PCCAS POOLED FUND STUDY: Influence of Asphalt Binder on Mix Performance in Fatigue; A Progress Report

Pavement Research Center (PRC)
University of California, Berkeley
2,3 March 2004

Objective:

- **Define the relationship between binder properties and pavement fatigue performance to assist Asphalt Binder Committee in its deliberations relative to PG binder specifications**

Purpose:

- **Examine influence of range in binder types on fatigue response of AC pavement structures of various thicknesses in representative environmental regions encompassed by PCCAS (Alaska, Washington, Oregon, California, Nevada, Arizona, and Hawaii)**

Binders:

Supplier	Asphalt
US Oil	PG64-22
Chevron	PG64-28
Koch	PG70-28
Koch	AC-20P (PG64-28)
Williams	PG52-28
Chevron	PG76-16
Huntway/Valero	PG64-34 (PBA-6a)
San Joaquin Refinery	PG64-10 (SJV AR-4000)
Oxnard*	PG64-16 (Calif. Coastal AR-4000)*

*Binder test data not available

Asphalt Binder Tests

- By suppliers:
  - PG Binder Specification Data
  - G* and δ, range in frequencies and range of temperatures (5°–30°C)
- By FHWA
  - PG Binders Specification Data
  - G* and δ, range in frequencies and range of temperatures (5°–30°C)
  - New tests developed in NCHRP 9-10 (Univ. of Wisconsin) (not available as yet)
  - Molecular weight distributions; relaxation spectra determinations

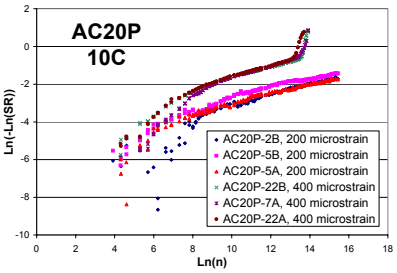
Mix Stiffness and Fatigue Tests – Basic Study

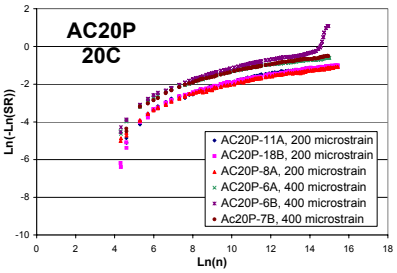
- One mix, Watsonville granite
- Nine (9) asphalts, one binder content
- One gradation, Caltrans dense-graded
- One air void content – 6 percent
- Three temperatures (10°C, 20°C, 30°C)
- One frequency (10 Hz)
- SHRP-developed fatigue equipment to define:
  - mix stiffness
  - fatigue response, N vs. ε_t (2 strain levels)

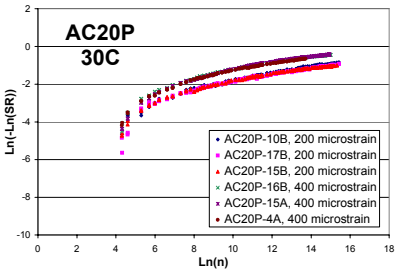
Binder Test Results

- 8 asphalts tested
  - RTFO and PAV aged residues
  - Master curves developed at 25°C G*, δ, G', G"

