May 22, 2008

University of Nevada – Reno; EZ-lime Report

This report summarizes the evaluation of the HMA mixtures that include E-Z lime from the Tucson, Arizona project. The laboratory experiment consisted of two parts: properties of the binders and properties of the mixtures. For this report, we will focus on the EZ-lime added directly to the mixture thru the RAP system at the hot plant since this method showed marked improvement. The addition of lime directly into the asphalt oil and then into the mixing chamber was not as conclusive ad direct addition of EZ-lime into the mixing chamber through the RAP collar and feeder system..

Properties of the Mixtures

This part of the experiment conducted an extensive effort to evaluate the properties of three HMA mixtures:

- Control Mix: original binder with 1% hydrated lime on wet aggregate
- RAP collar mix: original binder with 1% E-Z lime through the RAP collar
- In-Binder mix: 1% E-Z lime blended in the binder

The following properties were measured for the three mixtures:

- Dynamic modulus (E*) master curve as a function of multiple freeze-thaw cycles
- Permanent deformation characteristics of the mixtures measured in the repeated load triaxial (RLT) test

Figures 1 – 14 summarize the results of this part of the experiment. It should be noted that the 40 Hz, 10Hz, and 0.5 Hz loading frequencies were selected to represent truck loading conditions on highways, urban streets, and intersections, respectively. The data presented in these figures are self-explanatory; however, by looking at the trends, the following conclusions can be made:

- The dynamic modulus property decreases as the loading frequency is lowered which is a typical behavior for viscoelastic materials.
- The dynamic modulus of all three mixtures decreases as the number of F-T cycles increases. The reduction in the dynamic modulus levels-off after the sixth F-T cycle.
- The control and RAP collar mixtures have similar dynamic modulus properties at all loading frequencies and as a function of multiple F-T cycles.
- At the unconditioned stage (0 F-T), the mix with the 1% E-Z lime blended in the binder exhibits a higher dynamic modulus than the control and RAP collar mixes but it rapidly deteriorates as a function of F-T cycles. This observation indicates that the 1% E-Z lime blended into the straight bitumen will be highly moisture susceptible as compared to the control and the 1% E-Z lime RAP collar mixtures.
- The permanent deformation characteristics of all three mixtures are similar at both the unconditioned and after 6 F-T cycles stages.

Conclusion

Looking at the data generated from the binder and mix evaluations, the following conclusion can be made:

- **Introducing the E-Z lime through the RAP collar appears equal to and in some cases, better than standard addition methods of hydrated lime and/or the blending of the lime into the asphalt oil. Figures 7, 8, and 9 show a marked improvement of the properties with EZ-lime added into the mixing chamber via the recycle feeder system at the hot plant.**

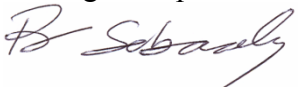
It should be noted that the data presented in this report are based on the testing and evaluation of HMA mix from Granite Construction in Tucson, Arizona and laboratory mixtures. The findings and conclusions of this study should be further validated on additional HMA mixtures with multiple aggregate sources and binder grades.

Please feel free to contact me if you need any additional information.

Sincerely,

W.R. Bill Bailey
President
International Construction Chemicals, Inc.
702-686-1041
bailey@wrbailey.com

Testing excerpts of notes from:



Peter E. Sebaaly
Pavement Engineer

Table 1 Properties of the control binder (PG76-10)

Test		Specification	Test Temp (°C)	Test Results							
				Replicates	Mean	Standard Deviation (SD)	AASHTO Allowable SD	Met SD Spec.	Range = (Max-Min)	AASHTO Allowable Range	Meet Range Spec.
Specific Gravity at 25°C		-	25	1.003 1.003	1.003	0.0001	0.0008	Yes	0.0001	0.0023	Yes
Flash Point, °C		≥ 230 ºC	-	345 350	347	-	-	-	5.6	8	Yes
Mass Loss, %		≤ 1%	-	0.005 0.004	0.0045	0.0004	0.0115	Yes	0.0006	0.0327	Yes
Test		**Specification**	**Test Temp (°C)**	**Test Results**							
				Replicates	**Mean**	**1S% = SD/Mean**	**AASHTO Allowable 1S%**	**Met 1S% Spec.**	**D2S% = Range/Mean**	**AASHTO Allowable D2S%**	**Meet Range Spec.**
Brookfield Viscosity		≤ 3000 Pa.s	135	650 658 655	654	0.6	1.2	Yes	1.22	3.96	Yes
DSR-Original, kPa		$G^*/\sin\delta$ ≥1.00 kPa	58	7.42 7.35 7.39	7.39	0.5	2.3	Yes	0.95	7.59	Yes
			64	3.23 3.19 3.20	3.21	0.6	2.3	Yes	1.25	7.59	Yes
			70	1.47 1.42 1.43	1.44	1.8	2.3	Yes	3.47	7.59	Yes
			76	0.69 0.67 0.67	0.68	1.5	2.3	Yes	2.81	7.59	Yes
DSR-RTFO, kPa		$G^*/\sin\delta$ ≥2.20 kPa	58	15.6 15.5 16.5	15.9	3.5	3.2	No	6.30	10.56	Yes
			64	6.70 6.77 7.06	6.84	2.8	3.2	Yes	5.26	10.56	Yes
			70	2.94 3.02 3.11	3.02	2.8	3.2	Yes	5.62	10.56	Yes
			76	1.35 1.41 1.42	1.39	2.7	3.2	Yes	5.02	10.56	Yes
DSR-RTFO+PAV, kPa		$G^*\sin\delta$ ≤ 5000 kPa	22	4360 4500 4580	4480	2.5	4.9	Yes	4.91	16.17	Yes
			19	5610 5770 5860	5747	2.2	4.9	Yes	4.35	16.17	Yes
Bending Beam Rheometer (BBR)	Stiffness	≤300 MPa	0	33.8 34.5	34.1	1.4	2.5	Yes	0.4	1.0	Yes
			-6	75.8 81.1	78.5	4.8	2.5	No	2.6	1.0	No
			-12	161.0 156.0	158.5	2.2	2.5	Yes	3.7	1.0	No
	m-Value	≥ 0.300	0	0.402 0.400	0.401	0.4	1.0	Yes	2.0	7.2	Yes
			-6	0.332 0.320	0.326	2.6	1.0	No	6.8	7.2	Yes
			-12	0.296 0.281	0.289	3.7	1.0	No	3.2	7.2	Yes

