspector

Reported by
Project Engineer J. E. Rice

Average these test results on 14-day or 28-day reports.

Copies: Original to District Materials Supervisor
District ... Engr. (On Bridge Construction Then Copy to District Bridge Engineer)
Construction Engineer. (On Road Construction)
Bridge Engineer. (On Bridge Construction)
Retain one copy for Resident Engineer's File.

NOTE: Reports are to be filled out completely and mailed not later than one day following the

F10

118/-160

MICHIGAN STATE HIGHWAY DEPARTMENT

BUREAU OF TESTING AND RESEARCH

BRIDGE CONCRETE PROPORTIONING

ROUTE _____ CROSSING Huron River

CONTRACTOR R. E. Kelley & Co. (Sutton-Kelly Co.

REPORT NO 10 DATE 5-4-60

Name and Location of Concrete Proportioning Plant: Cooper Supply Co. - Miller Rd. Plant - Detroit

Source of Cement: Peerless Type II Silo #: _____ Car #: _____ Truck #: _____

Source of Aggregate: Fine Gravel Age Crushed SAM E.C. Levy - Trenton 6B _____

Plan Volume of Pour 236.0 Cu. Yds. Grade A(28 AA) Chart No. 55MV-177(Rod.) Consistency: ☐ M ☐ D

PROPORTIONS

Time of Test	Wt. per cu. ft. (Bone Dry) Coarse Aggregate, Lbs	Quantities per sack of Cement from chart: Sand, Pounds	Coarse Aggregate, Pounds	Water, Pounds	Moisture Percent: Sand	Coarse Aggregate	Total Computed Mix: Cement, Sacks	Sand, Pounds	Coarse Aggregate, Pounds	Water, Pounds	Computed Water to be added at mixer, gallons	Actual water added at mixer, gallons	Relative Water Content	Slump, Inches
7:15 AM	74	158.0	156.0	53.6	5.0	4.7	7.0	1244	1461	277.1	33.3	29.7	1.25	3½
11:15 AM														3
1:15 PM														3½

Batcher A.M. Clear, Jack

P.M. Clear, Jack

Plant Plant 3b as batcher, Four 2 & 3

Time from 711 A.M. to 1145 P.M.

Number of Test Beams 5 Series 3-10

Date water gauge checked 4/26/34 Result OK

Date batch scale checked 4/9/35 Result OK

Automatic Controls Checked 6/3/60 Result OK

A	Plan Volume of Pour	236.0
B	Actual Quantity Placed by Batch Count	238.0
C	Difference between A & B	1.0
D	Overrun or Underrun C A	0.4
E	Total Concrete Batched	238.0
F	Excess	3.0
G	Total Cement Batched	446.5

RECEIVED

(*) Explain under Remarks

TEMPERATURES

Time	Atmosphere	Water	Fine Aggregate	Coarse Aggregate	Concrete	Housing	Air Content
7:30 AM		65°	56°	64°			
11:15 AM					55°		6.9 (Chace
1:15 PM					70°		7.3 (Chace
4:15 PM					70°		6.0 Roll-

REMARKS: 1 bag Darex added to 7 sacks of cement. Two stowe electric vibrators were used to consolidate the concrete. Concrete to be cured by leaving forms in place and top cured with curing compound. * Space from 1 & 2 performed all checks on the job. (*) Excess concrete wasted. Inspector: [illegible] as directed by Chief Engineer. See Revision No. 1 to Detail Drawing, Sh. Main Arch. [illegible] to obtain 28 day Strength earlier.

Submitted by Dale Cook Title Inspector Checked by _____ Title _____

Form 1

Report must be typed or written in ink in duplicate.

Reports are to be filled out complete and mailed to the Division Engineer of Tests on the day the test.

Original to District Materials Supervisor, Copy to Bridge Const. Engr., Copy to Dist. Br. Engr., Retain one copy.

1181-169

MICHIGAN STATE HIGHWAY DEPARTMENT
OFFICE OF TESTING AND RESEARCH
Lansing, Michigan

Project BI 801 of 821948, 31
F. A. No. I-75-1(64)43 part 1
Series No. G-198
Date 6-8-65

REPORT ON MODULUS OF RUPTURE

Chart No. 65MV-177 (Mod.)
Date Molded 6-4-65
Station No.
Time of Day 1:00 PM
Temperature 69 degrees F.
Grade of Concrete A(6AA)

Concrete used in Pier 38 S.B. Girder, Pour D & E
Cement Factor 7.5 Sacks per cu. yd.
Slump in 3½
Curing Method of Structure Top: Membrane curing Compound Side: Forms left in Place
Curing Method of Beam Buried in wet sand
Consistency

Source of
Cement Peerless Type II
Fine Aggregate Amer. Agg. Greenoaks
Coarse Aggregate E.C. Levy Co. Trenton (GB) (SA)
Coarse Aggregate (SA)

DATE OF TESTS
Beam A 6-8-65
Beam B
Beam C
Beam D

MACHINE NO. 31 JACK NO. 327142

Beam	Test No.	Load Applied Pounds	Modulus of Rupture, Lbs. per sq. in.	Average	Length of Beam Broken Off. In.	Average Temperature	Breadth of Beam	Depth of Beam	FACTOR
A	1	2100	671	6 5	12½	66	6 1/8	6 1/16	0.3198
4 Days	2	2100	679		13	66	6 1/16	6 1/16	0.3232
B	1								
7-days	2								
C	1								
14-days	2								
D	1								
14-days	2								
E	1								
28-days	2								
F	1								
28-days	2								

RECEIVED
JUN 1965
By
FIELD TESTING DIV.
DISTRICT 10

REMARKS Tested at 4 days to determine percentage of design strength, [illegible]

Molded by [illegible]
Mix Inspector

Tested by C. Haunt
Proportioning Plant Inspector

Reported by J. A. Rice
Project Engineer

Repeat 7-day test results on 14-day or 28-day reports.
Copies: Original to District Materials Supervisor
District Engineer. (On Bridge Construction This Copy
District Bridge Engineer).
Construction Engineer. (On Road Construction).
Bridge Engineer. (On Bridge Construction).
Retain one copy for Project Engineer's file.

NOTE:
Reports to be filled out completely and mailed not later than one day following the tes

F12

Form 1912
(Rev. 12/65)

1181-168

MICHIGAN STATE HIGHWAY DEPARTMENT
OFFICE OF TESTING AND RESEARCH
Lansing, Michigan

Project: [illegible] 801 of [illegible], 01
F. A. No. I-75-1(64)43 Part I
Series No. G-198 (11 day)
Date: June 15, 1965

REPORT ON MODULUS OF RUPTURE

Chart No. 69MV-177 Mod.
Date Molded: June 4, 1965
Station No.
Time of Day: 3:00 PM
Temperature: 71 degrees F.
Grade of Concrete: A(6AA)

Concrete used in: Girder, Pr. 38 SS, pours D & E
Cement Factor: 7.5 Sacks per cu. yd.
Sheep in: 3-1/4
Curing Method of Structure: Top: membrane curing compound Sides: forms left in place
Curing Method of Beam: Placed in sand & wetted
Consistency:

Source of Cement: Peerless Type II
Fine Aggregate: Amer. Agg. Co. - Green Oaks
Coarse Aggregate: E.C. Levy - Trenton (6AA)
Coarse Aggregate: (10A)

DATE OF TESTS
Beam A: June 15, 1965
Beam B:
Beam C:
Beam D:

MACHINE NO. 31 JACK NO. 327142

Beam	Test No.	Load Applied Pounds	Modulus of Rupture, Lbs. per sq. in.	Average	Length of Beam Broken Off, In.	Average Temperature	Breadth of Beam	Depth of Beam	FACTOR
A	1	2200	711	711	12 3/4	65°	6-1/16"	6-1/16"	0.3232
11 /7-days	2	2200	711		12	65°	6-1/16"	6-1/16"	0.3232
B	1								
7-days	2								
C	1								
14-days	2								
D	1								
14-days	2								
C	1								
28-days	2								
D	1								
28-days	2								

RECEIVED
JUN 21 1965
By
FIELD TESTING DIV.
DISTRICT 10

REMARKS

Molded by: J. Olszewski Jr. & P. Fay
Min. Inspector

Tested by: L. Minier
Proportioning Plant Inspector

Reported by: [signature]
Project Engineer J. F. [illegible]

Repeat 7-day test results on 14-day or 28-day reports.
Copies: Original to District Materials Supervisor
District Engineer. (On Bridge Construction This Copy to District Bridge Engineer).
Construction Engineer. (On Road Construction).
Bridge Engineer. (On Bridge Construction).
Retain one copy for Project Engineer's file.

NOTE:
Reports to be filled out completely and mailed not later than one day [illegible]

181-163

MICHIGAN STATE HIGHWAY DEPARTMENT
OFFICE OF TESTING AND RESEARCH
Lansing, Michigan

Project 81 M01 of 821040, 01
F. A. No. I-75-1(64)43 Part 1
Series No. C-198 (28 day)
Date 7/2/65

REPORT ON MODULUS OF RUPTURE

Chart No. 6317-177 (Modified)
Date Molded 6/2/65
Station No.
Time of Day 3:00 PM
Temperature 71 degrees F.
Grade of Concrete A(6AA)

Concrete used in Girder Pier 38 SB, Four D & E
Cement Factor 7.5 Sacks per cu. yd.
Slump in 3½
Type Membrane curing compound
Curing Method of Structure Sides: Forms left in Place
Curing Method of Beam Placed under wetted sand
Consistency

Source of Cement Peerless Type II
Fine Aggregate Amer. Agg. Co. Greenoaks
Coarse Aggregate E. C. Levy Co. Preston (4B) (6A) A
Coarse Aggregate (10A)

DATE OF TESTS
Beam A 6-8-65
Beam B 6-15-65
Beam C 7-2-65
Beam D

MACHINE NO 31 JACK NO. 327-42

Beam	Test No.	Load Applied Pounds	Modulus of Rupture Lbs per sq. in.	Average	Length of Beam Broken Off In.	Average Temperature	Breadth of Beam	Depth of Beam	FACTOR
A	1	2100	671	675	12¢	66°	6 1/8	6 1/16	0.3198
4 Days	2	2100	679		13	66°	6 1/16	6 1/16	0.3232
B	1	2200	711	711	12 3/4	65°	6 1/16	6 1/16	0.3232
11 Days	2	2200	711		12	65°	6 1/16	6 1/16	0.3232
C	1								
14-Days	2								
D	1								
14-Days	2								
C	1	2300	751	772	12¢	65°	6	6 1/16	0.3265
28-Days	2	2400	792		12¢	65°	6 1/16	6 1/16	0.3232
D	1								
28-Days	2								

RECEIVED

REMARKS

Molded by W. Wisniewski & F. Fry
Mat Inspector

Tested by T. Ledger
Prestressing Plant Inspector

Copies of these test results on 14-day or 28-day reports should be sent to: Materials Engineer, Testing Laboratory, Materials Supervisor (Original), District Engineer, (On Bridge Construction This Copy to District Bridge Engineer), Construction Engineer, (On Road Construction), Bridge Engineer, (On Bridge Construction). Retain one copy for Project Engineer's file.

By
FIELD TESTING OFFICE
MICHIGAN

Submitted by E. E. Rice
Project Engineer

F14

Reports to be filled out completely and mailed not later than one day following the test.

H. E. Hartingdill
P. L. Nordgren
A. J. Sinelli

181-182 Spec. 1964

MICHIGAN STATE HIGHWAY DEPARTMENT

J. J. Vrecan
J. Rice
File

OFFICE OF TESTING & RESEARCH
Lansing, Michigan

Bridge Dept. of Bridges, etc.

F.A. No. I-75-1 (64) 43 Part 1

Date 5-24-65 Report No. 197

REPORT OF CONCRETE INSPECTION

Length ____ Miles, Feet ____
Cross section ____ Reinforcement steel bars
Location of plant and bridge site Fisher Freeway over Rouge River

Contractor Sutton - Kelly
Project Engineer J. Rice
Plant Inspector T. Ledger
Site Inspector D. Faye

EQUIPMENT

Central Mix Supplier Cooper Supply Company
Address Miller Road - Detroit
Mixers ____
Mix-Agitating Plant ____
Finishing Machine ____
Longitudinal Float ____
Transverse Screed ____
Other ____

MATERIALS

Cement Peerless - Detroit Type I
Fine Agg. Am. Agg. Green Oak (47-3) Spec. 2NS
Coarse Agg. E. C. Jery Co. (Trenton) Spec. 6A
Coarse Agg. ____ Spec. ____
Grade of Concrete A

Mix Design Proportions

Mix Design No. 65 MV-177 Modified
Gal. per cu. ft. of mixed C.A. (dry rodded) 74

Material	Quantity Per Cubic Yard	Moisture Content of Agg. %	Corrected Batch, lb.
A 2NS	1,442	2.0	1249
A 6A	1,442	0.7	1461
A			
Cement	94	.705 per batch	705
Water	53.5		33.3 gals.

Water originally added at mix 33.0 gals.
Slump 2 1/2 in. Admixture Mixed ____ 0.3 gals.

Date Sampled and Tested 5-20-65
Method of Sampling ____
Workmanship of Finish Satisfactory
Condition of Forms Satisfactory
Curing Method Ponds Condition Satisfactory
Weather Sunny Test No. ____
Quality of Workmanship Satisfactory
Load Transfer Device No. ____

Place 2nd and 3rd of Pier 38 (Girder, Southbound)
Average Air Content 6.0 % A.E. Additive Darex 2 5/8 oz. per sack
Method of Test ____
Average Air Content ____ % A.E. Additive ____ oz. per sack
Method of Test ____
Concrete Placed ____ At ____ Time Last Sample ____ Date 5-21-65
Temperature 50 Slump 3" Time of Test ____
Remarks ____

K. Trace
James A. Farque
Assistant Engineer
Materials Supervisor

Testing and Research Engineer

F15

jas

1181 - 159

Form 360
Rev. 6-63

MICHIGAN STATE HIGHWAY DEPARTMENT
BUREAU OF TESTING AND RESEARCH

BRIDGE CONCRETE PROPORTIONING

PROJ. NO [illegible] CROSSING Rouge River
CONTRACTOR [illegible] (Geo.)
REPORT NO 71 DATE 7-10-65

Name and Location of Concrete Proportioning Plant: Cooper Supply Co. Miller Rd. Plant-Det.
Source of Cement: Peerless Type 1A Silo # _____ Car # _____ Truck # _____
Source of Aggregate: Fine Amer. Agg. Grosse Isle B.C. Levy Co. Trenton 65
Plan Volume of Pour 236.0 Cu. Yds. Grade A(6AA) Chart No. 65W-177 Consistency: ☐ Medium ☐ Dry

PROPORTIONS

Time of Test	Wt. per cu. ft. Bone Dry Coarse Aggregate, Lbs.	Quantities per sack of Cement from chart: Sand, Pounds	Coarse Aggregate, Pounds	Water, Pounds	Moisture Percent: Coarse Aggregate	Total Computed Mix: Cement, Sacks	Sand, Pounds	Coarse Aggregate, Pounds	Water, Pounds	Computed Water to be added at mixer, gallons	Actual water added at mixer, gallons	Relative Water Content	Slump-inches	Estimated sacks of cement per cu. yd. of concrete
8:30 A.M.	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.25	1½	7.5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		3	
[illegible]	[illegible]	49.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		3	

Weather: A.M. [illegible]
P.M. [illegible]
Pour [illegible]
Time from [illegible] to [illegible]
Number of Test Beams [illegible] Series [illegible]
Date water gauge checked 7-1-65 Result OK
Date batch scale checked 4-[illegible]-65 Result OK
With automatic Controller on scale "Tare" test ok

A	Plan Volume of Pour	236.0 cyds
B	Actual Quantity Placed by Batch Count	239.5 cyds
C	Difference between A & B	3.5 cyds*
D	[illegible]	1.5 %
E	Total Concrete Batched	240.0 cyds
(F)	Excess Ingredients	0.5 cyds*
(G)	Total Cement Batched	450.0 bbls

RECEIVED
JUL 13 1965
DISTRICT 10

By [illegible] FIELD ENGINEER
Remarks

TEMPERATURES

Time	Atmosphere	Water	Fine Aggregate	Coarse Aggregate	Concrete	Housing	Air Content %
7:30 A.M.	[illegible]°	[illegible]°	66°				
[illegible]					5.0°		7.5 (Chace)
[illegible]					[illegible]°		
[illegible]							[illegible] (Chace)
[illegible]							[illegible] (Chace)

Remarks: [illegible] were used to [illegible]

F16

1181-158

1912
12/63

MICHIGAN STATE HIGHWAY DEPARTMENT
OFFICE OF TESTING AND RESEARCH
Lansing, Michigan

I-75 Crossing Scare River

Project BI B01 of 82194G, G1
F. A. No. I-75-1(64)45 Part 1
Series No. G-203 (4 day)
Date 7/4/65

REPORT ON MODULUS OF RUPTURE

Chart No. 65MV-177 Modified
Date Molded 7/10/65
Station No.
Time of Day 3:00 PM
Temperature 81 degrees F.
Grade of Concrete A(6AA)

Concrete used in Girder Pier 39 NB, Pour B & E
Cement Factor 7.5 Sacks per cu. yd.
Slump in 2½
Curing Method of Structure Top: Membrane curing compound ~~Sides: forms left in place~~
Curing Method of Beam Placed under wetted sand
Consistency

Source of
Cement Peerless Type II
Fine Aggregate Amer. Agg. Co. Greencake
Coarse Aggregate E. G. Levy Co. Trenton (6A)A
Coarse Aggregate (7A)

DATE OF TESTS
Beam A 7/14/65
Beam B
Beam C
Beam D

MACHINE NO. 31 JACK NO. 327142

Beam	Test No.	Load Applied Pounds	Modulus of Rupture, Lbs. per sq. in.	Average	Length of Beam Broken Off, In.	Average Temperature	Breadth of Beam	Depth of Beam	FACTOR
A	1	2550	785	780	11½	64°	6 1/8	6 3/16	0.3070
28-days	2	2500	776		12½	64	6 3/16	6 1/8	0.3102
B	1								
7-days	2								
C	1								
14-days	2								
D	1								
14-days	2								
C	1								
28-days	2								
D	1								
28-days	2								

RECEIVED
JUL 20 1965
BY
FIELD TEST NO. D.
DISTRICT 10

REMARKS

[illegible]
Mix Inspector

Tested by J. Ledger F17
Proportioning Plant Inspector

Reported by J. E. Rice
Project Engineer

Repeat [illegible] test results on 14-day or 28-day reports.
Copies: Original to District Materials Supervisor
[illegible] Engineer. (On Bridge Construction This Copy
[illegible] District B[illegible] Engineer.
[illegible] Engineer. (On Road Construction).

NOTE:
[illegible] filled out completely and mailed not later than one day following the [illegible]

I-75 over Range Rd.