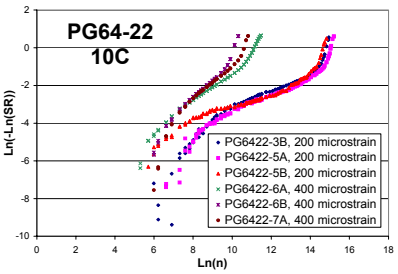
Fatigue Test Results: AC20P

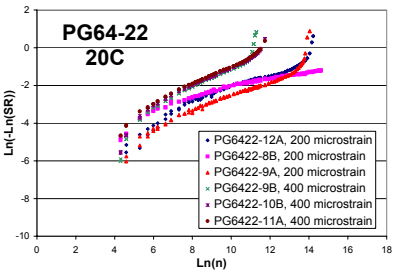


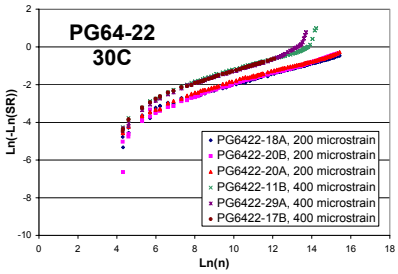




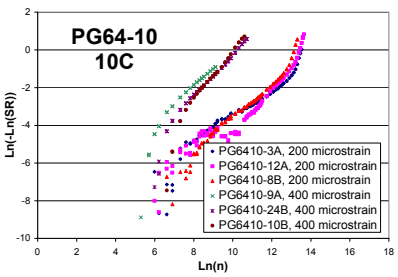
Fatigue Test Results: PG64-22

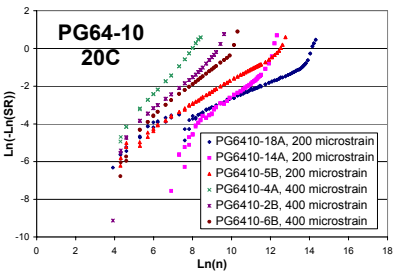


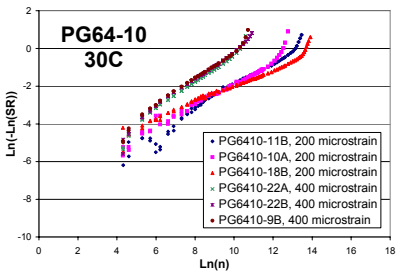




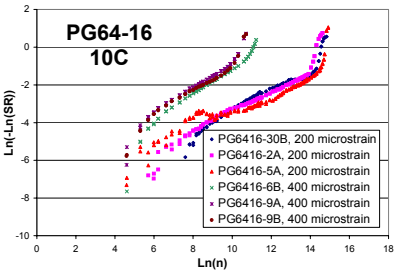
Fatigue Test Results: PG64-10

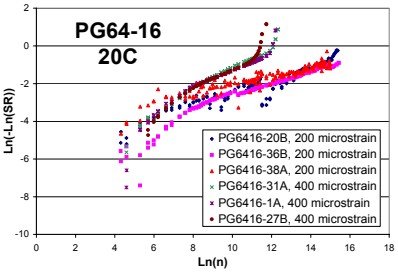


