September 2009
Technical Memorandum: UCPRC-TM-2008-02

Rehabilitation Design for 01-LAK-53, PM 3.1/6.9 Using Caltrans ME Design Tools: Findings and Recommendations

Authors:
Lorina Popescu, James Signore, John Harvey, Rongzong Wu,
Irwin Guada, and Bruce Steven

Partnered Pavement Research Program (PPRC) Contract Strategic Plan Element 3.4:
Development of Improved Rehabilitation Designs for Reflection Cracking

PREPARED FOR:
California Department of Transportation
Division of Research and Innovation
Office of Roadway Research, and
Division of Pavement Engineering
Office of Pavement Design

PREPARED BY:

University of California
Pavement Research Center
UC Davis, UC Berkeley

DOCUMENT RETRIEVAL PAGE			**Research Report**: UCPRC-TM-2008-02
Title: Rehabilitation Design for 01-LAK-53, PM 3.1/6.9 Using Caltrans ME Design Tools: Findings and Recommendations			
Authors: L. Popescu, J. Signore, J. Harvey, R. Wu, I. Guada, and B. Steven			
Prepared for: California Department of Transportation Division of Research and Innovation Office of Roadway Research and Division of Pavement Engineering Office of Pavement Design	**FHWA No.:** CA101201B	**Date Work Submitted:** February 3, 2010	**Date:** September 2009
Strategic Plan No.: 3.4	**Status:** Stage 6, final version		**Version No.:** 1

Abstract:
This technical memorandum presents the results of pavement evaluation and rehabilitation design for 01-LAK-53, PM 3.1/7.0. The pavement evaluation consisted of deflection testing, coring, and material sampling; backcalculation of stiffnesses using the *CalBack* program; and condition assessment. Designs were prepared using current Caltrans methods, and alternative rehabilitation designs were prepared using mechanistic-empirical software and models included in the *CalME* program.

Keywords: Backcalculation, deflection, asphalt, aggregate base, rehabilitation, pulverization

Proposals for implementation: Implement a plan for field evaluation of performance, including a control section, if one of the alternative mechanistic-empirical designs is constructed by Caltrans.

Related documents:

- *Calibration of CalME Models Using WesTrack Performance Data.* P. Ullidtz, J. Harvey, B.-W. Tsai, and C.L. Monismith. 2006. University of California Pavement Research Center, Davis and Berkeley. UCPRC-RR-2006-14.
- *Calibration of Incremental-Recursive Flexible Damage Models in CalME Using HVS Experiments.* P. Ullidtz, J.T. Harvey, B.-W. Tsai, and C.L. Monismith. 2006. University of California Pavement Research Center, Davis and Berkeley. UCPRC-RR-2005-06.
- *CalBack: New Backcalculation Software for Caltrans Mechanistic-Empirical Design.* Q. Lu, J. Signore, I. Basheer, K. Ghuzlan, and P. Ullditz. 2009. Journal of Transportation Engineering, ASCE.
- *Rehabilitation Design for 02-PLU-36, PM 6.3/13.9 Using Caltrans ME Design Tools: Findings and Recommendations.* J.M. Signore, B.D. Steven, J.T. Harvey, R. Wu, I.M. Guada, and L. Popescu 2009. University of California Pavement Research Center, Davis and Berkeley. UCPRC-TM-2008-01.
- *Rehabilitation Design for 06-KIN-198, PM 9.2/17.9 Using Caltrans ME Design Tools: Findings and Recommendations.* I. Guada, J. Signore, R. Wu, L. Popescu, and J.T. Harvey. 2010. University of California Pavement Research Center, Davis and Berkeley. UCPRC-TM-2008-03.

Signatures:

L. Popescu **First Author**	J. Harvey **Technical Review**	D. Spinner **Editor**	J. Harvey **Principal Investigator**	T. J. Holland **Caltrans Contract Manager**

DISCLAIMER

The contents of this technical memorandum document reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

ACKNOWLEDGMENTS

This work was funded and managed by the California Department of Transportation, Division of Research and Innovation, under the direction of Nick Burmas, Joe Holland, Michael Samadian, and Alfredo Rodriguez. The technical leads for this project were Bill Farnbach for the Pavement Standards Team and Imad Basheer for the PPRC Technical Advisory Panel (TAP) supported by the Caltrans Mechanistic-Empirical Design Technical Working Group, whose guidance is appreciated. The support of District 1 Caltrans engineers Wesley Johnson and Dave Waterman and the traffic control coordination by District 1 crew are gratefully acknowledged.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

BACKGROUND AND OBJECTIVES

In 2007, three projects were selected by the Caltrans Division of Pavement Management, Office of Pavement Engineering as case studies in rehabilitation design using Mechanistic-Empirical (ME) design procedures. Three pavements were used as case studies and their locations are shown in Figure 1:

- 02-PLU-36, PM 6.3/13.9 (in and near Chester)
- 01-LAK-53, PM 3.1/7.0 (near Clearlake)
- 06-KIN-198, PM 9.2/17.9 (Lemoore to Hanford)

The goal of these case studies is to use current rehabilitation field investigation techniques, including deflection testing, material sampling, and Dynamic Cone Penetrometer (DCP) testing, to provide inputs to newly developed ME design and analysis software programs and procedures developed jointly by the UCPRC and Caltrans.

These new programs are *CalBack*, for backcalculation of layer stiffnesses from Falling Weight Deflectometer (FWD) data, and *CalME*, for performance estimates of cracking and rutting based on ME damage models that consider traffic, climate, layer type, and backcalculated stiffnesses. *CalME* is also capable of producing designs using the Caltrans R-value and CT 356 procedures, which were performed here for comparison purposes.

This project had these objectives:

1. To refine office and field information-gathering methods and office design and analysis techniques with the new software in order to identify changes needed for implementation by Caltrans.
2. To produce alternative designs for Caltrans' consideration.

The work conducted for each of these case studies consisted of a review of existing documentation, a field site evaluation and a material evaluation, and development of new design and rehabilitation options. This work was performed by the University of California Pavement Research Center (UCPRC) as part of Partnered Pavement Research Center Strategic Plan Element (SPE) 3.4 in conjunction with Caltrans district offices and headquarters staff.

This technical memorandum is the second of three prepared and focuses on the pavement 01-LAK-53, PM 3.1/7.0, near Clearlake. The memo summarizes the work performed to aid the development of new design and rehabilitation software tools, while simultaneously providing Caltrans with alternative pavement designs.