Table 2 Properties of the binder blended with 0.5% EZ-Lime

Test		Specification	Test Temp (°C)	Test Results							
				Replicates	Mean	Standard Deviation (SD)	AASHTO Allowable SD	Met SD Spec.	Range = (Max-Min)	AASHTO Allowable Range	Meet Range Spec.
Specific Gravity at 25°C		-	25	1.053 1.052	1.0525	0.0006	0.0008	Yes	0.0008	0.0023	Yes
Flash Point, °C		≥ 230 ºC	-	328 333	331	-	-	-	5.6	8	Yes
Mass Loss, %		≤ 1%	-	0.005 0.004	0.0045	0.0007	0.0115	Yes	0.0010	0.0327	Yes
Test		**Specification**	**Test Temp (°C)**	**Test Results**							
				Replicates	**Mean**	**1S% = SD/Mean**	**AASHTO Allowable 1S%**	**Met 1S% Spec.**	**D2S% = Range/Mean**	**AASHTO Allowable D2S%**	**Meet Range Spec.**
Brookfield Viscosity		≤ 3000 Pa.s	135	808 810 812	810	0.2	1.2	Yes	0.49	3.96	Yes
DSR-Original, kPa		$G^*/\sin\delta$ ≥1.00 kPa	58	27.30 17.60 25.40	23.4	21.9	2.3	No	41.39	7.59	No
			64	10.50 8.45 11.30	10.1	14.6	2.3	No	28.26	7.59	No
			70	4.91 4.55 5.19	4.9	6.6	2.3	No	13.11	7.59	No
			76	2.48 2.97 2.53	2.7	10.1	2.3	No	18.42	7.59	No
			82	1.28 2.42 1.33	1.7	38.4	2.3	No	67.99	7.59	No
			88	0.78 2.38 0.77	1.3	70.3	2.3	No	122.44	7.59	No
DSR-RTFO, kPa		$G^*/\sin\delta$ ≥2.20 kPa	58	25.6 21.3 21.9	22.9	10.2	3.2	No	18.75	10.56	No
			64	11.4 9.24 9.53	10.1	11.7	3.2	No	21.48	10.56	No
			70	5.28 4.11 4.23	4.5	14.2	3.2	No	25.77	10.56	No
			76	2.62 1.90 1.96	2.2	18.5	3.2	No	33.33	10.56	No
DSR-RTFO+PAV, kPa		$G^*\sin\delta$ ≤ 5000 kPa	31	3040 2720 2730	2830	6.4	4.9	No	11.31	16.17	Yes
			28	4220 3770 3780	3923	6.5	4.9	No	11.47	16.17	Yes
			25	5740 5140 5160	5347	6.4	4.9	No	11.22	16.17	Yes
Bending Beam Rheometer (BBR)	Stiffness	≤300 MPa	0	39.9 45.0	42.5	8.5	2.5	No	0.4	1.0	Yes
			-6	77.9 83.2	80.6	4.7	2.5	No	1.5	1.0	No
			-12	176 167	171.5	3.7	2.5	No	1.2	1.0	No
	m-Value	≥ 0.300	0	0.388 0.386	0.387	0.4	1.0	Yes	12.0	7.2	No
			-6	0.339 0.332	0.336	1.5	1.0	No	6.6	7.2	Yes
			-12	0.287 0.282	0.285	1.2	1.0	No	5.2	7.2	Yes

Table 3 Properties of the binder blended with 1% EZ-Lime

Test		Specification	Test Temp (°C)	Test Results							
				Replicates	Mean	Standard Deviation (SD)	AASHTO Allowable SD	Met SD Spec.	Range = (Max-Min)	AASHTO Allowable Range	Meet Range Spec.
Specific Gravity at 25°C		-	25	1.051 1.052	1.052	0.0007	0.0008	Yes	0.0009	0.0023	Yes
Flash Point, °C		≥ 230 ºC	-	338.9 341.7	340.3	-	-	-	2.8	8	Yes
Mass Loss, %		≤ 1%	-	0.005 0.004	0.0045	0.0007	0.0115	Yes	0.0010	0.0327	Yes
Test		**Specification**	**Test Temp (°C)**	**Test Results**							
				Replicates	**Mean**	**1S% = SD/Mean**	**AASHTO Allowable 1S%**	**Met 1S% Spec.**	**D2S% = Range/Mean**	**AASHTO Allowable D2S%**	**Meet Range Spec.**
Brookfield Viscosity		≤ 3000 Pa.s	135	1221 1191 1241	1218	2.1	1.2	No	4.11	3.96	No
DSR-Original, kPa		$G^*/\sin\delta$ ≥1.00 kPa	58	9.9 24.5 26.8	20.4	44.9	2.3	No	82.84	7.59	No
			64	4.67 14.2 17	12.0	54.1	2.3	No	103.12	7.59	No
			70	2.28 9.410 12.6	8.1	65.3	2.3	No	127.46	7.59	No
			76	1.18 7.77 11.4	6.8	76.4	2.3	No	150.66	7.59	No
			82	0.648 7.63 11.7	6.7	83.9	2.3	No	165.96	7.59	No
			88	- 8.18 12.8	10.5	31.1	2.3	No	44.04	7.59	No
			94	- 9.52 14.8	12.2	30.7	2.3	No	43.42	7.59	No
DSR-RTFO, kPa		$G^*/\sin\delta$ ≥2.20 kPa	58	34.9 20.7 22	25.9	30.3	3.2	No	54.90	10.56	No
			64	20.3 9.79 10.6	13.6	43.1	3.2	No	77.49	10.56	No
			70	13.8 4.75 5.39	8.0	63.3	3.2	No	113.41	10.56	No
			76	11.8 2.42 3.02	5.7	91.4	3.2	No	163.23	10.56	No
			82	12.4 1.35 2.01	5.3	118.0	3.2	No	210.34	10.56	No
DSR-RTFO+PAV, kPa		$G^*\sin\delta$ ≤ 5000 kPa	22	4050 6250 4330	4877	24.6	4.9	No	45.11	16.17	No
			19	5290 4620 5610	5173	9.8	4.9	No	19.14	16.17	No
Bending Beam Rheometer (BBR)	Stiffness	≤300 MPa	0	32.1 31.9	32.0	0.4	2.5	Yes	1.9	1.0	No
			-6	62.2 64.8	63.5	2.9	2.5	No	1.7	1.0	No
			-12	123 138	130.5	8.1	2.5	No	0.7	1.0	Yes
	m-Value	≥ 0.300	0	0.405 0.394	0.400	1.9	1.0	No	0.6	7.2	Yes
			-6	0.327 0.335	0.331	1.7	1.0	No	4.1	7.2	Yes
			-12	0.294 0.291	0.293	0.7	1.0	Yes	11.5	7.2	No