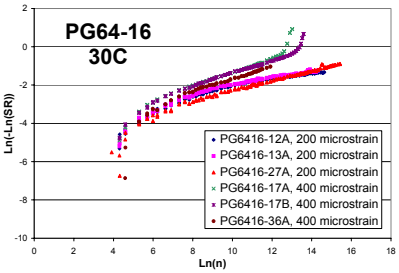




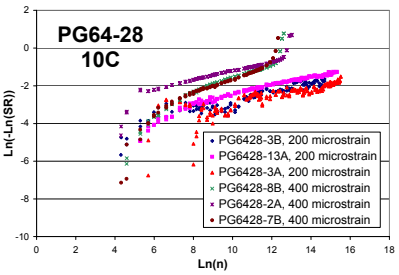
Fatigue Test Results: PG64-16

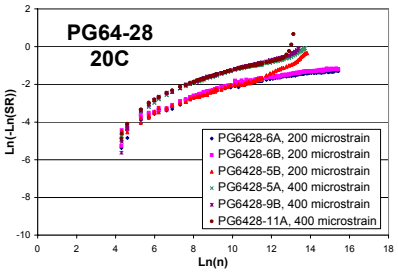


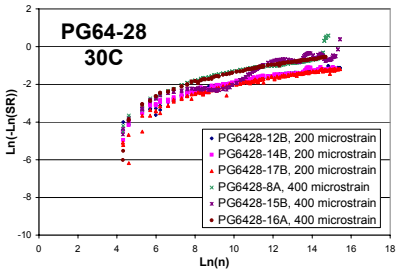




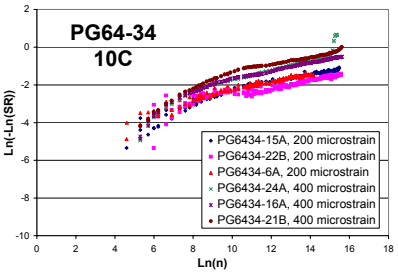
Fatigue Test Results: PG64-28

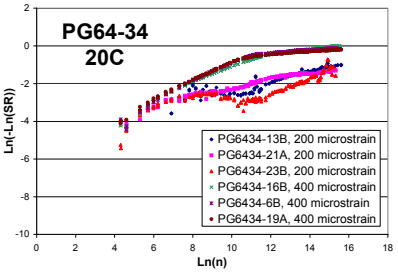


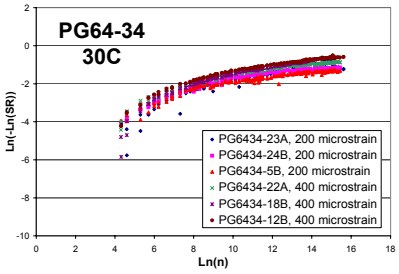




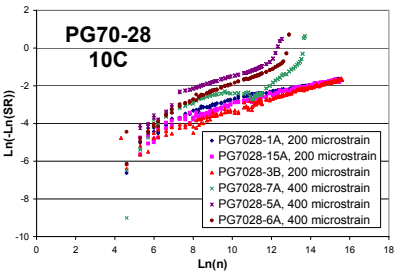
Fatigue Test Results: PG64-34