(Rev. 12/60)

MICHIGAN STATE HIGHWAY DEPARTMENT
OFFICE OF TESTING AND RESEARCH
Lansing, Michigan

Project BI B01 of 821940, 61
F. A. No. I-75-1(64)43 Part I
Series No. G-203 (10 day)
Date July 20, 1965

REPORT ON MODULUS OF RUPTURE

Chart No. 65 NW-17W Modified
Date Molded July 10, 1965
Station No.
Time of Day 3:00 PM
Temperature 81 degrees F.
Grade of Concrete A(6AA)

Concrete used in Girder, Pr. 39 NB, spans D & E
Cement Factor 7.5 Sacks per cu. yd.
Slump in 2½
Curing Method of Structure Top P Membrane curing compou Sides: forms left in place
Curing Method of Beam Placed under wetted sand
Consistency

Source of Cement Peerless Type II
Fine Aggregate Amer. Agg. Co. - Green Oaks
Coarse Aggregate E. C. Levy - Benton (6A A)
Coarse Aggregate (10A)

DATE OF TESTS
Beam A July 14, 1965
Beam B July 20, 1965
Beam C
Beam D

MACHINE NO. 31 JACK NO. 27142

Beam	Test No.	Load Applied Pounds	Modulus of Rupture, Lbs. per sq. in.	Average	Length of Beam Broken Off. In.	Average Temperature	Breadth of Beam	Depth of Beam	FACTOR
A	1	2550	788	780	11½	64°	6-1/8"	6-3/16"	0.3070
4 7-days	2	2500	776		12½	64°	6-3/16"	6-1/8"	0.3102
B	1	2900	891	913	13 3/4	67°	6-1/4"	6-1/8"	0.3071
10 7-days	2	2950	934		12	67°	6-3/16"	6-1/16"	0.3166
C	1								
14-days	2								
D	1								
14-days	2								
D	1								
28-days	2								
D	1								
28-days	2								

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JUL 22 1965
By
FIELD TESTING DIV.
DISTRICT 10

REMARKS

Sent J. Kelsch
Mix Inspector

Tested by T. Ledger
Proportioning Plant Inspector F18

Reported by
Project Engineer J. E. Mic

Repeat these test results on 14-day or 28-day reports
Copies: Original to District Materials Supervisor
District Engineer. (On Bridge Construction This Copy to District Bridge Engineer).
Construction Engineer. (On Road Construction).
Bridge Engineer. (On Bridge Construction).

NOTE:
Reports to be filled out completely and mailed not later than one day following th

MICHIGAN DEPARTMENT OF
OFFICE OF TESTING AND RESEARCH
Lansing, Michigan

Project M 201 of 82100, St.
F. A. No. I 75-1(66)43 Part 1
Survey No. G-203 (31 sky)
Date 8-10-65

REPORT ON MODULUS OF RUPTURE

Chart No. 65AV-177 Modified
Date Molded 7-10-65
Station No.
Time of Day 3:00 PM
Temperature 81 degrees F
Grade of Concrete [illegible]

Concrete used in Girder, Pier 39 NB, pours B & E
Cement Factor 7.5 Bags per cu. yd.
Slump in 2½
Curing Method of Structure Top: membrane curing compound Sides: forms left in place
Curing Method of Beam Placed under wetted sand

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FIELD TESTING DIV.

Source of Cement Peerless Type II By
Fine Aggregate Amer. Agg. Corp. - Green Oaks
Coarse Aggregate E. C. Levy - Trenton
Coarse Aggregate

DATE OF TESTS
Beam A 7-14-65
Beam B 7-20-65
Beam C 8-10-65
Beam D

MACHINE NO. 21
JACK NO. 27142

Beam	Test No.	Load Applied Pounds	Modulus of Rupture, lbs per sq. in.	Average	Length of Beam Broken Off, In.	Average Temperature	Breadth of Beam	Depth of Beam	FACTOR
A	1	2550	783	780	11¼	64°	6-1/8"	6-3/16"	0.3070
7-days	2	2500	776		12½	64°	6-3/16"	6-1/8"	0.3102
B	1	2900	891	913	13 3/4	67°	6-1/4"	6-1/8"	0.3071
14-days	2	2950	934		12	67°	6-3/16"	6-1/16"	0.3166
C	1								
7-days	2								
D	1								
14-days	2								
E	1	2950	906	906	12 3/4	66°	6-1/4"	6-1/8"	0.3071
28-days	2	2800	905		12½	66°	6-3/16"	6"	0.3232
F	1								
28-days	2								

REMARKS

Witnessed by J. Nelson
Mun Inspector

Tested by J. Fecher
Prestressing Plant Inspector

Reported by J. E. Rice
Project Engineer J. E. Rice

Report Friday test results on 14-day or 28-day reports.
Copies to: District Materials Supervisor
Resident Engineer (On Bridge Construction)
Project Engineer
Construction Engineer (On Road Construction)
Bridge Engineer. (On Bridge Construction)
Return this copy for Project Engineer's file.

Reports to be issued and completely and mailed not later than one day following the test.

1181-159

MICHIGAN STATE HIGHWAY DEPARTMENT

OFFICE OF TESTING AND RESEARCH

BRIDGE CONCRETE PROPORTIONING

PROJ. NO I 96 of 821940, C1

ROUTE I-275 CROSSING Rouge River

CONTRACTOR R. E. Dailey & Co. (Subs Jutton-Kelly

REPORT NO 72 DATE 7-29-65

Name and Location of Concrete Proportioning Plant Cooper Supply Co. - Miller Rd. Plant - Detroit

Source of Cement Penn-Dixie Type II Bin # ____ Car # ____ Truck # ____

Source of Aggregate: Fine Amer. Agg. - Gravesend, N.Y. Coarse R.C. Jarvis - Trenton, MI

Plan Volume of Pour 236.0 Cu. Yds. Grade A(6AA) Chart No. 65MY-17A Mod. Consistency: ☐ Medium ☐ Dry

PROPORTIONS

Time of Test	Wt. per cu. ft. (Bone Dry) Coarse Aggregate, Lbs.	Quantities per sack of Cement from chart: Sand, Pounds	Coarse Aggregate, Pounds	Water, Pounds	Moisture Percent: Sand	Coarse Aggregate	Total Computed Mix: Cement, Sacks	Sand, Pounds	Coarse Aggregate, Pounds	Water, Pounds	Computed Water to be added at mixer, gallons	Actual water added at mixer, gallons	Effective Water Cement Ratio	Slump, Inches	Entrained air, %
8:30 AM	76	158.0	286.0	53.6	4.2	2.2	7.5	1426	2574	402.7	48.7	53.2	1.42	3½	7
3:30 PM	76	158.0	286.0	53.6	5.0	3.5	7.5	1458	2580	380.0	53.6	58.0	1.25	3½	7
9 cyd loads batched in 4½ cyd batches							33.75	5557	6417	1452.1	174.2	158.4		3½	33.
5 cyd loads batched in 4 cyd batches							30.0	4936	5704	1290.8	154.8	140.8		3½	30.
4½ cyd load batched in 1½ cyd batch							11.25	1866	2187	420.0	50.4	42.0		3½	30.
5 cyd load batched in 4 cyd batches							30.0	4576	5632	1120.0	134.4	112.0		3½	30.

Weather: A.M. ____

A.M. & P.M. Partly cloudy & cool

Pours D & E, Pier 39 SB, Girder

Time, from 7:25 AM to 3:30 PM

Number of Test Beams 3 Series A-205

Date water gauge checked 7-1-65 Result OK

Date batch scale checked 4-9-65 Result OK

Auto. Controls Checked 7-1-65 Result OK

(A) Plant Volume of Pour 236.0 cyds.

(B) Actual Quantity Placed by Batch Count 241.5 cyds.

(C) Difference between A & B 5.5 cyds.

(D) Overrun or Underrun (-) C ÷ A 2.3%

(E) Total Concrete for Pour 250.5 cyds.

(F) Excess (E minus B) 9.0 cyds.

(G) Total Cement in Batches 469.7 bbls.

Explain under Remarks

By ____ FIELD TESTING DIV. District 12

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AUG 2 1965

TEMPERATURES

Time	Atmosphere	Water	Fine Aggregate	Coarse Aggregate	Concrete	Housing	Air Content %
8:30 AM		65°	66°	64°			
7:40 AM							6.5 Chace
8:00 AM					74°		
8:50 AM							7.0 Chace
11:30 AM							7.0 Rollam

REMARKS 2-5/8 oz. Darex added per sack of cement. Two Stowe electric vibrators were to vibrate the concrete. Concrete cured by leaving forms in place and top rolled with curing compound. High Early Concrete was used to obtain 70% strength earlier. (F) One 9 yd load rejected because too wet. J. Kibler of J & R took Rollameter air check.

Prepared by J. Clarewski Jr. & J. Kelsch (Asst.) Inspector L. Minier (Asst.) Checked by [signature] Project Engineer J. E. Rice

Reports are to be filled out completely and mailed not later than the day following the cast.

Original to District Materials Supervisor, Copy to Br Constr. Engr., Copy to Dist. Br. Engr., Retain one copy.

MICHIGAN STATE HIGHWAY DEPARTMENT
OFFICE OF TESTING AND RESEARCH
Lansing, Michigan

1181-168

Project [illegible]
F. A. No. I-75-1(64)43 Part I
Series No. G-205 (4 day)
Date August 2, 1965

REPORT ON MODULUS OF RUPTURE

Chart No. 65MV-177 (Modified)
Date Molded July 29, 1965
Station No.
Time of Day 3:00 PM
Temperature 70 degrees F
Grade of Concrete A(6AA)

Concrete used in Girder, Pier 39 [illegible], pours D & E
Cement Factor 7.5 Sacks per cu. y
Slump in 3½
Curing Method of Structure Top: membrane curing compo Sides: forms left in place
Curing Method of Beam Placed under wetted sand
Consistency

Source of Cement Peerless Type II
Fine Aggregate Amer. Agg. Co. - Greenoaks
Coarse Aggregate E.C.Levy - Trenton [illegible] (6AA)
Coarse Aggregate (10A)

DATE OF TESTS
Beam A 8-2-65
Beam B
Beam C
Beam D

MACHINE NO. 31 JACK NO. 32714

Beam	Test No.	Load Applied Pounds	Modulus of Rupture, Lbs. per sq. in.	Average	Length of Beam Broken Off, In.	Average Temperature	Breadth of Beam	Depth of Beam	FACTOR
A	1	2500	816	767	12	67°	6-1/8"	6"	0.3265
[illegible]-days	2	2200	718		13	67°	6-1/8"	6"	0.3265
B	1								
7-days	2								
C	1								
14-days	2								
D	1								
14-days	2								
C	1								
28-days	2								
D	1								
28-days	2								

RECEIVED
AUG 5 1965
By
FIELD TESTING DIV.
DISTRICT 10

REMARKS

Molded by [illegible]
Mix Inspector

Tested by [illegible] Leager
Proportioning Plant Inspector

Reported by [illegible]
Project Engineer [illegible]

Repeat [illegible] test results on 14-day or 28-day reports [illegible] to District Bridge Engineer.
Construction Engineer. (On Road Construction).
Bridge Engineer. (On Bridge Construction).
Retain one copy for Project Engineer's file.

NOTE
Reports to be filled out completely and mailed not later than one day following

DEPARTMENT OF HIGHWAYS
OFFICE OF TESTING AND RESEARCH
Lansing, Michigan

7181-162

S. A. No. I-75-1(64)45 Part 1
Series No. B-205 (7 day)
Date 8-5-65

REPORT ON MODULUS OF RUPTURE

Job No. 65MT-177 (Modified)
Molded 7-29-65
Mix No.
Time Day 3:00 PM
Temperature 70 degrees F.
Type of Concrete AE6Air

Concrete used in Girder, Pier 59 S.B., Power B & M
Cement Factor 7.5 Slump in. 3½
Top: Membrane curing Compound
Curing Method of Structure Sides: Burlap left-in-place
Curing Method of Beam Placed under wetted sand
Consistency

Type of Cement Fearless Type II
Fine Aggregate Amer. Agg. Co. - Greenoaks
Coarse Aggregate McNulty Co. Trenton (#57 & #4A
Coarse Aggregate (10A)

DATE OF TESTS
Beam A 8-2-65
Beam B 8-5-65
Beam C
Beam D

MACHINE NO. 31 JACK NO. 327142

Beam	Test No.	Load Applied Pounds	Modulus of Rupture, Lbs. per sq. in.	Average	Length of Beam Broken Off In.	Average Temperature	Breadth of Beam	Depth of Beam	FACTOR
A 4 days	1	2500	715	707	12	67°	6 1/8	6	0.3265
	2	2200	718		13	67°	6 1/8	6	0.3265
B 7 days	1	2350	783	784	12½	67°	6	6	0.3333
	2	2400	784		10½	67°	6	6 1/16	0.3265
C 14 days	1								
	2								
C 14 days	1								
	2								
C days	1								
	2								
E days	1								
	2								

RECEIVED
AUG 10 1965
By
FIELD TESTING DIV.
DISTRICT 10

REMARKS

Inspected by W. Nelson
Main Inspector

Tested by T. Ledger
Prestressing Plant Inspector

Reported by J. E. Rice
Project Engineer

Report follow test results on 14-day or 28-day reports.
Copies: Original to District Materials Supervisor
District Engineer. (On Bridge Construction This Copy to District Bridge Engineer)
Construction Engineer. (On Road Construction
Bridge Engineer. (On Bridge Construction
Retain one copy for Project Engineer's file.

NOTE:
Reports to be filled out completely and mailed not later than one day following the

P22

1131-164

MICHIGAN STATE HIGHWAY DEPARTMENT
OFFICE OF TESTING AND RESEARCH
Lansing, Michigan

Project: BI B01 of [illegible]
F. A. No. I-75-1(65)4[illegible] Part [illegible]
Series No. G-205 (28 day)
Date 8-26-65

REPORT ON MODULUS OF RUPTURE

Chart No. 65MV-177 (Modified)
Date Molded 7-29-65
Station No.
Time of Day 3:00 PM
Temperature 70 degrees F.
Grade of Concrete A(6AA)

Concrete used in Girder, Pr. 39 SB, pours B & [illegible]
Cement Factor 7.5 Sacks per [illegible]
Slump in 3½
Curing Method of Structure Top: membrane curing [illegible] Sides: forms left in [illegible]
Curing Method of Beam Covered with wet sand [illegible]
Consistency

Source of Cement Peerless Type II
Fine Aggregate Amer. Agg. Co. - Greenoaks
Coarse Aggregate [illegible] MA
Coarse Aggregate R. C. Levy - [illegible]

DATE OF TESTS
Beam A 8-2-65
Beam B 8-5-65
Beam C 8-26-65
Beam D

MACHINE NO. 1 JACK NO. 327142

Beam	Test No.	Load Applied Pounds	Modulus of Rupture Lbs. per sq. in.	Average	Length of Beam Broken Off. In.	Average Temperature	Breadth of Beam	Depth of Beam	FACTOR
	1	2500	[illegible]		12	[illegible]	6-1/8"	6"	0.3265
	2	2[illegible]00	[illegible]		12	67°	6-1/8"	6"	0.3265
	1	2350	789		12½	67°	6"	6"	0.3133
7-days	2	2400	784	784	10½	67°	6"	6-1/16"	0.3265
C	1								
14-days	2								
D	1								
[illegible]-days	2								
[illegible]	1	3000	[illegible]		12		6-1/8"	6-1/8"	0.3133
[illegible]	2	2400	[illegible]		12		6"	6-1/8"	0.3199
28-days	2								

RECEIVED

REMARKS

By [illegible] F23

Tested by A. [illegible] Inspector

Reported by [illegible]
Project Engineer [illegible]

S. E. MacDougall
A. A. Nordgren
A. Sinelli
. Vracan
J. Rice
File

Form 187 (Rev. 10-64)

MICHIGAN STATE HIGHWAY DEPARTMENT
OFFICE OF TESTING & RESEARCH
Lansing, Michigan

Project RI 801 of 82194G, C1

F.A. No. I-75-1 (64) 43 Part 1

Date 7-29-65 Report No. 200

REPORT OF CONCRETE INSPECTION

Length _____ Miles. Width _____
Cross section _____ Reinforcement steel bars
Location of [redacted] bridge site Fisher Expressway over Rouge River

Contractor Jutton - Kelly Company
Project Engineer J. Rice
Plant Inspector L. Minier
Mix Inspector J. Kelch

EQUIPMENT

Transit Mix Supplier Cooper Supply Company
Address Miller Road - Detroit
Mixers _____
Proportioning Plant _____
Finishing Machine _____
Longitudinal Float _____
Transportation _____
Vibrator _____

Batch Scales Checked (date) 4-9-65
Water Gauge Checked (date) 4-7-65
Mixer Performance Satisfactory
Condition of Finish Satisfactory
Curing Method forms & wetted burlap Condition Satisfactory
Brand Name --- Lot No. ---
Condition of Stockpiles Satisfactory
Load Transfer Device Mfg. ---

MATERIALS

Cement Peerless - Brennan Street Type _____
Fine Agg. American Agg. (47-3) Spec. _____
Coarse Agg. Levy Slag (Trenton) Spec. _____
Coarse Agg. _____ Spec. _____
Grade of Concrete A High-Early-Strength

Mixture Proportions

Mix Design No. 65 MV-177 Modified
Wt. per cu. ft. of loose C.A. (bone dry) 74

Material	Quantity Per Sack of Cement lb.	Moisture Content of Agg. %	Computed Batch, lb.
FA (2NS)	158.0	4.1	1234
CA (6AA)	186.0	2.2	1426
CA ( )			
Cement	94	7.5 sacks per batch	705
Water	53.6		38.7

Water actually used in mix 34.0
Slump 3 in. [redacted] Mixer [illegible]

Pour D and E of Pier 39 Southbound Girder
Average Air Content 7.0 % A.E. Additive Darex 2 5/8 oz. per [illegible]
Location of Test _____

Average Air Content _____ % A.E. Additive _____ oz. per [illegible]
Location of Test _____

Field Test Result _____ at _____ % air. Last [redacted] overrun 0.7 % date 6-26-65
Temperature Air 68 °F Concrete 84 °F Time of Test 11:30 A.M.
REMARKS _____