Outlined in the document are the procedures and findings of each step—from pre-site work to site investigation to rehabilitation design recommendations—based upon both current R-value and ME design procedures.

Figure 1: Map showing locations of three case studies.

PRESITE VISIT EVALUATION

Following site selection for this case study, UCPRC staff contacted District 1 personnel to obtain existing information regarding as-builts, construction history, coring logs, distress surveys, and deflection test results. This information was studied along with the Caltrans pavement video log to create a preliminary field testing plan. This plan was sent to Albert Vasquez at Caltrans HQ and to appropriate District Design, Materials, and Maintenance staff. Following this, plans were made for a pretesting site visit with district personnel. During this visit, exact deflection testing limits were established, coring plans were made, and possible trenching locations were identified. District personnel established a traffic control plan for one day of field evaluation and testing. The test plan was revised as requested and sent back to all personnel involved.

SITE DESCRIPTION

The pavement for this case study is on Route 53, located in Lake County near the town of Clearlake, between Post Mile 3.1, near Davis Ave., and Post Mile 7.0, which is located approximately one-half mile south of the junction with State Route 20.

Caltrans records show that the existing pavement structure was constructed in 1956 and has been overlaid with thin (0.10 ft to 0.20 ft) layers of HMA at various times. Construction records providing the post mile limits of each overlay and the asphalt layer thicknesses from field cores are discussed in detail in the next chapter, “Field Investigation—Findings.”

The two-lane highway section was divided into eight subsections (four northbound and four southbound) based on as-builts, current condition, and the ability to provide safe traffic control for the work crew and road users. The length of the subsections varied from 0.2 mi to 0.5 mi due to frequent changes in profile that induced traffic control restrictions.

For backcalculation analysis purposes, four of the sections were combined into two due to similarities in structure, resulting in a total of six analysis sections. The post miles and lengths of each section and a map of the site are shown in Table 1 and Figure 2, respectively.

Table 1: Subsection Locations and Lengths

Section	PM Start	PM End	Section Length in ft (m)	Description
A (North) B (South)	3.20	3.40	1,056 (322)	Between Davis Ave. and Polk St.
C (North and South)	3.60	3.97	1,954 (596)	Between Polk St. and Olympic Dr.
D (South) E (North)	4.90	5.27	1,954 (596)	Between Old Hwy. 53 and Ogulin Canyon Rd.
F (North and South)	6.50	6.97	2,482 (756)	Section ends approx. 0.5 mi south of junction with Hwy. 20.

Figure 2: Map showing subsection locations.

FIELD INVESTIGATION—FINDINGS

UCPRC and Caltrans personnel carried out a two-day site investigation on December 11 and 12, 2007. The investigation included collecting Falling Weight Deflectometer (FWD) data to assess the structural capacity of the existing pavement structure, coring at nine locations for hot-mix asphalt (HMA) layer thickness, trenching at one location, and Dynamic Cone Penetrometer (DCP) testing at 10 locations for granular base thickness and estimated subgrade stiffness. Photographs were taken of the pavement surface condition.

Pavement Condition. The pavement surface had fatigue cracking over approximately 8 percent of the wheelpath length in the selected test sections, with about 5 percent Alligator A and 3 percent Alligator B. There was transverse cracking typical of low-temperature cracking (uniformly spaced, extending transversely across the entire paved area with relatively straight cracks perpendicular to the direction of travel) over approximately 35 percent of the project area with typical crack width of 1/3 in. (8 mm) and typical crack spacing of 100 ft (30 m). Five out of nine cores debonded at the interface between layers three and four (at the interface between overlays placed in 1960 and 1978). Two cores were extracted from the top of the cracked areas (PM 3.3 North and PM 4 South). The core extracted at PM 3.3 North debonded and was cracked through, as seen in Figure 3. The core at PM 4 South debonded and was cracked through the top lift as seen in Figure 4.

According to as-built information, in 2003 an open-graded hot-mix asphalt (HMA-O) course was placed across all subsections in the entire project. At numerous locations, transverse and longitudinal fatigue cracks reflected to the surface of the HMA-O. It is likely that this open-graded layer covers additional distress in the wheelpaths in the structural HMA layers.

It could be concluded that the predominant distress mechanism was either top-down low-temperature cracking or reflection of existing low-temperature transverse cracks up through the thin overlays. The average (2004 to 2008) annual lowest temperature at this site is 17.5°F (-8.1°C), and there are an average of 78 days each year where the daily low temperature is below freezing. At the same time, it is apparent that there is a second distress mechanism of load-related cracking in the wheelpaths, referred to as alligator cracking. Several representative photographs of the pavement are shown in Figure 5, Figure 6, and Figure 7.

Electric and communication utilities pose no problem throughout the length of the project area. There are neither gas nor fiber-optic utilities underground to affect the design. Water and sewer lines pose no problem except for one location between PM 3.2 and PM 3.4, where the top of a culvert was hit during soil sampling. Thorough investigations need to be done at the above mentioned location to determine the depth below the grade of the culvert and its length across the section. This would allow for more flexibility in choosing the rehabilitation options since there is no strict limitation in matching the existing finished grade.

Figure 3: Core taken at Lake 53, PM 3.3 NB.
(Note that core is upside down in photograph.)

Figure 4: Core taken at Lake 53, PM 4.0 SB.
(Note that core is shown upside down.)

Figure 5: Lake 53 Alligator B crack in the wheelpath (PM 3.3 NB, north of Davis Ave.).

Figure 6: Lake 53 longitudinal crack in the wheelpath (PM 4.0 SB, near Olympic Dr.).

Figure 7: Lake 53 transverse crack (near PM 5.25 NB).

Pavement Drainage

The project location includes both cut and fill. It did not appear that major drainage problems had contributed to the pavement distresses.

Pavement Coring

HMA layer thicknesses from cores varied over a large range, from 0.33 ft (100 mm) to 0.69 ft (210 mm). These are presented in Table 2.

Table 2: HMA Thickness from Cores

Core Location North	HMA thickness ft (mm)	Core Location South	HMA thickness ft (mm)
PM 3.25	0.33 (100.5)	PM 3.20	0.58 (178.0)
PM 3.30	0.33 (100.5)	PM 3.40	0.69 (210.0)
PM 3.63	0.50 (152.0)	PM 4.00	0.58 (178.0)
PM 5.25	0.42 (128.0)	PM 4.90 (slab)	0.58 (178.0)
PM 6.70	0.50 (152.0)	PM 6.93	0.42 (128.0)

A ground-penetrating radar (GPR) investigation would be better able to show the variability in the thickness of the HMA layer between the core locations. One core was taken in each section, except for Sections A and B, where two cores per section were taken. A slab was cut at PM 4.9, Section D.

