KENTUCKY TRANSPORTATION CENTER

College of Engineering

RESULTS OF CREEP TESTS ON CONCRETE CYLINDERS FOR THE CABLE-STAYED BRIDGE AT OWENSBORO, KENTUCKY

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Report No.   KTC-00-12

Results of Creep Tests on Concrete Cylinders for the Cable-Stayed Bridge at Owensboro, Kentucky

By

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in cooperation with

Kentucky Transportation Cabinet
Commonwealth of Kentucky

June 2000

Introduction

The Kentucky Transportation Center was requested by the Kentucky Transportation Cabinet to conduct creep tests on the concrete from the new cable-stayed bridge over the Ohio River at Owensboro. The tests have been completed and the data is included herein.

Test Methods and Results

The creep tests were performed on cylinders according the ASTM C-512 (*Creep of Concrete in Compression*). In order to perform the creep tests the compressive strength of the cylinders must be determined. This was determined according to ASTM C-39 (*Compressive Strength of Cylindrical Concrete Specimens*). The modulus of elasticity was determined for one series according to ASTM C-469 (*Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression*). Three cylinders were loaded three days (3-day tests) after the cylinders were made, and three cylinders each were loaded at 30 days (30-day tests) and 90 days (90-day tests) after the cylinders were made. All of the tests ran for 180 days after loading.

Results of the 3-day tests, 30-day tests, and 90-day tests are listed in Sections 1, 2 and 3, respectively. Section 4 lists the results of the modulus and Poisson's ratio tests for the cylinders at 3 days. Section 5 lists the dimensions and weight of the cylinders. Section 6 lists the ASTM standard test methods referenced above. No analysis was performed on the data as the purpose of the tests was only to provide baseline data for future reference, if necessary.

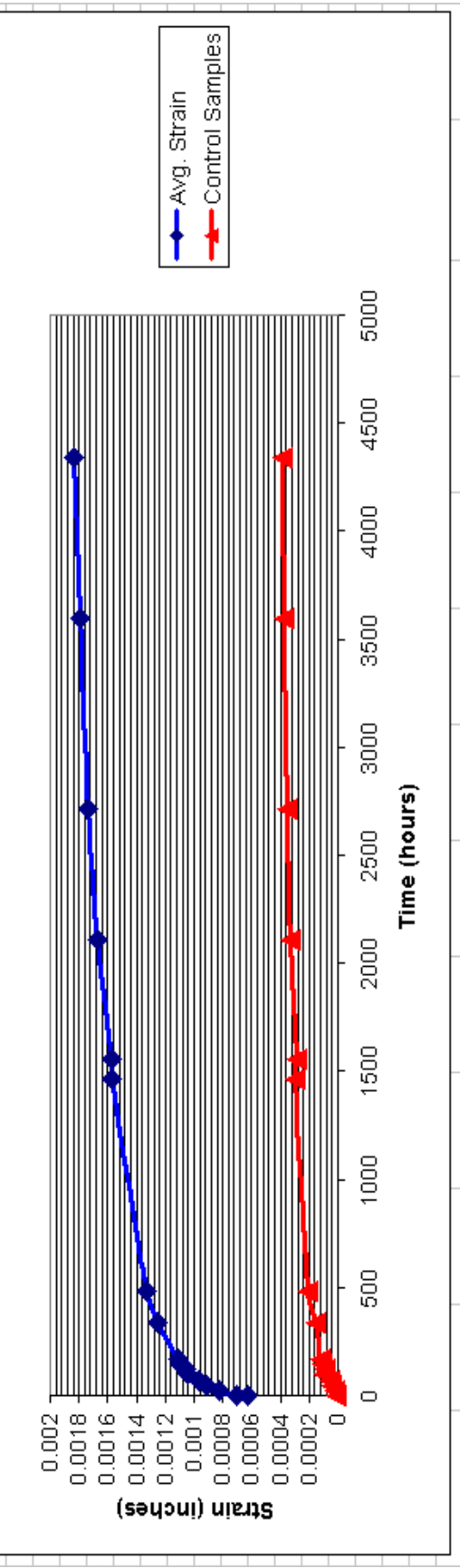**Virtual Image of Cable-Stayed Bridge, Owensboro**

Section 1

3-Day Creep Data

Strain values for 3-day samples. Average strain consists of 90 readings. 9 sets of tabs read ten times.

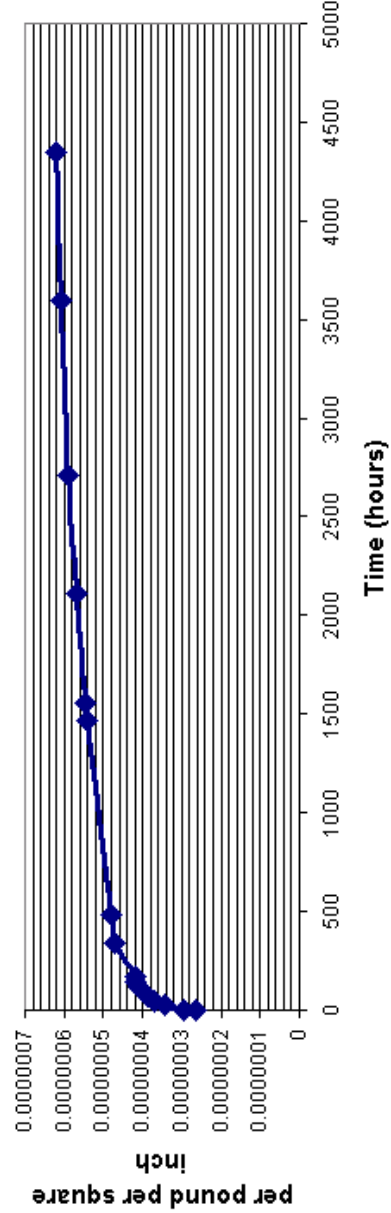The Average for the Control Samples consists of 90 readings. 9 sets of tabs read ten times.

All measurements read in inches

	S3B-1	S3B-2	S3B-3	S3M-1	S3M-2	S3M-3	S3T-1	S3T-2	S3T-3	Control Samples	Avg. Strain
after loading	1	0.000416971	0.000669554	0.000703806	0.000470842	0.000882457	0.000654385	0.000549679	0.000699331	0.000611967	6.81698E-06	0.000628777
3-hour	3	0.000476621	0.000765287	0.000785830	0.000519015	0.000982802	0.000727222	0.000612155	0.000754360	0.000666453	1.14667E-05	0.000698861
1-day	24	0.000566668	0.000905159	0.000916611	0.000619378	0.001141059	0.000856838	0.000737681	0.000877030	0.000786323	2.4146E-05	0.000822972
2-day	48	0.000664458	0.001033854	0.000963359	0.000751569	0.001252585	0.000911609	0.000878970	0.000976484	0.000818155	3.9531E-05	0.000916782
3-day	72	0.000710629	0.001095478	0.001024447	0.000789706	0.001310784	0.000956056	0.000936574	0.001027214	0.000863751	5.42159E-05	0.000968293
4-day	96	0.000769418	0.001174300	0.001087256	0.000872003	0.001411989	0.001037783	0.001009655	0.001096287	0.000922539	0.000103304	0.001042359
5-day	120	0.000777161	0.001177453	0.001095000	0.000888922	0.001426037	0.001046672	0.001021978	0.001114343	0.000950356	9.1995E-05	0.001055325
6-day	144	0.000821898	0.001227325	0.001142609	0.000927346	0.001481656	0.001090833	0.001065540	0.001147590	0.000979606	0.000114167	0.001098267
7-day	168	0.000825913	0.001241656	0.001150065	0.000934801	0.001491978	0.001107465	0.001075857	0.001161921	0.000987062	0.00012506	0.001108524
14-day	336	0.000930299	0.001394714	0.001294039	0.001074161	0.001671451	0.001263463	0.001221444	0.001308666	0.001120123	0.000153984	0.001253151
21-day	480	0.000995971	0.001486147	0.001361437	0.001143841	0.001765201	0.001334292	0.001285354	0.001375446	0.001183499	0.000205621	0.001325688
61-day	1464	0.001172624	0.001766465	0.001604642	0.001368079	0.002104652	0.001579185	0.001510613	0.001631676	0.001398003	0.000293157	0.001570660
2 month or 65 day	1560	0.001186676	0.001778217	0.001610092	0.001371233	0.002107805	0.001580045	0.001513765	0.001634256	0.001406893	0.000283443	0.001576554
3-month	2112	0.001265826	0.001881975	0.001716781	0.001465860	0.002229365	0.001685573	0.001607767	0.001725398	0.001479159	0.000331479	0.001673078
4-month	2712	0.001315725	0.001950765	0.001780450	0.001526078	0.002313081	0.001752101	0.001671963	0.001794758	0.001545690	0.000348808	0.001738957
5-month	3600	0.001356447	0.002014395	0.001829206	0.001586295	0.002393357	0.001812894	0.001734439	0.001848641	0.001593294	0.000371871	0.001796552
6-month	4344	0.001390860	0.002060255	0.001875094	0.001620705	0.002439229	0.001858776	0.001763098	0.001883034	0.001627706	0.000385251	0.001835417