84

[illegible]
[illegible]
Assistant District
Materials Supervisor

[illegible]
Testing and Research Engineer

[illegible] Date 8-9-65 Proof read by _____

DAILY TEMPERATURES

Station		Day of Month 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Average
SOUTH HAVEN EXP FARM	MAX	74	72	73	69	72	73	75	74	78	75	59	67	63		78	76	62	76	64	77		77	67	83	79	80	74	53	51	60	75	71.5
	MIN	45	48	58	42	50	59	[illegible]	56	62	54	46	48	43		60	54	44	42	46	41		51	47	55	65	58	51	43	42	38	48	50.3
* * *																																	
SOUTH CENTRAL LOWER 09																																	
BATTLE CREEK WBCK	MAX	82	84	81	87	70	73	83	84	83	76	65	76	71	78	74	77	57	81	71	72	81	76	64	77	83	81	68	55	57	65	77	73.8
	MIN	48	53	60	50	48	56	59	60	64	53	46	46	45	43	56	53	48	42	49	45	44	62	48	51	64	60	47	38	39	34	44	50.2
CHARLOTTE	MAX	81	85	82	78	71	75	85	85	85	79	67	78	74	79	76	78	63	84	77	72	84	80	73	77	85	82	69	57	59	68	77	76.3
	MIN	45	44	59	50	47	53	53	57	60	60	45	39	38	49	51	63	48	36	45	42	40	59	50	50	62	59	55	35	42	31	39	48.6
COLDWATER STATE SCHOOL	MAX	83	82	81	69	68	79	84	84	82	77	65	76	71	78	77	78	58	81	72	71	82	79	64	79	85	82	69	62	57	66	76	74.6
	MIN	48	56	61	50	48	55	57	58	62	53	47	47	45	44	55	54	44	43	49	46	45	61	54	53	63	62	48	40	39	36	44	50.5
EAST LANSING HORT FARM	MAX	76	83	82	81	70	76	85	85	85	81	72	78	76	78	79	79	78	82	82	70	81	81	73	76	84	81	73	64	56	66	74	77.0
	MIN	44	45	50	49	46	53	55	61	64	63	50	44	42	40	50	64	49	38	52	43	42	64	49	51	60	64	63	39	40	34	39	50.2
HASTINGS FISHERIES	MAX	81	84	82	73	74	79	88	85	84	76	65	78	75	81	80	77	59	85	73	76	85	83	78	80	85	81	72	54	58	69	78	76.6
	MIN	50	47	62	50	44	56	57	60	65	64	50	46	38	44	56	51	48	38	48	39	46	61	49	53	65	62	46	39	38	31	38	49.6
HILLSDALE	MAX	82	83	81	70	68	73	83	83	82	76	65	76	74	78	77	78	66	81	75	73	82	81	70	78	85	86	68	63	56	67	75	75.3
	MIN	47	57	60	54	48	54	57	59	61	61	45	45	44	43	51	61	51	41	50	43	42	63	48	52	61	60	53	37	36	36	41	50.4
IONIA 5 NW	MAX	78	82	80	75	71	77	87	80	80	78	68	66	72	76	74	74	59	81	72	71	82	82	74	76	83	79	72	50	56	64	72	73.9
	MIN	47	45	60	49	41	54	57	60	60	60	49	34	47	42	53	59	44	39	47	42	42	60	41	52	64	61	50	37	35	32	39	48.5
JACKSON FAA AIRPORT	MAX	82	84	82	69	66	75	84	84	83	77	64	76	70	75	78	79	56	81	70	72	82	75	63	78	83	82	70	60	55	66	74	73.9
	MIN	47	51	62	50	47	55	57	62	65	52	46	44	41	43	52	56	46	40	47	44	41	58	52	53	62	64	48	37	37	37	43	49.6
LANSING WB AIRPORT	MAX	80	84	84	64	71	77	85	85	86	77	64	79	68	77	76	79	58	83	72	73	78	75	58	78	86	76	69	49	57	68	74	73.7
	MIN	43	42	60	47	46	55	52	63	66	54	47	43	39	44	54	55	42	39	50	40	46	56	48	53	63	65	48	40	39	31	37	48.6
OWOSSO SEWAGE PLANT	MAX	70	79	80	68	69	75	84	83	83	77	65	77	67	74	76	77	64	78	69	70	79	73	64	76	85	81	68	55	56	65	71	72.8
	MIN	43	43	61	45	42	55	56	65	64	60	51	43	37	42	54	64	46	39	51	41	39	61	47	51	59	63	52	40	40	35	40	49.3
SAINT JOHNS	MAX	74	84	82	81	70	77	85	87	84	81	70	78	78	78	78	78	67	81	82	72	81	81	73	76	86	85	76	64	65	67	74	76.9
	MIN	45	45	61	46	43	45	55	62	64	63	51	46	40	41	55	64	45	41	50	40	44	62	45	51	62	63	58	40	39	36	39	99.7
THREE RIVERS	MAX	85	84	83	82	69	72	84	85	84	78	69	78	76	80	80	78	66	83	77	75	84	84	80	81	84	80	70	59	58	68	79	77.3
	MIN	49	54	59	96	52	59	55	60	65	62	46	43	48	45	59	65	51	41	51	42	41	62	54	55	65	61	51	37	37	35	44	51.7
* * *																																	
SOUTHEAST LOWER 10																																	
ADRIAN 2 NNE	MAX	78	84	82	67	67	73	83	86	86	77	65	77	73	77	82	83	82	64	74	71	83	82	62	75	86	85	70	67	56	68	77	75.3
	MIN	44	52	57	48	46	51	60	57	62	55	47	46	44	39	46	63	47	40	49	44	40	55	51	56	59	63	50	40	38	42	46	49.5
ANN ARBOR UNIV OF MICH	MAX	81	78	85	85	86	77	86	86	86	78	71	76	75	76	80	81	75	81	80	70	81	81	72	75	84	82	68	65	52	63	74	76.3
	MIN	51	45	43	48	46	54	60	61	66	65	48	48	46	46	52	62	53	46	55	46	46	64	48	51	58	64	64	41	40	46	48	51.9
DEARBORN	MAX	81		84	82	65	74	87	87	86	83	76	79	79	72	85		84	85	77	72	84	82		74	87	86	77	70				79.6
	MIN	47		59	47	45	54	58	56	65	64	49	49	45	41	48		54	48	43	47	42	63		49	56	61	62	29				51.6
DETROIT WBAP CITY	MAX	70	79	86	58	67	73	81	86	86	80	68	81	70	73	84	85	66	77	74	73	81	75	62	72	85	84	73	66	54	67	71	74.6
	MIN	44	50	57	46	45	52	57	57	68	60	52	51	45	46	54	65	52	46	58	48	45	54	49	53	58	66	50	44	42	45	47	81.7
DETROIT WBAP M WAYNE C	MAX	71	80	84	68	65	75	79	86	85	79	70	79	72	73	85	85	65	75	74	73	82	78	62	76	88	86	73	68	56	70	74	75.4
	MIN	43	48	58	46	46	53	56	54	62	58	47	44	44	43	48	62	48	41	50	47	43	53	50	54	57	62	51	41	38	42	42	49.4
DETROIT WBAP WILLOW RN	MAX	68	83	81	64	64	74	82	83	82	76	65	76	69	71	82	81	82	76	71	71	81	75	59	75	84	83	71	65	53	66	76	73.1
	MIN	40	44	51	47	45	51	56	53	61	56	45	43	43	39	43	61	50	38	49	42	35	49	45	50	56	61	50	40	37	41	42	47.3
FLINT WB AIRPORT	MAX	73	82	83	60	71	78	86	85	84	78	66	77	68	74	81	79	60	77	71	71	80	73	62	77	88	84	70	60	57	68	73	74.1
	MIN	44	46	57	48	48	56	60	63	64	55	48	43	40	41	53	56	47	39	49	42	40	52	49	52	60	64	50	40	39	37	40	49.1
GROSSE POINTE FARMS	MAX	58	60	84	83	59	63	66	84	85	84	76	77	78	66	82	83	83	72	72	68	75	79	66	65	80	85	76	74	66	69	69	73.9
	MIN	42	46	59	45	43	48	51	52	63	60	49	46	43		52	61	55	45	57	48	48	61	50	51	55	62	64	46	41	43	46	50.8
LAPEER	MAX	70	78	83	78	70	71	80	84	84	78	75	77	77	73	82	79	61	80	80	75	81	81	69	75	88	85	71	64	54	67	73	75.6
	MIN	41	45	55	45	49	51	56	59	64	62	48	44	43	38	51	51	46	37	54	40	48	59	46	47	57	53	64	41	39	37	42	49.0
MILFORD GM PROVING GRN	MAX	69	81	81	66	67	76	82	83	82	79	63	75	68	72	77	76	55	75	68	68	78	70	57	73	82	78	67	57	51	61	70	71.1
	MIN	45	47	60	46	47	53	57	62	65	53	45	44	42	44	53	55	43	38	48	44	44	51	49	51	57	62	47	38	38	38	39	48.5
MONROE SEWAGE PLANT	MAX	72	68	83	84	58	70	73	86	88	80	78	75	77	68	85	87	84	67	73	71	73	81	71	65	87	89	75	72	65	63	70	75.4
	MIN	43	50	57	47	47	50	53	57	62	64	48	49	47	45	55	64	56	48	59	50	45	62	52	55	58	64	65	45	39	48	48	52.6
MOUNT CLEMENS AF BASE	MAX	63	64	83	64	61	66	68	85	84	77	63	76	64	68	80	80	61	69	70	68	77	69	57	69	83	83	71	63	51	66	68	69.7
	MIN	40	45	49	43	45	48	51	51	61	56	48	41	40	37	50	59	45	39	49	42	39	45	42	48	53	65	50	41	39	43	44	46.7
PONTIAC STATE HOSPITAL	MAX	67	79	83	82	68	74	80	85	84	79	75	77	76	72	81	80	75	76	76	72	80	80	70	75	83	82	71	68	56	68		75.8
	MIN	43	46	58	45	47	50	56	55	65	64	48	45	44	44	48	63	50	42	56	45	44	61	48	49	56	63	64	42	40	41		50.7
PORT HURON SEWAGE PL	MAX	62	71	85	84	61	69	75	86	85	78	80	77	77	73	83	83	81	75	75	64	81	81	56	71	84	85	73	72	60	67	67	74.9
	MIN	38	40	57	39	40	48	47	52	60	58	49	46	42	39	49	59	48	43	50	43	44	52	45	46	52	54	64	44	41	42	49	48.1
WILLIS 5 SSW	MAX	69	35	83	64	64	78	84	85	85	77	66	76	72	73	85	82	61	77	73	70	82	78	61	73	86	84	70	66	55	67	75	74.4
	MIN	41	47	57	48	45	50	58	62	64	60	47	44	44	38	45	61	54	39	52	45	39	52	48	52	57	62	52	42	37	41	42	49.2

p. 37 SB

p. 37 NB

p. 38 NB

9 MAXIMUM AND MINIMUM TEMPERATURES ARE THE HIGHEST AND LOWEST HOURLY READINGS FOR EACH DAY.

From CLIMATOLOGICAL DATA 1965
US Dpt of Commerce
Weather Bureau

DAILY TEMPERATURES

Continued

Station		Day of Month 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Average
SOUTH HAVEN EXP FARM	MAX	80	78	70	76	86	84	76	78	69	66	68	71	70	65	74	70	67	63	78	83	75	86	84	70	72	81	90	87	80	65		75.4
	MIN	57	58	45	49	54	61	59	61	56	59	49	50	44	50	48	49	49	44	50	65	57	58	63	51	50	53	66	69	61	58		54.8
* * *																																	
SOUTH CENTRAL LOWER 09																																	
BATTLE CREEK WBCK	MAX	81	65	67	72	79	84	74	83	78	79	79	81	71	69	70	70	73	76	81	85	77	88	80	74	75	81	91	91	85	73		77.7
	MIN	59	49	42	43	49	66	62	59	59	58	50	52	45	48	48	48	51	50	51	61	53	52	63	51	49	49	63	69	58	55		55.7
CHARLOTTE	MAX	83	67	67	73	78	85	76	85	78	79	81	84	79	69	70	70	73	78	84	87	81	90	86	75	75	81	90	92	83	75		79.1
	MIN	54	52	40	45	47	64	62	57	56	51	50	45	40	47	46	47	50	44	44	52	61	45	64	45	46	50	57	72	55	52		51.3
COLDWATER STATE SCHOOL	MAX	82	67	66	72	82	85	74	84	79	82	81	83	72	71	72	74	74	80	83	86	79	90	84	76	75	83	90	93	85	74		79.3
	MIN	57	49	43	47	50	65	60	57	59	52	47	47	43	46	46	48	50	44	50	56	51	49	65	50	48	49	62	68	58	54		52.3
EAST LANSING HORT FARM	MAX	82	79	66	71	76	84	79	82	76	77	79	84	80	70	70	69	71	77	82	80	85	89	86	75	74	82	89	88	87	74		78.8
	MIN	54	53	40	44	47	65	63	59	59	57	48	53	46	48	45	48	51	50	52		63	48	66	51	51	49	61	74	61	57		53.9
HASTINGS FISHERIES	MAX	84	66	70	75	78	85	77	82	79	79	80	83	75	74	73	72	75	80	83	87	77	89	85	76	76	81	90	90	84	76		79.4
	MIN	54	57	40	43	50	66	62	60	58	57	47	46	40	46	44	46	47	46	47	59	61	50	63	48	46	49	60	74	60	54		52.7
HILLSDALE	MAX	81	67	69	73	81	85	73	83	78	81	81	82	75	71	73	74	73	76	82	85	80	90	84	74	76	82	89	89	84	74		78.8
	MIN	41	55	42	45	50	65	61	56	61	56	49	47	40	44	44	47	49	43	45	53	60	46	65	48	45	40	60	70	60	53		51.3
IONIA 9 NW	MAX	81	64	68	73	78	85	80	82	76	78	80	83	74	72	69	66	74	80	82	87	78	86	76	76	76	79	89	88	82	75		77.9
	MIN	50	52	41	43	49	61	62	58	60	59	49	53	39	47	46	45	47	50	52	60	60	49	67	47	49	52	59	76	57	54		53.1
JACKSON PAA AIRPORT	MAX	81	66	67	71	78	85	73	84	78	77	79	80	70	70	71	72	70	74	80	85	77	88	84	74	75	81	92	93	87	75		77.9
	MIN	57	48	40	47	51	67	60	60	61	56	48	47	42	44	44	47	50	47	51	59	52	48	64	49	46	49	59	69	59	53		52.5
LANSING WB AIRPORT	MAX	83	69	68	73	76	85	74	82	77	76	81	85	73	71	72	70	73	79	84	90	79	88	82	74	76	82	91	93	83	76		78.6
	MIN	55	46	39	42	52	67	63	62	58	55	46	47	42	45	43	47	49	46	47	55	53	50	58	48	49	49	62	71	56	49		51.7
OWOSSO SEWAGE PLANT	MAX	81	62	66	70	77	84	72	82	76	76	79	81	68	68	69	62	70	75	83	85	77	85	77	71	72	79	89	90	81	72		76.0
	MIN	50	52	36	41	49	64	64	60	60	56	48	51	42	44	43	47	49	47	49	58	63	51	67	50	48	46	64	75	59	54		52.9
SAINT JOHNS	MAX	82	83	67	72	78	87	79	82	79	77	80	83	79	72	70	69	72	78	83	87	78	86	88	77	76	80	89	91	91	79		79.8
	MIN	51	52	40	43	49	63	63	61	61	56	51	53	42	45	45	46	48	48	53	60	58	54	66	51	48	48	63	74	61	54		53.6
THREE RIVERS	MAX	83	71	68	75	84	85	74	86	80	83	82	83	79	74	74	73	76	78	84	87	85	90	88	77	77	84	90	91	82	75		80.6
	MIN	55	56	46	48	48	68	63	57	59	55	48	46	46	49	48	49	50	46	45	57	65	49	66	52	51	47	61	68	61	54		53.6
* * *																																	
SOUTHEAST LOWER 10																																	
ADRIAN 2 NNE	MAX	83	70	64	70	82	90	74	85	81	82	83	85	73	70	72	74	74	78	84	89	83	90	85	75	74	79	92	92	87	74		79.8
	MIN	54	51	46	47	46	60	60	54	63	60	51	53	44	46	51	52	52	48	51	58	55	48	65	54	47	47	56	67	62	51		55.3
ANN ARBOR UNIV OF MICH	MAX	82	79	65	72	80	89	73	84	83	78	81	84	81	68	68	72	70	76	81	87	87	89	86	84	75	81	91	92	90	75		80.1
	MIN	56	54	46	48	53	63	64	59	64	62	51	58	48	40	49	52	51	52	56	64	66	56	68	56	52	53	63	72	66	57		56.6
DEARBORN	MAX	82	82	66	70	79		83	78	77	75			80		67	68	67	79	80		81	85	83	77	69	79		87	83	81		77.4
	MIN		54	43	41	41		64	60	64	61				43		51	50	50	54		61	52	66	54	49	46		56	66	57		53.8
DETROIT WBAP CITY	MAX	84	66	67	69	79	87	75	81	80	80	79	85	71	66	72	73	72	79	85	86	81	85	86	73	75	80	90	92	88	76		78.8
	MIN	58	49	45	48	53	65	66	63	65	60	52	54	48	48	51	54	52	54	56	64	66	55	67	55	50	54	63	71	64	55		56.8
DETROIT WBAP M WAYNE C	MAX	82	68	67	72	78	89	75	82	80	80	81	86	73	69	74	74	73	81	85	90	84	88	87	77	75	83	92	94	90	76		80.2
	MIN	55	50	44	45	50	62	62	57	62	57	51	53	45	50	51	54	50	47	51	55	56	45	65	51	46	49	56	68	61	55		53.4
DETROIT WBAP WILLOW RN	MAX	80	66	65	70	76	89	72	82	78	78	78	83	70	66	71	73	71	78	83	89	81	88	85	76	75	80	91	93	87	76		78.3
	MIN	51	45	40	39	45	60	59	57	62	55	47	51	43	45	46	51	49	48	51	58	58	47	61	52	46	44	53	67	61	48		51.3
FLINT WB AIRPORT	MAX	83	64	67	72	80	88	73	84	76	77	80	84	70	70	71	71	73	78	85	88	79	88	83	74	75	80	90	94	86	76		78.6
	MIN	54	48	40	40	50	64	60	59	58	53	48	50	43	45	47	51	50	45	49	56	56	50	59	51	47	45	63	72	60	50		52.1
GROSSE POINTE FARMS	MAX	81	87	63	64	76	89	87	83	83	77	78	85	85	66	69	72	71	77	84	88	88	86	87	85	73	75	91	94	93	88		80.8
	MIN	55	54	48	47	54	61	62	60	63	58	55	57	45	46	52	53	49	50	53	60	65	54	62	52	50	50	62	69	65	57		55.6
LAPEER	MAX	82	72	65	70	80	89	86	83	83	76	79	82	77	68	68	66	70	78	84	88	85	87	86	75	75	79	90	92	89	76		79.3
	MIN	52	55	39	40	45	60	64	57	60	56	45	49	42	42	43	47	46	43	46	55	64	48	65	48	42	42	59	73	62	53		51.4
MILFORD GM PROVING GRN	MAX	79	60	63	67	72	83	70	80	74	74	78	81	67	65	68	68	69	76	81	83	78	85	81	71	72	78	88	90	84	72		75.2
	MIN	53	45	40	44	51	64	61	59	59	55	51	52	44	46	45	49	49	49	52	56	60	49	61	52	47	52	63	69	61	51		53.0
MONROE SEWAGE PLANT	MAX	80	82	60	63	73	86	86	82	83	82	83	86	86	70	66	68	70	78	85	90	90	83	86	87	74	73	88	94	95	90		80.6
	MIN	60	58	45	49	53	64	64	60	63	63	54	59	48	50	53	56	53	52	56	58	66	53	68	60	52	53	65	68	67	59		57.6
MOUNT CLEMENS AF BASE	MAX	81	61	63	65	73	84	74	78	74	72	75	82	66	62	68	70	69	76	81	87	78	83	84	69	71	78	87	92	85	73		75.4
	MIN	56	46	41	40	44	61	61	57	61	50	46	47	42	43	46	51	48	47	52	56	55	52	62	48	46	46	61	71	63	54		51.6
PONTIAC STATE HOSPITAL	MAX	82	81	68	69	77	87	80	82	81	78	80	83	80	67	69	71	71	77	84	86	84	87	87	75	75	80	90	92	87	79		79.8
	MIN	54	52	44	44	49	63	63	60	62	57	50	55	46	45	49	50	49	51	54	60	65	53	65	52	49	50	57	70	64	57		54.6
PORT HURON SEWAGE PL	MAX	76	62	59	69	81	89	88	82	81	78	77	82	60	56	63	62	66	71	84	88	88	86	85	81	68	77	89	93	93	67		76.6
	MIN	51	49	45	45	48	63	63	55	64	56	50	56	46	48	49	53	52	49	54	59	62	55	67	54	49	50	60	72	66	57		54.9
WILLIS 5 SSW	MAX	81	67	64	69	78	89	74	84	80	80	82	84	73	68	71	74	74	79	83	88	82	89	86	75	73	77	91	91	87	76		79.0
	MIN	56	52	43	46	46	60	63	55	61	57	49	50	41	48	49	54	51	46	47	53	59	45	61	51	46	47	56	67	60	55		52.4