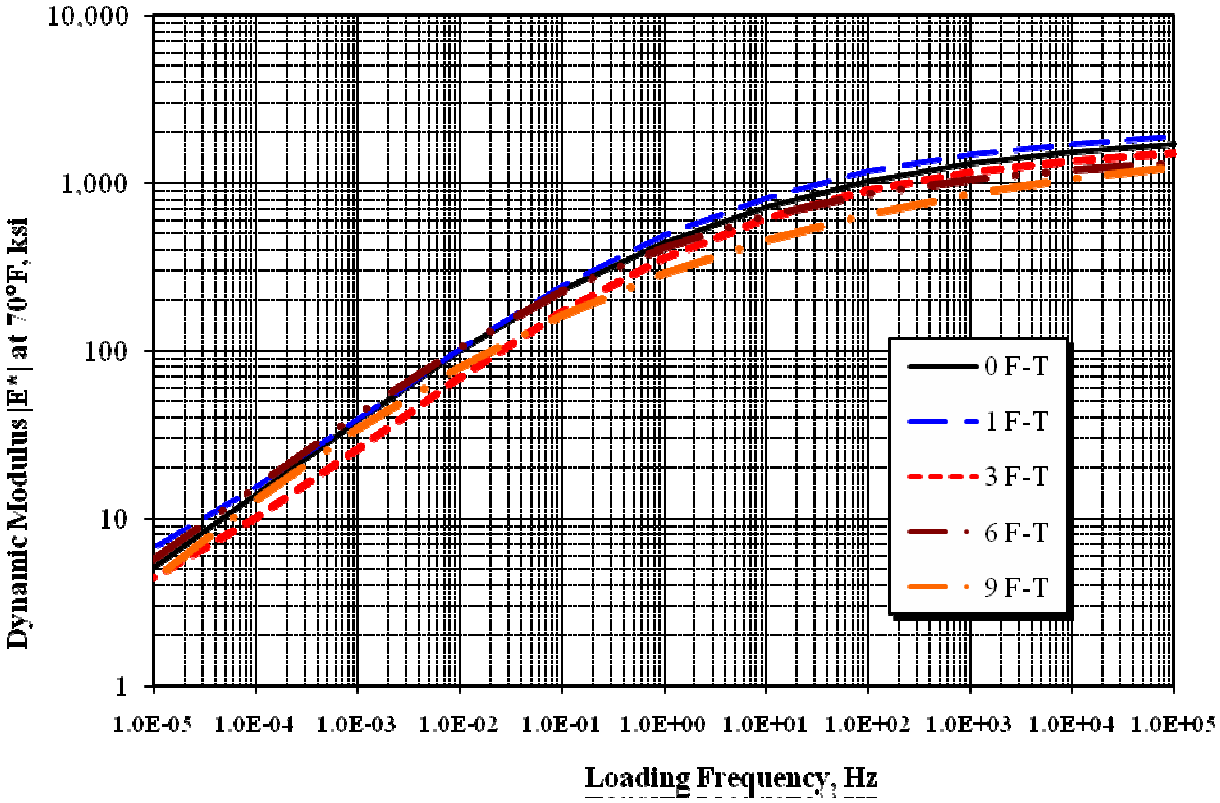


Figure 1 Dynamic modulus master curves at 70°F for the control mix

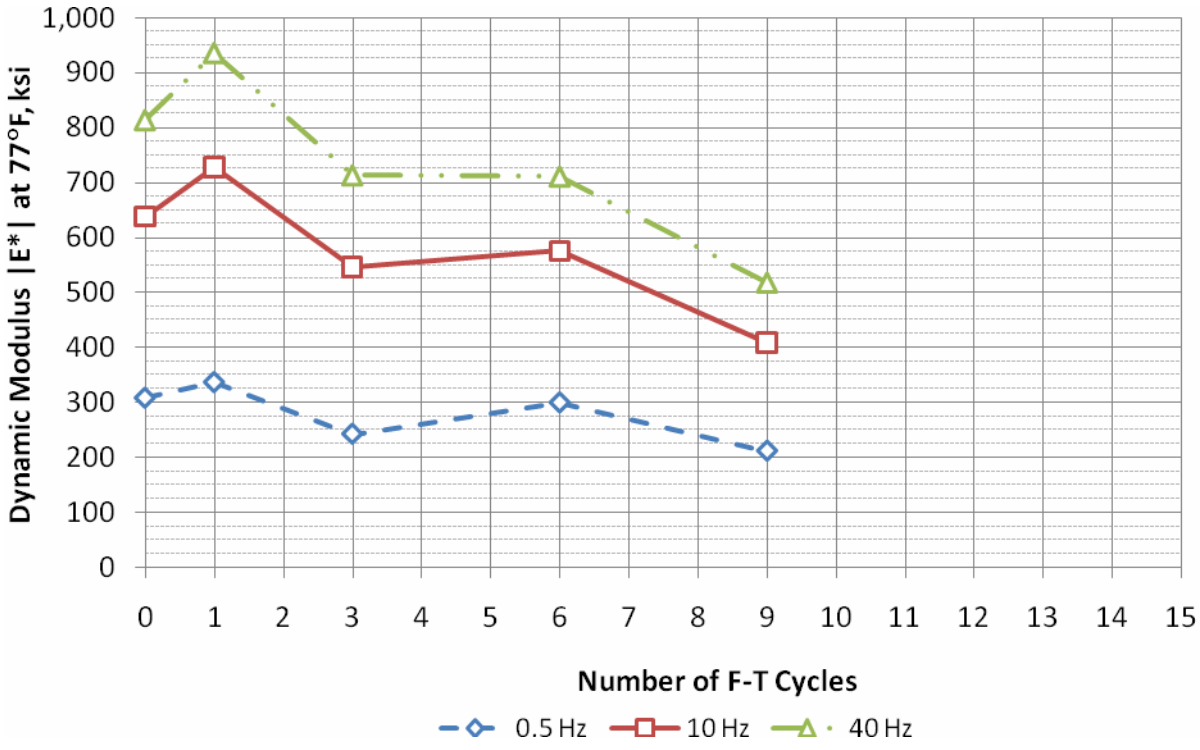


Figure 2 Dynamic modulus of the control mix at 77°F as a function of freeze-thaw cycles

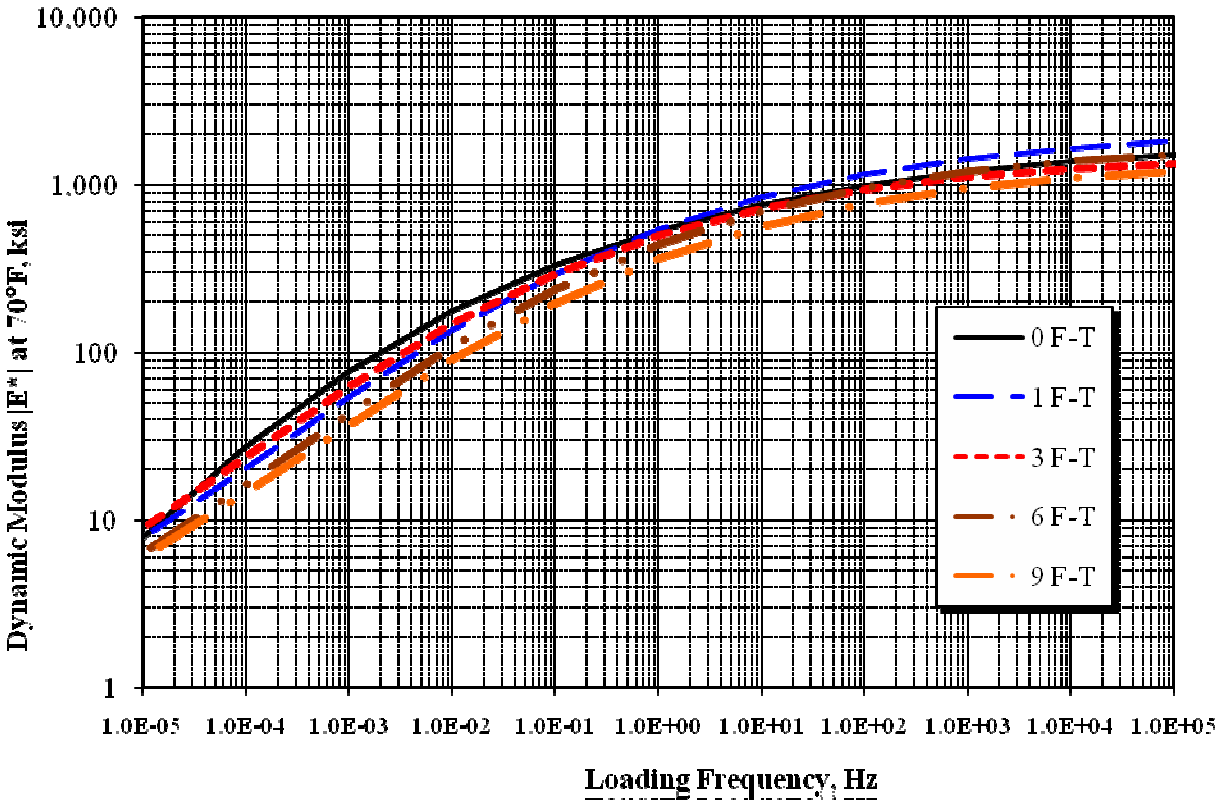


Figure 3 Dynamic modulus master curves at 70°F for the 1% EZ-lime in RAP collar mix