Average Strain of Loaded Samples and Shrinkage of Control Samples vs. Time for 3-day Samples

Legend: Avg. Strain; Control Samples

Y-axis: Strain (inches) — 0, 0.0002, 0.0004, 0.0006, 0.0008, 0.001, 0.0012, 0.0014, 0.0016, 0.0018, 0.002

X-axis: Time (hours) — 0, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, 5000

Total Load-Induced Strain per pound per square inch

difference between the average strain values of the loaded and control specimens divided by the average stress.   Measurements are defined as in section 8 of A.S.T.M. C 512

Area of Cylinder   28.367 inches

		Average Load	Average Stress	Total Load-Induced Strain per pound per square inch									Avg. Tot. Load Induced Strain
				S3B-1	S3B-2	S3B-3	S3M-1	S3M-2	S3M-3	S3T-1	S3T-2	S3T-3	
after loading	1	66495	2344.097014	1.7497E-07	2.8273E-07	2.9734E-07	1.9795E-07	3.7355E-07	2.7625E-07	2.3159E-07	2.9543E-07	2.582E-07	2.6533E-07
3-hour	3	66095	2329.996122	1.9964E-07	3.2353E-07	3.3235E-07	2.1783E-07	4.1688E-07	3.0719E-07	2.5781E-07	3.1884E-07	2.811E-07	2.95019E-07
1-day	24	65725	2316.952797	2.3415E-07	3.8025E-07	3.8519E-07	2.569E-07	4.8206E-07	3.5939E-07	3.0796E-07	3.6811E-07	3.29E-07	3.44774E-07
2-day	48	67050	2363.662002	2.6439E-07	4.2067E-07	3.9085E-07	3.0124E-07	5.1321E-07	3.6895E-07	3.5514E-07	3.964E-07	3.294E-07	3.71141E-07
3-day	72	66950	2360.136779	2.7813E-07	4.4119E-07	4.1109E-07	3.1163E-07	5.3241E-07	3.8211E-07	3.7386E-07	4.1226E-07	3.43E-07	3.87299E-07
4-day	96	66755	2353.262594	2.8306E-07	4.5511E-07	4.1812E-07	3.2665E-07	5.5612E-07	3.971E-07	3.8515E-07	4.2196E-07	3.481E-07	3.99044E-07
5-day	120	66725	2352.205027	2.9129E-07	4.6146E-07	4.2641E-07	3.388E-07	5.6715E-07	4.0586E-07	3.9537E-07	4.3463E-07	3.649E-07	4.09543E-07
6-day	144	66635	2349.032326	3.0129E-07	4.7388E-07	4.3781E-07	3.4618E-07	5.8215E-07	4.1577E-07	4.0501E-07	4.3994E-07	3.684E-07	4.18938E-07
7-day	168	66570	2346.740931	2.9865E-07	4.7581E-07	4.3678E-07	3.4505E-07	5.8247E-07	4.1863E-07	4.0516E-07	4.4183E-07	3.673E-07	4.19077E-07
14-day	336	66260	2335.81274	3.3235E-07	5.3118E-07	4.8808E-07	3.9394E-07	6.4965E-07	4.7499E-07	4.57E-07	4.9434E-07	4.136E-07	4.70571E-07
21-day	480	66030	2327.704727	3.3954E-07	5.5012E-07	4.9655E-07	4.0307E-07	6.7001E-07	4.8489E-07	4.6386E-07	5.0257E-07	4.201E-07	4.81189E-07
61-day	1464	67110	2365.777135	3.7175E-07	6.2276E-07	5.5436E-07	4.5436E-07	7.6571E-07	5.436E-07	5.1461E-07	5.6578E-07	4.67E-07	5.39993E-07
2 month or 65 day	1560	67090	2365.072091	3.8191E-07	6.3202E-07	5.6093E-07	4.5994E-07	7.7138E-07	5.4823E-07	5.2021E-07	5.7115E-07	4.75E-07	5.46753E-07
3-month	2112	66885	2357.845384	3.9627E-07	6.5759E-07	5.8753E-07	4.8111E-07	8.0492E-07	5.7429E-07	5.4129E-07	5.9118E-07	4.867E-07	5.68994E-07
4-month	2712	66690	2350.971199	4.1128E-07	6.814E-07	6.0896E-07	5.0076E-07	8.3552E-07	5.969E-07	5.6281E-07	6.1504E-07	5.091E-07	5.91308E-07
5-month	3600	66550	2346.035887	4.1968E-07	7.0013E-07	6.2119E-07	5.1765E-07	8.6166E-07	6.1424E-07	5.808E-07	6.2947E-07	5.206E-07	6.07271E-07
6-month	4344	66450	2342.510664	4.2929E-07	7.1505E-07	6.36E-07	5.2741E-07	8.7683E-07	6.2904E-07	5.8819E-07	6.3939E-07	5.304E-07	6.19065E-07

Total Load-Induced Strain vs. Time for 3-day Samples

Axis labels: per pound per square inch (vertical), Time (hours) (horizontal)

Legend: Avg. Tot. Load Induced Strain

4

Creep Strain as defined in section 8 of A.S.T.M. C 512

		S3B-1	S3B-2	S3B-3	S3M-1	S3M-2	S3M-3	S3T-1	S3T-2	S3T-3	Avg. Creep	Temp (F)	Humidity (%)
3-hour	3	2.46639E-08	4.08024E-08	3.5008E-08	1.9878E-08	4.3331E-08	3.0937E-08	2.622E-08	2.341E-08	2.2951E-08	2.9689E-08	73.5	50%
1-day	24	5.918E-08	9.75206E-08	8.7851E-08	5.8948E-08	1.0851E-07	8.3136E-08	7.6376E-08	7.2677E-08	7.0798E-08	7.9444E-08	73.4	50%
2-day	48	8.94162E-08	1.37944E-07	9.3508E-08	1.0329E-07	1.3966E-07	9.2697E-08	1.2356E-07	1.0097E-07	7.1255E-08	1.0581E-07	73.9	51%
3-day	72	1.03152E-07	1.58461E-07	1.1375E-07	1.1368E-07	1.5886E-07	1.0586E-07	1.4227E-07	1.1683E-07	8.4844E-08	1.2197E-07	73.7	54%
4-day	96	1.08087E-07	1.72385E-07	1.2078E-07	1.287E-07	1.8256E-07	1.2084E-07	1.5356E-07	1.2653E-07	8.9968E-08	1.3371E-07	73.2	54%
5-day	120	1.16313E-07	1.78738E-07	1.2907E-07	1.4085E-07	1.9359E-07	1.2961E-07	1.6378E-07	1.3921E-07	1.0676E-07	1.4421E-07	73.8	52%
6-day	144	1.26313E-07	1.91153E-07	1.4048E-07	1.4822E-07	2.086E-07	1.3952E-07	1.7342E-07	1.4451E-07	1.1026E-07	1.5361E-07	73.6	53%
7-day	168	1.23676E-07	1.93081E-07	1.3944E-07	1.4709E-07	2.0892E-07	1.4237E-07	1.7357E-07	1.464E-07	1.0916E-07	1.5375E-07	73	53%
14-day	336	1.5738E-07	2.48451E-07	1.9074E-07	1.9599E-07	2.761E-07	1.9873E-07	2.2541E-07	1.9891E-07	1.5546E-07	2.0524E-07	73.9	52%
21-day	480	1.64567E-07	2.67398E-07	1.9921E-07	2.0511E-07	2.9646E-07	2.0863E-07	2.3227E-07	2.0714E-07	1.6194E-07	2.1586E-07	73.4	51%
61-day	1464	1.96772E-07	3.40033E-07	2.5702E-07	2.5641E-07	3.9216E-07	2.6734E-07	2.8302E-07	2.7036E-07	2.0885E-07	2.7466E-07	73.7	50%
2 month or 65 day	1560	2.06932E-07	3.49295E-07	2.636E-07	2.6199E-07	3.9783E-07	2.7197E-07	2.8862E-07	2.7572E-07	2.1686E-07	2.8142E-07	73.8	50%
3-month	2112	2.21298E-07	3.74864E-07	2.9019E-07	2.8315E-07	4.3137E-07	2.9804E-07	3.0971E-07	2.9575E-07	2.2859E-07	3.0366E-07	73	51%
4-month	2712	2.36311E-07	3.98676E-07	3.1162E-07	3.028E-07	4.6196E-07	3.2064E-07	3.3123E-07	3.1961E-07	2.5094E-07	3.2598E-07	73	50%
5-month	3600	2.44703E-07	4.17401E-07	3.2385E-07	3.1969E-07	4.8811E-07	3.3798E-07	3.4921E-07	3.3405E-07	2.6247E-07	3.4194E-07	73.6	50%
6-month	4344	2.54314E-07	4.32321E-07	3.3867E-07	3.2945E-07	5.0328E-07	3.5278E-07	3.5661E-07	3.4396E-07	2.7224E-07	3.5373E-07	73.4	51%

