Creep Compliance and Tensile Strength of Hot-Mix Asphalt for Wearing Courses in Missouri

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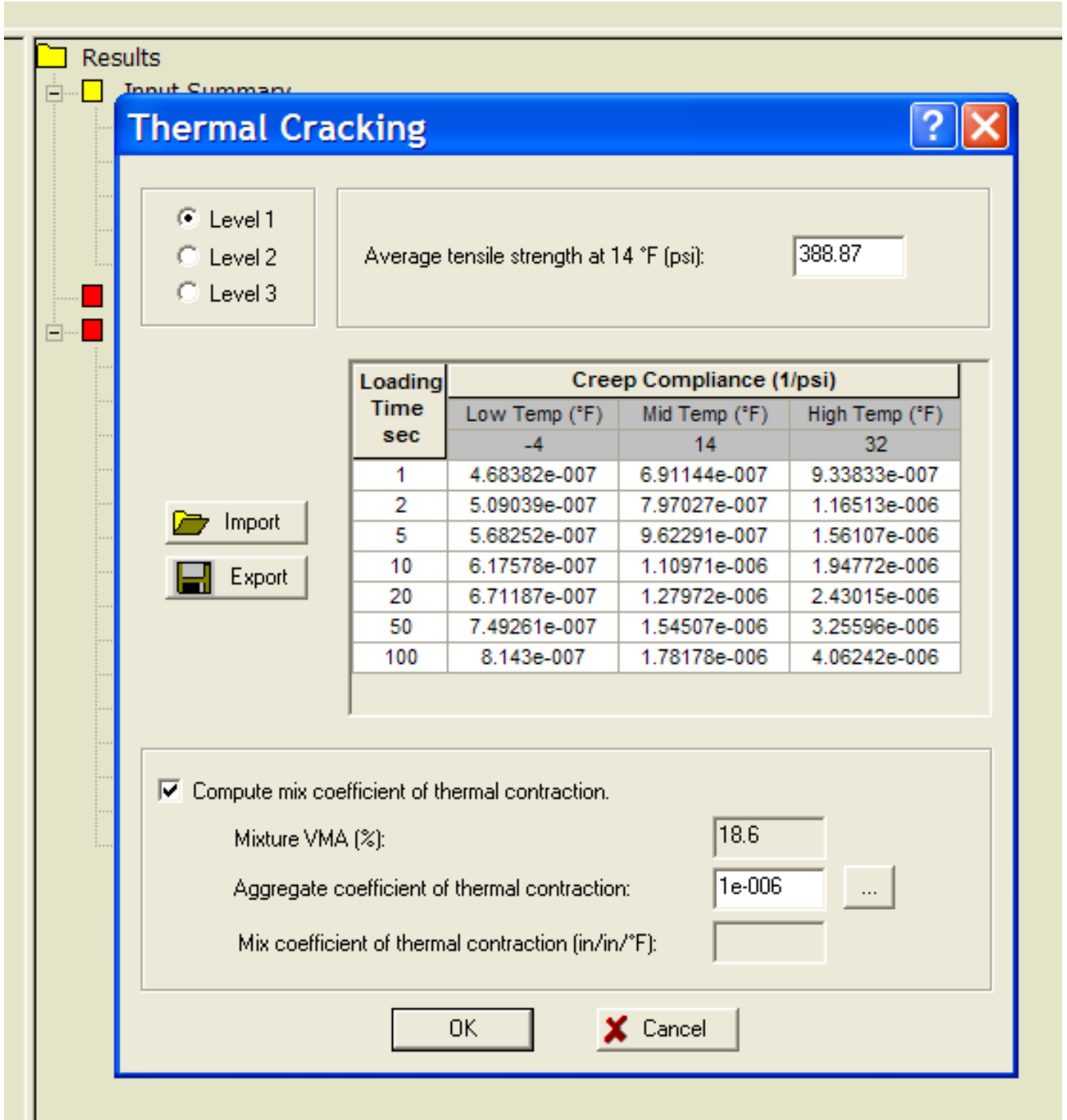
Thermal Cracking Module Level 1 Inputs

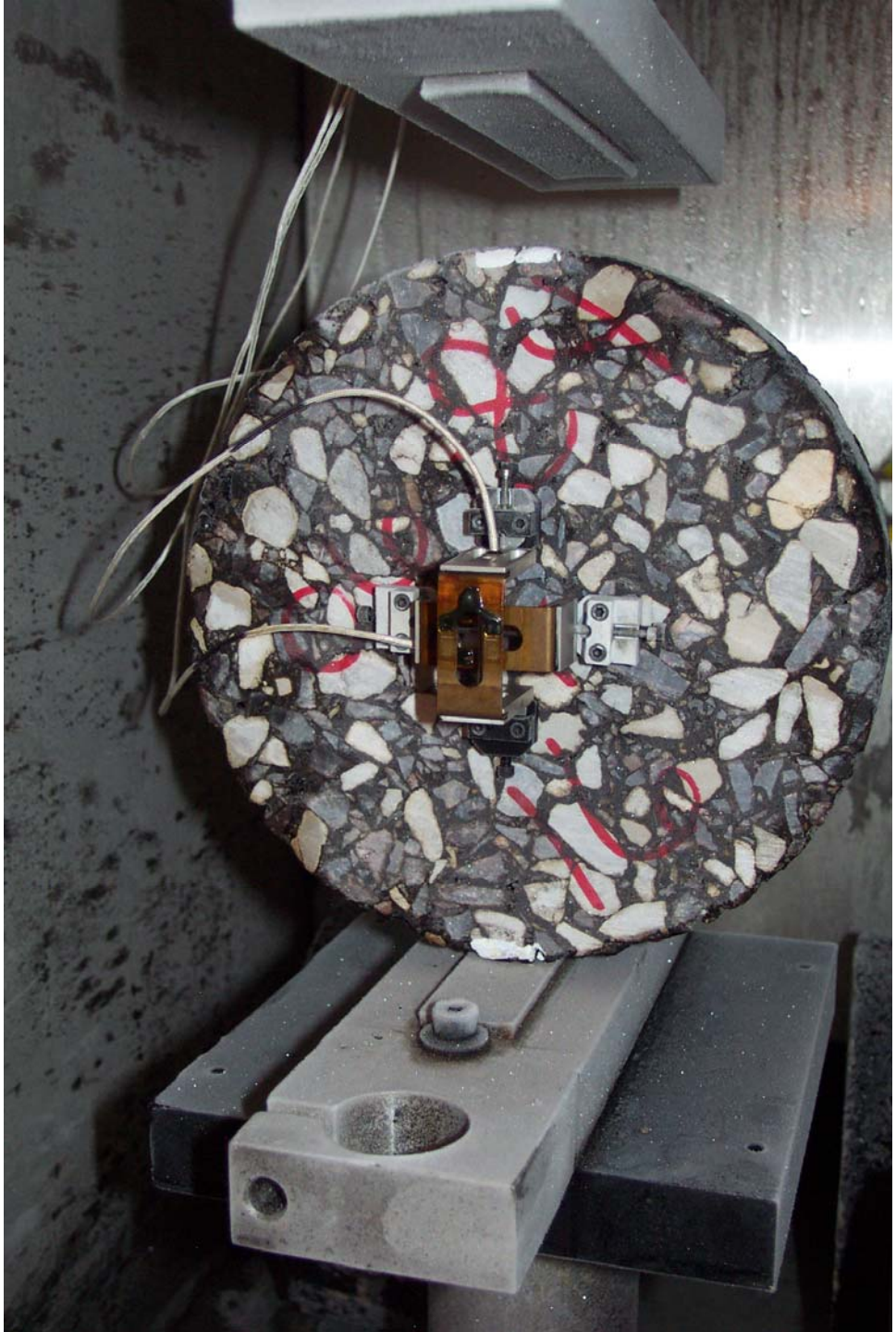
- ***Creep Compliance determined at -20, -10, and 0°C (-4, 14, and 32°F, respectively)***
- ***Creep Compliance determined at 1, 2, 5, 10, 20, 50, and 100 seconds at each temperature***
- ***Tensile Strength determined at -10°C***
- Aggregate and mixture Coefficient of Thermal Contraction (mix CTC can be calculated from other properties)
- Mixture VMA