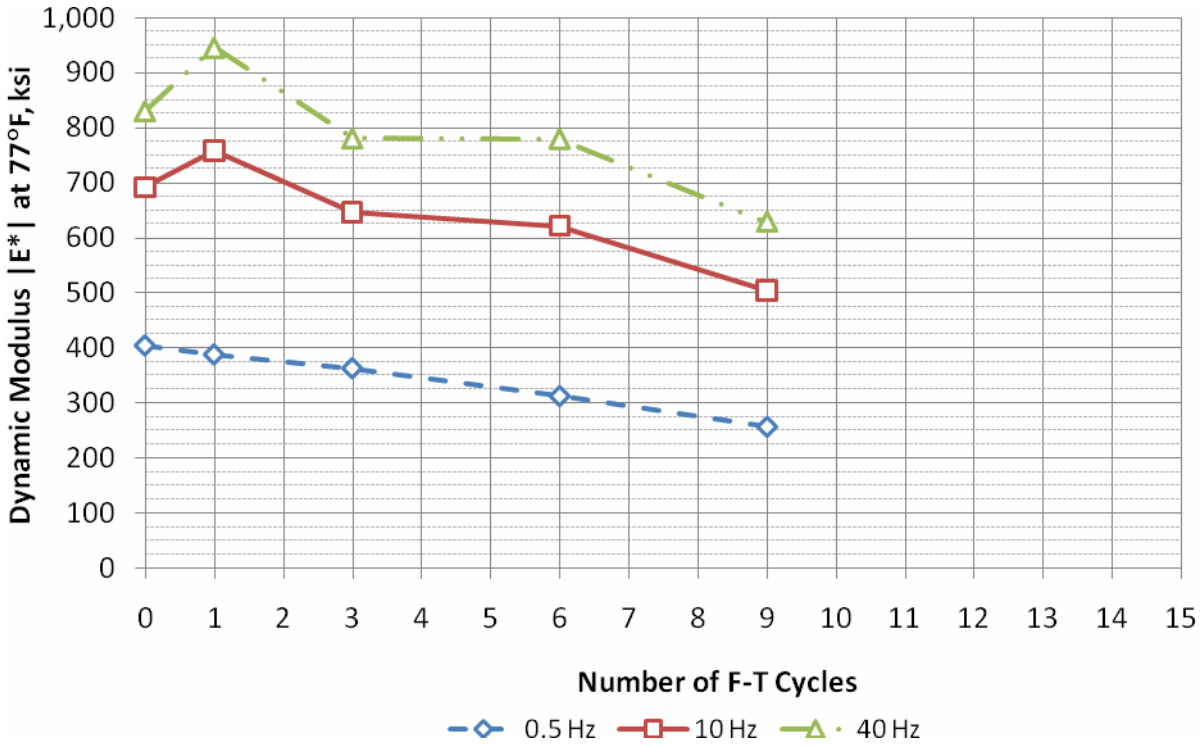


Figure 4 Dynamic modulus of the 1% EZ-lime in RAP collar mix at 77°F as a function of freeze-thaw cycles