Caltrans coring data from March 2007 was included in this analysis and was accounted for in the thickness variability function of the *CalME* analysis. Combined results showed a high variability of HMA layer thickness. A diagram of the core thicknesses along the project is shown in Figure 8.

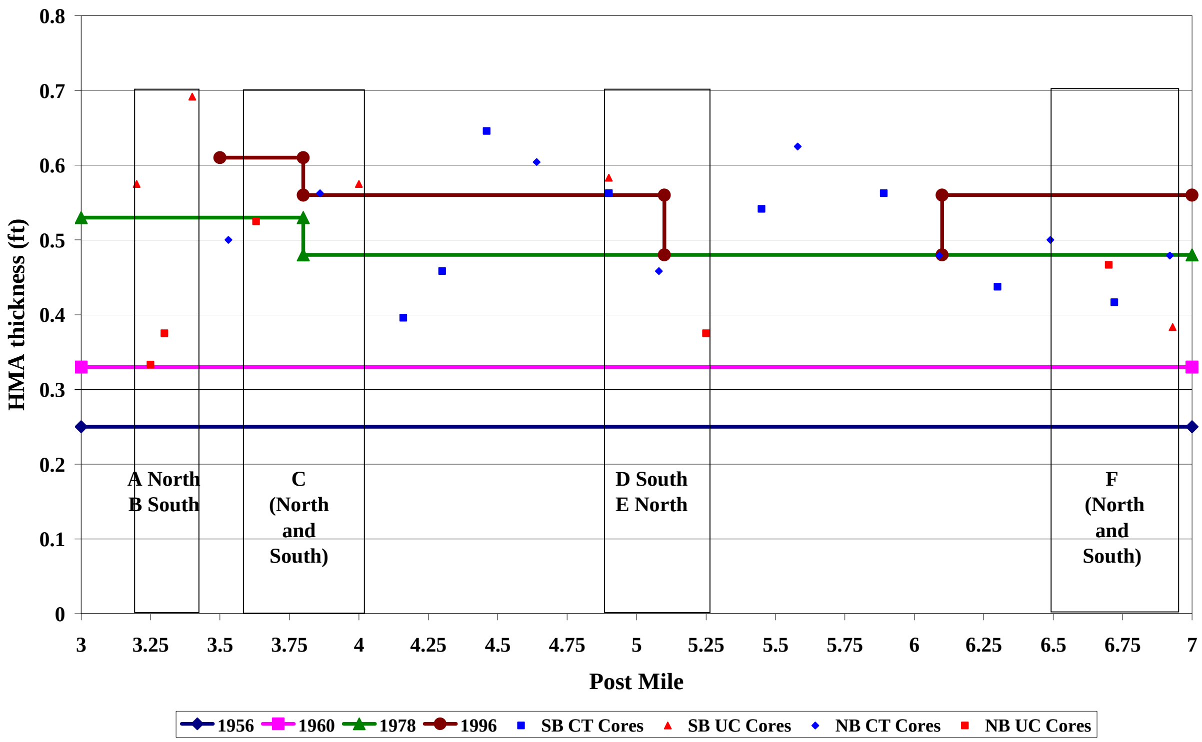

Figure 8: HMA core thicknesses (2007) by section, post mile, and construction history from as-builts.

Pavement Section Details

Table 3 expands on Table 1 and shows the layer thicknesses, 80th percentile deflection values, and backcalculated (with *CalBack*) layer stiffnesses (moduli) for the six pavement design sections. For backcalculation purposes the initial eight sections were combined into six according to their deflections, pavement structure, and alignment: A, B, C, D, E, and F. For design purposes, the six sections were further grouped together into three sections based upon their structural similarities as follows:

- A: 0.35-ft HMA/1.0-ft AB nominal thicknesses
- B&C: 0.53 to 0.69-ft HMA/1.0-ft AB nominal thicknesses
- E&F: 0.38 to 0.48-ft HMA/1-ft to 1.15-ft AB nominal thicknesses

Table 3: Pavement Details

Section	**PM**	**Field Station ft (m)**	**Section Length ft (m)**	**Landmark**	**No. Lanes Each Direction**	**HMA Thick. Range (ft)** ***(Cores)***	**HMA Thick. Typical for Backcalcu-lation**	**AB Thick. (ft)** ***(from DCP) UCS***	**SG Soil**	**80th % Defl. (mils)**	**FWD Avg Air Temp (°F)**	**Condition Survey**	**HMA Layer Stiffness Modulus (corrected to 68°F) psi (Mpa)**	**AB Layer Stiffness Modulus psi (MPa)**	**SG Layer Stiffness Modulus psi (MPa)**
	3.2	0+00 (0)		Davis St. - Rd 213BS											
North A			1050 (320)		1	0.33 to 0.38	0.36	0.98	SC-SM	20	44	30% Alligator B, 2% low-temperature cracking 8-mm wide, 100 ft (30 m) spacing	814,412 (5,617)	49,621 (342)	14,149 (98)
	3.399	10+50 (320)						GW-GC							
	3.393	10+17 (310)													
South B			1017 (310)		1	0.58 to 0.69	0.62	0.98	SC-SM	16.2	50	30% Alligator B	848,199 (5,850)	54,155 (373)	17,306 (119)
	3.2	0+00 (0)		Davis St. - Rd 213BS				GW-GC							
	3.6	0+00 (0)													
C (North + South)			1968 (600)		1	0.53 to 0.58	0.56	0.98	SC-SM	16.8	51	No distress on North-bound, 5% Alligator B and 5% Alligator A on South bound	877,645 (6,053)	49,804 (343)	19,263 (133)
	4	19+68 (600)		Olympic Drive				GW-GC							