Results
Input Summary
Thermal Cracking
Level 1
Level 2
Level 3
Average tensile strength at 14 °F (psi):
388.87
Loading Time sec
Creep Compliance (1/psi)
Low Temp (°F)
Mid Temp (°F)
High Temp (°F)
-4
14
32
1
4.68382e-007
6.91144e-007
9.33833e-007
2
5.09039e-007
7.97027e-007
1.16513e-006
5
5.68252e-007
9.62291e-007
1.56107e-006
10
6.17578e-007
1.10971e-006
1.94772e-006
20
6.71187e-007
1.27972e-006
2.43015e-006
50
7.49261e-007
1.54507e-006
3.25596e-006
100
8.143e-007
1.78178e-006
4.06242e-006
Import
Export
Compute mix coefficient of thermal contraction.
Mixture VMA (%):
18.6
Aggregate coefficient of thermal contraction:
1e-006
...
Mix coefficient of thermal contraction (in/in/°F):
OK
Cancel

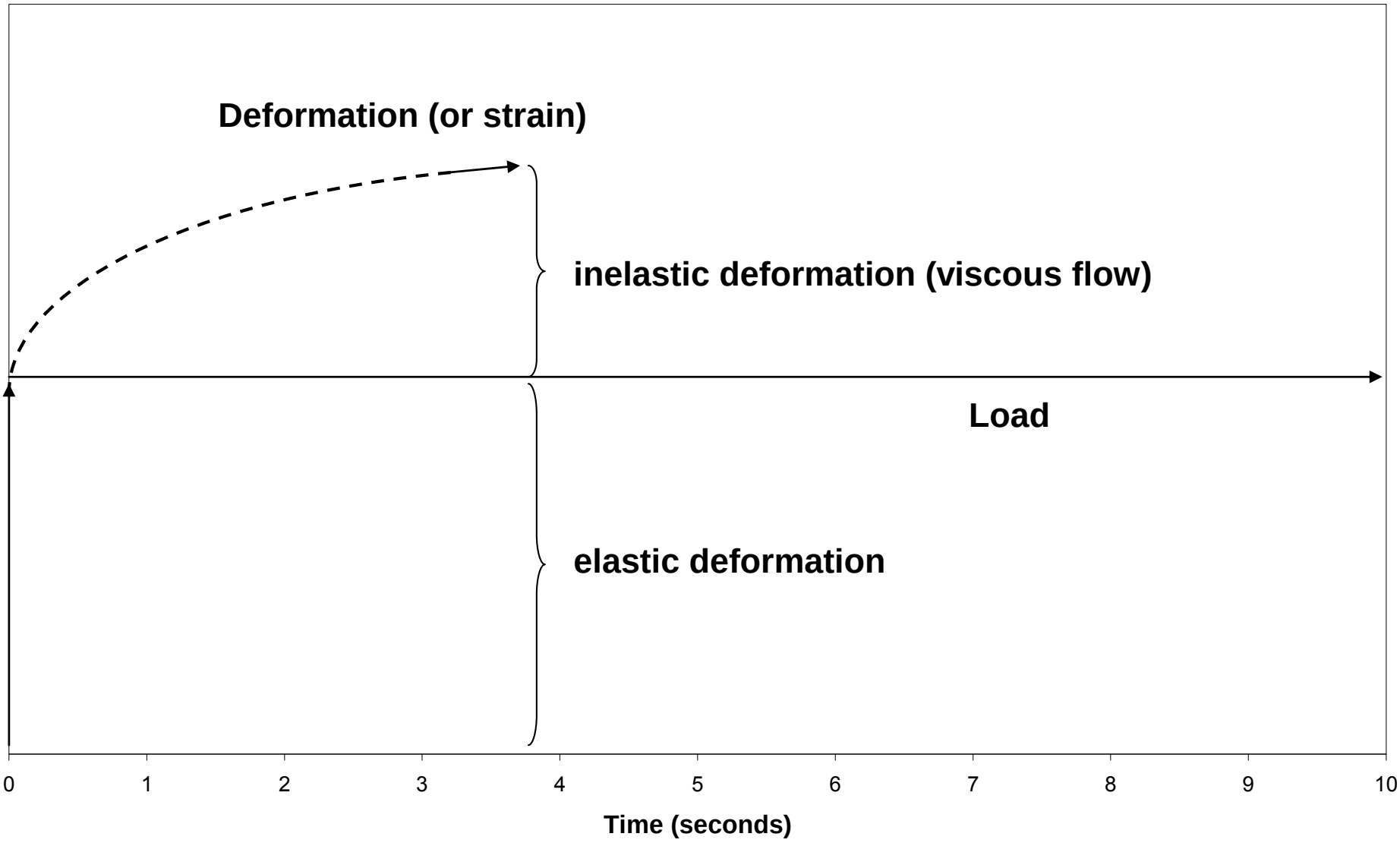
AASHTO T 322 Basics

- Indirect Tensile (IDT) method
- Maximum Aggregate Size ≤ 38 mm
- Specimens 38 to 50 mm high (thick) and 150 ± 9 mm in diameter
- Creep Compliance: “Zero or rebalance the electronic measuring system and apply a static load of fixed magnitude (± 2%) without impact to the specimen for 100 ± 2 seconds.”(Sec. 11.4)
- Tensile Strength: “After the creep tests have been completed at each temperature, determine the tensile strength by applying a load to the specimen at a rate of 12.5 mm of ram (vertical) movement per minute.” (Sec 11.5)