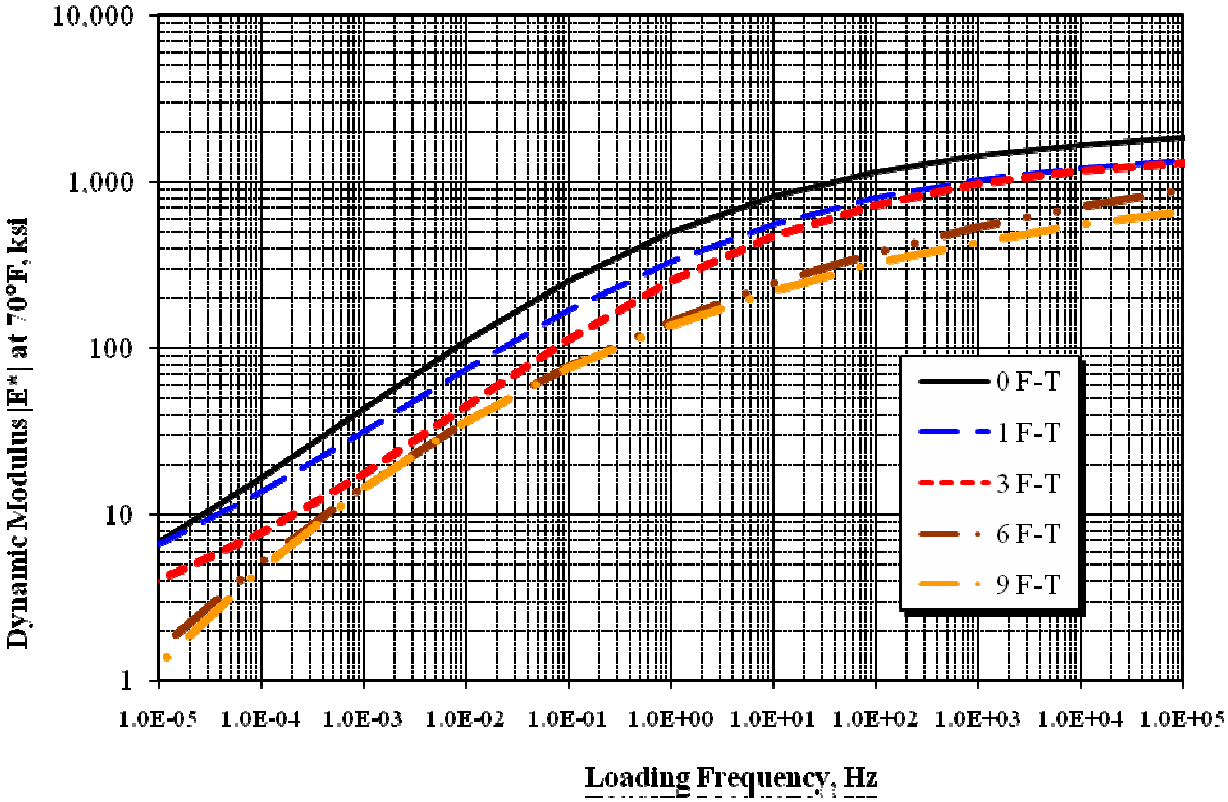


Figure 5 Dynamic modulus master curves at 70°F for the 1% EZ-lime in binder mix

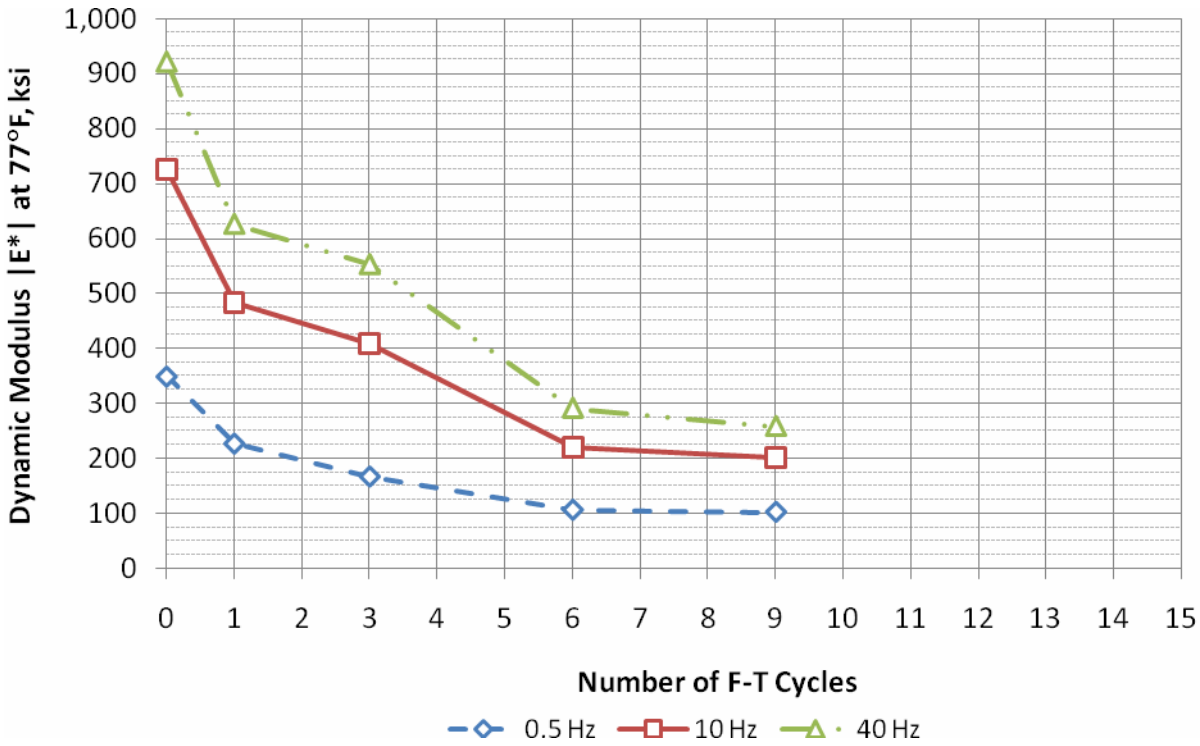


Figure 6 Dynamic modulus of the 1% EZ-lime in binder mix at 77°F as a function of freeze-thaw cycles