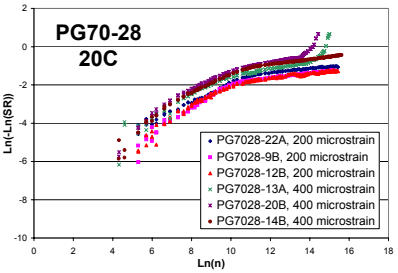


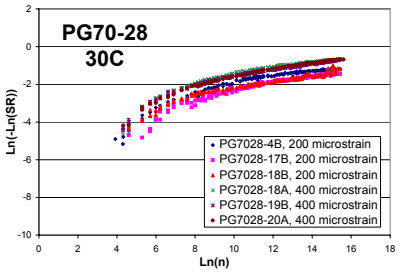




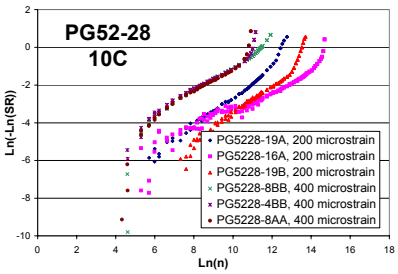
Fatigue Test Results: PG70-28

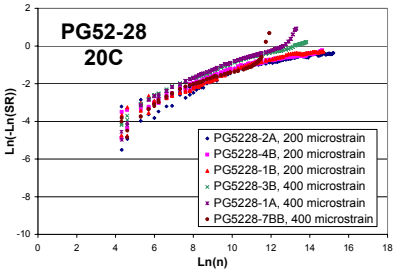


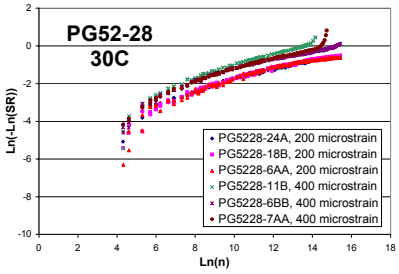




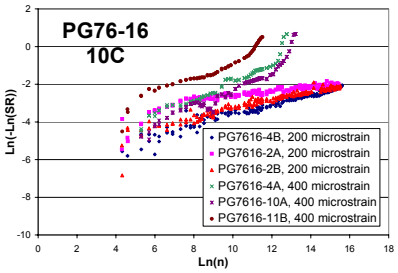
Fatigue Test Results: PG52-28

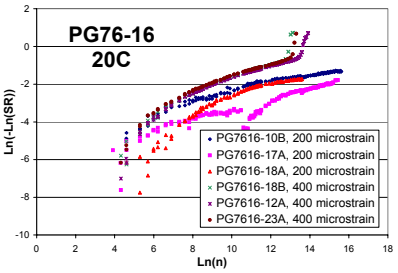


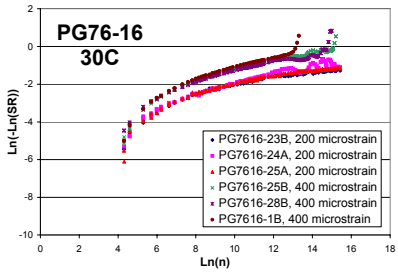