Creep Strain vs. Time for 3-day Samples

Avg. Creep

Time (hours)

per pound-force per square inch
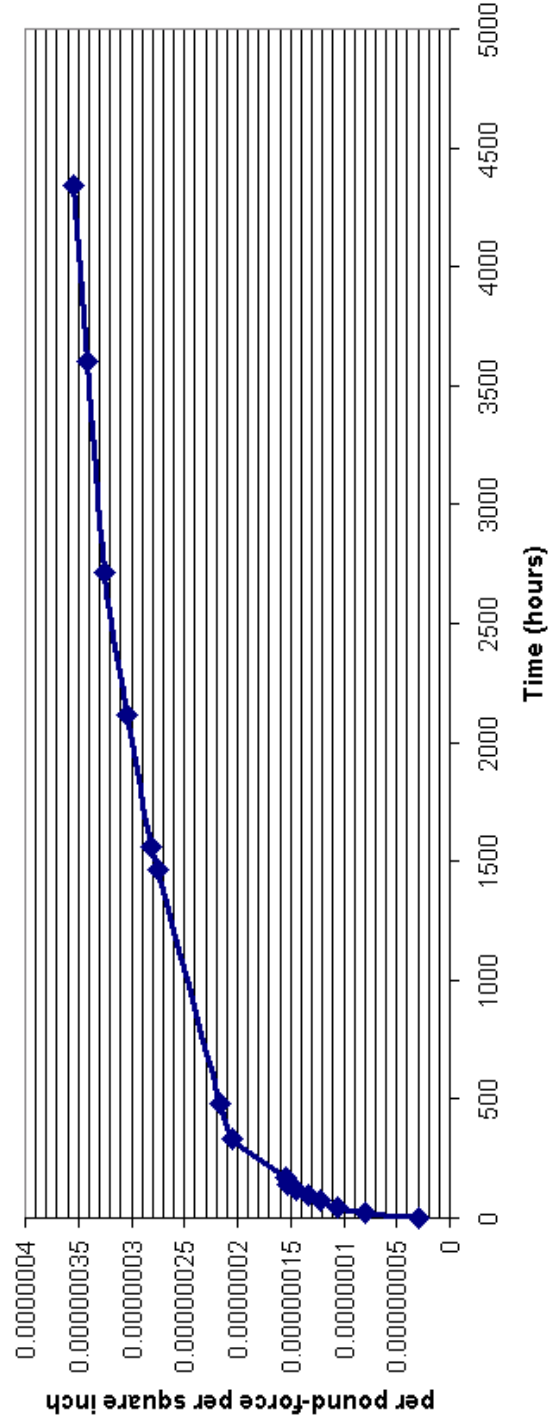
Section 2

30-Day Creep Data

Strain values for 30-day samples. Average strain consists of 90 readings. 9 sets of tabs read ten times.
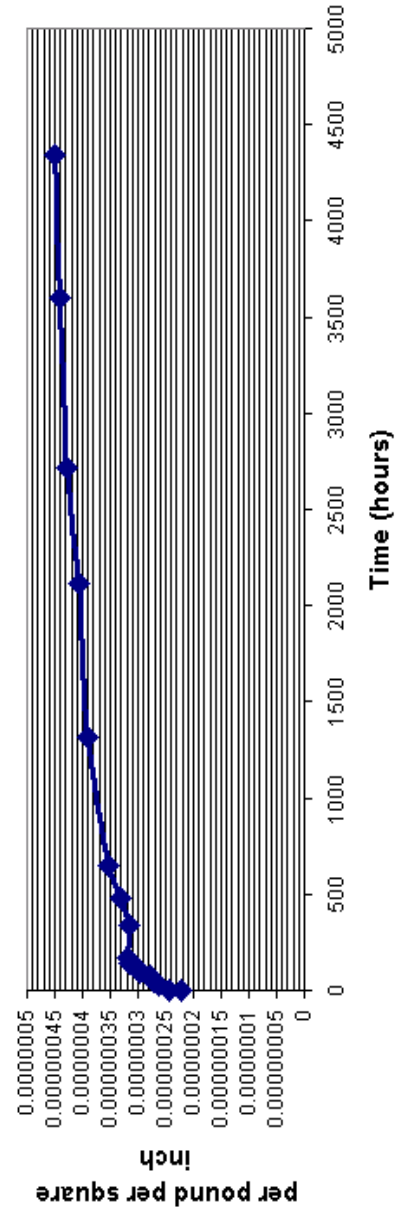The Average for the Control Samples consists of 90 readings. 9 sets of tabs read ten times.

All measurements read in inches

		S30B-1	S30B-2	S30B-3	S30M-1	S30M-2	S30M-3	S30T-1	S30T-2	S30T-3	Control Samples	Avg. Strain
after loading	1	0.000767261	0.000296092	0.000485653	0.000712490	0.000344890	0.000559512	0.000500560	0.000478282	0.00064731	-4.86848E-06	0.00053245
3-hour	3	0.000806813	0.000303545	0.000480490	0.000750336	0.000358852	0.000611706	0.000532114	0.000510951	0.00068836	-2.22011E-05	0.000561441
1-day	24	0.000891364	0.000337081	0.000542738	0.000830903	0.000357218	0.000689424	0.000594935	0.000559954	0.00076920	-6.74925E-06	0.000619202
2-day	48	0.000932636	0.000337654	0.000550197	0.000866456	0.000373846	0.000701469	0.000617309	0.000573137	0.00079100	-7.70463E-06	0.000638189
3-day	72	0.000961584	0.000356285	0.000576301	0.000901149	0.000397642	0.000722978	0.000636529	0.000599787	0.00081767	1.3136E-06	0.000663325
4-day	96	0.0010005435	0.000385808	0.000593799	0.000943870	0.000408249	0.000786930	0.000678122	0.000627584	0.00085926	-1.14026E-06	0.000698784
5-day	120	0.001024925	0.000409312	0.000609863	0.000961646	0.000428891	0.000809873	0.000687302	0.000645352	0.00087360	2.10896E-06	0.000716751
6-day	144	0.001104030	0.000427083	0.000665514	0.001039059	0.000459281	0.000840272	0.000741804	0.000694641	0.00093612	2.20545E-05	0.000767534
7-day	168	0.001104890	0.000415331	0.000653179	0.001039919	0.000381014	0.000832528	0.000728896	0.000680026	0.00092780	4.81628E-06	0.00075151
14-day	336	0.001116354	0.000423357	0.000666949	0.001044507	0.000394201	0.000822778	0.000740943	0.000690343	0.00093641	1.59054E-05	0.000759538
21-day	480	0.001175110	0.000462053	0.000720591	0.001110165	0.000389901	0.000883289	0.000803191	0.000743358	0.00099463	3.11086E-05	0.000809143
28-day	648	0.001272558	0.000580145	0.000753867	0.001212236	0.000486803	0.000937204	0.000919080	0.000806696	0.00106576	4.85648E-05	0.000892927
2-month	1320	0.001437646	0.000682187	0.000873774	0.001373370	0.000614668	0.001046181	0.001031526	0.000896959	0.00118392	9.24693E-05	0.001015581
3-month	2112	0.001506433	0.000722316	0.000931146	0.001442182	0.000649071	0.001097802	0.001088897	0.000948541	0.00123554	0.00011025	0.001069103
4-month	2712	0.001549425	0.000845568	0.001002861	0.001490924	0.000801017	0.001135084	0.001246667	0.001054571	0.00124988	0.000122039	0.001152889
5-month	3600	0.001605028	0.000889709	0.001047038	0.001552281	0.000862369	0.001190719	0.001285105	0.001104434	0.00129979	0.000145809	0.001204052
6-month	4344	0.001664070	0.000943023	0.001100393	0.001611345	0.000909960	0.001232589	0.001321249	0.001146273	0.00134166	0.000171744	0.001252285