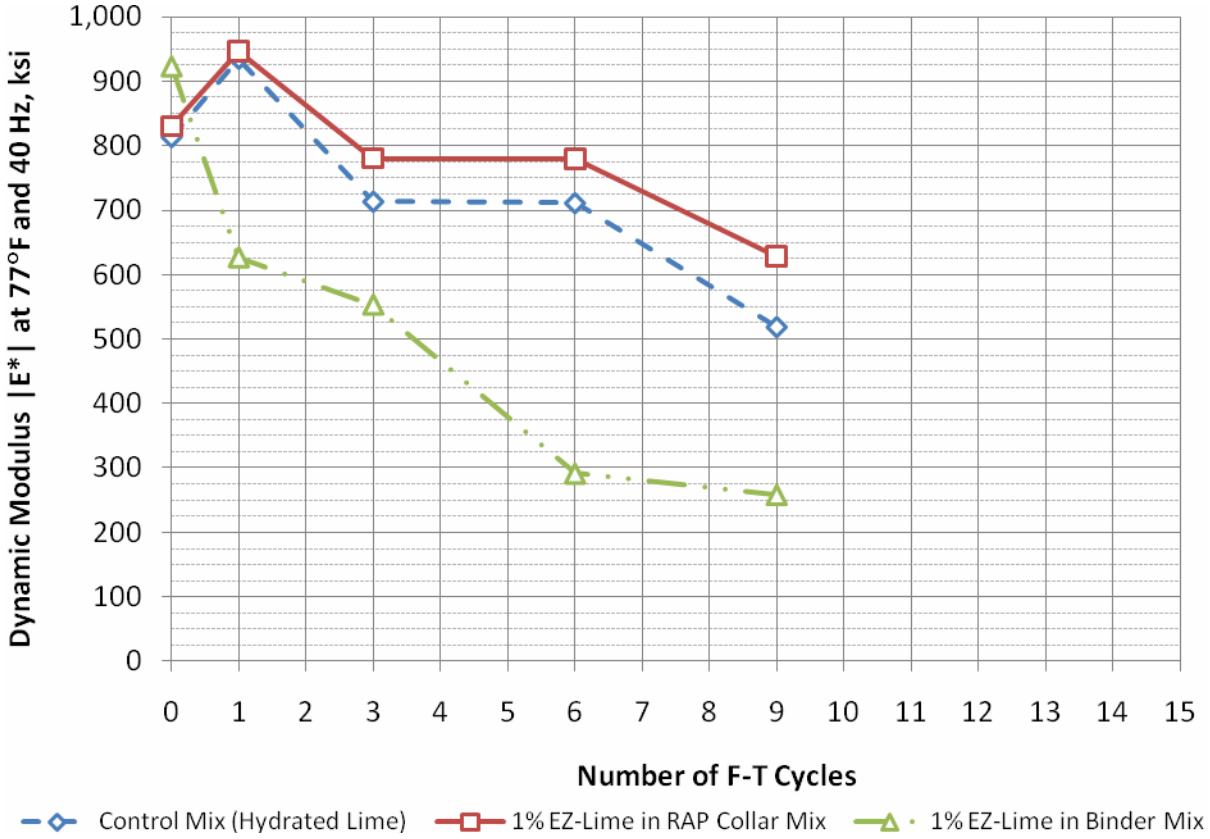


Figure 7 Dynamic modulus at 77°F and 40 Hz as a function of freeze-thaw cycles

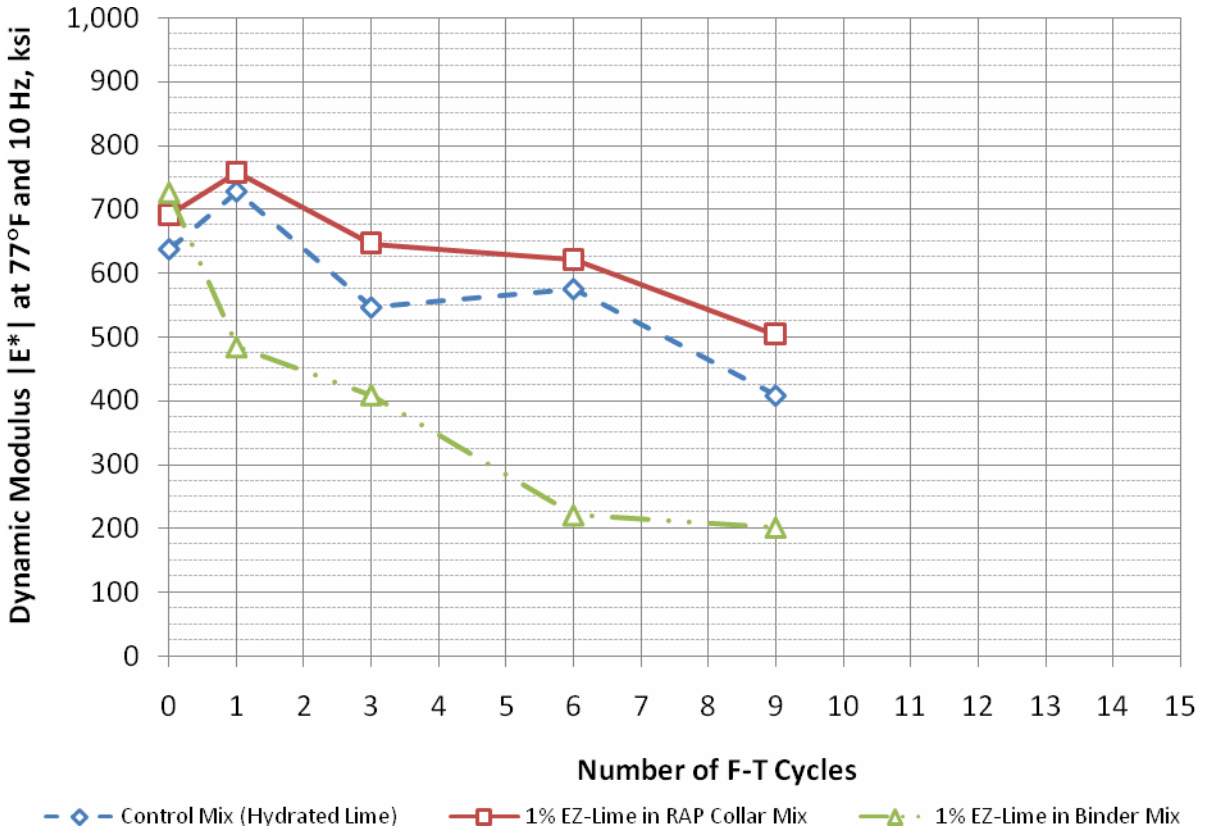


Figure 8 Dynamic modulus at 77°F and 10 Hz as a function of freeze-thaw cycles

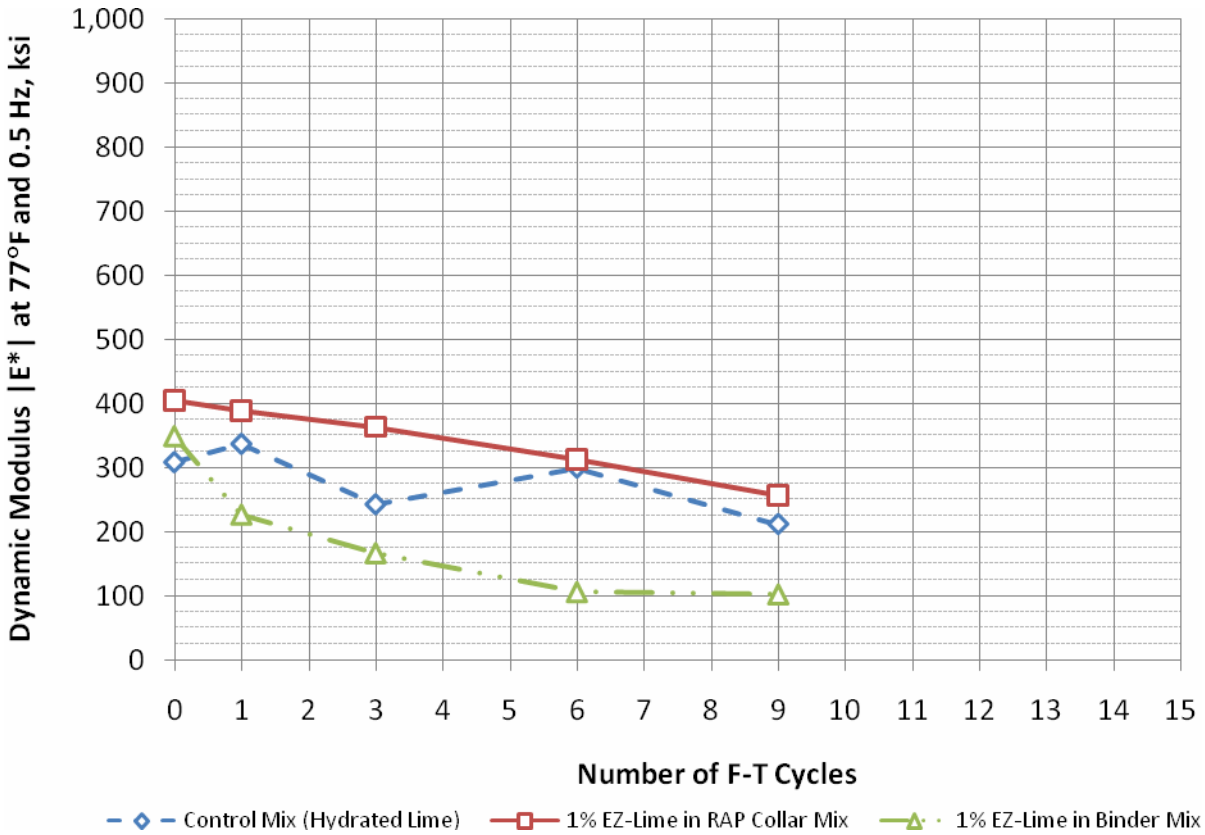