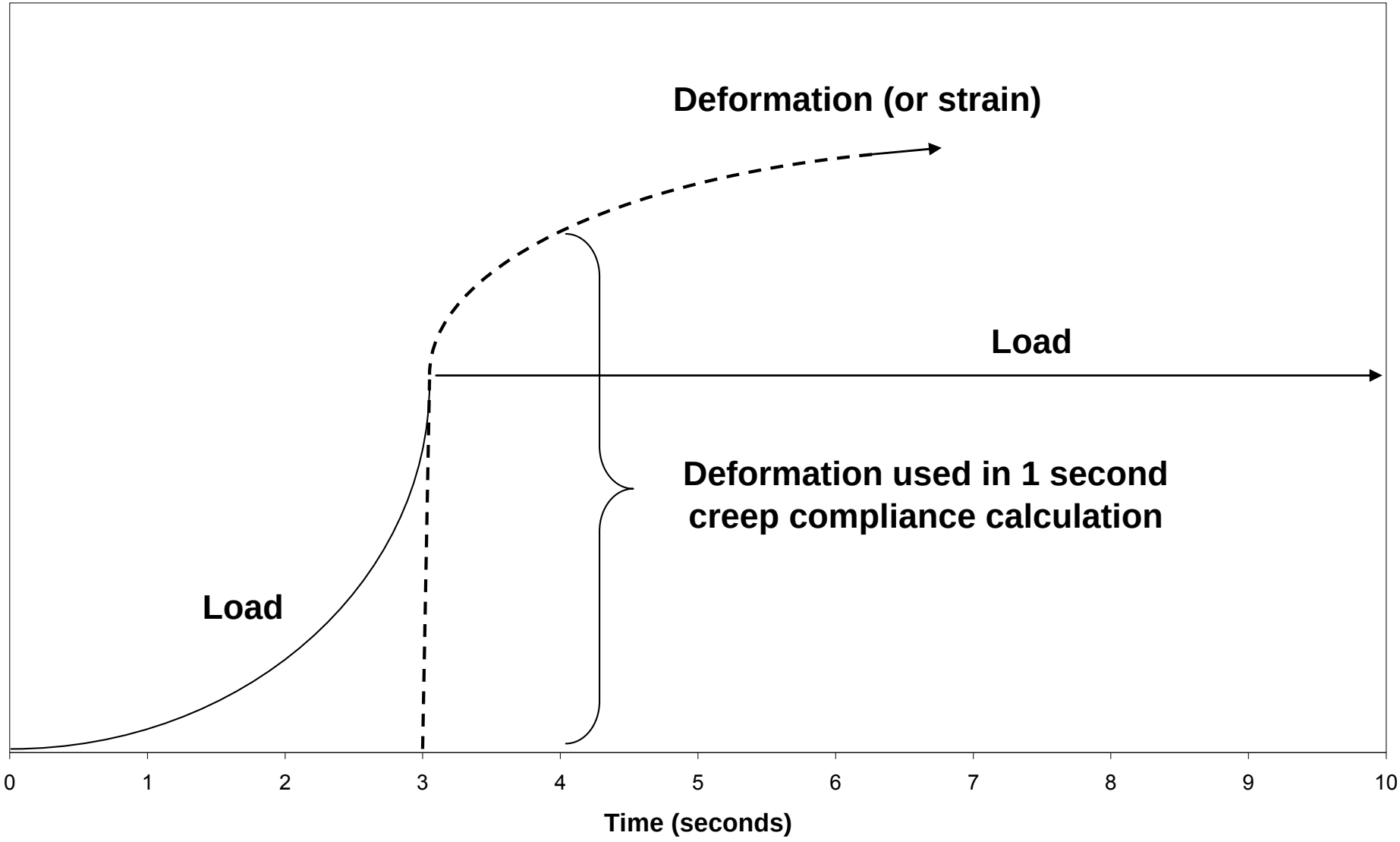

CAUTION
DANGER
HIGH VOLTAGE

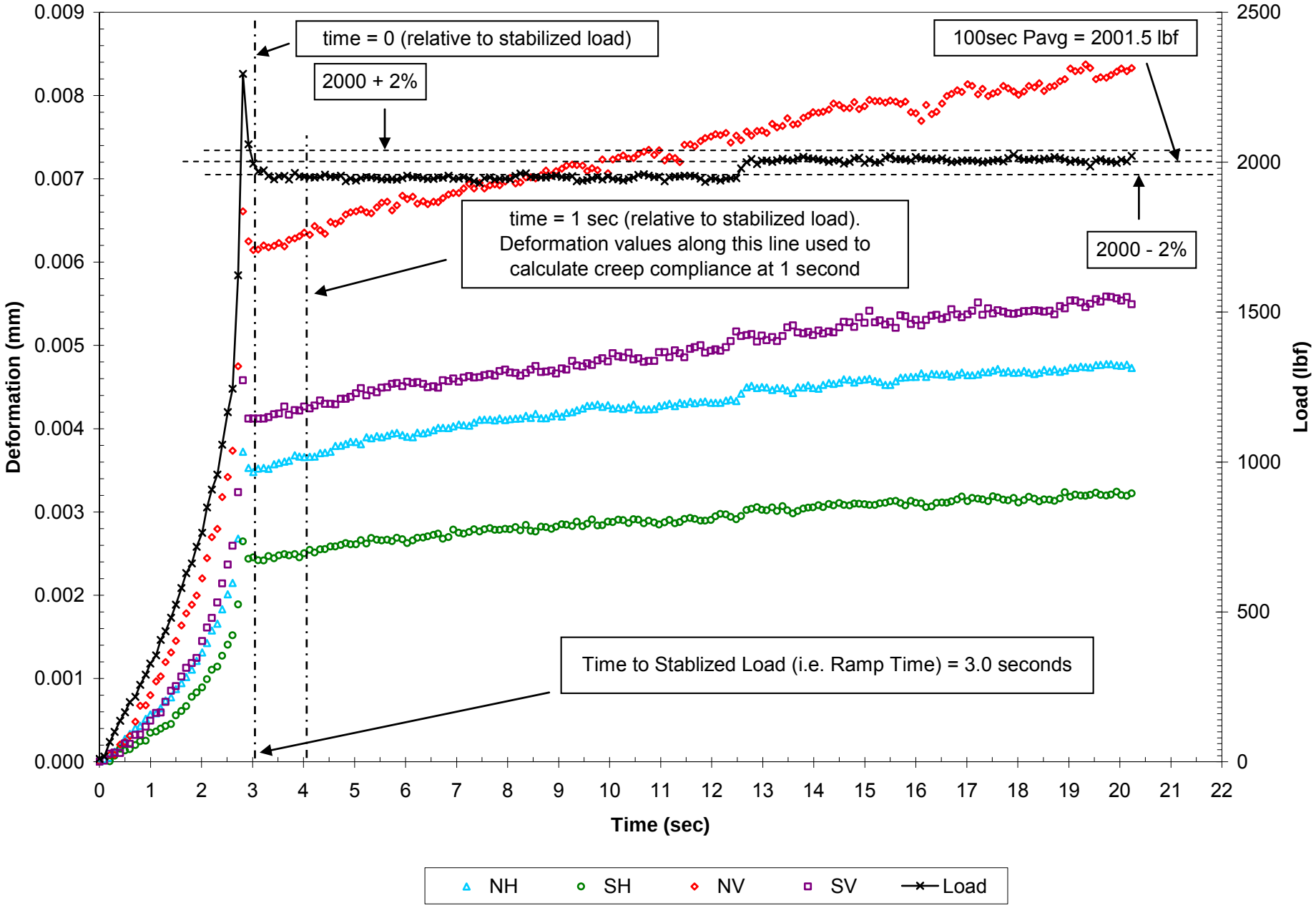