Average Strain of Loaded Samples and Shrinkage of Control Samples vs. Time for 30-day Samples

Strain (inches) vs. Time (hours)

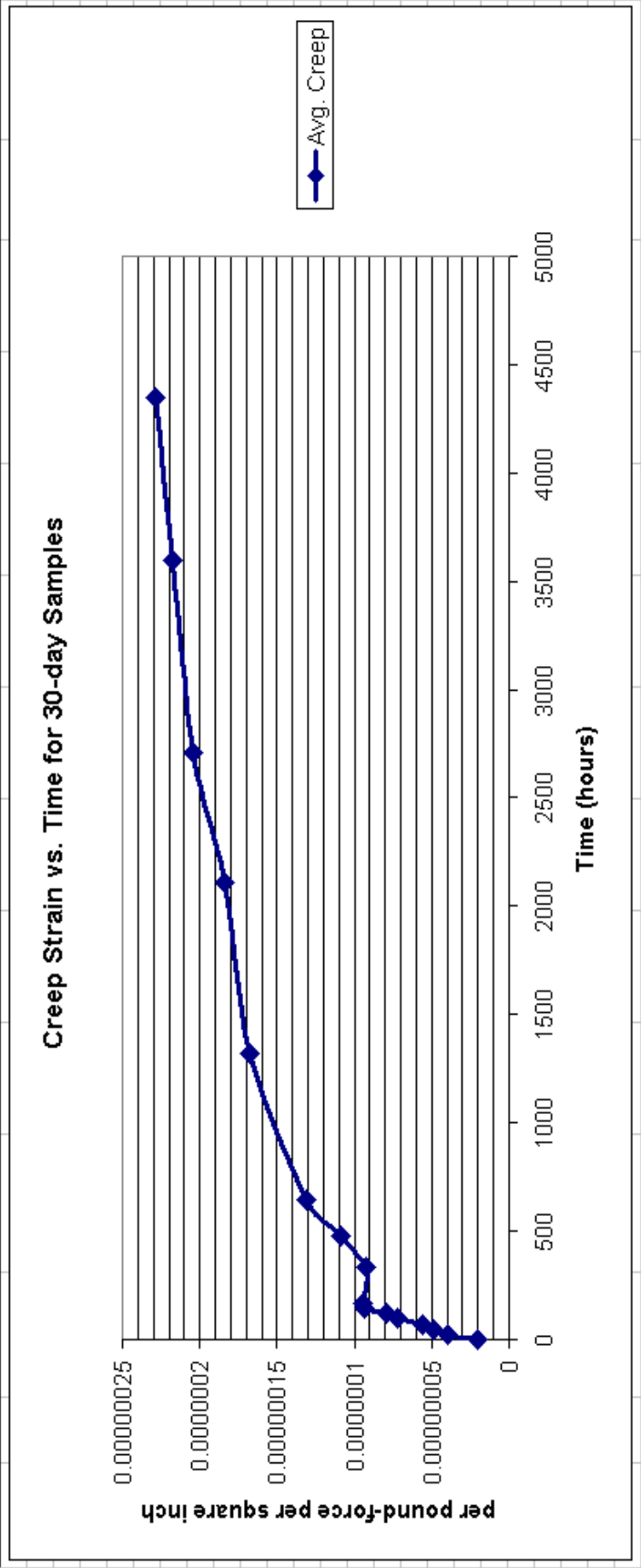Legend: Avg. Strain, Control Samples

7
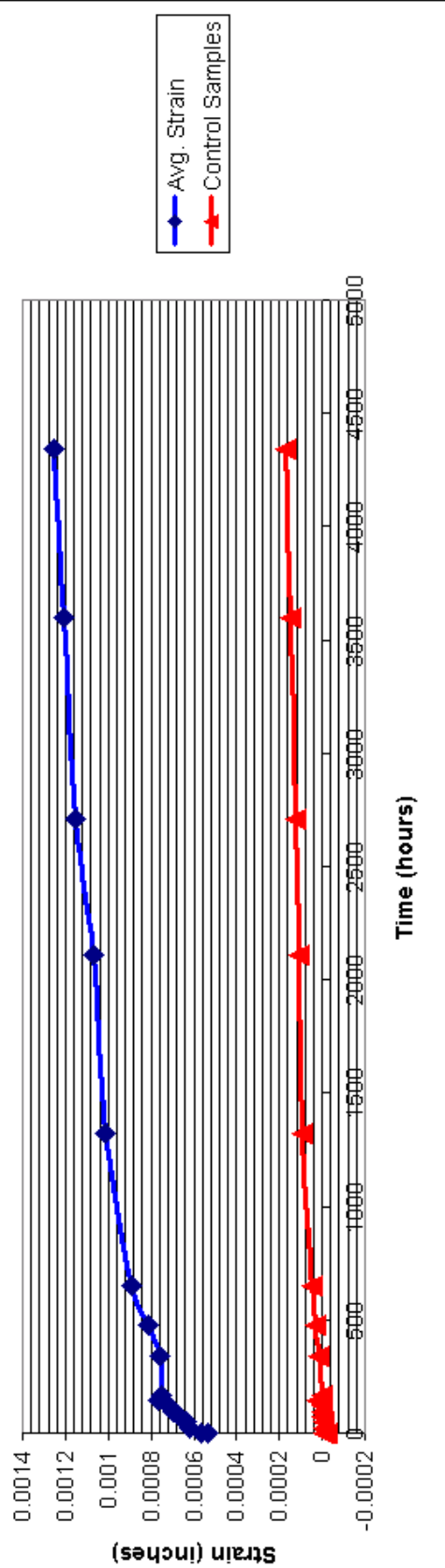
Total Load-Induced Strain per pound per square inch. Measurements are defined as in section 8 of A.S.T.M. C 512
difference between the average strain values of the loaded and control specimens divided by the average stress.

Area of Cylinder 28.367 inches

Total Load-Induced Strain per pound per square inch

		Average Load	Average Stress	S30B-1	S30B-2	S30B-3	S30M-1	S30M-2	S30M-3	S30T-1	S30T-2	S30T-3	Avg. Tot. Load Induced Strain
after loading	1	68310	2408.079811	3.2064E-07	1.2498E-07	2.037E-07	2.979E-07	1.4524E-07	2.3437E-07	2.0989E-07	2.0064E-07	2.708E-07	2.23132E-07
3-hour	3	67945	2395.212747	3.4611E-07	1.36E-07	2.0987E-07	3.2253E-07	1.5901E-07	2.6466E-07	2.3143E-07	2.2259E-07	3.008E-07	2.4367E-07
1-day	24	67605	2383.226989	3.7685E-07	1.4427E-07	2.3056E-07	3.5148E-07	1.5272E-07	2.9211E-07	2.5247E-07	2.3779E-07	3.256E-07	2.62649E-07
2-day	48	67425	2376.881588	3.9562E-07	1.453E-07	2.3472E-07	3.6778E-07	1.6053E-07	2.9836E-07	2.6296E-07	2.4437E-07	3.36E-07	2.7174E-07
3-day	72	67350	2374.237671	4.0445E-07	1.4951E-07	2.4218E-07	3.79E-07	1.6693E-07	3.0396E-07	2.6754E-07	2.5207E-07	3.438E-07	2.78831E-07
4-day	96	67165	2367.716008	4.2513E-07	1.6343E-07	2.5127E-07	3.9912E-07	1.729E-07	3.3284E-07	2.8689E-07	2.6554E-07	3.634E-07	2.95612E-07
5-day	120	67130	2366.48218	4.3221E-07	1.7207E-07	2.5682E-07	4.0547E-07	1.8034E-07	3.4134E-07	2.8954E-07	2.7181E-07	3.683E-07	3.01985E-07
6-day	144	66785	2354.320161	4.5957E-07	1.7204E-07	2.7331E-07	4.3197E-07	1.8571E-07	3.4754E-07	3.0571E-07	2.8568E-07	3.883E-07	3.16643E-07
7-day	168	66770	2353.791377	4.6736E-07	1.7441E-07	2.7545E-07	4.3976E-07	1.5983E-07	3.5165E-07	3.0762E-07	2.8886E-07	3.921E-07	3.1723E-07
14-day	336	66745	2352.910072	4.677E-07	1.7317E-07	2.767E-07	4.3716E-07	1.6078E-07	3.4293E-07	3.0815E-07	2.8664E-07	3.912E-07	3.16048E-07
21-day	480	66565	2346.56467	4.8752E-07	1.8365E-07	2.9383E-07	4.5985E-07	1.529E-07	3.6316E-07	3.2903E-07	3.0353E-07	4.106E-07	3.31563E-07
28-day	648	67545	2381.111855	5.1404E-07	2.2325E-07	2.9621E-07	4.8871E-07	1.8405E-07	3.732E-07	3.6559E-07	3.1923E-07	4.272E-07	3.54608E-07
2-month	1320	67030	2362.956957	5.6928E-07	2.4957E-07	3.3065E-07	5.4208E-07	2.2099E-07	4.0361E-07	3.9741E-07	3.4046E-07	4.619E-07	3.9066E-07
3-month	2112	66830	2355.906511	5.9263E-07	2.598E-07	3.4844E-07	5.6536E-07	2.2871E-07	4.1918E-07	4.154E-07	3.5583E-07	4.776E-07	4.07E-07
4-month	2712	68375	2410.371206	5.9219E-07	3.0017E-07	3.6543E-07	5.6791E-07	2.8169E-07	4.2029E-07	4.6658E-07	3.8688E-07	4.679E-07	4.27672E-07
5-month	3600	68055	2399.090492	6.0824E-07	3.1008E-07	3.7565E-07	5.8625E-07	2.9866E-07	4.3554E-07	4.7489E-07	3.9958E-07	4.81E-07	4.41102E-07
6-month	4344	67905	2393.802658	6.2341E-07	3.222E-07	3.8794E-07	6.0139E-07	3.0839E-07	4.4316E-07	4.802E-07	4.0711E-07	4.887E-07	4.51391E-07