Figure 9 Dynamic modulus at 77°F and 0.5 Hz as a function of freeze-thaw cycles

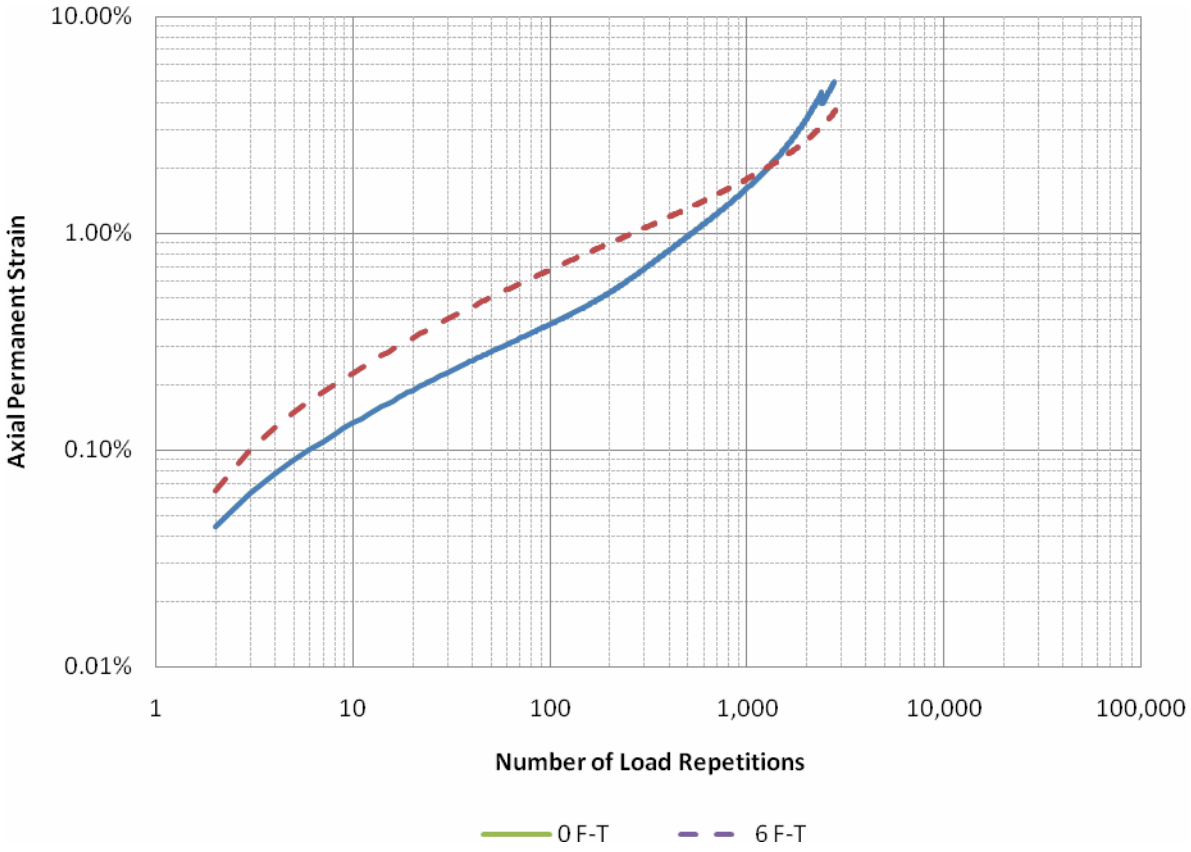


Figure 10 Axial permanent deformation at 122°F for the control mix

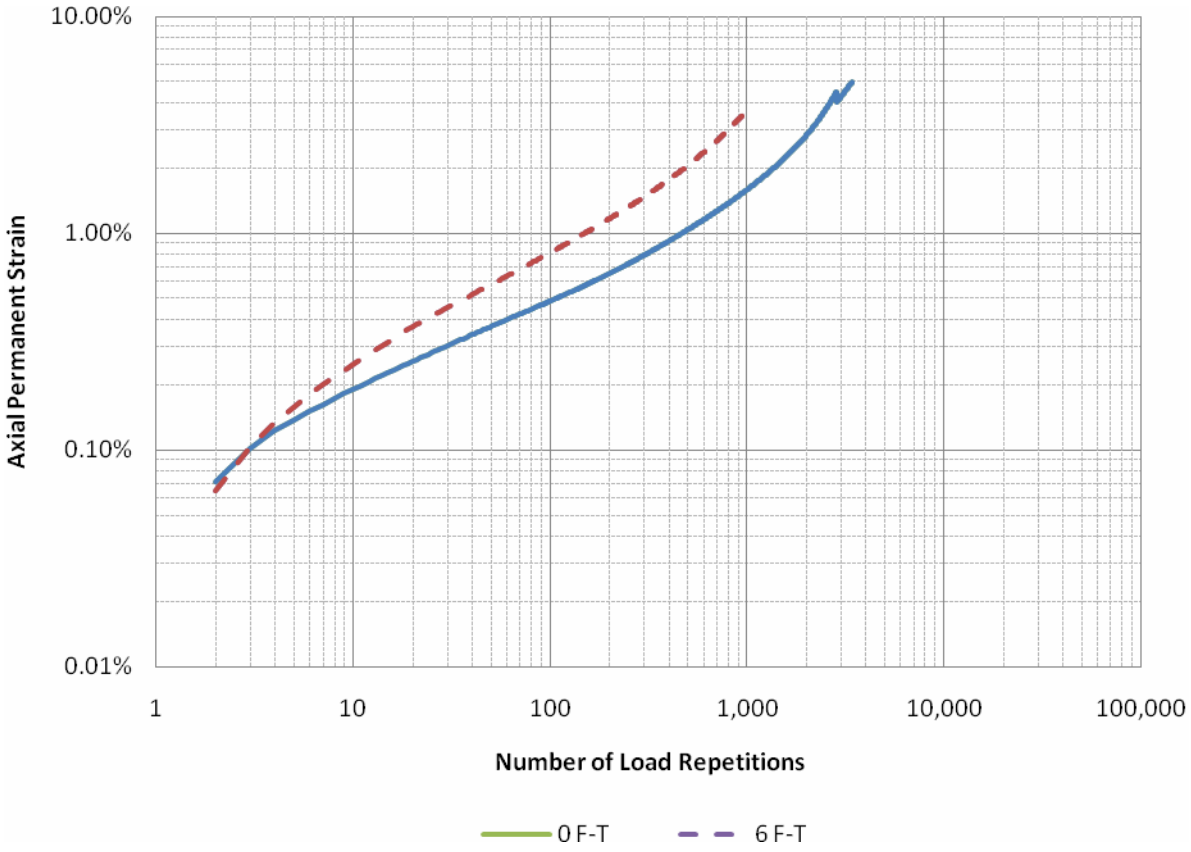


Figure 11 Axial permanent deformation at 122°F for the 1% EZ-Lime in RAP collar mix