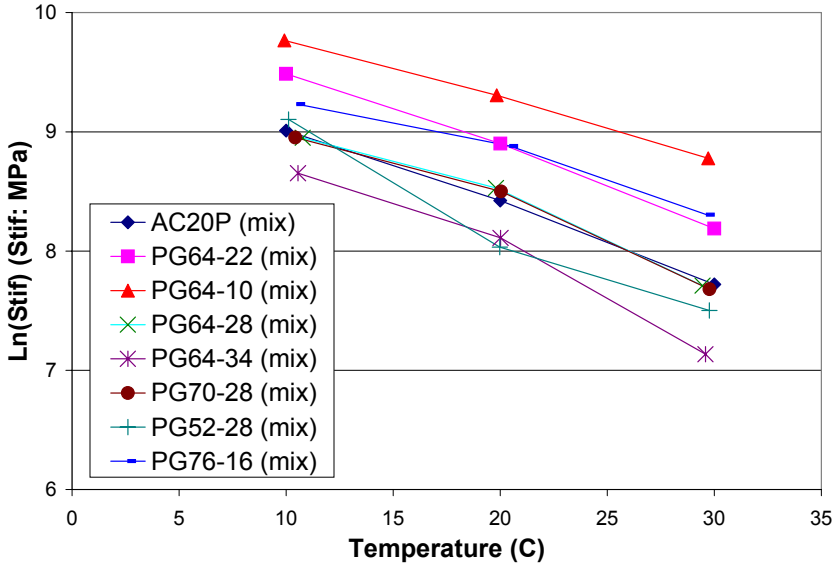
Fatigue Test Results: PG76-16



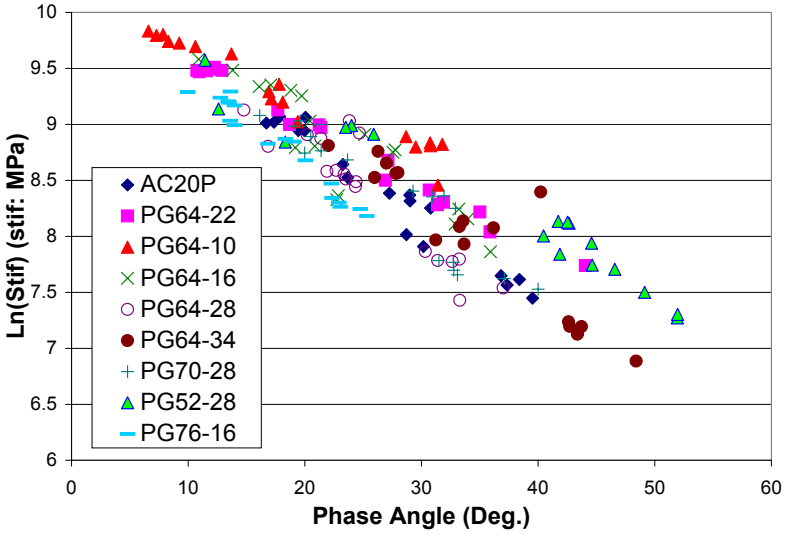




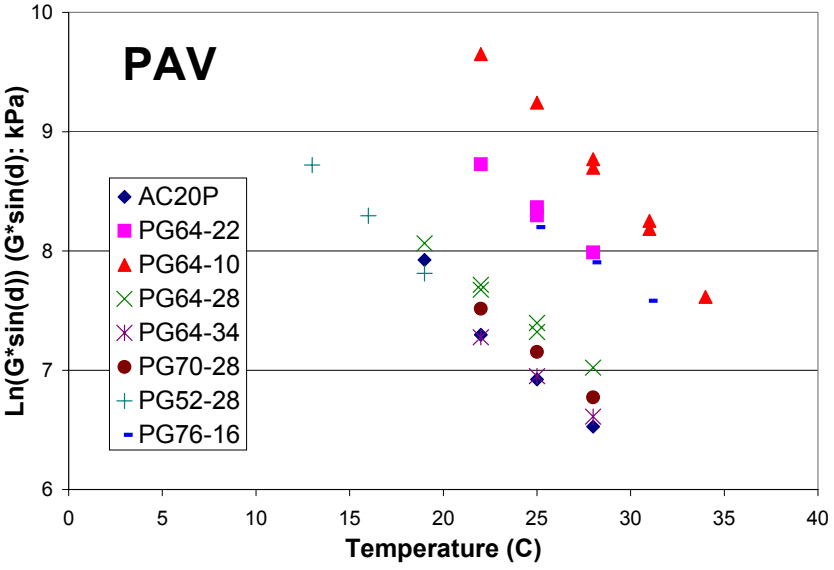
Average Mix Stiffness vs. Temperature



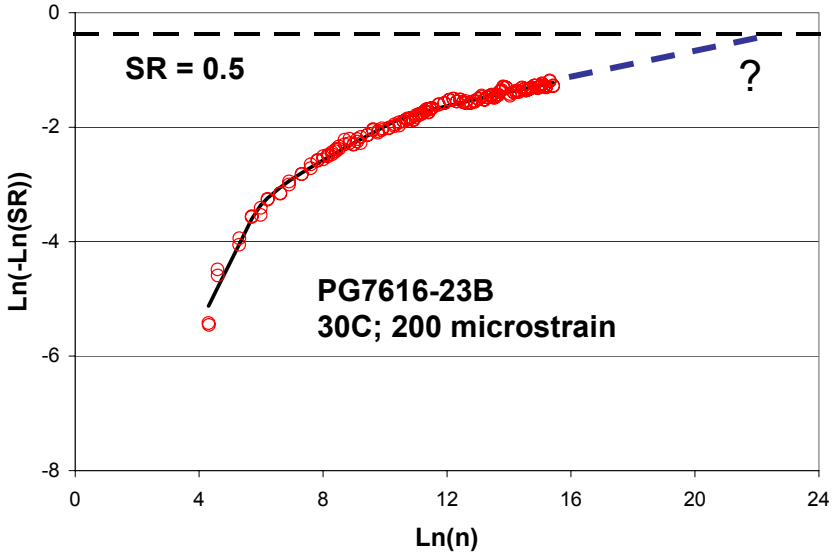
Initial Stiffness and Phase Angle



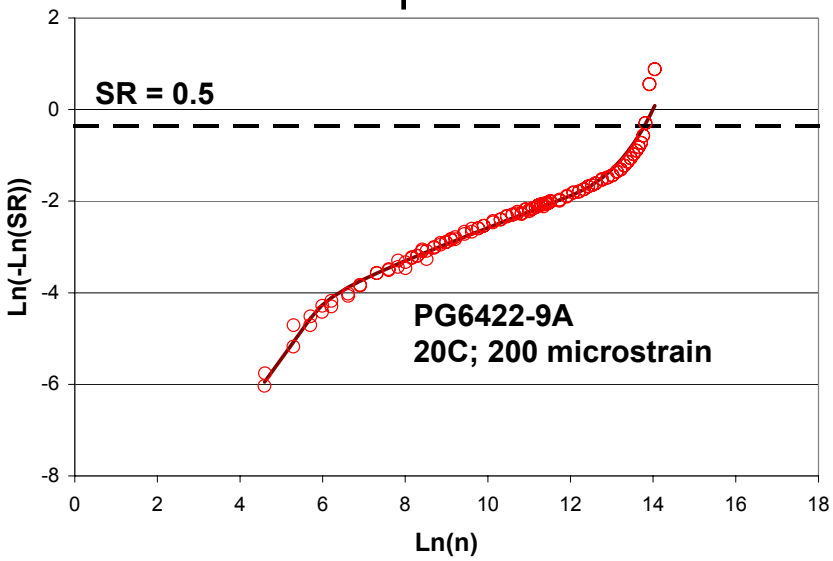
G*sin(δ) vs. Temperature



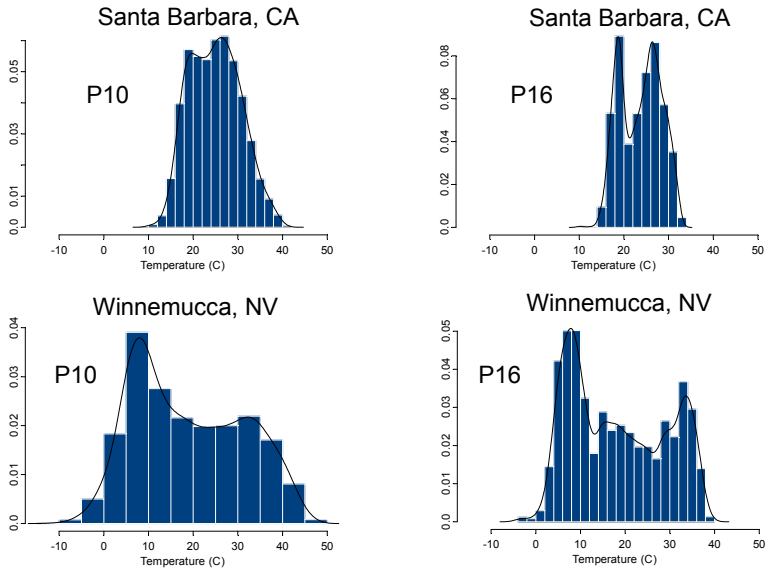
Fatigue Curve Fitting with Extrapolation