Total Load-Induced Strain vs. Time for 30-day Samples

Legend: Avg. Tot. Load Induced Strain

X-axis: Time (hours) — 0, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, 5000

Y-axis: per pound per square inch — 0, 0.00000005, 0.0000001, 0.00000015, 0.0000002, 0.00000025, 0.0000003, 0.00000035, 0.0000004, 0.00000045, 0.0000005

8

Creep Strain as defined in section 8 of A.S.T.M. C 512

		S30B-1	S30B-2	S30B-3	S30M-1	S30M-2	S30M-3	S30T-1	S30T-2	S30T-3	Avg. Creep	Temp (F)	Humidity (%)
3-hour	3	2.5472E-08	1.10191E-08	6.1749E-09	2.4638E-08	1.3762E-08	3.0286E-08	2.1538E-08	2.1953E-08	3.0005E-08	2.0539E-08	73.4	52%
1-day	24	5.62064E-08	1.92912E-08	2.6866E-08	5.3582E-08	7.4765E-09	5.7744E-08	4.2578E-08	3.7151E-08	5.4759E-08	3.9517E-08	73.3	53%
2-day	48	7.49784E-08	2.03195E-08	3.1022E-08	6.988E-08	1.5282E-08	6.3994E-08	5.3067E-08	4.3734E-08	6.52E-08	4.8608E-08	73	52%
3-day	72	8.38131E-08	2.45302E-08	3.8479E-08	8.1103E-08	2.1685E-08	6.9587E-08	5.7656E-08	5.1432E-08	7.301E-08	5.57E-08	73.1	50%
4-day	96	1.04484E-07	3.84474E-08	4.7573E-08	1.0123E-07	2.7661E-08	9.847E-08	7.6997E-08	6.4903E-08	9.2558E-08	7.248E-08	73.3	53%
5-day	120	1.11568E-07	4.70916E-08	5.3119E-08	1.0757E-07	3.5101E-08	1.0697E-07	7.9652E-08	7.1176E-08	9.7434E-08	7.8854E-08	73.5	51%
6-day	144	1.38929E-07	4.7057E-08	6.9612E-08	1.3408E-07	4.0468E-08	1.1317E-07	9.5826E-08	8.5045E-08	1.1742E-07	9.3512E-08	76	50%
7-day	168	1.46721E-07	4.94265E-08	7.1756E-08	1.4186E-07	1.4582E-08	1.1728E-07	9.7734E-08	8.6223E-08	1.213E-07	9.4099E-08	73.9	50%
14-day	336	1.47056E-07	4.81898E-08	7.2999E-08	1.3927E-07	1.5534E-08	1.0856E-07	9.8257E-08	8.6002E-08	1.2039E-07	9.2916E-08	73.6	51%
21-day	480	1.66881E-07	5.86694E-08	9.0128E-08	1.6195E-07	7.6573E-09	1.2879E-07	1.1914E-07	1.0289E-07	1.3978E-07	1.0843E-07	73.4	50%
28-day	648	1.93402E-07	9.82695E-08	9.2509E-08	1.9081E-07	3.8804E-08	1.3883E-07	1.557E-07	1.186E-07	1.5636E-07	1.3148E-07	73.5	52%
2-month	1320	2.48636E-07	1.24588E-07	1.2695E-07	2.4418E-07	7.575E-08	1.6924E-07	1.8752E-07	1.3982E-07	1.9107E-07	1.6753E-07	73	51%
3-month	2112	2.7199E-07	1.34821E-07	1.4474E-07	2.6746E-07	8.3467E-08	1.8481E-07	2.0551E-07	1.5519E-07	2.0682E-07	1.8387E-07	73.5	52%
4-month	2712	2.71544E-07	1.75194E-07	1.6173E-07	2.7002E-07	1.3645E-07	1.8592E-07	2.5669E-07	1.8625E-07	1.9708E-07	2.0454E-07	73.6	50%
5-month	3600	2.87598E-07	1.85097E-07	1.7196E-07	2.8836E-07	1.5344E-07	2.0118E-07	2.65E-07	1.9894E-07	2.1018E-07	2.1797E-07	73.3	51%
6-month	4344	3.02771E-07	1.97219E-07	1.8424E-07	3.0349E-07	1.6314E-07	2.0879E-07	2.7031E-07	2.0647E-07	2.179E-07	2.2826E-07	73.9	50%

Creep Strain vs. Time for 30-day Samples

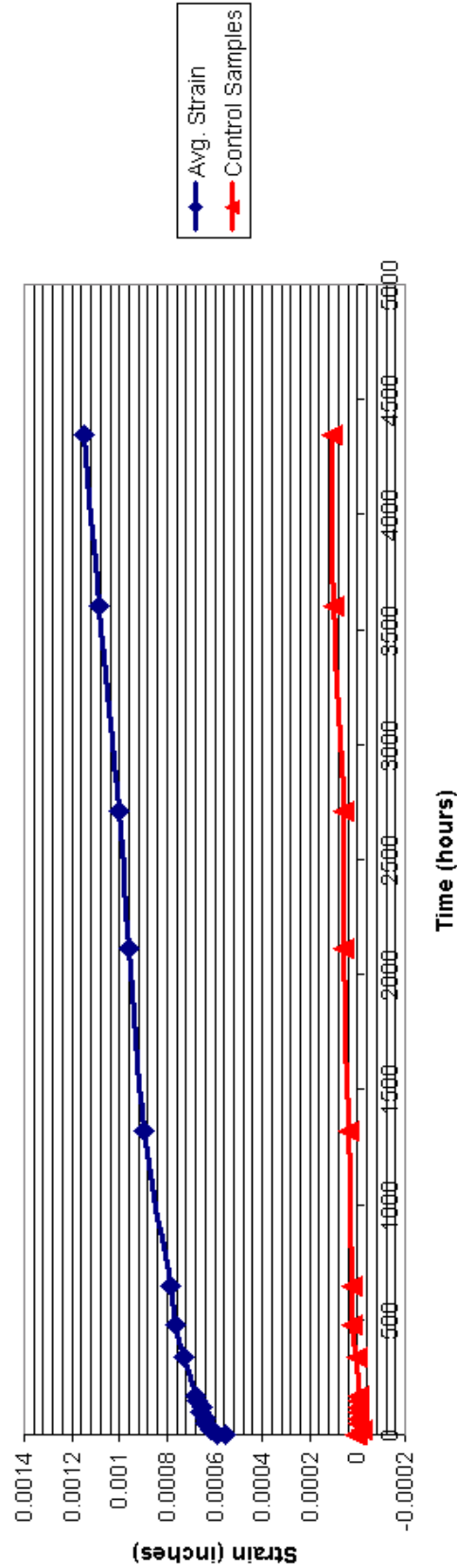per pound-force per square inch — Time (hours)

Legend: Avg. Creep

Section 3

90-Day Creep Data

Strain values for 90-day samples. Average strain consists of 90 readings. 9 sets of tabs read ten times.