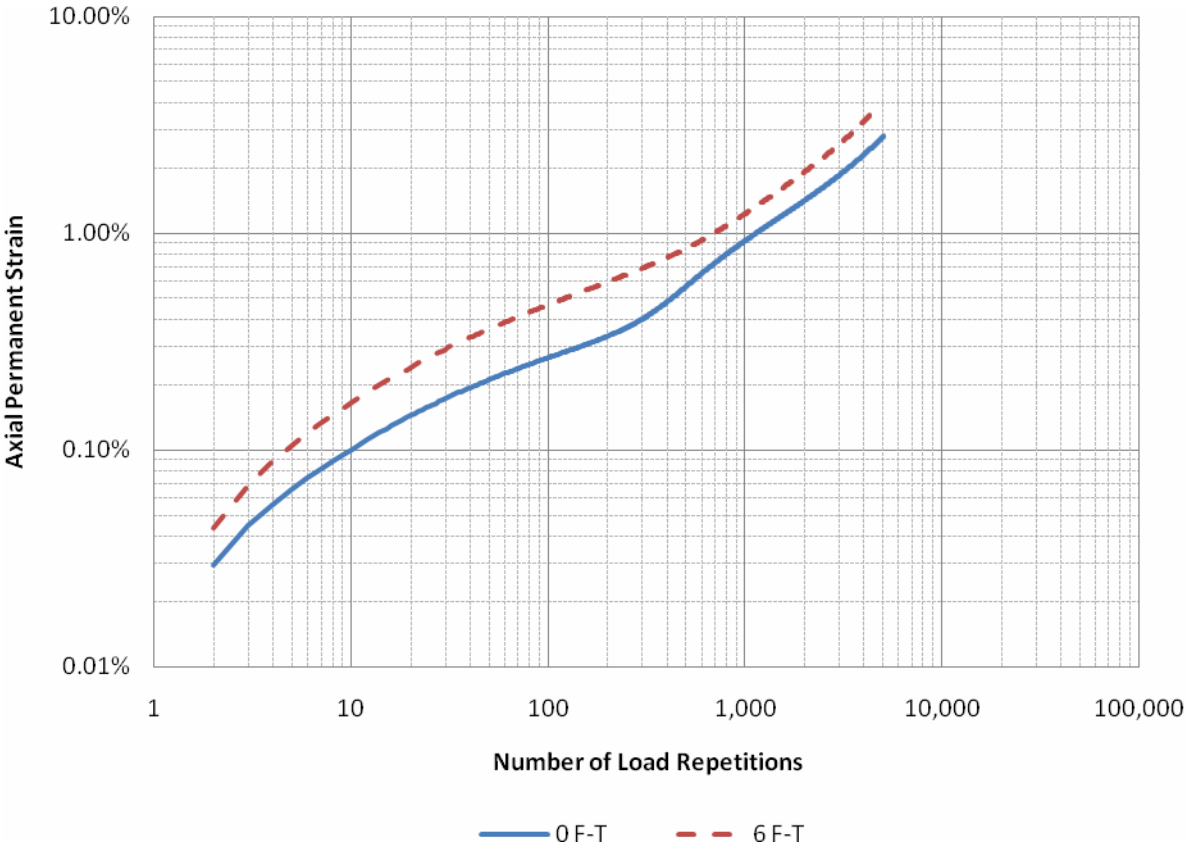


Figure 12 Axial permanent deformation at 122°F for the 1% EZ-Lime in Binder mix

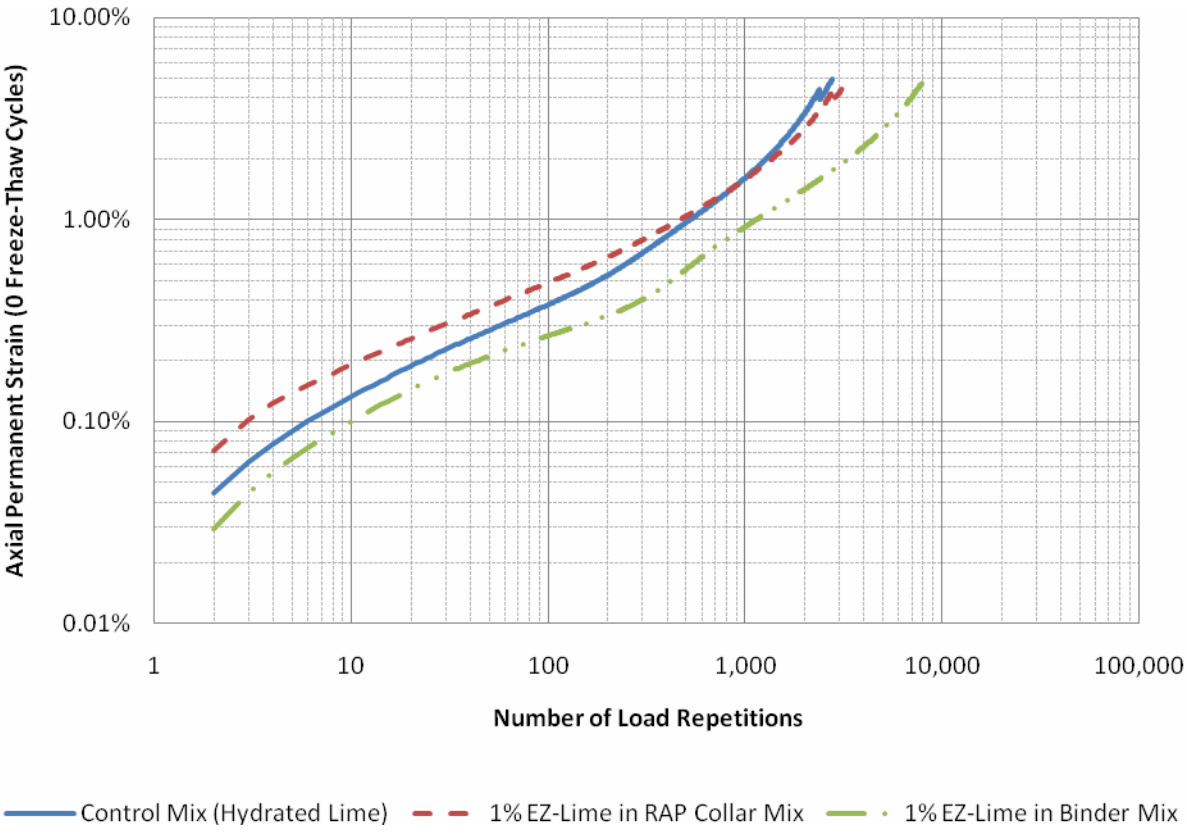


Figure 13 Axial permanent deformation at 122°F and 0 F-T

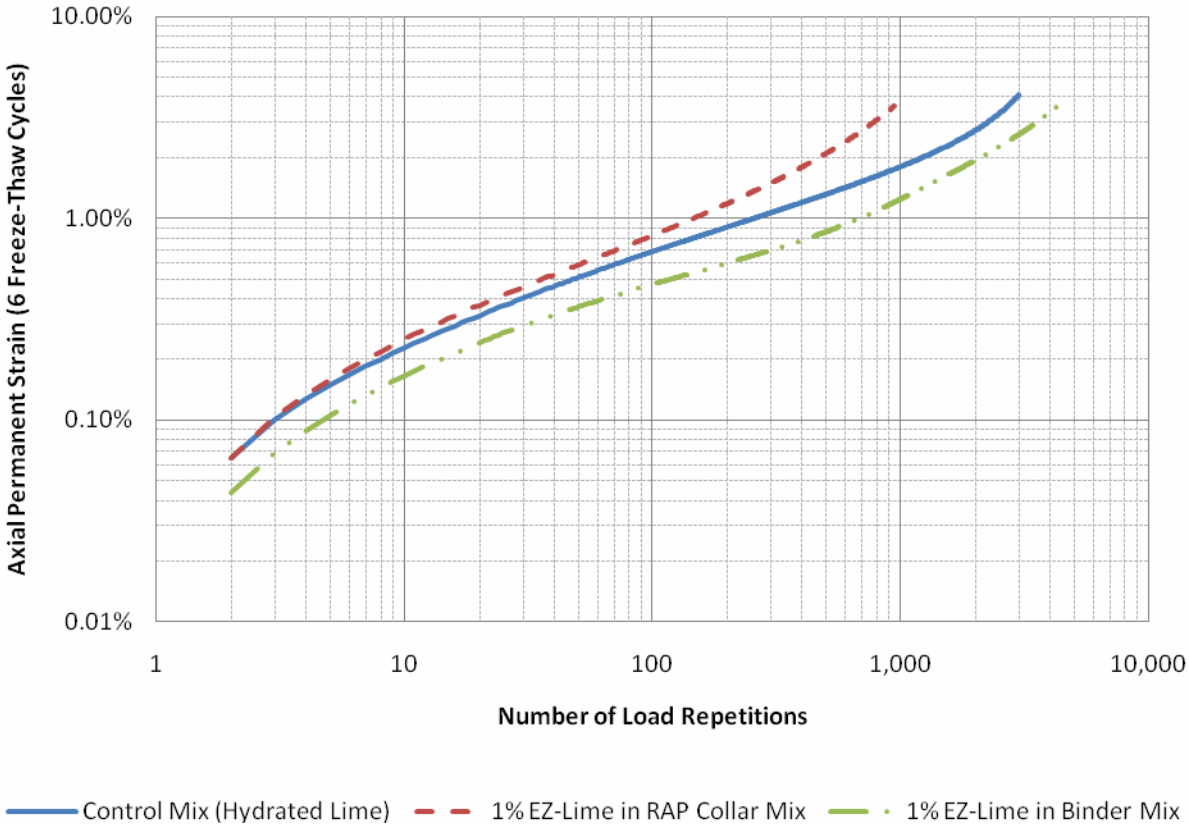


Figure 14 Axial permanent deformation at 122°F and 6 F-T