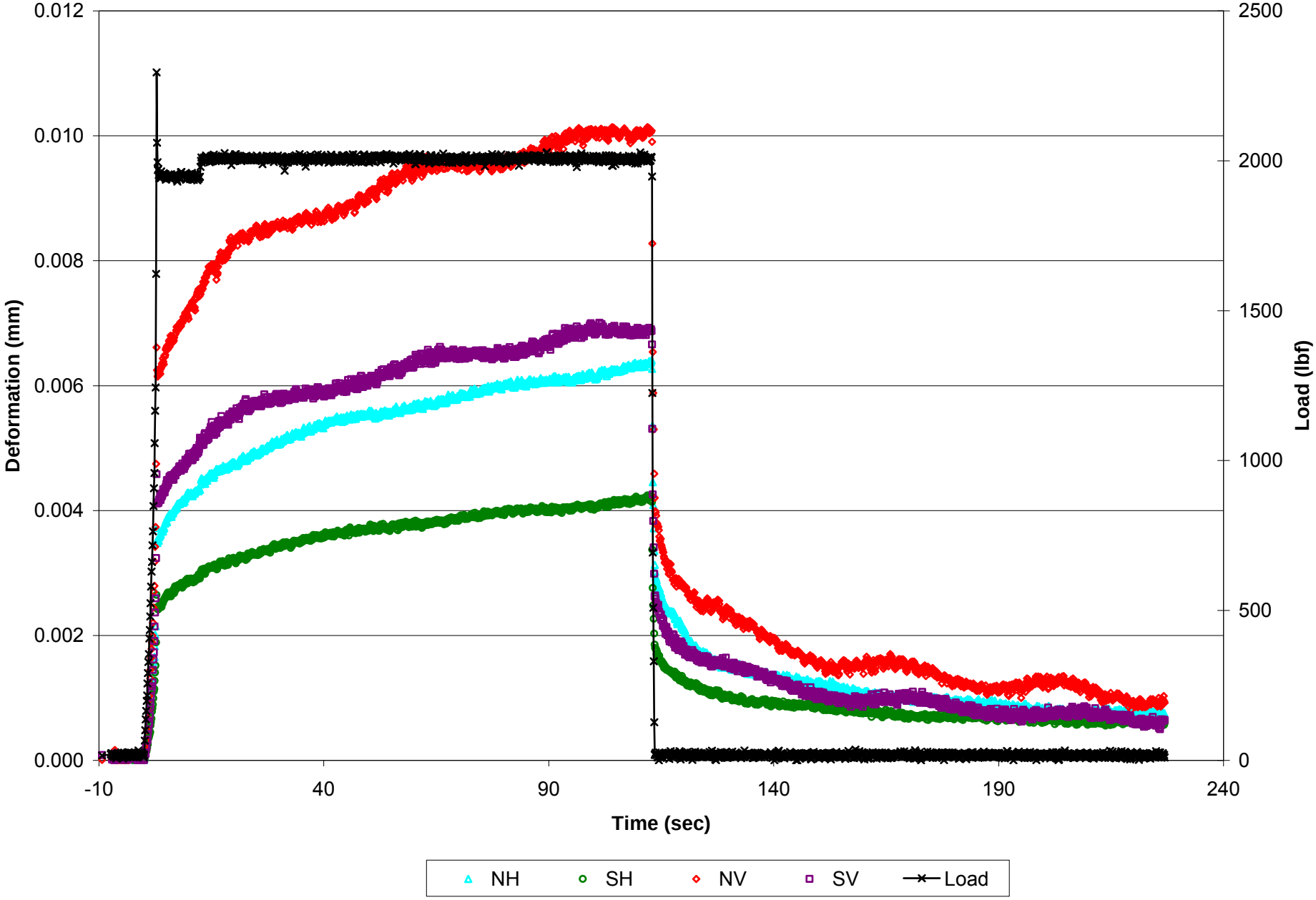
True Creep Load Profile: Instantaneous Loading/Unloading