The Average for the Dummy Samples consists of 90 readings. 9 sets of tabs read ten times.

								All measurements read in inches.				
		S90B-1	S90B-2	S90B-3	S90M-1	S90M-2	S90M-3	S90T-1	S90T-2	S90T-3	Control Samples	Avg. Strain
after loading	1	0.000705891	0.000395022	0.000693741	0.000645636	0.000579887	0.000365711	0.000544105	0.000536205	0.00054757	4.52276E-06	0.000557085
3-hour	3	0.000745874	0.000413655	0.000725561	0.000678806	0.000603691	0.000386634	0.000588539	0.000573728	0.00058627	8.56698E-06	0.000589173
1-day	24	0.000789309	0.000423688	0.000764835	0.000719030	0.000636098	0.000400104	0.000619786	0.000596929	0.00061981	-1.59854E-05	0.000618844
2-day	48	0.000819800	0.000442035	0.000784329	0.0007447699	0.000652731	0.000416154	0.000642147	0.000614115	0.00063243	-3.50221E-06	0.000639049
3-day	72	0.000822101	0.000436302	0.000801529	0.0007447699	0.000645848	0.000408129	0.000635840	0.000615833	0.00063472	-5.60411E-06	0.000638667
4-day	96	0.000840798	0.000453788	0.000820162	0.000762321	0.000664490	0.000421600	0.000660781	0.000628723	0.00065565	-3.34347E-06	0.000656479
5-day	120	0.000843675	0.000445762	0.000813856	0.000766334	0.000662195	0.000419880	0.000660781	0.000622994	0.00065278	-7.80132E-06	0.000654251
6-day	144	0.000869276	0.000449488	0.000833636	0.000784969	0.000672233	0.000433924	0.000677694	0.000645050	0.00067830	-6.17764E-06	0.000671619
7-day	168	0.000862372	0.000463248	0.000849689	0.000796437	0.000687720	0.000444242	0.000682855	0.000642758	0.00067658	-4.58566E-06	0.000678433
14-day	336	0.000934284	0.000487901	0.000895556	0.000855496	0.000733032	0.000475769	0.000747643	0.000708638	0.00075398	4.01207E-06	0.000732478
21-day	480	0.000983185	0.000513701	0.000938557	0.000892767	0.000758843	0.000501563	0.000779177	0.000740146	0.00078552	2.08904E-05	0.00076594
28-day	648	0.001011950	0.000530901	0.000950024	0.000909968	0.000781786	0.000507296	0.000802684	0.000751603	0.00079699	2.10175E-05	0.000782577
2-month	1320	0.001083862	0.000619766	0.001107692	0.000975908	0.000876427	0.000659198	0.000862312	0.000903413	0.00096040	3.52205E-05	0.000894331
3-month	2112	0.001166417	0.000672226	0.001188820	0.001045575	0.000940381	0.000711647	0.000909039	0.000978745	0.00102920	5.50287E-05	0.000960228
4-month	2712	0.001213304	0.000697165	0.001225227	0.001087719	0.000971067	0.000736582	0.000956914	0.001026580	0.00107507	5.5028E-05	0.000998848
5-month	3600	0.001308228	0.000768831	0.001325561	0.001165126	0.001048500	0.000813966	0.001034315	0.001109646	0.00116681	0.000100184	0.001082332
6-month	4344	0.001374387	0.000817564	0.001408695	0.001225332	0.001108726	0.000874153	0.001083050	0.001181254	0.00124422	0.000110057	0.001146375

Average Strain of Loaded Samples and Shrinkage of Control Samples vs. Time for 90-day Samples

Total Load-Induced Strain per pound per square inch

difference between the average strain values of the loaded and control specimens divided by the average stress.

Measurements are defined as in section 8 of A.S.T.M. C 512

Area of Cylinder	28.367	inches

Total Load-Induced Strain per pound per square inch

		Average Load	Average Stress	S90B-1	S90B-2	S90B-3	S90M-1	S90M-2	S90M-3	S90T-1	S90T-2	S90T-3	Avg. Tot. Load Induced Strain
after loading	1	68390	2410.899989	2.9092E-07	1.6197E-07	2.8588E-07	2.6592E-07	2.3865E-07	1.4981E-07	2.2381E-07	2.2053E-07	2.252E-07	2.29193E-07
3-hour	3	68180	2403.497021	3.0676E-07	1.6854E-07	2.9831E-07	2.7878E-07	2.4761E-07	1.573E-07	2.413E-07	2.3514E-07	2.404E-07	2.41567E-07
1-day	24	67815	2390.629957	3.3685E-07	1.8392E-07	3.2662E-07	3.0746E-07	2.7277E-07	1.7405E-07	2.6594E-07	2.5638E-07	2.66E-07	2.65549E-07
2-day	48	67900	2393.626397	3.4396E-07	1.8613E-07	3.2914E-07	3.1383E-07	2.7416E-07	1.7532E-07	2.6974E-07	2.5803E-07	2.657E-07	2.68442E-07
3-day	72	67620	2383.755773	3.4723E-07	1.8538E-07	3.386E-07	3.1602E-07	2.7329E-07	1.7356E-07	2.6909E-07	2.607E-07	2.686E-07	2.70276E-07
4-day	96	67650	2384.813339	3.5397E-07	1.9168E-07	3.4531E-07	3.2106E-07	2.8004E-07	1.7819E-07	2.7848E-07	2.6504E-07	2.763E-07	2.76677E-07
5-day	120	67510	2379.878027	3.5778E-07	1.9058E-07	3.4525E-07	3.2528E-07	2.8153E-07	1.7971E-07	2.8093E-07	2.6505E-07	2.776E-07	2.78188E-07
6-day	144	67420	2376.705327	3.6835E-07	1.9172E-07	3.5335E-07	3.3288E-07	2.8544E-07	1.8517E-07	2.8774E-07	2.74E-07	2.88E-07	2.85183E-07
7-day	168	67385	2375.471499	3.6496E-07	1.9694E-07	3.5962E-07	3.3721E-07	2.9144E-07	1.8894E-07	2.8939E-07	2.7251E-07	2.867E-07	2.8753E-07
14-day	336	67095	2365.248352	3.9331E-07	2.0458E-07	3.7693E-07	3.6E-07	3.0822E-07	1.9945E-07	3.144E-07	2.9791E-07	3.171E-07	3.07987E-07
21-day	480	66970	2360.841823	4.0761E-07	2.0874E-07	3.887E-07	3.6931E-07	3.1258E-07	2.036E-07	3.2119E-07	3.0466E-07	3.239E-07	3.15586E-07
28-day	648	66810	2355.201466	4.2074E-07	2.1649E-07	3.9445E-07	3.7744E-07	3.2302E-07	2.0647E-07	3.3189E-07	3.102E-07	3.295E-07	3.23352E-07
2-month	1320	68335	2408.961117	4.3531E-07	2.4265E-07	4.452E-07	3.905E-07	3.492E-07	2.5902E-07	3.4334E-07	3.604E-07	3.841E-07	3.56631E-07
3-month	2112	67990	2396.799098	4.637E-07	2.5751E-07	4.7304E-07	4.1328E-07	3.6939E-07	2.7396E-07	3.5631E-07	3.854E-07	4.064E-07	3.7767E-07
4-month	2712	67750	2388.338562	4.8497E-07	2.6886E-07	4.8996E-07	4.3239E-07	3.8355E-07	2.8537E-07	3.7762E-07	4.0679E-07	4.271E-07	3.95178E-07
5-month	3600	67675	2385.694645	5.0637E-07	2.8027E-07	5.1364E-07	4.4639E-07	3.975E-07	2.9919E-07	3.9156E-07	4.2313E-07	4.471E-07	4.11682E-07
6-month	4344	67775	2389.219868	5.2918E-07	2.9612E-07	5.4354E-07	4.6679E-07	4.1798E-07	3.1981E-07	4.0724E-07	4.4835E-07	4.747E-07	4.33748E-07

Total Load-Induced Strain vs. Time for 90-day Samples

y-axis: per pound per square inch

x-axis: Time (hours)