9 MAXIMUM AND MINIMUM TEMPERATURES ARE THE HIGHEST AND LOWEST HOURLY READINGS FOR EACH DAY.

Continued

DAILY TEMPERATURES

MICHIGAN
JULY 1958

Station		Day of Month 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
SOUTH HAVEN EXP FARM	MAX	76	77	75	80	78	81	79	81	79	76	78	79	84	82	74	78	76	75	76	78	77	84	89	85	76	75	77	76	74	73	70	
	MIN	47	62	57	57	62	50	63	63	69	54	53	57	65	68	64	58	64	59	56	52	51	69	72	71	61	65	66	54	49	49	62	
* * *																																	
SOUTH CENTRAL LOWER 09																																	
BATTLE CREEK WBCK	MAX	77	80	76	84	80	78	70	84	81	79	82	85	90	85	80	83	83	80	76	78	84	90	96	90	83	86	83	76	71	78	79	
	MIN	47	57	58	51	61	54	61	60	63	54	57	55	59	64	59	53	58	59	57	48	48	62	70	67	60	62	63	53	50	46	62	
CHARLOTTE	MAX	78	84	80	86	80	78	74	87	84	81	84	89	93	89	83	85	81	83	77	78	85	93	96	93	89	89	87	80	74	79	80	
	MIN	41	51	53	46	58	47	60	56	63	48	54	50	57	67	48	46	53	51	55	43	42	61	60	71	52	52	60	44	40	40	52	
COLDWATER STATE SCHOOL	MAX	77	78	77	83	83	79	73	85	81	78	80	84	90	84	81	83	84	81	75	75	83	89	93	91	83	84	83	77	73	77	79	
	MIN	43	52	54	50	55	50	61	60	62	54	55	55	58	61	57	49	58	61	56	48	46	61	69	65	59	60	62	50	49	43	60	
EAST LANSING HORT FARM	MAX	78	80	80	83	81	79	78	86	86	80	80	86	91	90	84	81	81	79	77	76	82	89	92	91	89	85	81	80	71	77	79	
	MIN	41	54	59	49	61		61	59	64	50	58	52	62	70	58	51	57	57	56	43	46	64	65	69	60	56	64	53	50	43	61	
HASTINGS FISHERIES	MAX	79	82	77	84	83	79	75	85	84	80	83	88	91	90	80	82	86	82	80	81	87	89	96	95	86	86	83	81	76	83	81	
	MIN	44	55	57	50	63	53	60	62	67	49	53	53	63	69	56	53	57	57	55	45	48	65	64	68	57	55	63	49	47	44	60	
HILLSDALE	MAX	78	75	77	80	83	77	72	85	80	78	81	84	88	84	80	82	85	80	76	75	82	87	92	94	82	83	82	76	73	77	77	
	MIN	46	46	57	48	56	46	60	59	58	51	52	53	58	68	53	47	56	61	55	43	44	60	68	67	56	57	64	45	45	44	58	
IONIA 5 NW	MAX	78	75	76	82	77	79	76	87	82	79	82	88	90	86	78	79	77	79	75	75	84	88	94	90	83	83	82	78	79	80	79	
	MIN	41	60	60	56	52	45	59	57	71	45	51	50	69	74	51	56	53	53	52	43	43	75	61	65	57	54	66	49	47	41	58	
JACKSON FAA AIRPORT	MAX	79	77	78	84	81	77	72	85	83	79	82	84	89	85	80	83	82	80	76	76	82	91	93	92	82	83	84	75	72	77	82	
	MIN	43	54	58	53	57	51	60	60	61	53	56	56	64	61	56	50	57	60	56	45	45	64	66	69	59	60	59	50	47	45	60	
LANSING WB AIRPORT	MAX	80	82	82	85	76	80	73	87	87	80	82	87	94	87	82	83	79	81	77	78	84	92	94	92	85	87	85	77	73	78	80	
	MIN	40	59	55	48	58	46	61	57	59	46	56	51	65	60	53	54	60	57	56	39	44	66	60	67	55	53	56	49	45	41	63	
OWOSSO SEWAGE PLANT	MAX	77	77	78	84	74	78	74	86	85	78	79	85	90	85	78	80	75	78	72	75	81	88	88	90	84	84	82	81	68	75	77	
	MIN	41	58	58	51	62	45	60	58	67	57	54	52	64	71	55	55	57	54	50	40	48	65	61	69	56	53	58	50	47	44	61	
SAINT JOHNS	MAX	79	80	79	85	85	79	79	86	87	84	81	86	91	93	85	80	80	80	79	77	90	94	93	91	86	85	85	83	73	79	79	
	MIN	43	57	57	50	62	46	60	59	67	49	54	53	65	69	55	57	55	56	51	42	45	62	69	57	55	59	58	53	48	43	62	
THREE RIVERS	MAX	78	80	80	83	82	79	77	85	84	79	82	85	89	87	80	84	83	82	79	76	81	89	92	92	82	84	82	79	77	80	78	
	MIN	46	56	59	51	58	54	63	60	66	55	59	53	60	69	55	50	59	61	56	49	47	63	70	69	59	58	65	54	50	46	62	
* * *																																	
SOUTHEAST LOWER 10																																	
ADRIAN 2 NNE	MAX	79	76	81	82	83	75	73	86	83	83	82	82	89	83	81	84	81	81	74	74	81	88	93	94	83	84	84	78	71	78	80	
	MIN	42	50	57	57	57	48	62	59	65	55	54	53	55	64	54	52	59	59	52	44	45	57	68	69	60	58	59	52	50	46	53	
ANN ARBOR UNIV OF MICH	MAX	78	77	78	81	80	79	73	85	85	83	84	86	90	90	86	83	82	79	79	72	78	87	90	88	81	81	78	82	70	77	78	
	MIN	49	55	62	58	63	50	61	61	66	56	61	60	62	72	61	60	62	60	57	48	50	60	66	68	59	61	54	56	49	49	58	
DEARBORN	MAX	76	75				77	74	84	85	80		80	85	85	82	78	78		73	68	73	88	89	95	83	85	86	85	71	76	80	
	MIN	45	53				46	62	60	67	56		56	58	56	57	62	62		57	46	50	59	66	52	62	62	67	57	53	49	57	
DETROIT WBAP CITY	MAX	78	79	82	81	80	75	74	86	86	78	77	82	88	86	78	84	77	80	71	73	79	87	85	95	85	81	86	78	71	76	78	
	MIN	47	60	64	59	57	50	64	62	69	60	61	58	61	70	59	61	64	63	57	50	55	63	68	70	63	62	65	59	57	51	59	
DETROIT WBAP M WAYNE C	MAX	78	80	84	82	84	78	74	86	86	80	80	81	90	85	82	84	79	79	71	72	79	91	90	96	85	83	85	78	72	78	80	
	MIN	41	50	59	54	56	50	61	58	67	58	56	55	56	65	54	54	58	63	55	48	51	58	69	68	62	61	63	54	50	49	58	
DETROIT WBAP WILLOW RN	MAX	77	79	81	82	83	76	71	84	84	78	80	80	88	84	81	85	80	80	71	72	78	88	90	93	83	82	83	77	70	76	80	
	MIN	42	52	59	51	51	43	61	56	64	53	54	52	56	64	53	54	58	58	51	44	46	56	66	66	61	59	62	54	50	46	54	
FLINT WB AIRPORT	MAX	79	81	80	84	77	78	76	86	87	78	82	86	93	88	81	82	76	80	75	75	82	89	90	93	88	86	85	78	66	76	78	
	MIN	40	55	60	52	53	45	61	59	60	51	56	53	65	64	55	53	59	57	50	41	50	66	63	69	56	58	57	50	48	44	56	
GROSSE POINTE FARMS	MAX	74	79	83	82	82	72	74	81	86	85	76	78	87	87	83	84	81	76	77	69	74	83	81	94	82	80	84	83	71	71	79	
	MIN	48	59	60	57	62	49	62	60	66	51	59	52	59	72	52	58	61	61	56	50	53	62	65	70	60	63	64	55	54	49	59	
LAPEER	MAX	79	79	79	84	82	78	75	84	84	81	79	85	92	90	86	80	79	78	76	74	82	89	89	90	90	85	84	78	67	75	79	
	MIN	36	54	58	58	60	41	59	58	65	49	53	50	65	72	53	50	55	57	44	37	44	59	59	71	54	53	54	50	49	40	50	
MILFORD GM PROVING GRN	MAX	76	76	75	79	75	75	70	82	83	76	80	81	88	84	77	80	75	75	70	71	77	87	87	86	81	81	81	74	64	74	74	
	MIN	42	60	60	53	54	47	60	59	63	54	59	56	65	63	55	54	59	59	51	46	49	64	64	66	59	59	63	55	50	46	61	
MONROE SEWAGE PLANT	MAX	76	80	82	82	84	73	75	86	87	84	77	79	89	90	82	87	87	79	79	73	77	91	90	97	84	83	85	83	71	75	80	
	MIN	50	60	62	58	62	50	64	60	68	59	58	60	61	70	59	59	61	62	58	50	54	64	70	69	64	61	65	59	52	51	62	
9 MOUNT CLEMENS AF BASE	MAX	73	79	81	82	76	72	73	81	84	75	76	79	88	85	76	83	75	76	69	70	75	83	83	92	82	78	82	73	67	72	77	
	MIN	40	61	60	51	50	45	64	61	62	53	57	51	56	60	55	54	60	59	50	42	46	63	64	65	59	59	57	56	50	46	56	
PONTIAC STATE HOSPITAL	MAX	78	78	80	85	81	77	75	85	85	84	81	82	88	89	86	84	81	79	77	73	78	89	89	94	85	85	85	80	70	77	77	
	MIN	45	58	59	53	63	46	59	59	68	53	58	56	62	72	56	56	61	60	55	46	50	62	65	71	60	59	62	54	52	48	55	
PORT HURON SEWAGE PL	MAX	79	79	80	83	81	77	74	78	84	84	75	79	87	87	83	82	80	71	68	69	77	86	86	94	85	81	82	76	70	70	78	
	MIN	50	55	60	55	59	48	61	62	67	56	58	55	61	72	60	62	62	63	54	48	50	62	65	70	60	64	62	55	55	51	57	
WILLIS 3 SSW	MAX	77	76	80	82	83	75	72	86	83	79	80	81	88	82	81	83	80	79	73	72	77	87	89	93	84	83	82	77	71	78	78	
	MIN	38	46	59	50	54	44	61	57	65	53	53	51	55	62	52	50	56	61	52	43	43	54	65	68	59	55	63	50	46	42	49	

9 MAXIMUM AND MINIMUM TEMPERATURES ARE THE HIGHEST AND LOWEST HOURLY READINGS FOR EACH DAY.

March 18, 1965

American Aggregates Corporation
Brighton, Michigan

Attention: D. D. Steinhiler, Plant Manager

Gentlemen:

Tests have been completed on the sample of coarse aggregate taken at your Green Oak plant, Pit No. 47-3 on March 4, 1965 to determine compliance with the requirements of the Supplemental Specifications for 31AA and 31A Aggregate Special coarse aggregates.

The results of the total carbonate content determination indicates that the material, as represented by the sample submitted, meets the specification carbonate content requirement for 31AA and 31A Aggregate Special.

Nothing in this letter should be construed as acceptance of any material produced from this source. Each shipment must be inspected for compliance with the specification requirements.

Very truly yours,

OFFICE OF TESTING AND RESEARCH

J. C. Brehler
Engineer of Materials
Field Testing Division

JCB:pc

cc: J. E. Meyer
C. B. Laird
C. J. Olsen
J. A. DeKamp

F28

(Coarse Aggregate)

MICHIGAN
STATE HIGHWAY DEPARTMENT
OFFICE OF TESTING AND RESEARCH
TESTING LABORATORY DIVISION
UNIVERSITY OF MICHIGAN
ANN ARBOR

REPORT OF TEST

Sheet 1 of 2

Project: General

Laboratory No.: 65A-786

Date: March 15, 1965

Report on sample of: COARSE AGGREGATE (Gravel)

Date sampled: March 4, 1965 Date received: March 4, 1965

Source of Material: American Aggregates Corporation (Green Oak) Pit No. 47-3

Sampled from: Source Quantity represented: ---

Submitted by: D. Pennington, Materials Inspector

Intended use: Bituminous concrete aggregate Specification: 1963 R&B Supp.

TEST RESULTS

Laboratory Number		
Passing, per cent by weight:		
3 inch sieve		
2½ inch sieve		
2 inch sieve		
1½ inch sieve		
1 inch sieve		
¾ inch sieve		
½ inch sieve		
⅜ inch sieve	100	
No. 4 sieve	47	
No. 10 sieve	8.3	
No. 40 sieve		
No. 200 sieve		
Loss by Washing, per cent	1.5	
Liquid Limit		
Plasticity Index		
Specific Gravity, dry		
Absorption, per cent		

1. Soft, [illegible] Particles, per cent	1.3	
2. Chert Particles, per cent		
3. Hard Absorbent Particles, per cent	1.2	
4. Sum of 1, 2, and 3, per cent		
5. Coke, per cent		
6. Iron, per cent		
7.		
8.		
9. Thin or Elongated Pieces, per cent	8.6	
10. Incrusted Particles (greater than ⅓ surface area), per cent		
11. Incrusted Particles (⅓ surface orea or less), per cent		
12. Crushed Material in Sample, per cent	100	
13. Deval Abrasion, per cent of wear		
Crushed Material in Abrasion, per cent		
Soft and Non-durable in Abrasion, per cent		
14. Los Angeles Abrasion, per cent of wear		
15. Gravel in Bank Run Material, per cent		

REMARKS:

cc:
File
J.C.Brehler
P.Serafin
G.Gallup (3)
J.DeKamp
A.H.Lawrence

CF

See Sheet 2.

F29

Signed: W.W. McLaughlin
Testing and Research Engineer

MICHIGAN
STATE HIGHWAY DEPARTMENT

OFFICE OF TESTING AND RESEARCH
TESTING LABORATORY DIVISION

UNIVERSITY OF MICHIGAN
ANN ARBOR

Project General

Laboratory No. 65A-786

Date March 15, 1965

REPORT OF TEST

Report on sample of COARSE AGGREGATE (Gravel)

Date sampled _____ Date received _____

Source of material _____

Sampled from _____ Quantity represented _____

Submitted by _____

Intended use _____ Specification _____

TEST RESULTS

Carbonate Content
(Per Cent by Weight)

Limestone	12.8
Dolomitic Limestone	1.4
Dolomite	20.7
Total Carbonate Content	34.9

REMARKS: Tested for information

CF

F30

Signed W. W. McLaughlin
Testing and Research Engineer

PETROGRAPHIC ANALYSIS OF COARSE AGGREGATE
AMERICAN AGGREGATE CORP. (GREEN OAK) PIT NO. 47-3
LABORATORY NO. 65A-786

SUMMARY REPORT

Sample:

On March 4, 1965 a sample of coarse aggregate was received in the Laboratory. Information accompany the sample stated that the material was obtained by D. Pennington on March 4, 1965 from the American Aggregate Corp. (Green Oak) Pit No. 47-3, located approximately 4 miles east and 2 miles south of Brighton, Livingston County. The material used in this analysis was a portion of the sample submitted to the Laboratory for a carbonate rock content determination.

Summary:

Petrographic examination has been completed on the coarse aggregate. The sample is composed of approximately 26 per cent igneous rock, 26 per cent metamorphic rock and 48 per cent sedimentary rock particles. The igneous and metamorphic rock particles are hard, fresh and dense. The sedimentary rock particles vary from very hard to soft, from fresh to moderately weathered and vary from slightly porous to very finely porous.

The gradation of the material, as determined by the Aggregate Unit, is as follows:

Sieve Size	Amount Passing (Per cent by weight)	Amount Retained (Per cent by weight)
3/8	100	0
No. 4	47	53
No. 10	8.3	38.7

The composition of this material, tabulated on the attached sheets, has been computed on the basis that 100 per cent of the sample is coarser than the No. 10 sieve. Material finer than the No. 10 sieve has not been examined.

DETAILED PETROGRAPHY

Test Procedures:

Representative portions - 500 particles - of each sieve fraction of the coarse aggregate were examined and identified megascopically by acid testing and a scratch test for hardness and microscopically with a stereomicroscope.

Composition:

Sedimentary rock particles constitute the largest fraction of the coarse aggregate with igneous and metamorphic rock particles being present in approximately equal amounts. The largest individual constituents are dolomite, quartzite and basic igneous detritus. The igneous and metamorphic rock particles are hard, fresh and dense. The carbonate rock particles of the sedimentary rock fraction vary from moderately hard to soft, vary from fresh to moderately weathered and vary from slightly porous to porous. The sandstone particles vary from moderately soft to soft, are moderately fresh and are porous. The siltstone particles are soft, moderately weathered and porous. The chert and cherty limestone particles are very hard, fresh and very finely porous.

Igneous Rocks:

Due to the small size of the material, valid separation of the igneous rocks into individual categories is not possible. The igneous rock particles have been separated into the following groups: acidic igneous detritus - particles derived from granites; intermediate igneous detritus - particles derived from diorites; and basic igneous detritus - particles derived from gabbros and basalts. The pink, buff, mottled white and pink, the mottled pink or red and black, the mottled white, pink and black colored acidic igneous detritus particles are hard, fresh, dense and vary from medium to fine grained These particles are angular in shape with dull to subvitreous lustered, ridged surfaces. The mottled buff, white and black and the mottled white and black colored intermediate igneous detritus particles are hard, fresh, dense and medium to very fine grained. These particles are angular in shape with dull to subvitreous lustered, ridged surfaces. The mottled whitish and dark green, the black and green and the medium to very dark green colored basic igneous detritus particles are hard, fresh, dense and fine grained to microcrystalline textured. These particles are angular in shape with dull, ridged surfaces.

Metamorphic Rocks:

Quartzite particles are one of the largest constituents of the sample. The colorless, white, pink, tan, light green and light gray colored quartzite particles are hard, fresh, dense and are fine grained to microcrystalline textured. These particles are angular in shape with dull to vitreous lustered, ridged surfaces. The light to medium green and reddish-brown colored metasediment particles are hard, fresh, dense and very fine grained to microcrystalline textured. These particles are angular in shape with dull, ridged surfaces. The light to medium green colored tillite particles are hard, fresh, dense and have a porphyritic type texture. The tillite particles are angular in shape with dull, ridged surfaces.

Sedimentary Rocks:

The whitish, tan, light gray and light brown colored limestone particles are moderately soft, fresh, slightly porous and very fine grained to microcrystalline textured. These particles are angular in shape with dull ridged

surfaces. A few limestone particles are fossiliferous. The tan and light brown colored dolomitic limestone particles are soft, moderately weathered, porous and very fine grained to microcrystalline textured. These particles are angular in shape with dull, ridged surfaces. The whitish, buff, tan, light brown and light gray colored dolomite particles vary from moderately hard to moderately soft, are fresh, vary from slightly porous to porous and are fine to very fine grained. The dolomite particles are angular in shape with dull, ridged surfaces. The light gray and yellowish-brown colored sandstone particles vary from moderately soft to soft, are moderately fresh, porous and are fine to very fine grained. The particles are subangular in shape with dull, rough, dented surfaces. The yellowish-brown colored siltstone particles are soft, moderately weathered, porous and are very fine grained to microcrystalline textured. These particles are subangular in shape with dull, rough, dented surfaces. The whitish, tan, buff, and light to medium brown colored chert and cherty limestone particles are very hard, fresh, very finely porous and microcrystalline textured. The particles are angular in shape with dull to subvitreous lustered, ridged surfaces.