Table 3: Pavement Details *(con't)*

Section	PM	Field Station ft (m)	Section Length ft (m)	Landmark	No. Lanes Each Direction	HMA Thick. Range (ft) (Cores)	HMA Thick. Typical for Back-calculation	AB Thick. (ft) *(from DCP) UCS*	SG Soil	80th % Defl. (mils)	FWD Avg Air Temp (°F)	Condition Survey	HMA Layer Stiffness Modulus (corrected to 68°F) psi (Mpa)	AB Layer Stiffness Modulus psi (MPa)	SG Layer Stiffness Modulus psi (MPa)
	4.925	0+00 (0)													
South D			131 (40)		1	0.56 to 0.58	0.57	1.31	SC-SM	11.4	56	No distress	1,291,662 (8,908)	37,968 (262)	13,559 (94)
	4.92	1+31 (40)						GW-GC							
	4.9	0+00 (0)													
North E			1968 (600)		1	0.38 to 0.46	0.41	1.15	SC-SM	17.1	57	5% Alligator B	1,214,625 (8,377)	64,534 (445)	16,791 (116)
	5.273	19+68 (600)		Ogulin Canyon Rd-205C				GW-GC							
	6.5	0+00 (0)													
F (North + South)			2493 (760)		1	0.38 to 0.48	0.44	0.98	SC-SM	21.5	53	70% Alligator B, 10% transverse cracks 8-mm, 100 ft (30 m) spacing	718,938 (4,958)	43,305 (299)	20,733 (143)
	6.972	24+93 (760)						GW-GC							

Deflection Data with Falling Weight Deflectometer (FWD)

The UCPRC Dynatest Heavy Weight Deflectometer was used for deflection testing. Three load levels (nominally 6,000 lb, 9,000 lb, and 13,000 lb) with one drop per load level were made at each testing location. Deflection testing was conducted in both directions, north and south, on each subsection, with locations staggered between the two lanes. For Sections A and B, FWD test spacing was 20 ft (6 m) in each lane. For Sections C, E, and F, FWD spacing was 40 ft (12 m) in each lane. Section D, located between PM 4.925 and 4.9 SB, was only 40 ft (12 m) long and was tested at 5-ft (1.5-m) intervals due to traffic control constraints.

Backcalculations were based on deflections of 13,000 lbs. Initial seed moduli that were based on values stored in *CalBack* were used as the initial trial moduli. These data were used for backcalculation estimation of layer stiffnesses with *CalBack*. The lack of bonding was not explicitly modeled during the backcalculation because of uncertainty regarding its extent, although it appears fairly widespread. The effect of the lack of bonding would be to reduce the backcalculated stiffness of the existing HMA layer. Those layers would have greater backcalculated stiffnesses than those shown in Table 3 if there were better bonding. All backcalculated HMA stiffnesses were corrected to a pavement temperature of 68°F (20°C) using a typical HMA master curve.

An example of a deflection bowl and the corresponding deflection modulus are presented in the two plots in Figure 9. The plot on the upper right captures the deflection bowl of Test Point 12, Lake 53, PM 3.2 NB, and the lower-right plot shows its corresponding deflection modulus. The inward shape of the tail of the deflection modulus plot indicates a non-linear subgrade.

Material Sampling for Laboratory Testing and Analysis

Gradation tests were performed on sampled base and subgrade materials. The Unified Soil Classification System and visual observation were used to classify the granular materials. The aggregate base material throughout the length of the project was well-graded gravel with silty clay and sand (GW-GC). The subgrade samples were silty clayey sand (SC-SM). Results of the sieve analysis for the base and the subgrade materials are presented in Table 4.

The results from the flexural and shear tests were necessary to calculate the material input parameters for *CalME*. Flexural bending beam fatigue and flexural frequency sweep tests (AASHTO T-321) were performed on the bottom lift of the beams cut from the slab. Repeated Simple Shear Test at Constant Height (AASHTO T-320) tests were performed on the extracted cores. Prior to testing, the cores were photographed and their thicknesses were measured. Air-void contents were measured for both the cores and the beams.

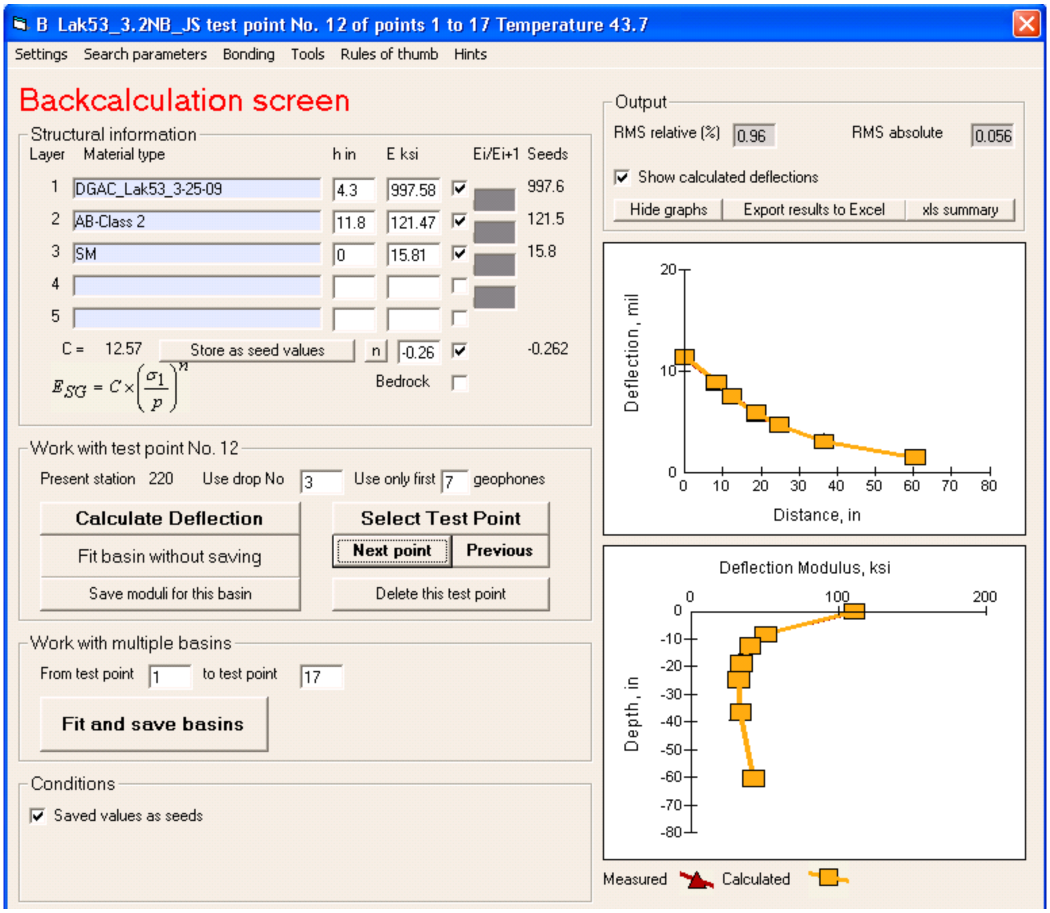

Figure 9: *CalBack* screen shot of the deflection bowl and corresponding deflection modulus at Test Point 12, Lake 53, PM 3.2 NB.