Legend: Avg. Tot. Load Induced Strain
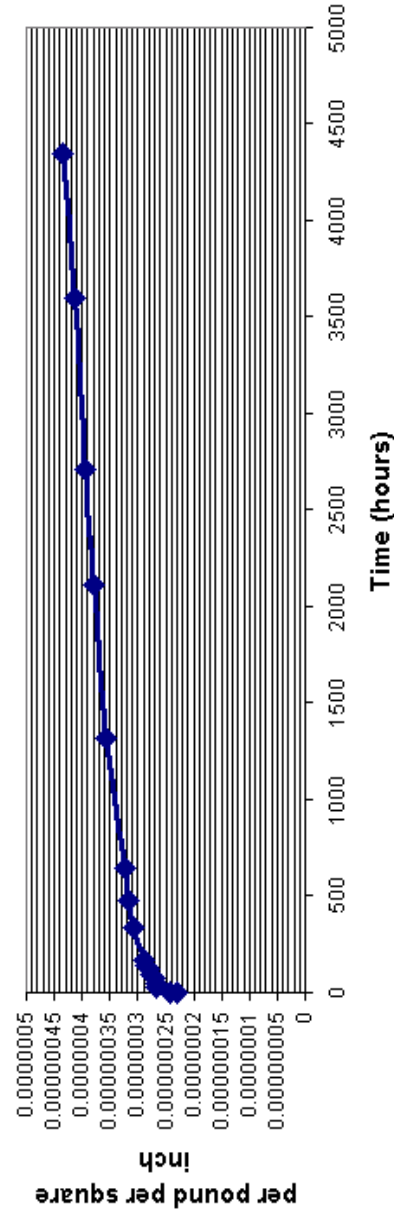
Creep Strain as defined in section 8 of A.S.T.M. C 512

		S90B-1	S90B-2	S90B-3	S90M-1	S90M-2	S90M-3	S90T-1	S90T-2	S90T-3	Avg. Creep	Temp (F)	Humidity (%)
3-hour	3	1.58488E-08	6.56875E-09	1.2437E-08	1.2854E-08	8.9561E-09	7.4838E-09	1.7494E-08	1.4608E-08	1.5114E-08	1.2374E-08	73.5	50%
1-day	24	4.59391E-08	2.19431E-08	4.0741E-08	4.1534E-08	3.4115E-08	2.4235E-08	4.2134E-08	3.5849E-08	4.0708E-08	3.6355E-08	73	50%
2-day	48	5.30405E-08	2.41623E-08	4.3261E-08	4.7911E-08	3.5508E-08	2.5508E-08	4.5927E-08	3.7493E-08	4.043E-08	3.9249E-08	73	51%
3-day	72	5.63119E-08	2.34097E-08	5.2721E-08	5.0093E-08	3.4637E-08	2.3749E-08	4.528E-08	4.0164E-08	4.3374E-08	4.1082E-08	73	50%
4-day	96	6.30501E-08	2.9712E-08	5.9437E-08	5.5136E-08	4.1385E-08	2.8372E-08	5.4671E-08	4.4506E-08	5.1083E-08	4.7483E-08	73.6	53%
5-day	120	6.68659E-08	2.861E-08	5.9376E-08	5.9361E-08	4.2874E-08	2.9892E-08	5.7122E-08	4.4521E-08	5.2324E-08	4.8994E-08	73	50%
6-day	144	7.74319E-08	2.97492E-08	6.7476E-08	6.6953E-08	4.679E-08	3.5358E-08	6.393E-08	5.3472E-08	6.2747E-08	5.599E-08	73.5	51%
7-day	168	7.40469E-08	3.49711E-08	7.3747E-08	7.1283E-08	5.2788E-08	3.9128E-08	6.5582E-08	5.1979E-08	6.1502E-08	5.8336E-08	73.5	51%
14-day	336	1.02393E-07	4.26103E-08	9.1059E-08	9.4075E-08	6.957E-08	4.9638E-08	9.0589E-08	7.7375E-08	9.1833E-08	7.8794E-08	73	49%
21-day	480	1.16691E-07	4.6771E-08	1.0283E-07	1.0338E-07	7.3929E-08	5.3788E-08	9.7384E-08	8.4128E-08	9.8633E-08	8.6393E-08	74	51%
28-day	648	1.29826E-07	5.45199E-08	1.0857E-07	1.1152E-07	8.4365E-08	5.6655E-08	1.0808E-07	8.9668E-08	1.0422E-07	9.4159E-08	73.5	50%
2-month	1320	1.44393E-07	8.06823E-08	1.5932E-07	1.2457E-07	1.1055E-07	1.0921E-07	1.1953E-07	1.3987E-07	1.5881E-07	1.2744E-07	73.6	51%
3-month	2112	1.72781E-07	9.55364E-08	1.8717E-07	1.4736E-07	1.3074E-07	1.2414E-07	1.325E-07	1.6486E-07	1.812E-07	1.4848E-07	73.5	50%
4-month	2712	1.94058E-07	1.06891E-07	2.0409E-07	1.6647E-07	1.449E-07	1.3555E-07	1.5381E-07	1.8626E-07	2.0185E-07	1.6598E-07	73.5	51%
5-month	3600	2.15454E-07	1.18301E-07	2.2776E-07	1.8046E-07	1.5885E-07	1.4938E-07	1.6775E-07	2.026E-07	2.2185E-07	1.8249E-07	73.3	51%
6-month	4344	2.38266E-07	1.34152E-07	2.5767E-07	2.0087E-07	1.7934E-07	1.7E-07	1.8343E-07	2.2781E-07	2.4945E-07	2.0455E-07	73	50%

Creep Strain vs. Time for 90-day Samples

Time (hours)

per pound-force per square inch

Avg. Creep

13
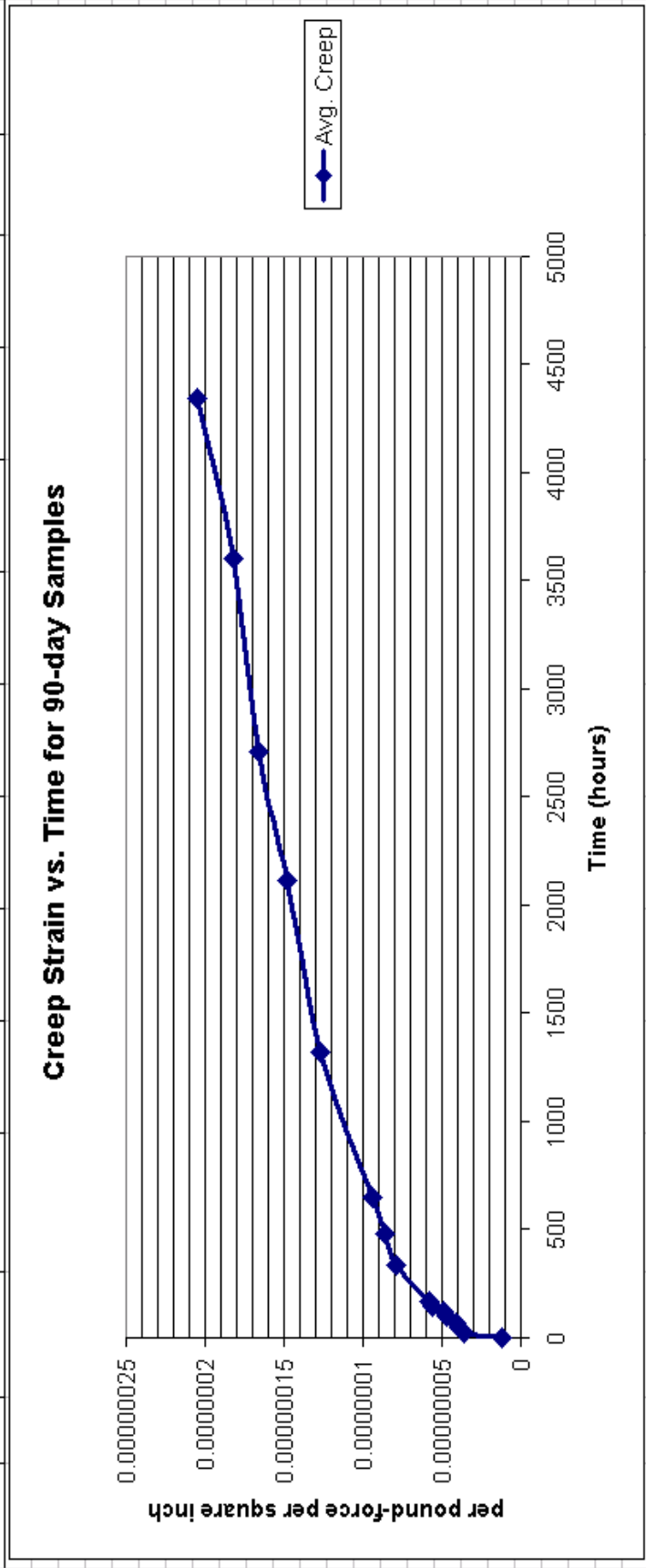
Section 4

Modulus of Elasticity

Static Modulus of Elasticity for 3 Day Creep Samples

DATE: 5/27/1999

Load Rate 60000 lbs per minute
Vertical Gage Length = 16 inches
Horizontal Gage Length = 12 inches

Compressive Strength for 3 day breaks

	A	B	C	Avg.
Max Load	166700	173400	176000	172033.3333
X-Sect(A)	28.2744	28.2744	28.2744	
Comp Str.	5895.79266	6132.756133	6224.712107	6084.4203

Static Modulus of Elasticity

40% of: 172033.3333 "=" 68813.33333 lbs.