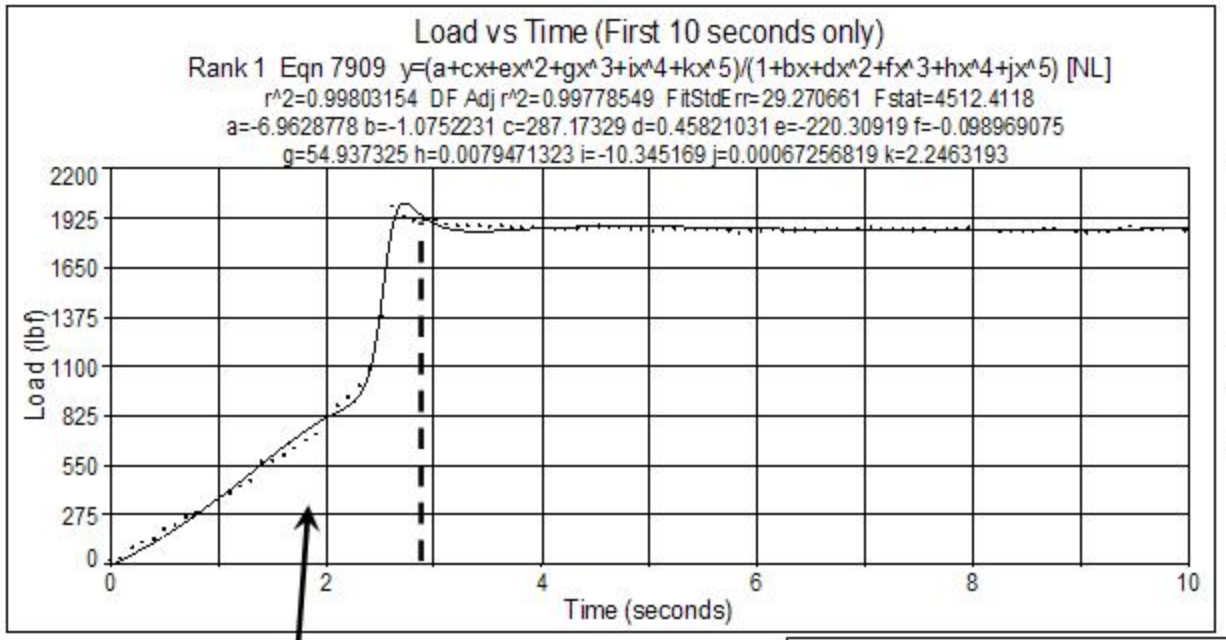


Assumed Creep Load: Non-Instantaneous Loading



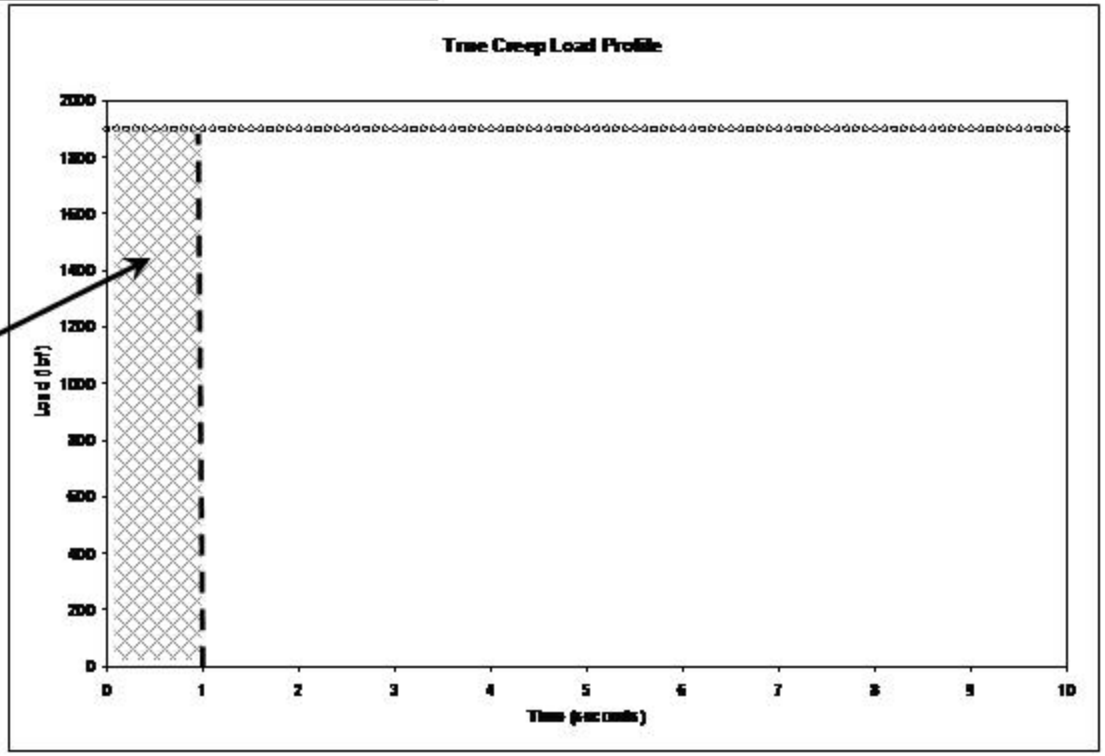

time = 0 (relative to stabilized load)
2000 + 2%
100sec Pavg = 2001.5 lbf
time = 1 sec (relative to stabilized load).
Deformation values along this line used to
calculate creep compliance at 1 second
2000 - 2%
Time to Stablized Load (i.e. Ramp Time) = 3.0 seconds
Deformation (mm)
Load (lbf)
Time (sec)
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0
500
1000
1500
2000
2500
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
NH
SH
NV
SV
Load

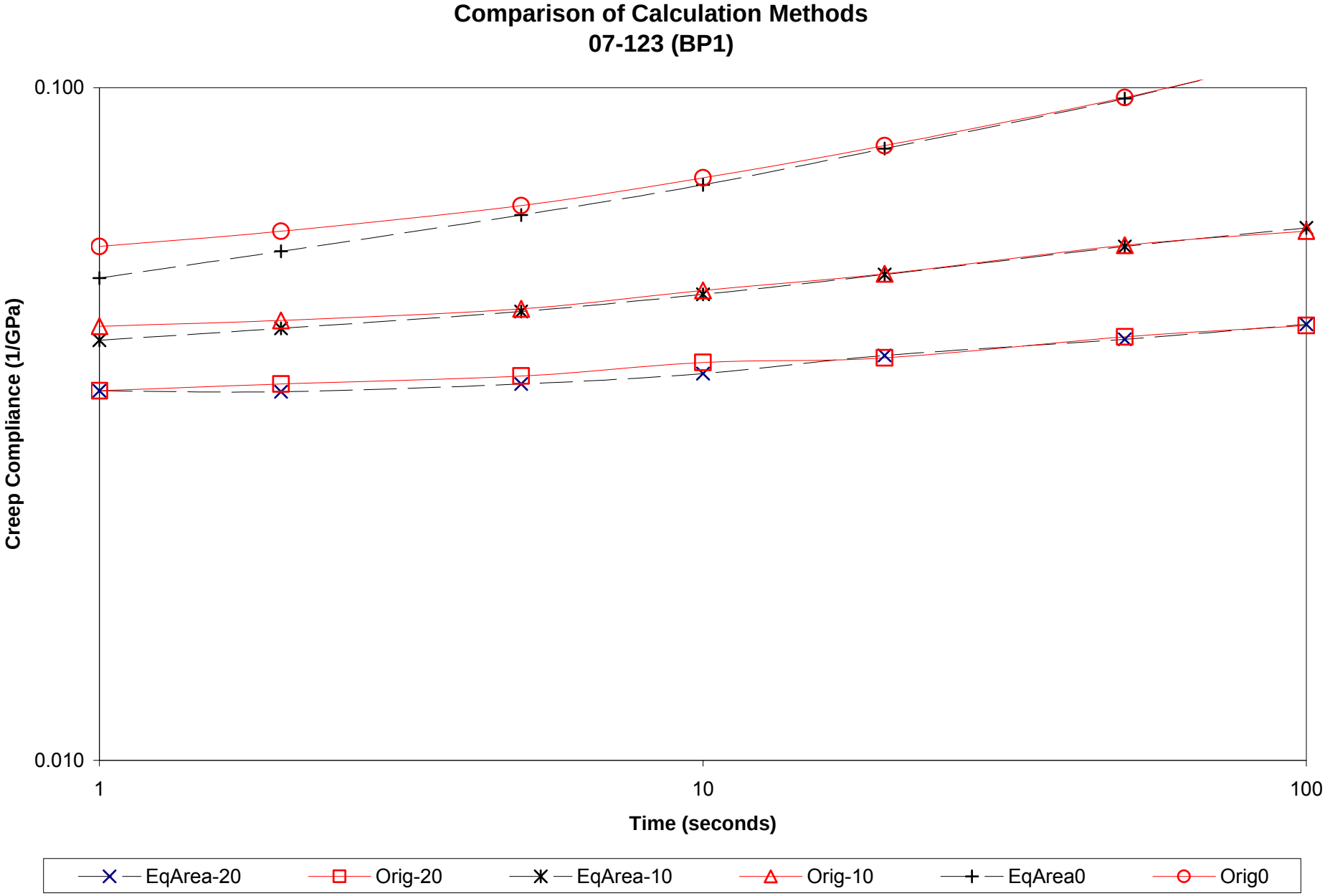

0.012
0.010
0.008
0.006
0.004
0.002
0.000
Deformation (mm)
2500
2000
1500
1000
500
0
Load (lbf)
-10
40
90
140
190
240
Time (sec)
NH
SH
NV
SV
Load



Based on integration of the fitted equation (Eqn 7909), the area under the load-time curve (up to 2.85 sec) is equal to area under the curve of a 1 second true creep load (below).

Areas are equal; 1900 lbf-sec




Comparison of Calculation Methods
07-123 (BP1)
0.100
0.010
Creep Compliance (1/GPa)
1
10
100
Time (seconds)
EqArea-20
Orig-20
EqArea-10
Orig-10
EqArea0
Orig0