Table 4: Sieve Analysis for Base and Subgrade Materials

Soil Sample Location	Sieve Size and Percent Passing												Soil Type
	2 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	#4	#8	#16	#30	#50	#100	#200	
Lake 53 #9 Base	100.0	82.3	75.6	64.5	58.6	44.7	34.5	26.8	20.6	15.0	11.5	9.4	GW-GC, Well-graded Gravel with Silty Clay and Sand
Lake 53 #5 SG	100	100	100	97.8	95.8	89.6	83.2	77.2	70.4	58.3	44.0	32.4	SC-SM, Silty, Clayey Sand

Dynamic Cone Penetrometer (DCP) Testing

The DCP was used to estimate the thickness and stiffness of the granular layer(s) based on the depth of penetration per blow. As seen from Figure 10, only two granular layers were identified from the DCP results: base and subgrade. Therefore three layers were used in backcalculation: HMA, base, and subgrade. Penetration depths substantially greater than 2 ft (0.6 m) were possible in six of the nine tests. The three locations with penetration rates less than 0.5 ft (0.15 m) were identified in Section B and Section F North. At STA 17688

(Section B) it was suspected that the DCP tip hit the top of a culvert. At STA 17424 (Section B) and STA 35376 (Section F North) it appeared that a stiff base material and/or large rocks impeded the DCP tip. The DCP results from the six locations were in general consistent, showing uniform stiffness with depth. The weakest location was found at STA 19166 (Section C North). DCP readings at STA 25872 (Section D South) were taken in a trench after removal of the HMA top layer. The top few inches were very weak due to moisture resulting from the wet saw cut method.

Additional Information

Additional information collected (see Table 5) included pavement profile grades and cross slopes, GPS latitude and longitude for core location (in wheelpath/not in wheelpath), and general topographic information (cut or fill).

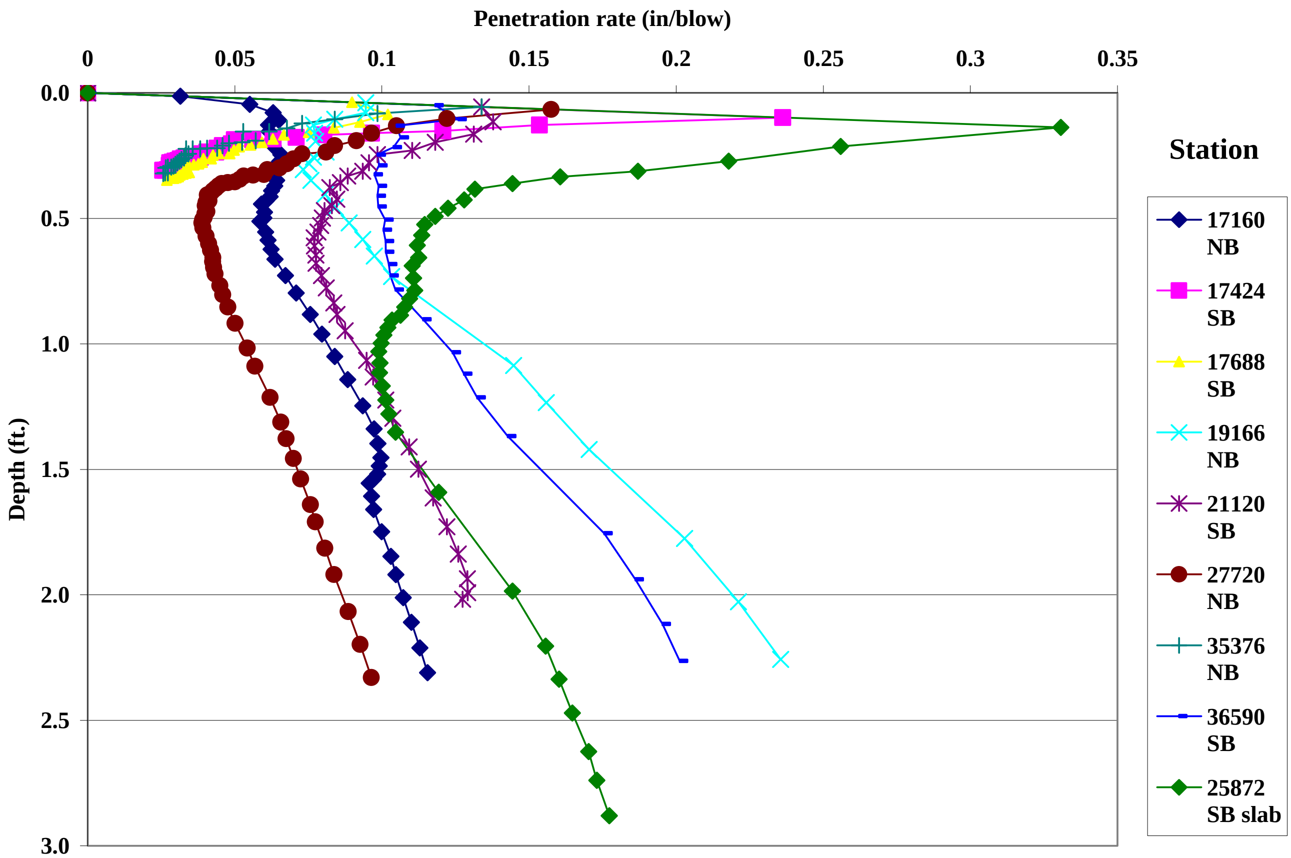

Figure 10: DCP locations and results.
(Depth is depth below top of AB layer.)