G. H. Gallup
Geologist IIA

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102565
Attachments

TABLE I

CALCULATIONS OF RESULTS OF PARTICLE COUNTS

Constituents	Composition of Fractions Retained on Sieves Shown Below			
	No. 4		No. 10	
	Number of Particles	Per Cent	Number of Particles	Per Cent
Acidic Igneous Detritus	43	8.6	48	9.6
Intermediate Igneous Detritus	8	1.6	19	3.8
Basic Igneous Detritus	68	13.6	71	14.2
Quartzite	97	19.4	81	16.2
Metasediments	33	6.6	21	4.2
Tillite	17	3.4	9	1.8
Limestone	56	11.2	68	13.6
Dolomitic Limestone	5	1.0	5	1.0
Dolomite	131	26.2	138	27.6
Sandstone	14	2.8	12	2.4
Siltstone	3	0.6	--	--
Chert	14	2.8	22	4.4
Cherty Limestone	11	2.2	6	1.2
Totals	500	100.0	500	100.0
Gradation-Per Cent Retained on Individual Sieves		57.8		42.2

	Weighted Percentages of Constituents in Each Sieve Fraction		Weighted Composition of Sample
	No. 4	No. 10	
Acidic Igneous Detritus	5.0	4.1	9.1
Intermediate Igneous Detritus	0.9	1.6	2.5
Basic Igneous Detritus	7.9	6.0	13.9
Quartzite	11.2	6.8	18.0
Metasediments	3.8	1.8	5.6
Tillite	2.0	0.8	2.8
Limestone	6.5	5.7	12.2
Dolomitic Limestone	0.6	0.4	1.0
Dolomite	15.1	11.6	26.7
Sandstone	1.6	1.0	2.6
Siltstone	0.3	--	0.3
Chert	1.6	1.9	3.5
Cherty Limestone	1.3	0.5	1.8
Total in Sieve Fraction	57.8	42.2	100.0

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TABLE II

COMPOSITION OF SAMPLE

Constituents	Amount, as number of particles in per cent		
	In Fractions Retained on Sieves Shown Below[a]		In Whole Sample[b]
	No. 4	No.10	Total
Acidic Igneous Detritus	8.6	9.6	9.1
Intermediate Igneous Detritus	1.6	3.8	2.5
Basic Igneous Detritus	13.6	14.2	13.9
Quartzite	19.4	16.2	18.0
Metasediments	6.6	4.2	5.6
Tillite	3.4	1.8	2.8
Limestone	11.2	13.6	12.2
Dolomitic Limestone	1.0	1.0	1.0
Dolomite	26.2	27.6	26.7
Sandstone	2.8	2.4	2.6
Siltstone	0.6	--	0.3
Chert	2.8	4.4	3.5
Cherty Limestone	2.2	1.2	1.8
Totals	100.0	100.0	100.0

(a) Based on count of 500 particles in each sieve fraction.

(b) Based on gradation of sample as received disregarding portion passing No. 10 sieve and the distribution of constituents by sieve fractions shown at left.

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OFFICE MEMORANDUM

MICHIGAN
STATE HIGHWAY DEPARTMENT
JOHN C. MACKIE, COMMISSIONER

July 20, 1964

To: Paul J. Serafin, Bituminous Engineer
Testing Laboratory Division

From: G. H. Gallup

Subject: Petrographic Analyses of Bituminous Concrete Coarse Aggregates

Attached are petrographic analysis reports on coarse aggregates from the American Aggregate Corp. (Green Oak) Pit No. 47-3 submitted to the writer on April 4, 1964.

The materials utilized for petrographic analyses were portions of samples submitted to the National Crushed Stone Association.

OFFICE OF TESTING AND RESEARCH

G. H. Gallup

G. H. Gallup, Geologist
Testing Laboratory Division

GHG:mm

Attachments

cc: C.J. Olsen
R.H. Vogler

OFFICE MEMORANDUM

MICHIGAN
STATE HIGHWAY DEPARTMENT
JOHN C. MACKIE, COMMISSIONER

July 24, 1964

To: W. W. McLaughlin, Testing and Research Engineer
Office of Testing and Research

From: C. J. Olsen

Subject: Petrographic Analyses of Bituminous Concrete Coarse Aggregates

Attached are petrographic analyses of coarse aggregates from the American Aggregate Corp. (Green Oak) Pit No. 47-3, prepared by G.H. Gallup, Geologist.

OFFICE OF TESTING AND RESEARCH

C. J. Olsen, Director
Testing Laboratory Division

CJO:mm

Attachments

cc: E.A. Finney
J.C. Brehler

RLG	CJO
JCB	EAF
ARS	RHS
AEM	

M.S.H.D.
OFFICE OF
TESTING AND RESEARCH
JUL 27 1964
RECEIVED
ADMINISTRATIVE UNIT

PETROGRAPHIC ANALYSIS OF COARSE AGGREGATE 31A
AMERICAN AGGREGATE CORP. (GREEN OAK) PIT NO. 47-3
LABORATORY NO. 64A-2196

SUMMARY REPORT

Sample:

On April 4, 1964, a sample of crushed natural gravel was obtained from Mr. Paul J. Serafin. Information accompanying the sample stated that the material was obtained from the American Aggregate Corp. (Green Oak) Pit No. 47-3, produced to meet current specification requirements for Coarse Aggregate 31A for use on a cooperative research program by the National Crushed Stone Association.

Summary:

Petrographic examination has been made on the crushed natural gravel of 3/8-inch maximum size. The sample is composed of approximately 25 per cent igneous, 34 per cent metamorphic and 41 per cent sedimentary rock particles. All rock particles, with the exception of the sandstones, some cherts, and shales, appear to be fresh and dense.

The gradation of the material as reported by the Aggregate Unit is as follows:

Sieve Size	Amount Passing (Per cent by weight)	Amount Retained (Per cent by weight)
3/8	100	0
No. 4	61	39
No. 10	12.6	48.4
Loss by Washing	1.5	

The composition of this material, tabulated on the attached sheets, has been computed on the basis that 100 per cent of the sample is coarser than the No. 10 sieve. Material in the sample finer than this size has not been analyzed.

DETAILED PETROGRAPHY

Test Procedure:

Representative portions - 500 particles - of each sieve fraction of the crushed natural gravel were examined and identified megascopically by acid testing and a scratch test for hardness and microscopically with a petrographic microscope and a stereomicroscope.

Composition:

Sedimentary rocks constitute the largest fraction of the crushed natural gravel, metamorphic rocks the next largest constituent and igneous rocks the smallest constituent. The largest individual constituents of the whole sample are quartzite, dolomite and limestone. Nearly all the igneous and metamorphic rock particles are dense, tough and predominantly unweathered. The carbonate rock constituents of the sedimentary fraction appear fresh and moderately dense on fractured faces, but the sandstone particles are predominantly soft, porous, and weakly bonded. The composition of the gravel is shown on the attached tables and the constituents are described below.

Igneous Rocks:

Igneous rocks present are granites, granodiorites, diorites, gabbros, basalts and felsites. The acidic and intermediate igneous rocks - granites, granodiorites and diorites - are dense, tough and unweathered. Colors range from pink to red and whitish to dark gray with a few buff colored particles. Granitoid textures are predominant in these rocks in both macro- and microcrystalline grain size particles. A few particles have gneissic (banded) textures. The basic igneous rocks are gabbros and basalts. The gabbros are medium to dark mottled green, fine grained, dense and tough. Some unfractured faces are slightly to moderately weathered. The basalts are dark green to black, very fine grained to microcrystalline textured, dense and tough. A few basalt particles are amygdaloidal. The remaining igneous rock constituents are the light to medium green and gray, dense, tough and microcrystalline to porphyritic textured felsites and small amount of acidic and intermediate igneous rock detritus.

Metamorphic Rocks:

Quartzites of various colors are the dominant metamorphic rock type present and constitutes the largest single rock type in the sample. All of these particles are unweathered, tough, dense and have fine grained or microcrystalline textures. The metasediments and tillites present are dense, tough, unweathered, green and gray with fine grained to microcrystalline and porphyritic type textures.

Sedimentary Rocks:

A large percentage of the sedimentary rock fraction is composed of carbonate rocks. The limestones and dolomites are similar in most physical characteristics such as: the whitish, buff and light to medium gray color; the fresh appearance on fractured faces and the slight to moderate weathering on unfractured faces; moderate hardness and porosity; and the fine grain to microcrystalline textures. The dolomites are predominantly light to dark gray, slightly harder than and have larger grain sizes than the other carbonate rocks. Chert particles found in this sample are whitish and light to dark gray, dull to vitreous lustered, dense to very porous, hard and unweathered. Many of these cherts contain

enough calcium carbonate to be considered as cherty limestones but for convenience are classed strictly as chert. The sandstone particles are predominantly soft to moderately soft, porous, fine grained, whitish to buff and light gray in color and cemented predominantly with calcium carbonate cement. Shale is a minor constituent of the sample and is dark gray, very fine grained, soft, porous and moderately weathered.

George H. Gallup

George H. Gallup,
Geologist II

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TABLE I

CALCULATIONS OF RESULTS OF PARTICLE COUNTS

Constituents	Composition of Fractions Retained on Sieves Shown Below			
	No. 4		No. 10	
	Number of Particles	Per Cent	Number of Particles	Per Cent
Granite	19	3.8	--	--
Granodiorite	9	1.8	--	--
Diorites	13	2.6	4	0.8
Gabbro	15	3.0	18	3.6
Basalt	41	8.2	47	9.4
Felsites	16	3.2	16	3.2
Acid-Igneous Detritus	10	2.0	16	3.2
Intermediate Igneous Detritus	5	1.0	20	4.0
Quartzite	112	22.4	117	23.4
Metasediments	38	7.6	45	9.0
Tillite	8	1.6	14	2.8
Limestone	75	15.0	77	15.4
Dolomitic Limestone	27	5.4	17	3.4
Dolomite	75	15.0	86	17.2
Sandstone	27	5.4	17	3.4
Chert	10	2.0	4	0.8
Shale	--	--	2	0.4
Totals	500	100.0	500	100.0
Individual Per Cent Retained on Sieve		44.7		55.3

	Weighted Percentages of Constituents in Each Sieve Fraction		Weighted Composition of Sample
	No. 4	No. 10	
Granite	1.7	--	1.7
Granodiorite	0.8	--	0.8
Diorites	1.2	0.4	1.6
Gabbro	1.3	2.0	3.3
Basalt	3.7	5.2	8.9
Felsites	1.4	1.8	3.2
Acid-Igneous Detritus	0.9	1.8	2.7
Intermediate Igneous Detritus	0.5	2.2	2.7
Quartzite	10.0	12.9	22.9
Metasediments	3.4	5.1	8.5
Tillite	0.7	1.5	2.2
Limestone	6.7	8.5	15.2
Dolomitic Limestone	2.4	1.9	4.3
Dolomite	6.7	9.5	16.2
Sandstone	2.4	1.9	4.3
Chert	0.9	0.4	1.3
Shale		0.2	0.2
Total in Sieve Fraction	44.7	55.3	100.0

TABLE II

COMPOSITION OF SAMPLE

Constituents	Amount, as number of particles in per cent		
	In Fractions Retained On Sieves Shown Below[a]		In Whole Sample[b]
	No. 4	No. 10	Total
Granite	3.8	--	1.7
Grandiorite	1.8	--	0.8
Diorite	2.6	0.8	1.6
Gabbro	3.0	3.6	3.3
Basalt	8.2	9.4	8.9
Felsites	3.2	3.2	3.2
Acid Igneous Detritus	2.0	3.2	2.7
Intermediate Igneous Detritus	1.0	4.0	2.7
Quartzite	22.4	23.4	22.9
Metasediments	7.6	9.0	8.5
Tillite	1.6	2.8	2.2
Limestone	15.0	15.4	15.2
Dolomitic Limestone	5.4	3.4	4.3
Dolomite	15.0	17.2	16.2
Sandstone	5.4	3.4	4.3
Chert	2.0	0.8	1.3
Shale	--	0.4	0.2
Totals	100.0	100.0	100.0

(a) Based on count of 500 particles in each sieve fraction.

(b) Based on gradation of sample as received disregarding portion passing No. 10 sieve and the distribution of constituents by sieve fractions shown at left.

PETROGRAPHIC ANALYSIS OF COARSE AGGREGATE 25A
AMERICAN AGGREGATE CORP. (GREEN OAK) PIT NO. 47-3
LABORATORY NO. 64A-2197

SUMMARY REPORT

Sample:

On April 4, 1964, a sample of crushed natural gravel was obtained from Mr. Paul J. Serafin. Information accompanying the sample stated that the material was obtained from the American Aggregate Corp. (Green Oak) Pit No. 47-3, produced to meet current specification requirements for Coarse Aggregate 25A for use on a cooperative research program by the National Crushed Stone Association.

Summary:

Petrographic examination has been made on the crushed natural gravel of 5/8-inch maximum size. The sample is composed of approximately 29 per cent igneous, 31 per cent metamorphic and 40 per cent sedimentary rock particles. All rock types, with the exception of sandstone and shale particles, appear generally to be fresh and dense. Uncrushed faces of some basic igneous rock types, predominantly gabbros, exhibit slight to moderate weathering.

The gradation of the material as reported by the Aggregate Unit is as follows:

Sieve Size	Amount Passing (Per cent by weight)	Amount Retained (Per cent by weight)
5/8	100	0
1/2	95	5
3/8	59	36
No. 4	20	39
No. 10	7.4	12.6
Loss by Washing	1.1	

The composition of this material, tabulated on the attached sheets, has been computed on the basis that 100 per cent of the sample is coarser than the No. 10 sieve. Material finer than this size has not been analyzed.

DETAILED PETROGRAPHY

Test Procedure:

Representative portions - 500 particles - of each sieve fraction of the crushed natural gravel were examined and identified megascopically by acid testing and a scratch test for hardness and microscopically with a petrographic microscope and a stereomicroscope.

Composition:

The material is a crushed natural gravel composed of nearly equal portions of igneous, metamorphic and sedimentary rock types. The largest individual constituents are quartzite, limestone and dolomite. Nearly all the igneous and metamorphic rock particles are dense, tough and predominantly unweathered. The carbonate rock constituents of the sedimentary fraction appear fresh and moderately dense on fractured faces but the sandstone particles are predominantly soft, porous and weakly bonded. The composition of the gravel is shown on the attached tables and the constituents are described below.

Igneous Rocks:

Igneous rocks present are granites, granodiorites, diorites, gabbros, basalts and felsites. The acidic and intermediate igneous rocks - granites, granodiorites and diorites - are dense, tough and unweathered. Colors range from pink to red and whitish to dark gray with a few buff colored particles. Granitoid textures are predominant in these rocks in both macro- and microcrystalline grain size particles. A few particles have gneissic (banded) textures. The basic igneous rocks are gabbro and basalts in nearly equal proportions. The gabbros are medium to dark, mottled green, fine grained, dense, and tough. Some unfractured faces of these particles are slightly to moderately weathered. The basalts are dark green to black, very fine grained to microcrystalline textured, dense and tough. A few basalts are amygdaloidal. The remaining igneous rock constituents are the light to medium green and gray, dense, tough, microcrystalline to porphyritic textured felsites and a minor amount of acidic and intermediate igneous rock detritus.

Metamorphic Rocks:

Quartzites of various colors are the dominant metamorphic rock particles present and constitute the largest rock type present in the sample. All these particles are unweathered, dense and tough and have fine grained or microcrystalline textures. The metasediments and tillites present are dense, tough, unweathered, green and gray with fine grained to microcrystalline and porphyritic type textures.

Sedimentary Rocks:

A large percentage of the sedimentary rocks present is composed of limestone, dolomitic limestone and dolomite. The limestones and dolomitic limestones are similar in most physical characteristics such as: the whitish, buff and light to medium gray color; the fresh appearance on fractured faces and the slight to moderate weathering on unfractured faces; moderate hardness and porosity; and the fine grain to microcrystalline textures. The dolomites are predominantly light to dark gray, slightly harder than and have larger grain

sizes than the other carbonate rocks. Uncrushed surfaces on the carbonate rock fraction appear slightly to moderately weathered. Chert particles found in this sample are whitish and light to dark gray, dull to vitreous lustered, dense to very porous, hard and unweathered. Many of these cherts contain enough calcium carbonate to be considered as cherty limestones but for convenience are classed strictly as chert. The sandstone particles are predominantly soft to moderately soft, porous, fine grained, whitish to buff and light gray in color and cemented predominantly with calcium carbonate cement. Shale is a minor constituent of the sample and is dark gray, very fine grained, soft, porous and moderately weathered.

George H. Gallup

George H. Gallup,
Geologist II

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GHG:mm

TABLE I

CALCULATIONS OF RESULTS OF PARTICLE COUNTS

Constituents	Composition of Fractions Retained on Sieves Shown Below							
	1/2-in.		3/8-in.		No. 4		No. 10	
	Number of Particles	Per Cent	Number of Particles	Per Cent	Number of Particles	Per Cent	Number of Particles	Per Cent
Granite	38	7.6	39	7.8	28	5.6	6	1.2
Granodiorite	17	3.4	11	2.2	6	1.2	--	--
Diorites	24	4.8	23	4.6	25	5.0	4	0.8
Gabbro	23	4.6	37	7.4	31	6.2	23	4.6
Basalt	35	7.0	36	7.2	24	4.8	27	5.4
Felsites	23	4.6	21	4.2	15	3.0	6	1.2
Acid-Igneous Detritus	--	--	--	--	--	--	28	5.6
Intermediate Igneous Detritus	--	--	--	--	--	--	15	3.0
Quartzite	108	21.6	90	18.0	117	23.4	145	29.0
Metasediments	44	8.8	32	6.4	23	4.6	24	4.8
Tillite	20	4.0	25	5.0	11	2.2	9	1.8
Limestone	60	12.0	63	12.6	83	16.6	70	14.0
Dolomitic Limestone	32	6.4	38	7.6	40	8.0	42	8.4
Dolomite	61	12.2	63	12.6	64	12.8	46	9.2
Sandstone	10	2.0	12	2.4	21	4.2	34	6.8
Chert	5	1.0	10	2.0	10	2.0	16	3.2
Shale	--	--	--	--	2	0.4	5	1.0
Totals	500	100.0	500	100.0	500	100.0	500	100.0
Individual Per Cent Retained on Sieve		5.4		38.9		42.1		13.6

	Weighted Percentages of Constituents in Each Sieve Fraction				Weighted Composition of Sample
	1/2-in.	3/8-in.	No. 4	No. 10	
Granite	0.4	3.0	2.4	0.2	6.0
Granodiorite	0.2	0.9	0.5	--	1.6
Diorite	0.3	1.8	2.1	0.1	4.3
Gabbro	0.2	2.9	2.6	0.6	6.3
Basalt	0.4	2.8	2.0	0.7	5.9
Felsites	0.2	1.6	1.3	0.2	3.3
Acid Igneous Detritus	--	--	--	0.8	0.8
Intermediate Igneous Detritus	--	--	--	0.4	0.4
Quartzite	1.2	7.0	9.9	4.0	22.1
Metasediments	0.5	2.5	1.9	0.7	5.6
Tillite	0.2	1.9	0.9	0.2	3.2
Limestone	0.6	4.9	7.0	1.9	14.4
Dolomitic Limestone	0.3	3.0	3.4	1.1	7.8
Dolomite	0.7	4.9	5.4	1.3	12.3
Sandstone	0.1	0.9	1.7	0.9	3.6
Chert	0.1	0.8	0.8	0.4	2.1
Shale	--	--	0.2	0.1	0.3
Total in Sieve Fraction	5.4	38.9	42.1	13.6	100.0

TABLE II

COMPOSITION OF SAMPLE

Constituents	Amount, as number of particles in per cent				
	In Fraction Retained On Sieves Shown Below[a]				In Whole Sample[b]
	1/2-in.	3/8-in.	No. 4	No. 10	Total
Granite	7.6	7.8	5.6	1.2	6.0
Granodiorite	3.4	2.2	1.2	--	1.6
Diorite	4.8	4.6	5.0	0.8	4.3
Gabbro	4.6	7.4	6.2	4.6	6.3
Basalt	7.0	7.2	4.8	5.4	5.9
Felsites	4.6	4.2	3.0	1.2	3.3
Acid Igneous Detritus	--	--	--	5.6	0.8
Intermediate Igneous Detritus	--	--	--	3.0	0.4
Quartzite	21.6	18.0	23.4	29.0	22.1
Metasediments	8.8	6.4	4.6	4.8	5.6
Tillite	4.0	5.0	2.2	1.8	3.2
Limestone	12.0	12.6	16.6	14.0	14.4
Dolomitic Limestone	6.4	7.6	8.0	8.4	7.8
Dolomite	12.2	12.6	12.8	9.2	12.3
Sandstone	2.0	2.4	4.2	6.8	3.6
Chert	1.0	2.0	2.0	3.2	2.1
Shale	--	--	0.4	1.0	0.3
Totals	100.0	100.0	100.0	100.0	100.0

(a) Based on count of 500 particles in each sieve fraction.