Plant-Produced Mixes

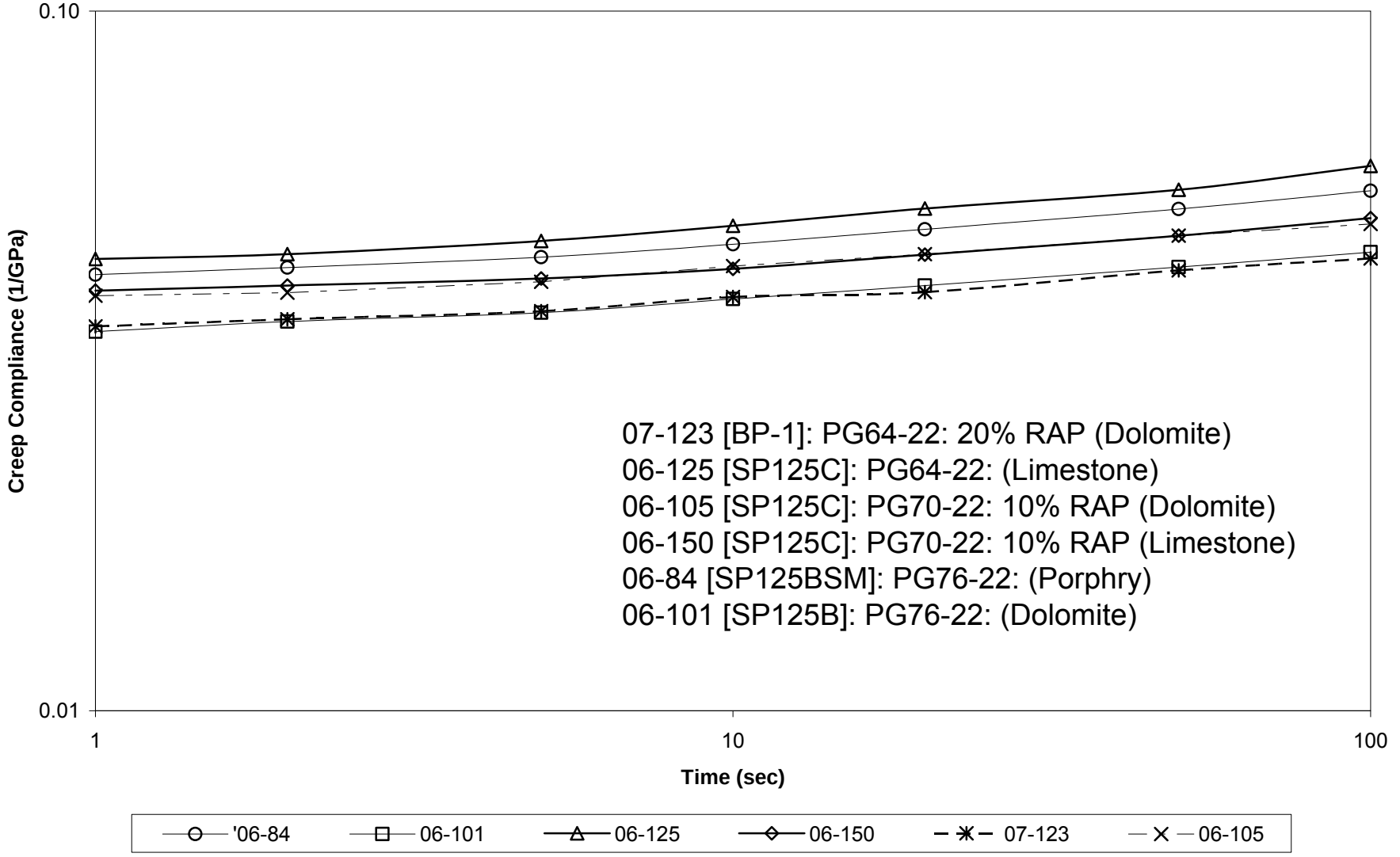
Table 1: HMA Mixes and Target % Air Voids

HMA Mix Type	MoDOT ID [Description] % RAP** (Aggregate Type)	Virgin PG Binder Grade	No. Replicate Tests		
			4% Voids	6.5% Voids	9% Voids
Superpave	06-101 [SP125B] (Dolomite)	76-22 (modified)	3*	3*	3*
Superpave	06-150 [SP125C] 10% RAP (Limestone)	70-22 (modified)	3*	3*	3*
Superpave	06-125 [SP125C] (Limestone)	64-22	3*	3*	3*
Superpave	06-105 [SP125C] 10% RAP (Dolomite)	70-22 (modified)		3	
Superpave (Stone Matrix)	06-84 [SP125BSM] (Porphry)	76-22 (modified)	3*	3*	3*
Marshall	07-123 [BP-1] 20% RAP (Dolomite)	64-22		3	

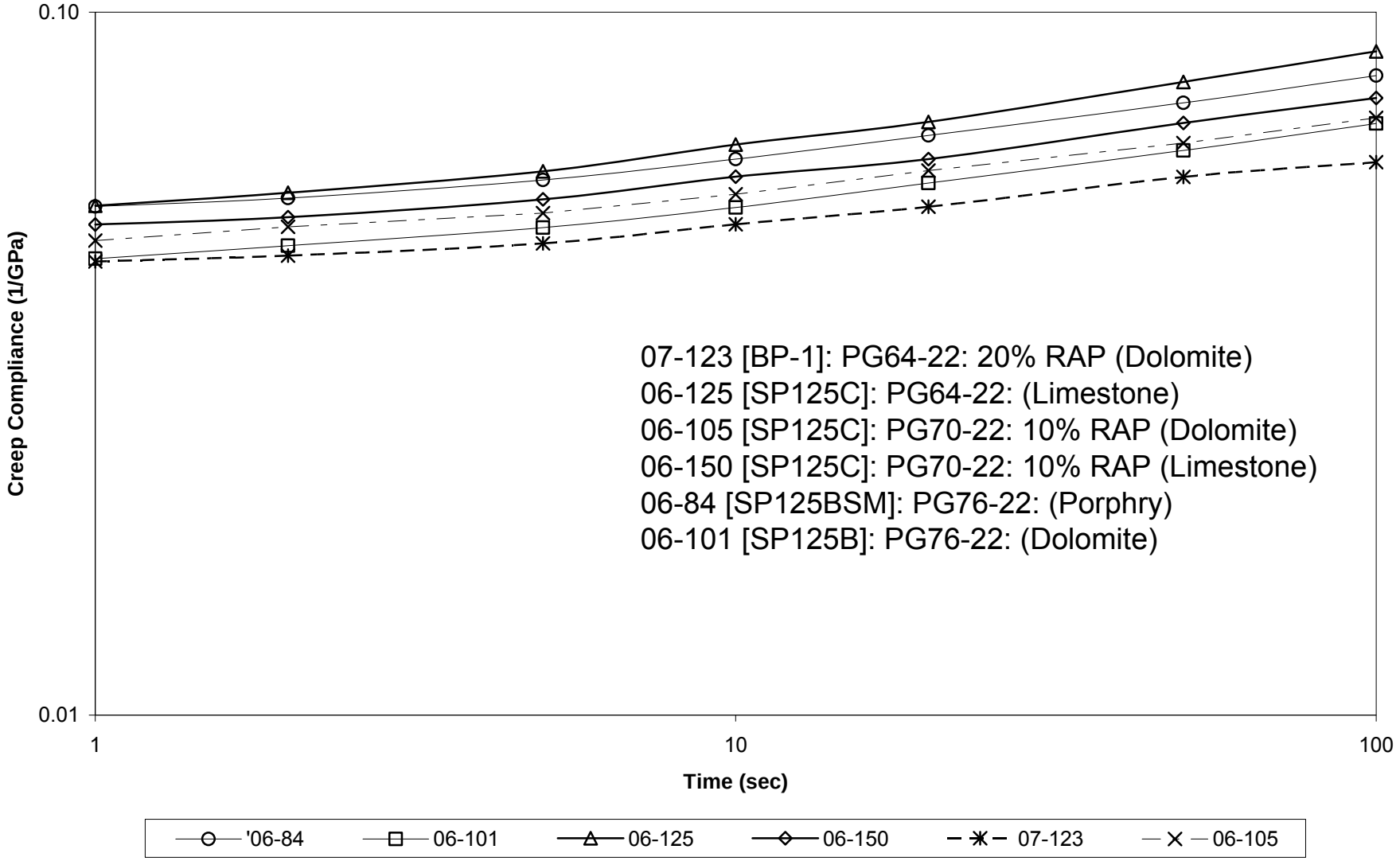
*Additional IDT strength testing at 4.4 and 21°C (40 and 70°F, respectively)