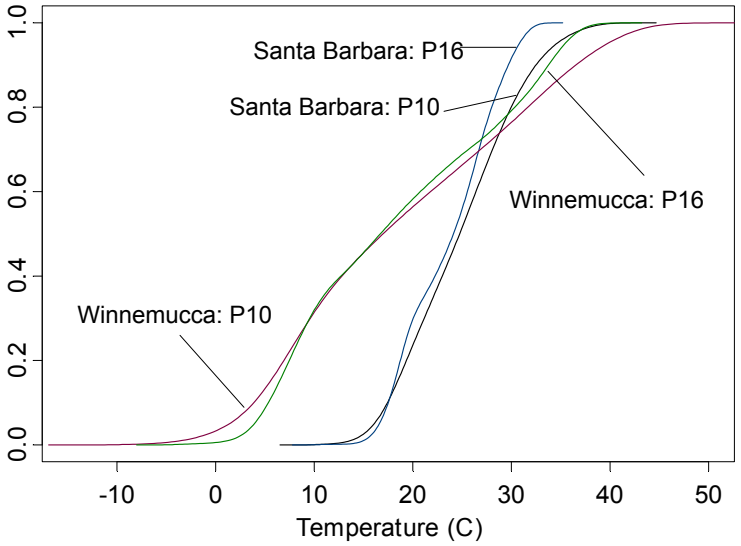
Fatigue Curve Fitting with Interpolation



Temperature (Tb) Distribution



Temperature Distribution Functions



Fatigue Analysis System

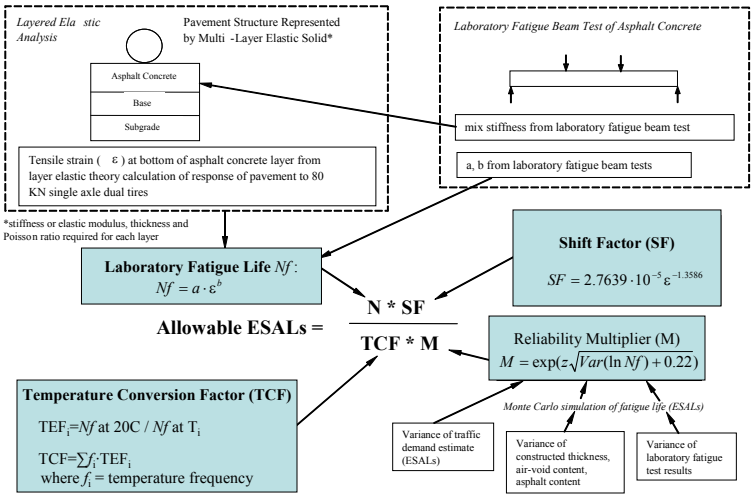
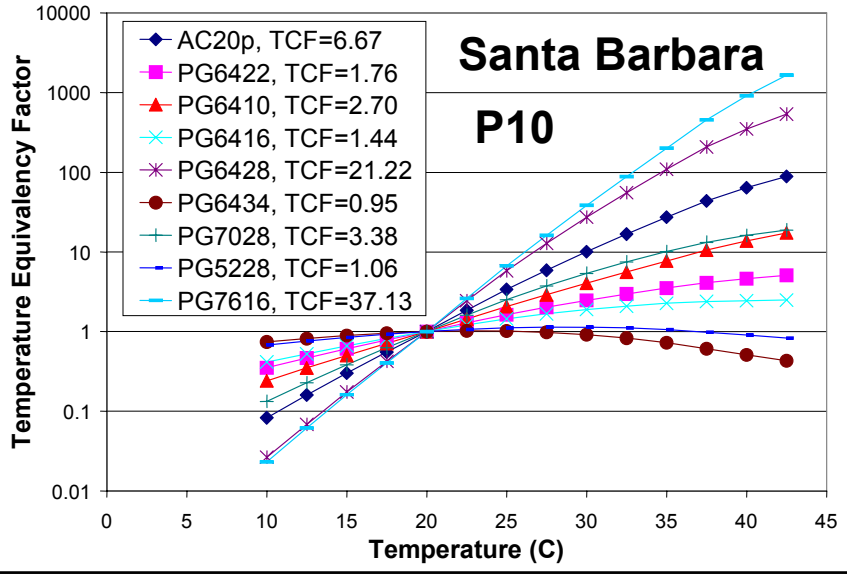


Figure 1.7. Methodology followed in the fatigue analysis system to determine ESALs (after Harvey 1997).