(b) Based on gradation of sample as received disregarding portion passing No. 10 sieve and the distribution of constituents by sieve fractions shown at left.

Appendix G.

Literature Review

This appendix includes the literature review as revised on June 7, 1996 in response to MDOT 's comments.

Cause of Concrete Pier Cap Deterioration on the I-75 Bridge over River Rouge in Detroit, and Effectiveness of Repair Methods

Literature Review

Submitted to

Michigan Department of Transportation

By

Will Hansen, Associate Professor
Department of Civil and Environmental Engineering
University of Michigan, Ann Arbor, Michigan

Phil Mohr, Graduate Student Research Assistant
Department of Civil and Environmental Engineering
University of Michigan, Ann Arbor, Michigan

Rachel Detwiler, Senior Engineer
Construction Technology Laboratories, Inc.
Skokie, Illinois

Revised June 7, 1996

CAUSE OF CONCRETE PIER CAP DETERIORATION ON THE I-75 BRIDGE OVER RIVER ROUGE IN DETROIT, AND EFFECTIVENESS OF REPAIR METHODS

Revised Literature Review

1. INTRODUCTION

1.1 Background

The I-75 bridge over the Rouge River in Detroit was built in 1965 with an HS20 design live load. Its main span is a high level, 3 span, continuous, steel girder bridge with a composite concrete deck. The substructure is entirely reinforced concrete. The adjacent spans are also steel girder spans with composite concrete decks.

The bridge, which is in a heavy industrial area, has experienced considerable deterioration over its life. A superstructure rehabilitation project was conducted in 1989. In 1994, a contract was awarded to address cracking in the pier caps of piers 37 to 40. Piers 37 and 40 were considered separately from piers 38 and 39, as the former are directly beneath deck joints and the latter were not. These deck joints above piers 37 and 40 have allowed water and chlorides from the bridge deck above to enter the pier cap concrete. These two piers are more severely deteriorated than are caps 38 and 39. Cores taken from piers caps 37 and 40 show high chloride content, but adequate compressive strength. Petrographic examination indicated the presence of alkali silica reactivity (ASR) associated with the fine aggregates. It was concluded that concrete overstressing and chloride damage led to the deterioration of caps 37 and 40. Pier caps 38 and 39 show deterioration similar to that in caps 37 and 40, though to a lesser extent. Petrographically examined fragments from these piers yielded similar findings to the cores from caps 37 and 40.

A repair method was established, including epoxy injection of all cracks, concrete chipping and replacement, and application of a penetrating surface sealer to repel water. Temporary supports for piers 37 and 40 were used during repair. It was found that chipping was so easy on pier cap 40, that one of the two pier caps for this pier was completely removed. The remaining caps were injected and surface treated as planned. The cracking proved so extensive though, that contract funds ran out before much of the work could be completed.

A second contract is planned to complete the rehabilitation. It has been decided that a total replacement of pier caps 37 and 40 will be carried out. The proposed plan of injecting and sealing pier caps 38 and 39, along with post tensioning is currently under investigation.

In this project, mainly the pier caps are considered. Variation in the paste color of the concrete surfaces appear to indicate that several mix designs were used for construction of the piers. In general, a relatively buff colored paste appeared to be present at most columns, while a relatively gray paste appeared to be present at most pier caps. Cracking is much more severe in the pier caps (where 7.5 sacks of cement per cubic yard of concrete were used) than in the columns (where 6 sacks of cement per cubic yard of concrete were used). To some extent, the reduced cracking in the columns may also be associated with the longitudinal confinement due to loading in the columns.

Cracking in the columns is variable. In general a relatively fine crack is observed in the columns, approximately centered in the width of the column, and associated with the buff colored concrete. Some more severe cracking is evidenced in the columns, for instance at the top of one column in Pier 38 north-bound, where the paste color is gray. Extensive pattern cracking is observed in all pier caps of Piers 37 to 40.

1.2 Objective

The objective of this project is to determine the extent of deterioration in pier caps 38 and 39, to determine the impact of ASR on the structure, and to determine the feasibility of the proposed repair methods. In this investigation, specific emphasis is placed on the role of the use of blast-furnace slag as coarse aggregate. Specifically, the effects of slag on ASR and long-term durability are being investigated. The creep properties of ASR affected concrete are of importance in evaluating the proposed post-tensioning. This literature review summarizes the state of the art information on topics related specifically to the needs of this project.

2. BLAST-FURNACE SLAG AS COARSE AGGREGATE

Blast-furnace slag is a byproduct of iron production. It is formed when iron ore (a mixture of iron oxides, silica, and alumina) is reduced through chemical reactions to iron. The silica and alumina compounds combine with calcium, added to the furnace in the form of limestone or dolomite, to form the slag. The properties of slag are highly dependent on its chemical composition, as well as the conditions under which it is cooled. There are three basic types of slag; air cooled slag, foamed or expanded slag, and granulated slag. Air cooled slag develops a crystalline structure similar to natural igneous rocks. This type of slag produces a strong aggregate frequently used in concrete. Foamed slag is produced by injecting water into the molten slag. The occluded gasses and steam produced in the process form the expanded light-weight structure of the slag. The result is a strong light-weight aggregate suitable for concrete applications. Finally, granulated slag is a rapidly cooled slag, where crystals are not allowed to form. This type of slag is often ground and used as an additive to portland cement, as it has hydraulic setting properties. (Lee, 1974)

Though the use of slag as aggregate in concrete has achieved wide acceptance, the use of slag is not without inherent difficulties, and should be monitored closely. Foamed slags, used as lightweight aggregate, tend to have highly angular particle shapes, which can have harmful effects on workability, finishing, and bleeding of the concrete. The use of special mix designs containing increased air entrainment, increased cement content, or the use of mineral admixtures can help protect against these effects. The typically high absorption capacity of slags requires careful monitoring during mixing and proportioning to ensure a proper consistency concrete. Finally, segregation is possible with foamed slag aggregates, as excessive vibration or improper placing practice may cause the slag to rise upward in the concrete. In general, the same precautions that would be taken with any lightweight aggregate should be taken with foamed slag. (Popovics, 1979)

The chemical composition of blast-furnace slag may be somewhat variable. Typically, though, the composition falls into a fairly well defined range, as shown in Table #1.

Chemical Constituent	% by Mass
Lime (CaO)	36-43%
Silica (SiO_2)	28-36%
Alumina (Al_2O3)	12-22%
Magnesia (MgO)	4-11%
Total Sulfur (as S)	1-2%
Total Iron (as FeO or Fe_2O_3)	0.3-1.7%

***Table #1** Chemical constituents of blast-furnace slag (by mass). (After Lee, 1974)*

Concrete made with slag aggregate is often more permeable than standard concretes, allowing a greater infiltration of chlorides and other pollutants into the concrete. It can be noted from Table #1, though, that slag contains a certain percentage of Fe_2O_3, which is the same oxide that forms as a passivating layer on reinforcing steel. In this manner, the use of slag as aggregate can actually inhibit the corrosion of reinforcing steel in the concrete, even in the presence of high chloride concentrations. (Lee, 1974)

The high silica content of blast-furnace slags makes them potentially susceptible to ASR reactivity. Just as highly siliceous volcanic glasses have been found to be reactive, blast-furnace slag may also be reactive, requiring special testing and acceptance criteria, as described later in this report.

As was discussed earlier, the properties of slag can be greatly affected by the method of cooling. During slag formation, dicalcium silicate compounds can occur in at least three different crystalline forms. When the slag is cooled slowly, to form a dense aggregate, a phase change in the dicalcium silicate, which can occur at atmospheric temperatures, can lead to harmful expansive volume change. This unstable dicalcium silicate on its own, or combined with slag's alkaline reactivity may lead to harmful deterioration of the concrete. It should be noted that the unstable phase of dicalcium silicate does not form when the slag is cooled rapidly, as in foamed slag and granulated

slag. Furthermore, it should be noted that a careful monitoring of slag composition can avoid the harmful properties described here. (Lee, 1974)

In fact, extensive research has shown that ground granulated blast-furnace slag is beneficial in concrete for many of the same reasons slag as coarse aggregate may be harmful. For example, ground granulated blast-furnace slag may increase workability, reduce bleeding and segregation, and reduce concrete permeability. Furthermore, when ground into a fine powder, the siliceous slag reacts so rapidly with the hydroxide ions in the cement that harmful levels of hydroxide ions are not allowed to build up, and the expansive ASR reaction may never occur. (Ozyildirim, 1990)

The reduction in permeability is brought forth by the fineness of the slag particles. In addition, the slag acts as an additional binding agent in the paste as it has some cementitious value. The reduced permeability in turn inhibits the ingress of external water and alkalis, which could accelerate or induce ASR. If there was to be any reaction of the slag, its uniform distribution through the system would prevent the buildup of alkali-silica gel rich zones where damage from expansion would be likely to occur. In aggregates, the harmful expansion is typically associated with gel-rich zones surrounding and penetrating the aggregate, also known as the reaction rim, and cracks emanating outward from reactive particles. Petrography has shown that the slag aggregate from this bridge shows no evidence of reactivity.

3. LONG-TERM DURABILITY AND CREEP PROPERTIES OF ASR AFFECTED STRUCTURES

3.1 Creep and Drying Shrinkage

The effects of creep in structures are complicated by drying shrinkage that occurs simultaneously. During the early stages of drying of a concrete member, the center remains moist as the outside edges dry. This puts the center of the member in compression, and the edges in tension as they try to shrink from moisture loss. The occurrence of ASR, which takes place in the moist center, further increases the compression in the center and the tension at the surfaces of the member. In this way, the effects of drying shrinkage can be more severe in ASR affected concretes than in nonreactive concretes.

Over the long term, stresses in the concrete are relaxed by creep of the cement paste. The process of creep is complex and has two components, drying creep and basic creep. Basic creep is the amount of creep movement under constant relative humidity conditions. This type of creep is decreased with decreasing relative humidity. Drying creep on the other hand is the creep effect associated with the drying of the specimen. Total creep during drying can be much larger than basic creep. The basic creep component decreases as the specimen dries. The extent of ASR expansion in affected concrete is determined in part by the concrete's creep properties. Because ASR expansion

is inhibited by external and internal restraint, any reduction in such restraint can lead to increased expansion. Creep allows for such continued ASR expansion. (Helmuth, 1993)

3.2 Restraint From Expansion

Reacting aggregate particles are restrained from expanding by internal and external forces. The cohesive strength of concrete portions that are not expansive restrain the ASR affected particles. Furthermore, other forces such as the weight of the structure, reinforcing steel, prestressing or post-tensioning can restrain the expansion.

It should be noted that pressure cannot stop the alkali-silica reaction. On the contrary, the solubility of the reactive silica is increased with increasing pressure. Thus, increasing pressure, caused either by expansive swelling of the ASR reaction or by external means, can actually accelerate the further dissolution of reactive silicas. Because the dissolution of silicas produces a negative volume change, this in turn reduces the pressures caused by the expansive gel formation. If an external pressure is applied, this reaction cycle may continue until all available reactive silicas are consumed, assuming the availability of moisture and alkalis. (Helmuth, 1993) It should also be noted that ASR gel can diffuse into the paste under confining pressure.

At the same time, significant changes are evident in the expansion behavior through the application of external loading. Even small loads have been shown to have significant effects on the expansion caused by ASR. This is true both for loads applied initially to the specimen, as well as loads applied after some expansion has occurred. (Helmuth, 1993)

When concrete that is subjected to ASR is unconfined, the resulting distress is often manifested as a random distribution of cracks, typically referred to as map cracking. The map cracking usually consists of a pattern of larger cracks that bound a network of barely visible finer cracks. When the expansive forces of the ASR are restrained, for example by reinforcing steel, the cracks tend to run parallel to the reinforcing steel. In general, the cracks tend to run in the direction in which the restraint is applied. (Building Research, 1982)

3.3 Combined Effects of Chlorides and ASR

Concrete that is affected by ASR, and contains chlorides from de-icing salts, marine environments or other contaminating environments such as heavy industrial applications, suffers from increased susceptibility to expansion in a twofold manner.

First, the inclusion of salts accelerates the ASR reaction and expansion process. When salts enter into the concrete, typically in solution, they can provide a semi-infinite supply of alkali to the reaction (as well as moisture). In this way the reaction is only limited by the available reactive silicas in the aggregate. (Helmuth, 1993)

Second, the presence of ASR has been shown to increase the corrosion rate of embedded steel in the concrete. The occurrence of ASR in NaCl contaminated mortars raises the Cl^-/OH^- ratio in the mortar's pore solutions. In addition, ASR increases the corrosion rate of embedded steel in mortars of a given Cl^-/OH^- ratio. This indicates that increased corrosion rates in mortars containing reactive aggregates can be attributed both to an increase in the Cl^-/OH^- ratio, and to a microstructural change in the mortar, caused by the ASR. It can further be concluded that salt contaminated concretes are at greater risk of chloride induced corrosion of reinforcing steel if the concrete is affected by ASR. (Kawamura, 1989)

4. AVAILABLE REPAIR METHODS

The following is a discussion of available repair methodologies that may be useful, in whole or in part, in accomplishing repairs to the deteriorated piers. Selection and design of an appropriate comprehensive repair approach must account for existing deterioration and structural requirements, as well as anticipated construction costs and longevity of repairs. Some modification of the following discussion will likely occur as additional information becomes available. The final project report will provide a more detailed analysis of prospective repair techniques.

4.1 Post-Tensioning

Research has shown that ASR-related deterioration can be significantly reduced if affected concrete is adequately restrained through inducing confining stresses via application of post-tensioning. Available data indicate that confining stresses on the order of 450 psi in biaxial directions or 300 psi in triaxial directions are effective. Uniaxial restraint would not be considered of significant benefit with respect to reduction of effects of ASR. (Stark, 1993) Post-tensioning can also be effective in increasing pier cap capacity beyond the original design strength, and could possibly be accomplished without shoring of bridge decks. Issues to be considered during design of such repairs would include the following:

1. A comprehensive repair approach would likely require restoration of severely deteriorated concrete in conjunction with post-tensioning.

2. Biaxial or triaxial post-tensioning will be difficult to accomplish. Adequate confinement of ongoing ASR would likely require drilling through the entire thickness of the pier caps in a gridwork pattern for their full length. It is possible that embedded reinforcing steel could be cut or damaged in the process. The joint between north- and south-bound lanes would inhibit post-tensioning along the length of the pier caps, although adequate anchorages could likely be designed, or grouting of this joint and post-tensioning both piers as a single unit may be feasible.

3. Member shortening and post-tensioning losses must be accommodated in the repair design. Pier columns and bridge bearings will resist effects of post-tensioning to some extent.

4. Several sequences of post-tensioning may be required to maintain prestress, since creep losses are expected to be significant within ASR-affected concrete.

5. In general, significantly less cracking was observed in columns than in pier caps. As previously stated, this may be due to differing concrete mixes used in various portions of the structure. However, it may also be related to confinement effects of longitudinal column compression combined with transverse restraint provided by reinforcing steel.

6. In order to adequately restrain the deteriorating concrete from continued expansion, it may be necessary to use steel jacketing in conjunction with post-tensioning. The jacketing could cover all or portions of the exposed pier cap surface, and would provide additional support in critical areas.

4.2 Epoxy Injection

Pressure injection of epoxy resin into cracks in pier caps can be used to restore significant structural capacity to damaged concrete. However, a number of issues must be considered prior to selection of epoxy injection as a repair method. These would include the following:

1. Epoxy injection of cracked surfaces will not stop ASR within affected members.

2. Epoxy injection will likely induce random water-impermeable planes within the pier caps. Hence, water and vapor transmission through injected pier cap concrete may be significantly less than through non-injected concrete. If sources of water are available, this could lead to critical saturation of concrete and increased freeze-thaw- and ASR-related deterioration.

3. Epoxy injection may not be fully effective in restoring the strength of deteriorated concrete. This is due to the likelihood that epoxy will not fully penetrate fine cracks (that may or may not be interconnected with surface cracks), deep cracks, and cracks containing various potential contaminants. Hence, an assessment should be made of the effectiveness of the injection process through confirmation coring and testing, and repairs should be designed accordingly.

4. Epoxy injection may be most effective if used in conjunction with surface sealers. In order for a sealer to be effective, it must be able to prevent ingress of water and salts into the concrete, while allowing water vapors to escape. Trapped water can create vapor pressures sufficient to cause the sealant to spall off. In addition the

sealer should be able to span minor cracks without losing integrity if there is crack movement.

4.3 Partial and Full Pier Cap Replacement

An alternative to crack injection that could be used for repairs to severely cracked concrete would be partial-depth concrete removal and replacement. Typically, ASR-related cracks widen significantly near unconfined concrete surfaces. Partial depth concrete removal could be used to remove severely cracked concrete, facilitate placement of post-tensioning hardware if necessary, and add supplemental reinforcing steel if required for pier cap strengthening. Cross-sectional dimensions of repaired pier caps could also be increased for additional strengthening. If continued ASR is judged likely, post-tensioning could be used for ASR confinement.

In the event that deterioration due to ASR or other factors is very severe, and continued deterioration is likely regardless of what repair method is used, it may be necessary to perform a complete pier cap replacement. Because this option would require a temporary support structure, this is considered the least favored repair method.

5. TEST METHODS

5.1 Tests for Slag to Be Used As Aggregate

ASTM C 33 gives the general provisions for materials to be used as aggregates for concrete. These include the size gradation and allowable content of various deleterious materials for the given exposure conditions. Crushed air-cooled blast-furnace slag is excluded from the abrasion requirements of ASTM C 33. A preliminary estimate of the soundness of the aggregate is to be given according to ASTM C 88. ASTM C 127 and ASTM C 128 describe the methods for determining the specific gravity and absorption of coarse and fine aggregate, respectively. This information is necessary in the proportioning of concrete mixtures.

There are a number of different tests which may be used in evaluating the potential alkali reactivity of an aggregate. This section briefly summarizes several standard test methods for use in qualifying aggregates for use in concrete. The recommended course of action basically follows Portland Cement Association's *Guide Specification for Concrete Subject to Alkali-Silica Reactions* (1995). According to the PCA *Guide Specification*, the best method for evaluating the susceptibility of an aggregate to ASR is its previous performance under field conditions. In order to be able to rely on past performance to predict future performance, the previous conditions of exposure must have been at least as severe as those expected in the proposed structure or pavement, the alkali content and water/cement ratio of the existing concrete at least as high as in the proposed concrete, the dosage of pozzolan(s) in the existing concrete less than in the proposed concrete, the existing concrete at least 15 years old, and the aggregate representative of that used in the

existing concrete. In general it is almost impossible to meet all of these requirements; thus one must resort to the use of accelerated laboratory tests. Such tests by their nature are less than satisfactory: they may be biased to give either false positives or false negatives, or they may cause a different mechanism to take place in the test than occurs in the field. The best approach is to use several test methods in concert and employ sound engineering judgment in evaluating the results. The tests discussed below may be performed in any order. Note that even if an aggregate is determined to be reactive, it can still be used in concrete provided appropriate measures are taken to control the reactivity. The reader is referred to the PCA *Guide Specification* for recommendations on control measures and how to evaluate their adequacy.