**Recycled Asphalt Pavement

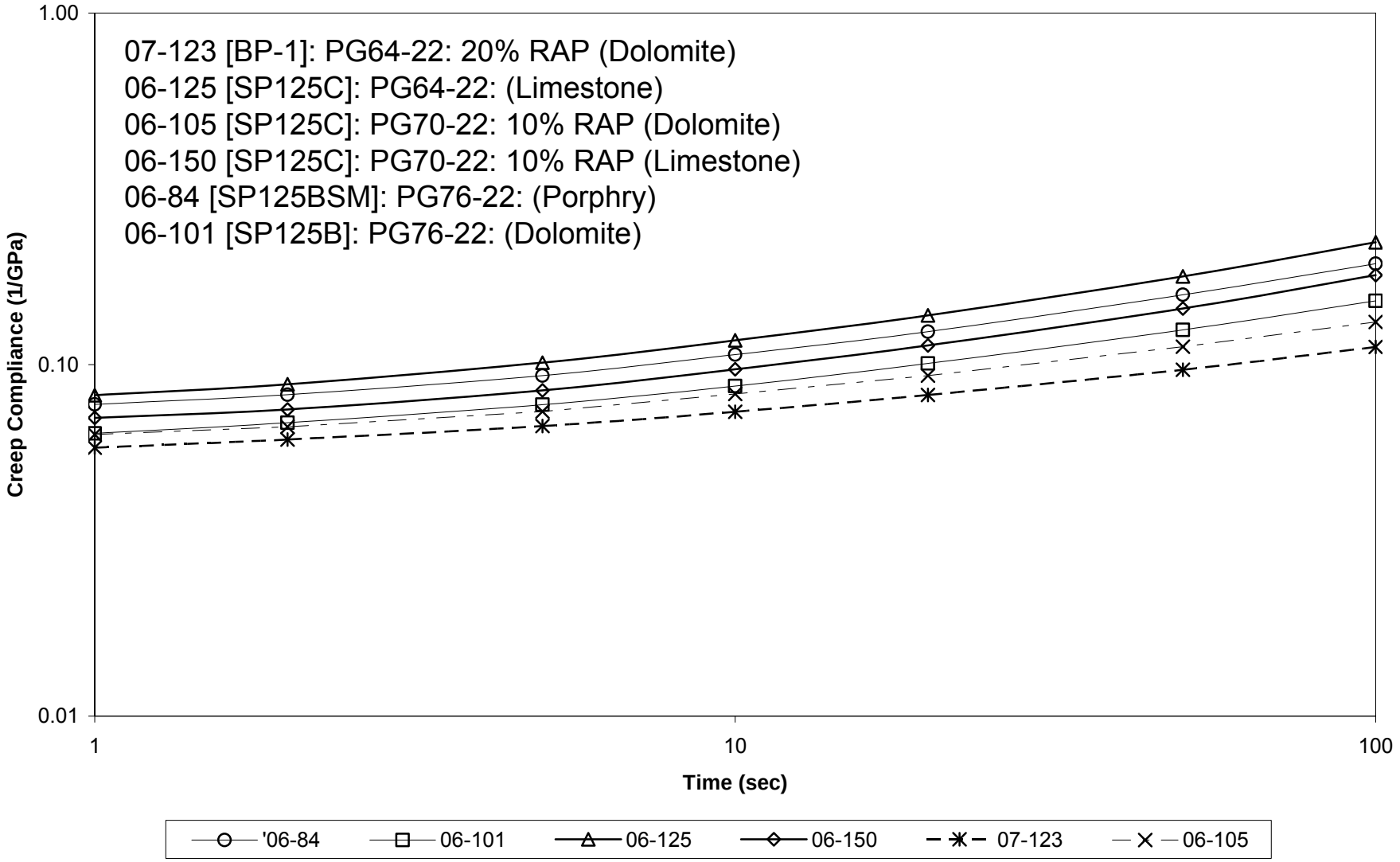
6.5% Voids: -20 deg C



6.5% Voids: -10 deg C



6.5% Voids: 0 deg C

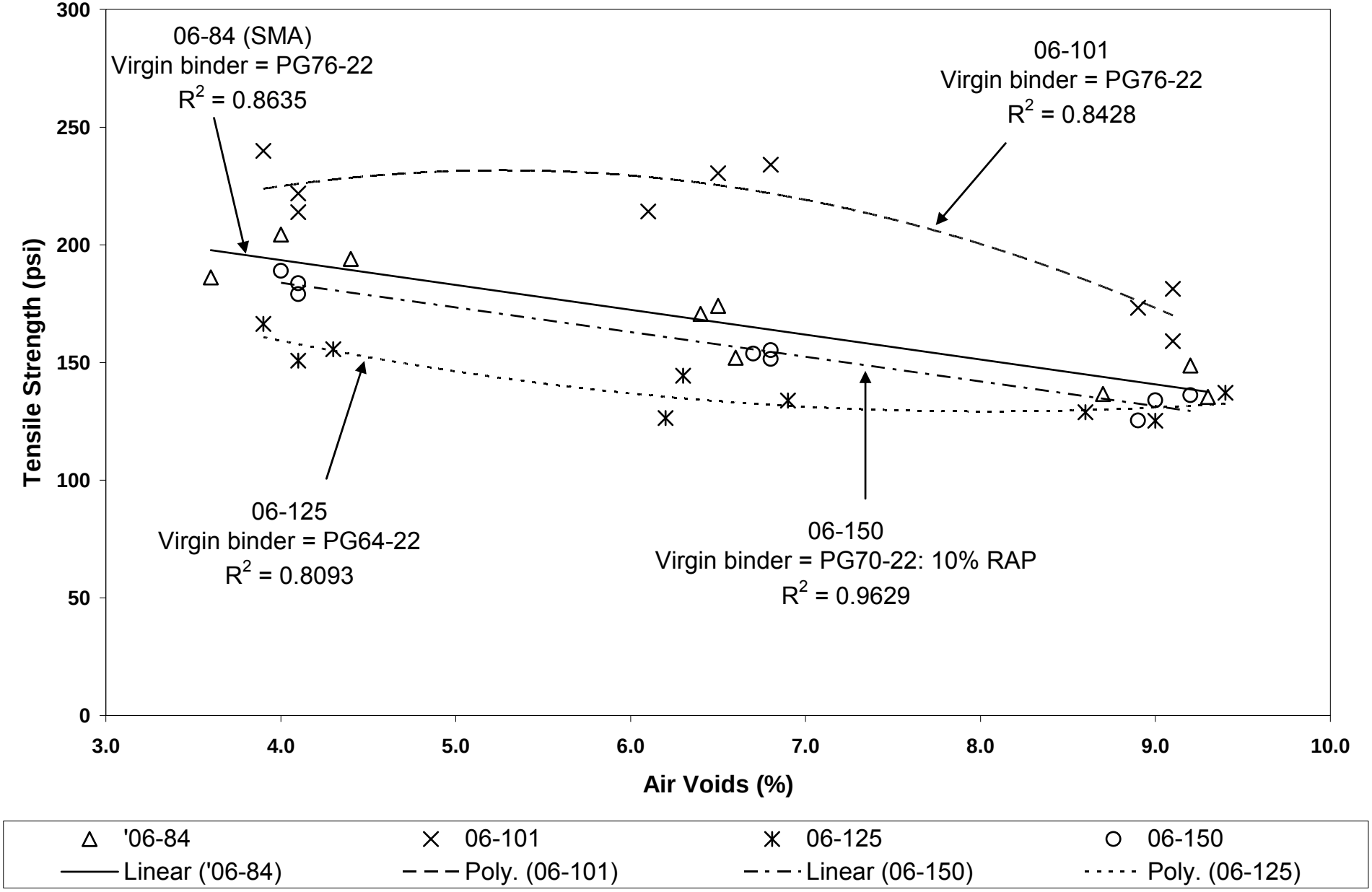


COMPARISON OF CREEP COMPLIANCE VALUES OF THE 06-125 MIX (PG64-22, NO RAP) TO LEVEL 3 TYPICAL VALUES (UNITS OF 1/GPa)