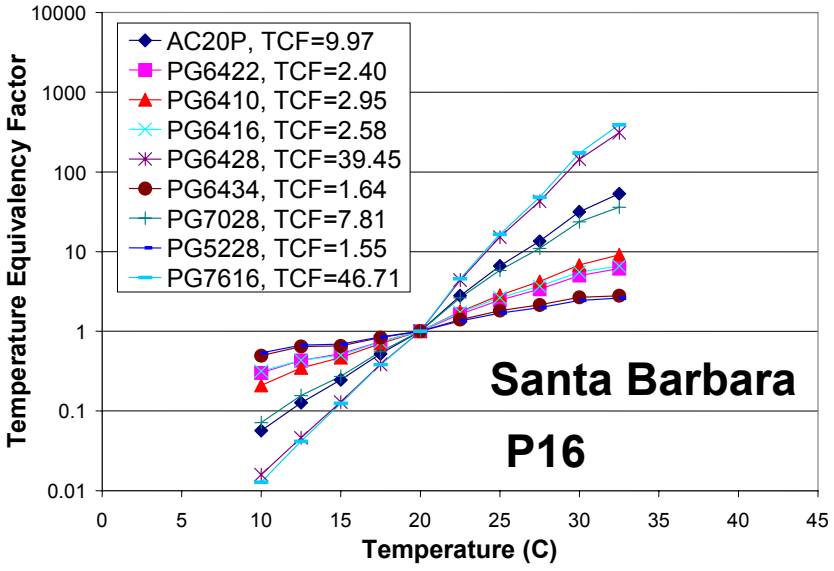
Pavement Structures

TI	R	Layer	Thickness (in)	Stiffness (psi)	Poisson's Ratio
7 (P10)	5	Surface	3.6	Varies	0.40
		Base	7.2	30,000	0.45
		Subbase	10.2	20,000	0.45
		Subgrade		3,850	0.50
15 (P16)	5	Surface	8.4	Varies	0.40
		Base	6.6	20,000	0.45
		Subbase	10.2	20,000	0.45
		Subgrade		3,850	0.50

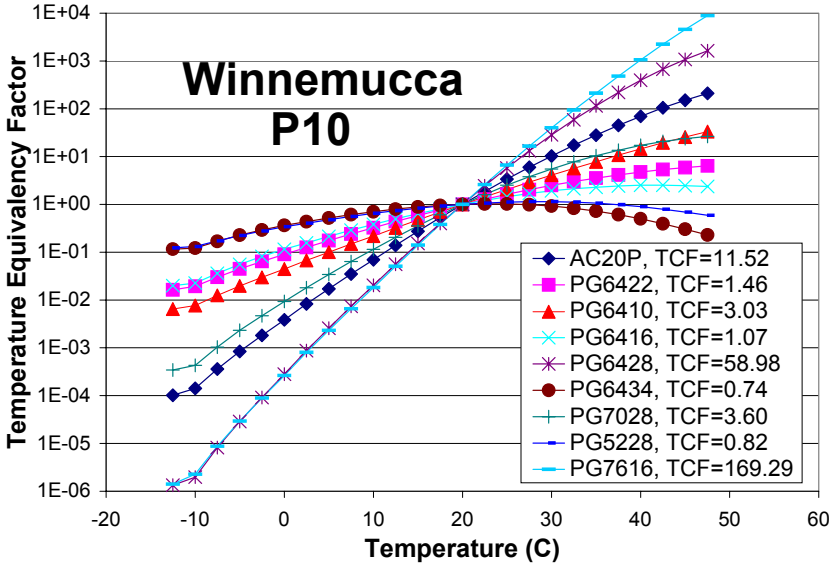
TEF Spectrum and TCF (1)



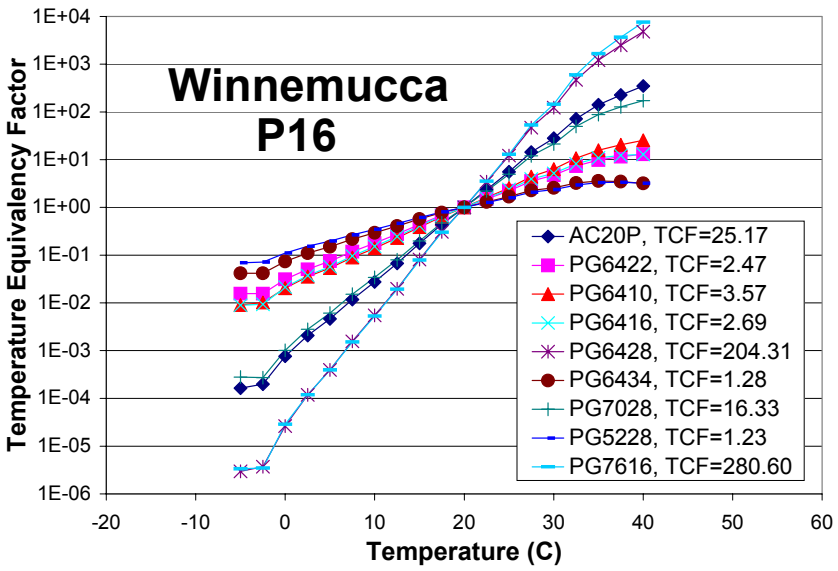
TEF Spectrum and TCF (2)