Certain mineralogical constituents are known to react with alkalis in cement and concrete. ASTM C 295 provides a guide for the petrographic examination of aggregates to determine the quantities of these minerals present. PCA's *Guide Specification* recommends limits on these constituents as described in section 5.2.2. In addition, X-ray fluorescence can provide useful information about the chemistry of the aggregate. Results are reported as oxide contents. Analysis of the available alkalis by ASTM C 114 will indicate the presence of alkalis that may become available over time. ASTM C 114 also gives procedures for determining the contents of sulfate and sulfide sulfur, which can combine with oxygen to form sulfate. Sulfate in aggregates can cause an internal form of sulfate attack. Such sulfide compounds as pyrite (FeS_2) can be expansive under certain conditions. The methods for analyzing for alkalis, sulfate, and sulfide sulfur are all wet chemical methods.

Aggregates should also be evaluated by ASTM C 1260 (formerly P 214) for potential alkali reactivity. It is based on an accelerated test method developed in South Africa. In this test, aggregates to be used as fine aggregates are sieved and recombined to achieve the prescribed grading requirements with a minimum of crushing. Coarse aggregates are crushed to the appropriate sizes. Mortar bars made from the aggregate are exposed to a 1N NaOH solution at 80°C for 14 days. According to the PCA *Guide Specification*, a 14-day expansion exceeding 0.10% indicates a potentially reactive aggregate. Note that this test should not be considered as a "go-no go" test; that is, an aggregate having an expansion of just under 0.10% should not automatically be considered "safe". Oberholster (1993), one of the developers of the South African version of the test, recommends a graded approach, with expansions of more than 0.05% warranting some control measures and expansions exceeding 0.10% warranting more stringent control measures.

Coarse aggregate determined by either ASTM C 295 or ASTM C 1260 to be potentially reactive may be further evaluated by ASTM C 1293 (adopted from CSA-A23.2-14A). In this test method, coarse aggregate is sieved and recombined to a specified grading. Concrete is made from this aggregate and a cement having an alkali content of approximately 1.0%. NaOH is used to bring the total alkali content of the cement to 1.25% as a means of moderately accelerating the test. Concrete prisms are exposed to a 100% R.H. environment at 38°C (100°F) for one year. According to the PCA *Guide*

Specification, a mean expansion greater than 0.04% indicates a potentially reactive aggregate. For additional information, the prisms can be cut open and examined petrographically for signs of incipient ASR. The test can also be continued beyond one year; normal Canadian practice is to continue the test for two years.

In sorting out the results from these three tests, any field data indicating alkali reactivity of the aggregate in service takes precedence over all else: the aggregate is clearly reactive. ASTM C 1260 is generally used as a screening test; if an aggregate does not appear reactive on this test, it should be considered innocuous (taking into account Oberholster's recommendation to take some precautions for aggregates having expansions of 0.05-0.10%). The CSA prism test (ASTM C 1293) is considered to be more definitive. Although it takes longer than ASTM C 1260, it has been extensively correlated with field performance in Canada.

Other test methods include ASTM C 227 and ASTM C 289. ASTM C 227, which is designed primarily to evaluate specific combinations of cement, pozzolan (if used), and aggregate, involves exposing mortar bars to a 100% R.H. environment at 100°F (38°C) for up to 12 months and measuring the expansion at intervals. Thus the time required is as long as for the CSA test, but the result is less definitive because it involves mortar rather than concrete. ASTM C 1260, which is designed specifically to screen for reactive aggregates, provides results in 14 days which are as good as or better than ASTM C 227. Also, the expansion found by ASTM C 227 could be the result of some mechanism(s) other than ASR, while ASTM C 1260 is designed to force ASR.

ASTM C 289 is a wet chemical method for determining the potential alkali reactivity of an aggregate. In this test the aggregate is crushed, combined with a 1N solution of NaOH, and then stored at 80°C for 24 hours. The reduction in alkalinity and quantity of dissolved silica indicate the potential for alkali reactivity of the aggregate. However, the presence of such minerals as carbonates or certain magnesium silicates may render the results inaccurate. ASTM C 295, which examines the lithology and mineralogy rather than the chemistry, will provide more accurate and complete information. The reactivity of an aggregate is not determined so much by the chemistry as by the mineralogy. Silica can be close to inert in the form of large, well-ordered crystals; somewhat reactive in microcrystalline, highly fractured, or cryptocrystalline form; and highly reactive if amorphous. A chemical test cannot easily distinguish these differences. The petrographic examination will also show the distribution of the various minerals in the aggregate, which will also affect its reactivity in concrete.

5.2 ASR Test Methods

5.2.1 Field Examination

In the field, ASR manifests itself by a characteristic "map cracking" or "pattern cracking". However, as Stark (1991) points out, restraint due to abutting concrete or embedded steel reinforcement may affect the development of the crack pattern. For

example, a highway pavement may exhibit more cracking in the longitudinal direction due to greater restraint in the longitudinal direction. Palmer et al. (1988) observe that combinations of poor workmanship, weathering, shrinkage, or differential stresses due to general deterioration or damage can result in cracking, and that these mechanisms are not always easily distinguished from ASR. Thus in a condition survey of a deteriorated structure it is essential to keep an open mind and consider all possible causes of cracking. Stark (1991) gives the example of ASR cracking that may be confused with D-cracking due to freeze/thaw cycling. Cracking that is more severe along pavement joints may appear to be D-cracking, although it could be due to ASR. The two may be distinguished by noting that D-cracking is roughly parallel to the joint, while cracking associated with ASR has a more random orientation. One should also keep in mind that more than one mechanism could have caused the deterioration observed.

Palmer et al. (1988) provide an excellent general discussion of how to conduct a field inspection. Specific observations of certain features during the condition survey may point to ASR; these observations must then be followed up by a laboratory investigation to confirm and supplement the findings. Features that may point to ASR include:

(a) **Cracking.** Record the position, disposition, and pattern of cracking. Photography may be used for general documentation, but major cracks should also be documented on scale drawings showing length, width, apparent depth, continuity, surface displacement, path (around or across aggregate particles), and obvious association with reinforcement, stress orientation, or surface discoloration. Typically, in the absence of restraint or loading, the crack pattern can be described as a three-armed star.

(b) **Discoloration.** Surface discoloration is sometimes a feature of ASR and may occur along cracks or as surface patches. Staining due to rust indicates corrosion of the reinforcement. Note that ASR is not the only possible cause of light-colored stains.

(c) **Efflorescence and exudations.** Since gel is the product of ASR, the presence of either fresh or dried gel, especially along cracks, may indicate ASR. Samples of any exudation should be collected for later analysis.

(d) **Pop-outs**. Expansion of an aggregate particle or of gel close to the surface may cause detachment of a conical portion of the surface, leaving a small pit. Note that pop-outs can also be caused by frost damage.

Stark (1991) discusses the uranyl acetate test, which can be used on concrete in either the field or the laboratory to identify ASR gel. This test works best on newly exposed surfaces such as fresh fractures, cores, or ground or sawn surfaces. *Note that performing this test requires the use of certain safety gear, which is not discussed in the following general description of the method.* The surface should first be rinsed with tapwater. Then the uranyl acetate solution is applied. After 3-5 minutes (to allow the solution to react with any ASR gel that may be present), rinse the surface with tapwater. Under UV light the ASR gel appears bright yellowish-green. Deposits are generally localized in cracks, voids, and aggregate particles. Broad films of gel on sawn or cored surfaces may indicate smearing during the cutting process. With experience, the bright

fluorescence of ASR gel can be easily distinguished from the weaker fluorescence of carbonated paste and calcite deposits, and the natural fluorescence of some minerals.

The uranyl acetate test was originally developed by Naitesayer and Hover (1988). They found that analyzing the concrete within one hour of treatment with the uranyl acetate solution was necessary; otherwise the background flourescence would increase dramatically. Stark et al. (SHRP-C-343) state that the uranyl acetate test "requires discrimination between broad, faint areas of flourescence which reflect, for example, pretreatment locations of alkali absorbed on cement hydration products, and ASR gel deposits, which usually occur within the periphery of reacted aggregate particles." Both of these potential errors can contribute to false positive results.

Core samples should be taken from several areas of the structure for detailed study in the laboratory. It is important to obtain representative samples from areas of the structure that are in different stages of deterioration. One petrographer uses the rule "the good, the bad, and the ugly" in selecting her samples, that is, some concrete that is in good condition, some that has started to deteriorate, and some that is severely deteriorated. Palmer et al. (1988) outline the documentation required for each core: location, diameter, length, and orientation of the core; fractures, joints, and disintegration; number of pieces (if not intact); size, position, and condition of any reinforcement present; and other features such as damp patches and fresh gel. Photographs should also be taken of the core location, and the condition of the concrete inside the core hole should be noted.

5.2.2 Laboratory Examination

Even if the uranyl acetate test has been performed in the field, it may be worthwhile to perform it again under the more controlled conditions of the laboratory for confirmation. A standard petrographic examination (ASTM C 856) will provide such evidence as reaction rims and/or gel around aggregate particles and allow the identification and quantification of reactive constituents in the aggregate. PCA's *Guide Specification for Concrete Subject to Alkali-Silica Reactions* (1995), while directed at the prevention rather than the diagnosis of ASR, provides useful limits on the quantities of the various reactive minerals that may be present in the aggregate:

- Optically strained, microfractured, or microcrystalline quartz exceeding 5.0%
- Chert or chalcedony exceeding 3.0%
- Tridymite or cristobalite exceeding 1.0%
- Opal exceeding 0.5%
- Natural volcanic glass in volcanic rocks exceeding 3.0%

The petrographer can also identify any potentially reactive constituents that have not yet reacted. It is important that the petrographer approach the examination with an open mind, as other destructive mechanisms may be implicated instead of or in addition to ASR.

If necessary, the petrographic examination can be supplemented by scanning electron microscopy and/or chemical analyses of portions of the specimen. For example, the alkali content of the concrete can be estimated. If good records of the concrete mix design are available, the cement alkali content can also be estimated. Records of the field performance of the aggregates can also be useful.

In order to estimate the potential for further expansion due to ASR, one each of a set of three cores can be exposed at 100°F for 12 months to (1) immersion in water, (2) immersion in 1 N NaOH solution, or (3) storage over water in a sealed container. Expansion of the core stored in NaOH solution of more than 0.030 percentage points greater than for the companion core stored in water is considered indicative of expansive ASR. Note that this test is not a standard test; thus the results are not directly comparable from one laboratory to another, and it is not known how many replicates are required to produce a reliable result.

5.3 Chloride Test Methods

5.3.1 ASTM C 1152

The chloride ion content can be determined for either acid- or water-soluble chlorides. Generally the acid-soluble chloride ion content is considered the "total" chloride ion content, while the water-soluble chloride ion content is a better indication of the chloride ions actually available to the steel.

ASTM C 1152 provides for two methods of sampling the concrete to be tested. Ideally, a core will be taken from the structure, with samples sliced from the core and pulverized for analysis. Alternatively, a rotary impact drill may be used to take powder samples directly. ASTM C 1152 cautions that the latter method may produce unrepresentative samples. In addition, it is difficult to control conditions in the field sufficiently to prevent contamination or loss of some of the specimens, while intact cores are less sensitive to errors in handling. Once the samples are obtained and pulverized, they are analyzed for acid-soluble chlorides by the method described in ASTM C 114. In this method, the sample is first dissolved in dilute nitric acid. Methyl orange is used to indicate when the solution is sufficiently acidic for the test. The solution is heated to boiling, then filtered. The filtrate is allowed to cool to room temperature and is then titrated with silver nitrate solution to determine the chloride ion concentration. It should be noted that some aggregates contain chlorides that will show up as acid soluble chlorides, but most likely will not effect corrosion.

A more precise sampling method is currently being developed at the University of Toronto and at CTL. (Detwiler et al., 1996) In this method a nominal 4-inch core is milled off in layers of approximately 1 mm thickness. Each layer is collected as a separate sample, which is analyzed according to ASTM C 114 for acid-soluble chlorides. The chloride concentration is plotted as a function of the distance from the surface. Depending

on the conditions of exposure, the data may be used to compute the apparent diffusion coefficient. Since the conditions of Fick's Second Law generally are not obtained in real structures, this is generally not appropriate for field concrete without a certain amount of extrapolation. However, conditions approaching those assumed in Fick's Law may be imposed in the laboratory setting so that an apparent diffusion coefficient can be calculated. The apparent diffusion coefficient can then be used *with caution* to give some indication of the future service life. Even without an apparent diffusion coefficient, the data from these detailed chloride profiles can be instructive, however.

5.3.2 "Rapid Chloride" Test

Another convenient and commonly-used test is ASTM C 1202 (similar to AASHTO T 277). In this test a 4-inch concrete cylinder or nominal 4-inch core is sliced to a thickness of 2 inches, vacuum saturated, and placed in a cell with NaCl solution on one side and NaOH solution on the other. A potential difference of 60 V direct current is maintained across the cell. The test measures the total charge passed in six hours, with the values divided into broad categories indicating the chloride ion penetrability.

Essentially the test measures the electrical conductivity of the concrete, which can be roughly correlated with the concrete's resistance to chloride ion penetration. Buenfeld and Newman (1987) point out that while the diffusion coefficient of an ion through concrete depends primarily on the microstructure of the concrete, conductivity depends on both microstructure and pore solution chemistry. Concretes can differ significantly in pore solution chemistry, particularly when they contain different amounts of supplementary cementing materials. Thus the comparison of concretes containing different amounts of supplementary cementing materials -- let alone different materials -- is dubious. Zhang and Gjørv (1991) point out that the relation between electrical conductivity and diffusion may vary with the mechanism and type of diffusion. For example, ions diffuse through cement paste by volume diffusion, but the presence of cracks or other voids will result in surface diffusion. Thus small defects will affect the accuracy of measurement. They also state that the measurement of electrical conductivity according to ASTM C 1202 is based on the rate of ion penetration before steady state is reached.

Hooton (1989) emphasizes the need for caution in interpreting the test results. Lower-quality concrete is difficult to evaluate properly because the temperature of the specimens rises when the current is applied, artificially increasing the rate of ion diffusion and necessitating discontinuation of the test. Even concretes that would normally be expected to perform well may exhibit such temperature increases. On the other hand, good-quality concretes are difficult to distinguish because the total charge passed in six hours is so low. The variability of the test results is another reason for caution. Hooton observes that the test results have been abused by those who try to attach some significance to minor differences between concretes in order to show that one is superior to another.

Broadly speaking, however, ASTM C 1202 does provide comparable results to other test methods. Detwiler and Fapohunda (1993) compared the results with those obtained from a similar test method in which most of the concerns outlined above had been minimized or eliminated and found that the two test methods resulted in comparable rankings of eighteen different concretes containing different supplementary cementing materials. Detwiler et al. (1996) found that ASTM C 1202 gave similar rankings of high-quality concretes with and without silica fume to the detailed chloride profile tests. ASTM C 1202 has the additional advantages of being a quick, simple, and relatively inexpensive test. Since it is also a standard test, it is easy to obtain comparable results from one laboratory to another, and the precision of the test is established. So long as one does not read more into the results than are warranted, it is a good indication of the general quality of the concrete and its ability to resist the ingress of chloride ions.

5.3.3 Corrosion Potential Survey

In addition to removal of samples for determination of the chloride ion content and the resistance to chloride ion penetration, a corrosion potential survey is often included as a nondestructive test method in the structural evaluation of a concrete element. The corrosion potential survey is used to determine the probability of corrosion taking place on the reinforcing steel.

ASTM C 876, "Half Cell Potentials of Uncoated Reinforcing Steel in Concrete," outlines the procedures and materials required to perform this test. A copper-copper sulfate half-cell is used in combination with a high-impedance digital voltmeter to measure electrical potentials of the embedded reinforcing steel within concrete.

Typically, a connection to reinforcing steel is made by drilling into the steel reinforcement and fitting a small knurled steel pin into the steel. An alligator clamp is then connected to the steel pin which is connected to the negative terminal of the high-impedance digital voltmeter. The positive terminal of the high-impedance digital voltmeter is connected to the copper-copper sulfate half-cell. Electrical potential measurements are taken by prewetting the concrete surface, placing a small water-soaked cellulose sponge at a specific test location, and placing the half-cell in contact with the sponge.

Potential measurements are usually recorded on a 4 ft (or smaller) grid. If the concrete surface is sealed with paint or a sealer, the coating must be removed by grinding to expose the concrete surface. Potential measurements are valid from 32 to 120°F. A temperature correction of the potential measurement is required when the temperature is outside of the 72±10°F range.

According to ASTM C 876-91, laboratory testing of reinforced concrete specimens indicates the following regarding significance of the corrected numerical value of the potentials measured relative to the copper-copper sulfate (CSE) half-cell.

(a) If potentials over an area are numerically less than -0.20 Volts CSE, there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area at the time of measurement.

(b) If potentials over an area are in the range of -0.20 to -0.35 Volts CSE, corrosion activity of the reinforcing steel in that area is uncertain.

(c) If potentials over an area are numerically greater than -0.35 Volts CSE, there is a greater than 90% probability that reinforcing steel corrosion is occurring in that area at the time of measurement.

Results can be presented in tabular form or in the preferred graphical method presented in Figure #1. Note that the potentials are presented in 50 millivolt increments.