Sample 3-A

Load	Vert. 1	Vert. 2	Avg. Vert.	Long. Strain	Stress(psi)	Horizont. 1	Horizont. 2	Avg.Horizont	Transverse Strain
0	0	0	0	0	0	0	0		0
				0	0		0		0
8600				0.00005	304.1620689	0	0		0
8000	0.0008	0.0008	0.0008	0.00005	282.9414594	0	0	0	0
10000	0.001	0.001	0.001	0.0000625	353.6768243	0	0	0	0
15000	0.0015	0.0015	0.0015	0.00009375	530.5152364	0.0001	0	0.00005	4.16667E-06
20000	0.0021	0.002	0.00205	0.000128125	707.3536485	0.0002	0.00015	0.000175	1.45833E-05
25000	0.0028	0.0027	0.00275	0.000171875	884.1920607	0.0003	0.0002	0.00025	2.08333E-05
30000	0.0033	0.0033	0.0033	0.00020625	1061.030473	0.0004	0.0003	0.00035	2.91667E-05
35000	0.00395	0.0039	0.003925	0.000245313	1237.868885	0.0005	0.0004	0.00045	0.0000375
40000	0.0046	0.0045	0.00455	0.000284375	1414.707297	0.0006	0.0005	0.00055	4.58333E-05
45000	0.005	0.0051	0.00505	0.000315625	1591.545709	0.0008	0.0006	0.0007	5.83333E-05
50000	0.0057	0.0057	0.0057	0.00035625	1768.384121	0.0009	0.0007	0.0008	6.66667E-05
55000	0.0064	0.0064	0.0064	0.0004	1945.222533	0.001	0.0008	0.0009	0.000075
60000	0.007	0.007	0.007	0.0004375	2122.060946	0.0011	0.00095	0.001025	8.54167E-05
65000	0.0077	0.0077	0.0077	0.00048125	2298.899358	0.0012	0.00105	0.001125	0.00009375
68800	0.0082			0.0005125	2433.296551	0.0013	0.0011		0.000108333
68800		0.008	0.008	0.0005	2433.296551				9.16667E-05

Run 1   E = 4649416.4 psi   u = 0.2342342

Run 2   E = 4731410 psi   u = 0.2037037

S2 = stress at 40% of ult. Load
e2 = Longitudinal strain @ S2
S1 = stress @ strain of 50 uin/in
E = Young's Modulus of Elasticity
u = Poisson's ratio
et2 = transverse strain at mid-height of the specimen
   produced by stress S2
et1 = transverse strain at mid-height of the specimen
   produced by stress S1
Longitudinal Strain at .000050 - .000050 * 16 = .0008
E = ((S2-S1)/((e2-0.000050))*A)
u = (et2-et1)/(e2-0.000050)

Sample 3-C

Load	Vert. 1	Vert. 2	Avg. Vert.	Long. Strain	Stress(psi)	Horizont. 1	Horizont. 2	Avg. Horizont	Transverse Strain
0	0	0	0	0	0	0	0		0
8600		0.0008	0	0.00005	304.1620689		0.0001		8.33333E-06
8000	0.0008	0		0.00005	282.9414594	0.0001	0		8.33333E-06
10000	0.001	0.001	0.001	0.0000625	353.6768243	0.0002	0.0001	0.00015	0.0000125
15000	0.0016	0.0016	0.0016	0.0001	530.5152364	0.0003	0.0002	0.00025	2.08333E-05
20000	0.0022	0.0021	0.00215	0.000134375	707.3536485	0.00035	0.00035	0.00035	2.91667E-05
25000	0.0029	0.0029	0.0029	0.00018125	884.1920607	0.00045	0.00045	0.00045	0.0000375
30000	0.0036	0.0036	0.0036	0.000225	1061.030473	0.00055	0.00055	0.00055	4.58333E-05
35000	0.0043	0.0044	0.00435	0.000271875	1237.868885	0.00065	0.00065	0.00065	5.41667E-05
40000	0.005	0.0052	0.0051	0.00031875	1414.707297	0.0008	0.0008	0.0008	6.66667E-05
45000	0.0057	0.0059	0.0058	0.0003625	1591.545709	0.0009	0.0009	0.0009	0.000075
50000	0.0065	0.0066	0.00655	0.000409375	1768.384121	0.001	0.001	0.001	8.33333E-05
55000	0.0071	0.0073	0.0072	0.00045	1945.222533	0.0011	0.00105	0.001075	8.95833E-05
60000	0.0079	0.0079	0.0079	0.00049375	2122.060946	0.0012	0.00115	0.001175	9.79167E-05
65000	0.0085	0.0086	0.00855	0.000534375	2298.899358	0.00135	0.0013	0.001325	0.000110417
68800	0.009			0.0005625	2433.296551	0.00145			0.000120833
68800		0.0091		0.00056875	2433.296551		0.0014		0.000116667

S2 = stress at 40% of ult. Load
e2 = Longitudinal strain @ S2
S1 = stress @ strain of 50 uin/in
E = Young's Modulus of Elasticity
u = Poisson's ratio
et2 = transverse strain at mid-height of the specimen
      produced by stress S2
et1 = transverse strain at mid-height of the specimen
      produced by stress S1
Longitudinal Strain at .000050 - .000050 * 16 = .0008
E = ((S2-S1)/((e2-0.000050))*A)
u = (et2-et1)/(e2-0.000050)

| Run 1 | | E = | 4195814.8 | psi |
| | | u = | 0.2195122 | |

| Run 2 | | E = | 4104355.6 | psi |
| | | u = | 0.2088353 | |

		E		**u**
3A	run 1	4649416.414 psi		0.23423423
	run 2	4731409.96 psi		0.2037037
3C	run1	4195814.813 psi		0.2195122
	run2	4104355.628 psi		0.20883534
Standard Deviation		315963.1696		0.01349133
Average		4420249.204		
Coefficient of Variation		7.148084984		

16

Section 5

Cylinder Height, Diameter, and Weight

unit weight of concrete for Owensboro Bridge						
Date						
cylinder	weight(lbs)	height(in)	diameter(in)	area(in^2)	volume(ft^3)	unit weight (lbs/cf)
1	28.3	11.977	5.9935	28.21310601	0.195548826	144.7208896
2	29.1	11.965	6.006	28.33091082	0.196168604	148.3417804
3	29.2	12.0195	5.99	28.18016464	0.196013593	148.9692604
4	29	11.981	6.014	28.40643471	0.196954568	147.2420784
5	28.7	12.022	6.006	28.33091082	0.197103131	145.6090519
6	29.2	12.001	5.997	28.24606662	0.196169586	148.8508006
7	29	11.995	5.993	28.20839892	0.195810038	148.1027242
8	28.7	11.9915	5.9935	28.21310601	0.195785568	146.5889461
9	28.8	12.011	5.9995	28.26962169	0.196496774	146.5672915
10	28.4	12.0025	5.997	28.24606662	0.196194106	144.7546036
	average (Diam.)		5.99895	inches		
	average (area)		28.26443873	inches^2		
average unit weight		146.9747427	lbs/cf			

Section 6

ASTM C-39
ASTM C-469
ASTM C-512

C39/C39M-01 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

1. Scope

1.1 This test method covers determination of compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores. It is limited to concrete having a unit weight in excess of 50 lb/ft^3 [800 kg/m^3].

1.2 The values stated in either inch-pound or SI units are to be regarded separately as standard. The SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes which provide explanatory material. These notes shall not be considered as requirements of the standard.

C469-94e1 Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression

1. Scope

1.1 This test method covers determination of (*1*) chord modulus of elasticity (Young's) and (*2*) Poisson's ratio of molded concrete cylinders and diamond-drilled concrete cores when under longitudinal compressive stress. Chord modulus of elasticity and Poisson's ratio are defined in Termninology E 6.

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

C512-87(1994) Standard Test Method for Creep of Concrete in Compression

1. Scope

1.1 This test method covers the determination of the creep of molded concrete cylinders subjected to sustained longitudinal compressive load. This test method is limited to concrete in which the maximum aggregate size does not exceed 2 in. (50 mm).

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.