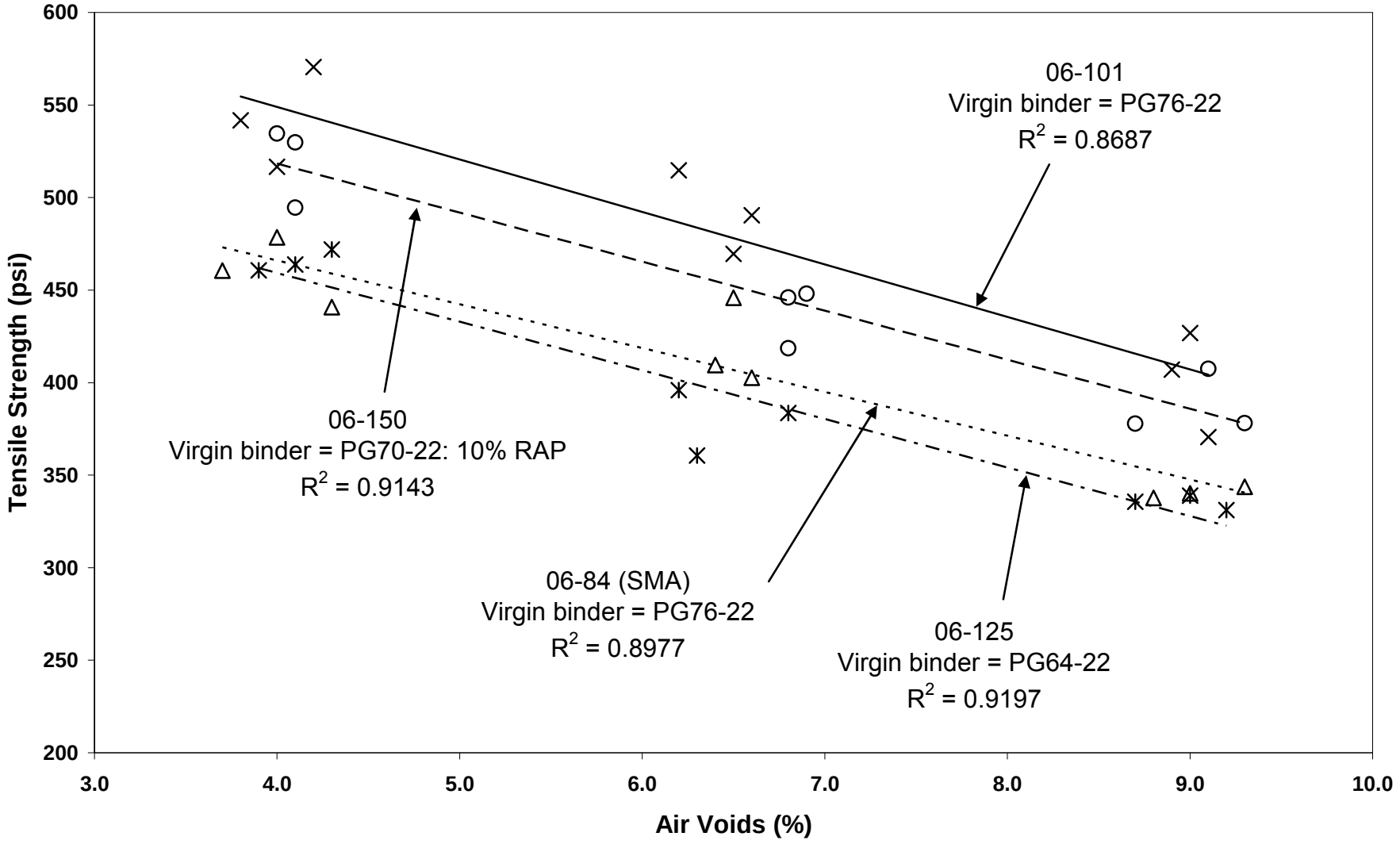
Temp (deg C)	Time (sec)	06-125 (Voids = 4%)		06-125 (Voids = 6.5%)		06-125 (Voids = 9%)	
		D(t) (1/psi)	D(t) (1/Gpa)	D(t) (1/psi)	D(t) (1/Gpa)	D(t) (1/psi)	D(t) (1/Gpa)
-20	1	2.5035E-07	0.03631	3.0510E-07	0.04425	3.3867E-07	0.04912
	2	2.5648E-07	0.03720	3.0997E-07	0.04496	3.4573E-07	0.05014
	5	2.6933E-07	0.03906	3.2352E-07	0.04692	3.5754E-07	0.05186
	10	2.8235E-07	0.04095	3.4009E-07	0.04933	3.7427E-07	0.05428
	20	2.9128E-07	0.04225	3.6010E-07	0.05223	3.9264E-07	0.05695
	50	3.1535E-07	0.04574	3.8300E-07	0.05555	4.1835E-07	0.06068
	100	3.2748E-07	0.04750	4.1431E-07	0.06009	4.4649E-07	0.06476
-10	1	3.3791E-07	0.04901	3.6567E-07	0.05304	4.1683E-07	0.06046
	2	3.4928E-07	0.05066	3.8180E-07	0.05538	4.2892E-07	0.06221
	5	3.7034E-07	0.05371	4.0938E-07	0.05938	4.5714E-07	0.06630
	10	3.9875E-07	0.05783	4.4683E-07	0.06481	4.9356E-07	0.07159
	20	4.2747E-07	0.06200	4.8141E-07	0.06982	5.3069E-07	0.07697
	50	4.7736E-07	0.06924	5.4865E-07	0.07957	5.9145E-07	0.08578
	100	5.2629E-07	0.07633	6.0627E-07	0.08793	6.4465E-07	0.09350
0	1	5.3193E-07	0.07715	5.6385E-07	0.08178	6.7142E-07	0.09738
	2	5.6947E-07	0.08260	6.0557E-07	0.08783	7.1841E-07	0.10420
	5	6.3890E-07	0.09266	6.9872E-07	0.10134	8.1813E-07	0.11866
	10	7.1948E-07	0.10435	8.0840E-07	0.11725	9.3953E-07	0.13627
	20	8.2759E-07	0.12003	9.5273E-07	0.13818	1.0931E-06	0.15854
	50	1.0377E-06	0.15051	1.2298E-06	0.17837	1.3791E-06	0.20002
	100	1.2568E-06	0.18228	1.5379E-06	0.22305	1.6955E-06	0.24591

	Time	-20C	-10C	0C
AC-20	1	0.030	0.035	0.062
Pen 60-70	2	0.032	0.039	0.068
PG 64-22	5	0.035	0.043	0.080
	10	0.037	0.047	0.091
	20	0.039	0.051	0.108
	50	0.041	0.057	0.137
	100	0.045	0.059	0.163

Tensile Strength: 21°C (70°F)



Tensile Strength: 4.4°C (40°F)



Tensile Strength: -10°C (14°F)