TEF Spectrum and TCF (3)



TEF Spectrum and TCF (4)



Predicted ESALs
(Santa Barbara: P10)

Binder Type	Nf@20C	SF	TCF	M (90%)	PredESALs
AC20P	6.15E+07	1.97	6.68	2.04	8.90E+06
PG64-22	9.47E+05	2.69	1.76	1.91	7.58E+05
PG64-10	9.84E+05	3.74	2.70	2.04	6.69E+05
PG64-16	2.04E+06	2.62	1.44	2.12	1.75E+06
PG64-28	4.05E+07	1.94	21.22	2.45	1.51E+06
PG64-34	1.51E+06	1.45	0.95	3.06	7.57E+05
PG70-28	4.26E+07	1.91	3.38	2.29	1.05E+07
PG52-28	1.23E+05	1.69	1.06	1.87	1.05E+05
PG76-16	4.21E+09	2.62	37.13	3.28	9.07E+07

Predicted ESALs (Santa Barbara: P16)

Binder Type	Nf@20C	SF	TCF	M (90%)	PredESALs
AC20P	9.16E+13	23.65	9.97	8.93	2.34E+13
PG64-22	1.62E+11	36.89	2.40	3.88	6.43E+11
PG64-10	1.44E+10	55.35	2.95	5.15	5.24E+10
PG64-16	5.16E+15	35.34	2.58	10.37	6.83E+15
PG64-28	2.56E+15	22.93	39.45	45.16	3.29E+13
PG64-34	6.12E+12	15.39	1.64	10.21	5.63E+12
PG70-28	1.47E+17	22.93	7.81	23.98	1.80E+16
PG52-28	8.02E+09	19.27	1.55	3.05	3.27E+10
PG76-16	2.69E+21	35.34	46.71	152.09	1.34E+19

Predicted ESALs (Winnemucca: P10)

Binder Type	Nf@20C	SF	TCF	M (90%)	PredESALs
AC20P	6.15E+07	1.97	11.52	2.04	5.16E+06
PG64-22	9.47E+05	2.69	1.46	1.91	9.10E+05
PG64-10	9.84E+05	3.74	3.03	2.04	5.96E+05
PG64-16	2.04E+06	2.62	1.07	2.12	2.35E+06
PG64-28	4.05E+07	1.94	58.98	2.45	5.43E+05
PG64-34	1.51E+06	1.45	0.74	3.06	9.65E+05
PG70-28	4.26E+07	1.91	3.60	2.29	9.87E+06
PG52-28	1.23E+05	1.69	0.82	1.87	1.36E+05
PG76-16	4.21E+09	2.62	169.29	3.28	1.99E+07

Predicted ESALs (Winnemucca: P16)

Binder Type	Nf@20C	SF	TCF	M (90%)	PredESALs
AC20P	9.16E+13	23.65	25.17	8.93	9.64E+12
PG64-22	1.62E+11	36.89	2.47	3.88	6.24E+11
PG64-10	1.44E+10	55.35	3.57	5.15	4.33E+10
PG64-16	5.16E+15	35.34	2.69	10.37	6.55E+15
PG64-28	2.56E+15	22.93	204.31	45.16	6.35E+12
PG64-34	6.12E+12	15.39	1.28	10.21	7.19E+12
PG70-28	1.47E+17	22.93	16.33	23.98	8.63E+15
PG52-28	8.02E+09	19.27	1.23	3.05	4.12E+10
PG76-16	2.69E+21	35.34	280.60	152.09	2.22E+18

ANOVA Analysis of Ln(PredESALs)

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
structure	1	2596.639	2596.639	175141.1	0.000000000
climate	1	1.431	1.431	96.5	0.000009683
binder	8	496.314	62.039	4184.5	0.000000000
structure:climate	1	0.188	0.188	12.7	0.007400531
structure:binder	8	184.596	23.074	1556.4	0.000000000
climate:binder	8	3.951	0.494	33.3	0.000023521
Residuals	8	0.119	0.015		

Factors and Levels

- Structure: P10 and P16
- Climate: Santa Barbara and Winnemucca
- Binder: 9 binders

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structure	1	2596.639	2596.639	175141.1	0.000000000
climate	1	1.431	1.431	96.5	0.000009683
binder	8	496.314	62.039	4184.5	0.000000000
structure:climate	1	0.188	0.188	12.7	0.007400531
structure:binder	8	184.596	23.074	1556.4	0.000000000
climate:binder	8	3.951	0.494	33.3	0.000023521
Residuals	8	0.119	0.015		

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