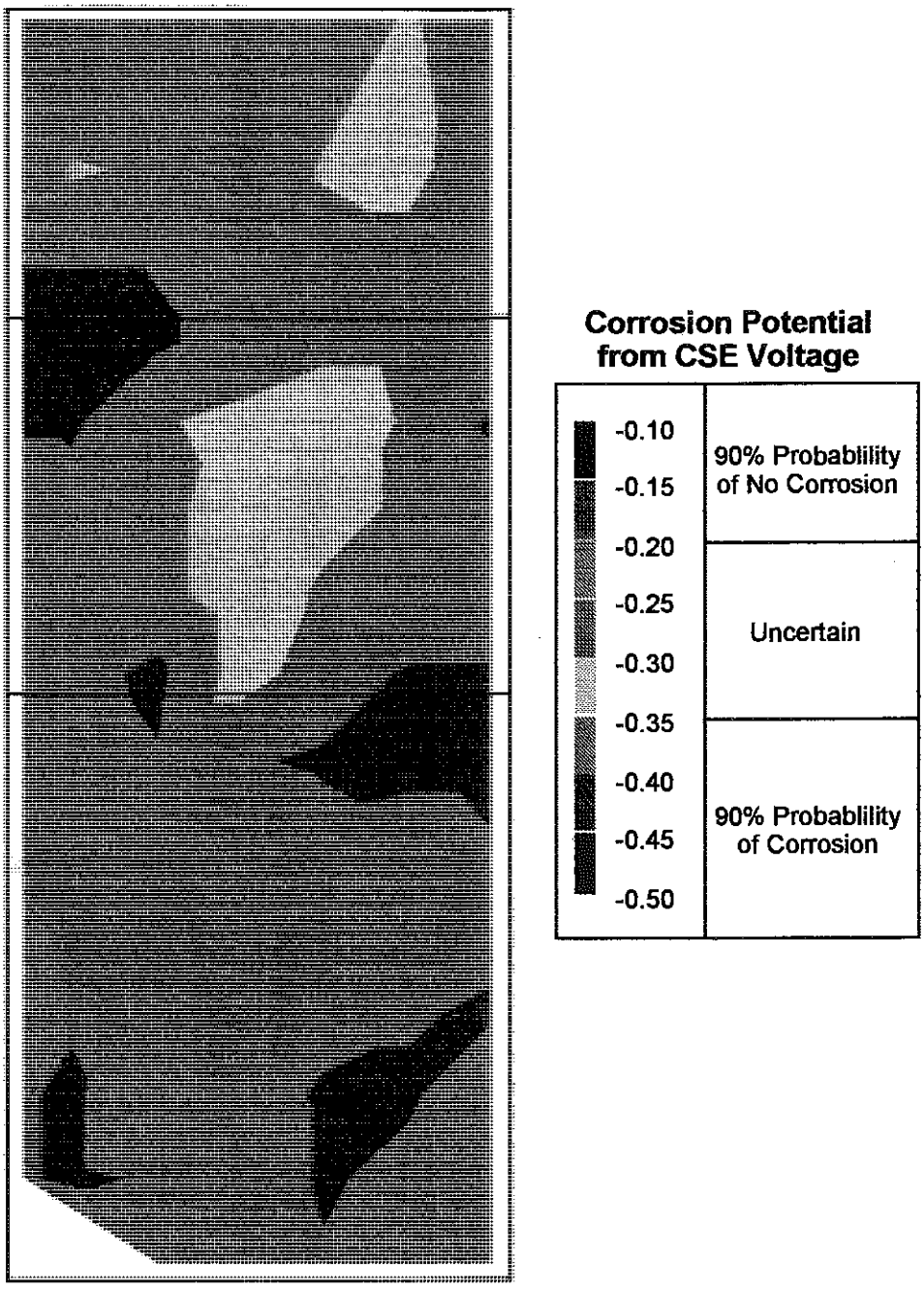

Figure #1 *Corrosion Potential of Reinforcement.*

6. ALKALI SILICA REACTIVITY, CAUSES, MECHANISMS AND PREVENTION

6.1 Causes and Mechanisms and Manifestations of ASR in Bridge Structures

Alkali-Silica Reactivity (ASR) is one of several types of harmful Alkali-Aggregate Reactions (AAR) that occur in concrete. The two fundamental processes of ASR are the swelling and/or dissolution of soluble silica and the formation of alkali-silica gels. The alkali-silica gels are formed by the reaction of the soluble silicas with calcium ions supplied by cement hydration reactions. These gels are expansive, creating internal forces in the concrete that may lead to cracking and crack opening. (Helmuth, 1993)

6.1.1 ASR Reaction Chemistry

ASR is a heterogeneous chemical reaction which occurs in siliceous aggregate particles. The reaction occurs between the alkaline pore solution of the cement paste and the silica particles in the fine or coarse aggregates. The reaction takes place when large amounts of hydroxyl ions are present in the pore solution due to high alkali concentrations. These hydroxyl ions in turn cause the silica in the aggregates to enter into solution. The combination of alkalis and silicas in solution precipitates out alkali silicates. The alkali silicates swell when combined with water, creating the expansive ASR gel. (Johansen, 1995)

The composition of ASR susceptible aggregate has a significant influence on the reaction process. Porous silica-containing aggregates react rapidly, with ASR gel forming first at the aggregate surface, and moving inward. Tensile stresses that build up during the reaction can cause both the aggregate and surrounding paste to crack. In denser polycrystalline aggregates, the reaction occurs primarily on the surface and at grain boundaries. The formation of expansive gel is usually limited and cracking is typically confined to the grain boundary regions. (Johansen, 1995)

6.1.2 Manifestations of ASR in Bridge Structures

ASR can be found in any concrete element of a bridge, including the bridge deck, parapet walls, substructure, and abutments. The cracking patterns exhibited tend to run parallel to the direction of loading in members subjected to restraint or loading. In unrestrained members, the crack pattern is more random, as will be described later. On bridge decks, the predominant pattern of cracks is longitudinal along the deck, with some curvature of the cracks toward the transverse direction at the ends of the deck. In the substructure, horizontal crack patterns extending along the length of pier caps, and long vertical cracks in columns can be indicative of ASR. Furthermore, the presence of a white or brownish deposit in and around cracks is frequently associated with ASR. It should be noted that ASR deterioration may, in some cases, be easily confused with other types of distress such as freeze-thaw deterioration and cracking due to corrosion of embedded

steel. The use of microscopic evaluation and/or other test methods is required to ensure proper identification of the cause of distress. (Stark, 1991)

6.1.3 Moisture and Temperature Conditions

It has been shown that the moisture condition of the concrete is very important in the occurrence of ASR. A relative humidity of roughly 80% must be maintained in order to sustain expansive alkali-silica reactions. The moisture condition of a concrete element varies highly non-linearly through its thickness, and is dependent on its exposure to environmental conditions. Furthermore, climate region and seasonal variation play a significant role in the moisture state within the element. In cold moist climates such as the one in Michigan, it is not uncommon for the moisture state within the center of a concrete element to remain above the 80% relative humidity threshold year round. This promotes an increased susceptibility to ASR. (Helmuth, 1993)

In addition to the moisture state of the concrete, temperature plays a significant role in ASR development. Research conducted in Canada (Alasali, 1989), showed that specimens stored at high temperatures (38°C) expanded more rapidly than specimens stored at room temperature (23°C). Greatly increasing the temperature (to 80°C) led to massive increases in expansion of the specimens. While such high temperature is not experienced in the field, it is an effective method of accelerating ASR in laboratory studies.

While lower temperatures have been shown to inhibit ASR development, it is not recommended to place concrete at cold temperatures as a method of inhibiting ASR reactivity. Because ASR acts over a span of years, it is most beneficial to ensure the highest quality concrete at the onset by avoiding cold weather concreting. Furthermore, pozzolanic additives, which are used to inhibit ASR, tend to retard the hydration reaction. The combined effects of cold temperature and the use of pozzolans can lead to permeability problems in the hardened concrete. (Mohr, 1993)

6.2 ASR Prevention

There are a number of effective methods of limiting and preventing the expansive alkali-silica reaction. The three primary approaches to reducing reactivity are to reduce the content of reactive alkalis, to avoid use of reactive silica bearing aggregates, and to inhibit movement of the reactants through the concrete by densifying the mix with pozzolanic additives. Other methods, such as the use of ASR inhibiting admixtures has also been successful.

6.2.1 Avoidance of Reactive Silica-Bearing Aggregates

Petrographic evaluation of aggregates in accordance with ASTM C295 is used to determine the constituents of concrete aggregates. It has been found that the aggregates

that are susceptible to ASR, tend to contain silica constituents in quantities shown in Table # 2.

Reactive Constituent	Maximum Tolerable Amount	
	Kosmatka	Corps. of Engineers
Opal	0.5%	0%
Chert and Chalcedony	3%	--
Chert with any Chalcedony	--	5%
Tridymite and Cristobalite	1%	1%
Strained or Microcrystalline Quartz	5%*	--
Highly Strained Quartz	--	20%
Volcanic Glasses (>55% Silica)	0%	3%

** as found in granites, granite gneiss, graywackes, argillites, phyllites, siltstones, and natural sands and gravels*

***Table #2** Constituents of aggregates prone to ASR (after Lane, 1992)*

Aggregates that are found to be susceptible to ASR based on the above table, should be evaluated further for ASR using ASTM C227 or ASTM C 1260. These test methods measure expansion of mortar bars cast using the aggregate in question. The amount of expansion measured after a set period of time determines the acceptance/rejection criteria for that aggregate. For ASTM C227, a 0.05% expansion after 3 months, or a 0.10% expansion after 6 months leads to rejection of the aggregate. ASTM C 1260 specifies that a mean expansion after 14 days of 0.10% indicates unacceptable expansion levels. (Kosmatka, 1991)

6.2.2 Use of Low Alkali Cements

The use of low alkali cements is a viable option where large portions of available aggregates are reactive. In a study conducted in Virginia it was found that a significant increase in ASR expansion occurs if the cement alkali content is greater than 0.40%. Furthermore, the study shows that expansion of cement paste mortars is roughly linear with increasing alkali content at ages of two months or more (it takes roughly one month for the alkali concentration of the cement paste pore solutions to stabilize, especially in high alkali cements). This indicates that expansion of cement mortars is primarily a function of the alkali content of the cement, if aggregate type is kept constant. (Lane, 1995)

Traditionally a portland cement alkali content of 0.60% or less has been considered acceptable in providing protection against ASR expansion. It has been found though, that cements with alkali contents exceeding 0.40% can yield excessive expansions. Furthermore, it has been found that expansions exceeding 0.10% are typically associated with the onset of damage in mortar bars. Thus, the use of 0.10% expansion as an acceptance criteria for cements is recommended. (Lane, 1995)

6.2.3 Use of Pozzolans to Inhibit Reactivity

Pozzolanic materials such as fly ash, silica fume, and ground granulated blast-furnace slag, are frequently added to concrete as a means of inhibiting expansion due to ASR. For effective protection against ASR, the type and amount of pozzolan used, as well as the method by which it is introduced into the mix can be important. For example, data by Lane and Ozyildirim (1995) shows that fly ash, slag, and silica fume each have varying degrees of effectiveness, based on the level at which they are added. Typically pozzolans are added as a cement replacement, with replacement being made by mass of total cementitious material. For fly ash (class F), a 15% replacement is sufficient to protect mortar bars which contain cement with a 0.6% alkali content from ASR expansion. At 35% fly ash replacement, mortar bars with 0.92% cement alkali content are held to acceptable expansion levels (less than 0.1%). Similar trends are seen for slag and silica fume additions. It was shown that a 35% fly ash replacement, a 50% slag replacement, or a 7% silica fume replacement can sufficiently reduce expansion even in mortar bars made with high alkali cement.

Pozzolans influence the ASR reaction in several ways. First, their addition as a cement replacement reduces the amount of alkalis available, as the cement content has been reduced. Second, pozzolans densify the mix, reducing the permeability of the concrete. This restrains the movement of free alkalis, and inhibits the reaction process. Finally, and most importantly, pozzolans are composed primarily of glassy silica or silicates which react in the presence of hydroxide ions in a manner similar to the way reactive aggregates react. Because of the extremely fine nature of these pozzolans as compared with aggregates, they react much more quickly. In this way, the reaction actually uses up available hydroxide ions so rapidly that harmful concentrations may never form. The product of this reaction, commonly referred to as a pozzolanic reaction, is cementitious in nature, and contributes to the concrete strength while reducing concrete permeability. At the same time, there are no longer enough hydroxide ions available to force siliceous aggregates into solution, which would lead to the expansive alkali-silicate gel. (Lane, 1992)

There has been some controversy over the effectiveness of fly ash in reducing the harmful effects of ASR. After extensive research in the 1980's it was concluded that the class C fly ash requires a much larger cement replacement than does class F fly ash in order to protect against ASR expansion. Furthermore, when used in low replacement amounts, class C fly ash has actually been found to contribute to expansion in some cases, rather than inhibiting it. Class F fly ash is thus recommended for use with ASR susceptible materials. (Lane, 1992)

6.2.4 Use of ASR Inhibiting Admixtures

Lithium based admixtures have been found to inhibit ASR expansion when added in small dosages to concrete containing highly reactive aggregates. Lithium compounds

come in both liquid and powder forms. Lithium fluoride and lithium carbonate salts are powders, while lithium hydroxide solution is available as a liquid or as a powder. Lithium carbonate is effective in preventing expansion at a dosage of 1% by weight of cement. Lithium fluoride is effective in dosages of 0.5% to 1% by weight of cement. (Concrete Technology Today, 1993)

Lithium based admixtures react with siliceous aggregates in a manner similar to alkalis in cement. In normal cement pastes, the KOH or NaOH in solution reacts with the silicas in the aggregate to form the ASR gel. The addition of lithium changes this reaction process. The lithium in solution reacts with the silicas, creating a gel similar to the ASR gel formed by normal cement pastes. The difference with the gel formed by the lithium reaction is that it is not expansive, when used in conjunction with a low alkali cement. When added to alkali bearing cements, lithium appears to be effective only if it has been added above a threshold amount, where the effects of the alkalis can be counteracted by the lithium. The use of lithium as an ASR inhibitor is still a relatively young area of research, with further study ongoing to better understand the reaction processes. (Diamond, 1992)

Lithium-based compounds have also been used in surface applications to inhibit further degradation due to ASR in hardened concrete. These applications are currently an experimental technology. This approach was first studied at CTL in 1991. In these initial studies, ASTM C 227 mortar bars exhibiting expansions due to ASR were soaked in saturated solutions of various lithium compounds. Continued expansion due to ASR was virtually eliminated by soaking mortar bars in a saturated LiOH solution for a period of 2 days. (Stark, 1993) Other lithium compounds were not as effective as the LiOH in suppressing further expansion. A similar experiment was performed by spraying an ASR affected highway pavement section with a saturated LiOH solution. Results indicated that surface cracks transmitted the lithium ions into the concrete; however, diffusion of the lithium was too slow to be effective in the bulk of the concrete. (Stark, 1993)

6.2.5 Use of Surface Sealers and Injections to Inhibit ASR

Surface sealers and injection materials present a significant advantage of being able to be applied either at time of construction or to existing deteriorating structures. In this way they may be effective in both prevention and repair applications. Numerous papers have been published on the effects of various sealers and injections, and their respective effectiveness in mitigating ASR. While the conclusions are not necessarily in agreement as to which types of sealants and injections are most effective, the following guidelines appear to be appropriate.

Surface barrier coatings must fulfill three basic requirements in order to be effective in preventing ASR deterioration. First, they must prevent the ingress of aggressive agents such as water and chlorides into the concrete. Second, they must permit evaporation of moisture trapped within the concrete. Third, they should have the ability to bridge minor cracks while maintaining the continuity and integrity of the coating. In this

way, contaminants can be kept out of the concrete, and entrapped water will be allowed to escape. (Swamy, 1992) Several types of coatings are used for ASR prevention. The more common among these are monomers, polymers, epoxies, acrylic rubbers, and silanes.

Injection or penetrant materials have the function of filling existing cracks, and preventing free movement of contaminants through the cracks. The type of penetrant to be used depends on the crack width. It is also recommended to use penetrants in conjunction with sealers, as penetrants alone do not stop the ingress of contaminants. If the reaction process in already taking place, the repair method may not manifest immediate results. Instead, the water trapped in the concrete may continue the expansion process for some time. (Moriya, 1989)

7. CHLORIDE ATTACK - CAUSES, MECHANISMS AND PREVENTION

7.1 Causes and Mechanisms of Chloride Attack

The introduction of chlorides into concrete containing reinforcing steel can lead to the corrosion of the steel, and damage to the concrete. The pH of non-carbonated concrete is on the order of 12 to 13. In the high-alkaline environment of concrete, a cohesive oxide film forms on the surface of the reinforcing steel, protecting it from further corrosion. The introduction of chloride ions destroys the passivity of the steel, allowing for corrosion to take place if sufficient moisture and oxygen are present. The corrosion of the steel leads to loss of cross-section as well as the formation of a corrosion product that takes up greater volume than the uncorroded steel. This expansive corrosion reaction can lead to internal forces building up and causing cracking in the concrete. (Hope, 1987)

Nielsen (1979) attributes the ability of chloride ions to break down the passivating layer to their tendency to polarize, as illustrated in Figure #2. The coating of Fe_2O_3 on the iron surface has a positive charge, which creates an electric double layer of ions (A). The negative chloride ions are attracted to the electric double layer. Near the surface, the chloride ions become polarized and elongated (B). The chloride ions then become part of the electric double layer, dissolving ferrous (Fe^{+2}) ions (C). The cycle continues as more chloride ions are attracted to the site. Since the chloride ions are not consumed in any of the corrosion reactions, the effect is intensified, resulting in pitting corrosion (D).

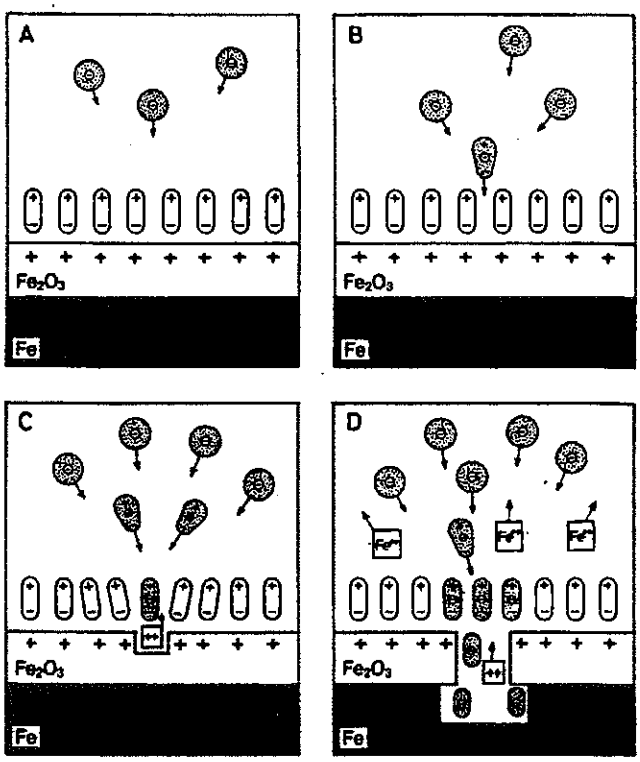

Figure #2 Chloride ion attack of Reinforcement (Nielsen, 1979)

The maximum chloride ion concentration that can be tolerated before corrosion initiates can vary from 0.03-0.4% by mass of concrete. Nielsen (1979) explains that not all chloride ions are free to attack the steel, since they can be chemically bound or physically absorbed by the cement gel. The activity of chloride ions also depends on the concentrations of other ions in the pore solution, particularly Na^{+}, Ca^{+2}, and OH^{-}. In addition, the rate of corrosion will depend on the availability of oxygen and water at the steel surface as well as the electrical conductivity of the concrete.

Chlorides may be introduced into the concrete by several means. At the time of mixing, they may be added in chloride bearing admixtures, or they may be present in chloride bearing aggregates. Once the concrete has hardened, chlorides can permeate the concrete in de-icing salt solutions. It is not the total chloride content in a concrete that is of importance for corrosion, but rather the amount of free chlorides. Some chlorides are bound in aggregates or through the formation of chloroaluminate. These chlorides are not harmful to reinforcing steel. The free chlorides on the other hand, when present in sufficient concentration in the vicinity of the steel can cause serious and rapid deterioration of the steel. (Hope, 1987)

7.2 Protection Against Chloride Attack

Corrosion of steel occurs when the chloride ion content in the vicinity of the reinforcing steel is on the order of 1.2 lb/yd^3. To reduce the susceptibility of a concrete to

chloride intrusion from de-icing salts, low permeability mix designs are sometimes used. This has become common practice for bridge decks where chloride corrosion of reinforcement has long been identified as a leading concern. By reducing the chloride ion permeability of a concrete, the infiltration and free movement of chloride ions in the concrete is reduced, protecting it from the buildup of chloride ion concentrations around the reinforcing steel. In bridge decks, pozzolanic additives and polymeric additives are frequently used to reduce concrete permeability. (Sprinkel, 1993)

Surface sealers such those mentioned in section 6.2.5 are also used to protect against chloride intrusion. It has been shown that the use of sealers can significantly reduce chloride intrusion when the sealers are applied at the time of construction. Sealers can protect the concrete for 10 years or more. At the same time, experimental data shows that sealers are not as effective in preventing corrosion as are pozzolanic and polymeric additives. Furthermore, it is unknown whether later application of sealers, or reapplication of sealers will yield positive results. (Sprinkel, 1993)

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