Table 5: Core Location Information

			GPS Coordinates - NAD83		Cross-Slope						
Core ID	Core Diameter (in.)	Core Location	GPS Latitude	GPS Longitude	Drains Side-ways	Drains Median	Per-cent	Grading	Grading Pct.	Comment	Date Sampled
Core #1	6	RWP	38 57.290N	122 37.370W	X		3.5	uphill	1	Core taken between PM 3.20–3.40 NB (approx. core PM 3.25).	12/11/2007
Core #2	6	RWP	38 57.307N	122 37.369W	X		2.5	uphill	1.2	Core taken between PM 3.20–3.40 NB (approx. core PM 3.30).	12/11/2007
Core #3	6	RWP	38 57.447N	122 37.364W	X		0.5	downhill	0.9	Core taken in a cut profile, between PM 3.40–3.20 SB.	12/11/2007
Core #4	6	RWP	38 57.436N	122 37.365W	X		1.8	downhill	0.5	Core taken in a fill profile, between PM 3.40–3.20 SB. Soil sample not taken due to the fact that sample was above a culvert (drainage pipe).	12/11/2007
Core #5	6	RWP	38 57.642N	122 37.305W	X		7.1	downhill	1.2	Core taken in a cut profile, between PM 3.63–4.0 NB (approx. core PM 3.63 NB).	12/11/2007
Core #6	6	RWP	38 57.895N	122 37.091W	X		4.8	uphill	0.9	Core taken in a fill profile, between PM 4.0–3.63 SB (approx. core PM 4.00 SB).	12/11/2007
Core #7	6	RWP	38 58.904N	122 36.765W	X		4.2	uphill	1.2	Core taken in a fill profile between PM 4.9–5.4 NB (approx. core at PM 5.25 NB).	12/11/2007

			GPS Coordinates - NAD83		Cross-Slope						
Core ID	**Core Diameter (in.)**	**Core Location**	**GPS Latitude**	**GPS Longitude**	**Drains Side-ways**	**Drains Median**	**Per-cent**	**Grading**	**Grading Pct.**	**Comment**	**Date Sampled**
Core #8	6	RWP	39 00.074N	122 36.311W		X	6.2	uphill	3.2	Core taken in a cut and fill profile between PM 6.5–7.0 NB (approx. core PM 6.7 NB).	12/11/ 2007
Core #9	6	RWP	39 00.302N	122 36.389W	X		6.3	downhill	0.9	Core taken in a cut profile between PM 7.0–6.5 SB (approx. core PM 6.93 SB).	12/11/ 2007
Core #10	Slab cut	BWP	39 00.286N	122 36.376W	X		1.8	downhill	0.7	Slab cut in a fill profile on 12/12/2007 (approx. PM 4.9 SB).	12/12/ 2007

BWP Between wheelpath (Center)
RWP Right wheelpath
LWP Left wheelpath
Edge Between the right wheelpath and the edge of the pavement

DESIGN PROCEDURES AND REHABILITATION RECOMMENDATIONS

Procedure Overview

The new mechanistic-empirical (ME) design method used in this project is a multistep process being developed by Caltrans in conjunction with the UCPRC. Input for the procedure was derived from the results of the field investigation. A recently developed iteration of *CalME (ver. 1.02 [3-07-2011])* was used in the analysis; this version of the software is also capable of performing current Caltrans R-value and overlay thickness design calculations in addition to ME designs. However, *CalME* features such as Maintenance and Rehabilitation strategies are outside the scope of this study.

An outline of the new ME design method followed in this project is laid out in the following sections “Determine Design Inputs” and “Preliminary Design Options: General.” Detailed design alternatives appear in Table 6 through Table 9.

Determine Design Inputs

- The existing surface/base/subgrade materials were characterized in terms of the following:
  - Layer thickness (above subgrade)—Core thicknesses were used for the bound and surface layers. DCP tests were performed to determine base and subbase thicknesses. Available as-built information was reviewed.
  - Material classification—Visual assessments and sieve analyses tests were performed to classify the materials, which provide information regarding approximate stiffnesses.
  - Stiffness—*CalBack* was used with layer thickness, material classification, and FWD (deflection) test results to determine layer stiffnesses.
  - Resistance to permanent deformation and fatigue cracking—Shear test and beam fatigue tests on a crushed granite aggregate and an unmodified PG 64-16 binder (for Low Mountain/North Coast climate region per the Caltrans climate region map) were used to develop inputs representative of the material in the field for *CalME* analysis. This material was entered into the *CalME* Standard Materials Library. Shear and beam fatigue results from the *CalME* Standard Materials Library for a typical RHMA-G material and a gap-graded MB binder mix from elsewhere in the state were used for some design options. In-situ HMA was also characterized in terms of permanent deformation and fatigue cracking resistance using the Repeated Simple Shear Test at Constant Height (AASHTO T 320) and the Flexural Beam (AASHTO T 321) tests, respectively.
- Traffic—Traffic inputs in *CalME* include the traffic growth rate, number of axles in the first year (the year the analysis starts), and axle load spectra. This information is available from data processed from the Weigh-in-Motion (WIM) stations installed on most California routes. On project sites without a

WIM station, axle load spectra were determined using the *CalME* pattern recognition algorithm that extrapolates data from other WIM stations near the project location. *CalME* also includes the WIM processed database. However, there is no WIM station on State Route 53 and therefore the *CalME* pattern recognition algorithm was used to determine the traffic load spectra. Based on this algorithm, the axle load spectra at the site were classified as Group 1a. The Group 1a default values for traffic growth rate and number of axles in the first year were adjusted. The site-specific parameters mentioned above were found using actual truck traffic counts and estimates of future traffic at the project location (details are included in Appendix A [Traffic]). The default design period of 20 years was kept.

The following were used in *CalME:*

  - 1.4 percent traffic growth
  - 478,456 axles in the first year (TI=9)
  - Group 1a axle load spectra

- Climate—The project was located in the Low Mountain climate region, but at the time this analysis was done climate data specific to this region were not available in the *CalME* climate database. The annual average air temperatures, annual low temperatures, and annual average precipitation for the Lake 53 site were compared to those of the North Coast, Inland Valley, and Mountain/High Desert climate regions that were the options available in *CalME.* Climate data for the North Coast region best matched the Lake 53 site characteristics and was selected for the *CalME* analysis.
- Expected Performance—A 20-year design was assumed with a limiting failure criteria of fatigue cracking extent of 0.15 ft/ft^2 (0.5 m/m^2), which approximately corresponds to early Alligator A cracking, and vertical compression of the HMA of 0.02 ft (10.0 mm) corresponding to 0.04 ft (12.5 mm) total rut depth.

Preliminary Design Options: General

Two approaches were used to find design thicknesses: Caltrans current methods as coded in *CalME,* and the mechanistic-empirical designs using *CalME.* All designs were evaluated for predicted performance based on *CalME* performance prediction models.

For *CalME* ME designs, an iterative process is used. First, preliminary designs were input into *CalME* and the performance predictions were compared against predetermined failure criteria for rutting and cracking. If a design thickness failed one or both of the design criteria, it was eliminated and a thicker alternative was tried. Designs that failed much later than the design life were also eliminated, and a thinner alternative thickness was tried. This iterative process was followed for each of the rehabilitation design options to find the minimum acceptable thickness for each one.

The rehabilitation design strategies that were considered are shown below. Pulverization designs were selected based on criteria from the Caltrans *Flexible Pavement Rehabilitation Using Pulverization* guidelines.

- Deflection-based overlay design (CTM 356) using HMA
- Deflection-based overlay design (CTM 356) using RHMA-G
- Reflective cracking mill and fill overlay (HDM 630) using HMA
- *CalME* design for RHMA-G mill and fill (maintain grade)
- *CalME* design for terminal blend asphalt rubber mill and fill (maintain grade)
- R-value design for pulverization of existing pavement and overlay to create pavement structure of pulverized aggregate base (PAB) and HMA overlay
- *CalME* design for pulverization and overlay
- *CalME* design for pulverization and overlay with lime/cement
- *CalME* design for rich bottom design (if pulverized depth is more than 0.5 ft [150 mm])

This project was broken up into six sections according to their pavement structure and alignment: A, B, C, D, E, and F. For design purposes, the six sections were grouped together based upon their structural similarities as follows:

- A: 0.35 ft HMA/1.0 ft AB nominal
- B&C: 0.53 to 0.69 ft HMA/1.0 ft AB nominal
- E&F: 0.38 ft to 0.48 ft HMA/1 ft to 1.15 ft AB nominal
- Section D was not included in this analysis due to its very limited FWD data set.

Table 6, Table 7, and Table 8 show the design options considered for subsections A, B&C**,** and E&F, respectively. Table 9 shows the pulverization design options considered for the entire section (PM 3.1 to PM 7.0). Detailed *CalME* results are included in Table A.3 (Appendix A).

Table 6: Design Alternatives—Section A

Design Option	Design Structural Section Existing Section: A • 0.10 ft (25 mm) OGAC • 0.35 ft (110 mm) HMA • 1.00 ft (300 mm) AB • SG		**Grade Change ft (mm)	20-Year Performance Predicted by *CalME* (90% Reliability)	
				Rutting mm in.	Cracking m/m^2 ft/ft^2
*1. Caltrans deflection-based overlay—Structural overlay requires 0.15 ft. Reflective cracking overlay design—requires 0.25 ft. *Process: Mill 0.1 ft OGAC and place 0.25 ft PG 64-16 HMA overlay.*	PG 64-16 HMA OL	• 0.25 ft (75 mm) PG 64-16 HMA overlay • 0.35 ft (110 mm) existing HMA • 1.00 ft (300 mm) existing AB • SG	+0.25 ft (75 mm)	2.0 0.08	0.0 0.0
Process: Mill 0.1 ft OGAC and place 0.15 ft RHMA-G overlay.	RHMA-G OL	• 0.15 ft (45 mm) RHMA-G overlay • 0.35 ft (110 mm) existing HMA • 1.00 ft (300 mm) existing AB • SG	+0.15 ft (45 mm)	2.1 0.08	0.06 0.02
2. *CalME*—HMA mill and fill overlay design. *Process: Mill 0.15 ft (0.1 ft OGAC and 0.05 ft HMA), overlay with 0.20 ft PG 64-16 HMA.*	• 0.20 ft (60 mm) PG 64-16 HMA overlay • 0.3 ft (95 mm) existing HMA • 1.00 ft (300 mm) existing AB • SG		+0.15 ft (45 mm)	2.36 0.09	0.007 0.002
2a. *CalME*—RHMA-G mill and fill overlay design. *Process: Mill 0.2 ft (0.1 ft OGAC and 0.1 ft HMA), overlay with 0.1 ft RHMA-G.*	• 0.10 ft (30 mm) RHMA-G overlay • 0.25 ft (80 mm) existing HMA • 1.00 ft (300 mm) existing AB • SG		0	3.5 0.14	9.978 3.0
2b. *CalME*—RHMA-G mill and fill overlay design. *Process: Mill 0.2 ft (0.1 ft OGAC and 0.1 ft HMA), overlay with 0.1 ft RHMA-G terminal blend (>15% rubber).*	• 0.10 ft (30 mm) RHMA-G terminal blend overlay (>15% rubber) • 0.25 ft (80 mm) existing HMA • 1.00 ft (300 mm) existing AB • SG		0	4.31 0.17	5.131 1.56

* Caltrans design methods used but performance simulated with *CalME*.

** Grade changes are based on structural pavement section only, not on presence or absence of District optional open-graded surfacing. Grade changes do not include potential bulking effects of the pulverization process, which can add approximately 0.05 ft to 0.15 ft grade elevation depending on the thickness of the pulverized layer.

Table 7: Design Alternatives—Section B&C

Design Option	Design Structural Section Existing Section: B&C • 0.10 ft (25 mm) OGAC • 0.6 ft (180 mm) HMA • 1.00 ft (300 mm) AB • SG		Grade Change ft (mm)	20-Year Performance (90% Reliability) Rutting mm in.	20-Year Performance (90% Reliability) Cracking m/m^2 ft/ft^2
*1. Caltrans deflection-based overlay—Structural overlay required 0.15 ft. Reflective cracking overlay design—requires 0.2 ft PG 64-16 HMA overlay or 0.15 ft RHMA-G overlay. *Process: Mill 0.1 ft OGAC and place overlay (PG 64-16 HMA or RHMA-G).*	PG 64-16 HMA OL	• 0.2 ft (60 mm) PG 64-16 HMA overlay • 0.6 ft (180 mm) existing HMA • 1.00 ft (300 mm) existing AB • SG	+0.2 ft (50 mm)	1.18 0.05	0.017 0.005
	RHMA-G OL	• 0.15 ft (45 mm) RHMA-G overlay • 0.60 ft (180 mm) existing HMA • 1.00 ft (300 mm) existing AB • SG	+0.15 ft (45 mm)	0.76 0.03	0.001 0.0003
2. *CalME*—HMA mill and fill overlay design. *Process: Mill 0.35 ft (0.1 ft OGAC and 0.25 ft HMA), overlay with 0.25 ft PG 64-16 HMA.*	• 0.25 ft (75 mm) PG 64-16 HMA overlay • 0.35 ft (105 mm) existing HMA • 1.00 ft (300 mm) existing AB • SG		0	5 0.2	0 0
2a. *CalME*—RHMA-G mill and fill overlay. *Process: Mill 0.25 ft (0.1 ft OGAC and 0.15 ft HMA), overlay with 0.15 ft RHMA-G.*	• 0.15 ft (45 mm) RHMA-G overlay • 0.45 ft (135 mm) existing HMA • 1.00 ft (300 mm) existing AB • SG		0	3.4 0.13	0.258 0.08
2b. *CalME*—RHMA-G mill and fill overlay. *Process: Mill 0.25 ft (0.1 ft OGAC and 0.15 ft HMA), overlay with 0.15 ft RHMA-G terminal blend (>15% rubber).*	• 0.15 ft (45 mm) RHMA-G terminal blend (>15% rubber) overlay • 0.45 ft (135 mm) existing HMA • 1.00 ft (300 mm) existing AB • SG		0	4.52 0.18	0.764 0.23

* Caltrans design methods used but performance simulated with *CalME*.

Table 8: Design Alternatives—Section E&F

Design Option	Design Structural Section Existing Section: E&F • 0.10 ft (25 mm) OGAC • 0.40 ft (130 mm) HMA • 1.10 ft (335 mm) AB • SG		Grade Change ft (mm)	20-Year Performance (90% Reliability)	
				Rutting mm in.	Cracking m/m^2 ft/ft^2
*1. Caltrans deflection-based overlay—Structural overlay required 0.15 ft. Reflective cracking overlay design—requires 0.25 ft PG 64-16 HMA. *Process: Mill 0.1 ft OGAC and place overlay (PG 64-16 HMA or RHMA-G overlay).* *Process: Mill 0.1 ft OGAC and place 0.15 ft HMA overlay.*	PG 64-16 HMA OL	• 0.25 ft (75 mm) PG 64-16 HMA overlay • 0.4 ft (130 mm) existing HMA • 1.10 ft (335 mm) existing AB • SG	+0.25 ft (75 mm)	2.7 0.1	0 0
	RHMA-G OL	• 0.15 ft (45 mm) RHMA-G overlay • 0.4 ft (130 mm) existing HMA • 1.10 ft (335 mm) existing AB • SG	+0.15 ft (45 mm)	4.05 0.16	8.781 2.68
2. *CalME*—HMA mill and fill design. *Process: Mill 0.15 ft (0.1 ft OGAC and 0.05 ft HMA), overlay with 0.25 ft PG 64-16 HMA.*	• 0.25 ft (75 mm) PG 64-16 HMA overlay • 0.4 ft (115 mm) existing HMA • 1.10 ft (335 mm) existing AB • SG		+0.2 ft (60 mm)	3.11 0.12	0.446 0.14
2a. *CalME*—RHMA-G + SAMI-F mill and fill. *Process: Mill 0.2 ft (0.1 ft OGAC and 0.1 ft HMA), overlay with 0.1 ft RHMA-G.*	• 0.1 ft (30 mm) RHMA-G overlay • 0.35 ft (100 mm) existing HMA • 1.10 ft (335 mm) existing AB • SG		0	4.5 0.18	9.163 2.79
2b. *CalME*—RHMA-G + SAMI-F mill and fill. *Process: Mill 0.2 ft (0.1 ft OGAC and 0.1ft HMA), overlay with 0.1 ft RHMA-G terminal blend (>15% rubber).*	• 0.1 ft (30 mm) RHMA-G terminal blend (>15% rubber) overlay • 0.35 ft (100 mm) existing HMA • 1.00 ft (335 mm) existing AB • SG		0	5.22 0.21	6.491 1.98

* Caltrans design methods used but performance simulated with *CalME*.

Table 9: Pulverization Design Options

Design Option	Design Structural Section Pulverized pavement structure design— Single depth design throughout the project Existing Sections: • 0.10 ft (25 mm) OGAC • 0.45 ft (130 mm) HMA • 1.00 ft (300 mm) AB • SG	****Grade Change ft (mm)	20-Year Performance (90% Reliability)	
			Rutting mm in.	Cracking m/m^2 ft/ft^2
*3. Caltrans R-value pulverized (non-stabilized) and HMA overlay. *Process: Pulverize existing HMA plus 0.15 ft AB, add overlay.*	• 0.45 ft (135 mm) PG 64-16 HMA overlay • 0.85 ft (260 mm) PAB non-stabilized • 0.75 ft (225 mm) existing AB • SG	+0.55 ft (165 mm)	3.3 0.13	0 0
4. *CalME*—pulverized (non-stabilized) PAB and HMA overlay.	• 0.5 ft (150 mm) PG 64-16 HMA overlay • 0.35 ft (105 mm) PAB non-stabilized • 0.7 ft (210 mm) existing AB • SG	+0.05 ft (10 mm)	2.38 0.05	0 0.
**4a. *CalME*—pulverized with 2% cement as PAB and HMA overlay.	• 0.5 ft (150 mm) PG 64-16 HMA overlay • 0.35 ft (105 mm) PAB 2% cement • 0.5 ft (150 mm) existing AB • SG	-0.15 ft (-50 mm)	2.24 0.08	0 0
**4b. *CalME*—pulverized 3% lime as PAB and HMA overlay.	• 0.5 ft (150 mm) PG 64-16 HMA overlay • 0.35 ft (105 mm) PAB 3% lime • 0.65 ft (195 mm) existing AB • SG	0 ft (-5 mm)	3.15 0.12	0 0
**4c. *CalME*—pulverized non-stabilized PAB and RHMA-G overlay over new HMA.	• 0.10 ft (30 mm) RHMA-G overlay • 0.49 ft (120 mm) PG 64-16 HMA • 0.35 ft (105 mm) PAB non-stabilized • 0.7 ft (210 mm) existing AB • SG	+0.05 ft (10 mm)	1.93 0.08	0 0

Design Option	Design Structural Section Pulverized pavement structure design— Single depth design throughout the project Existing Sections: • 0.10 ft (25 mm) OGAC • 0.45 ft (130 mm) HMA • 1.00 ft (300 mm) AB • SG	****Grade Change ft (mm)	20-Year Performance (90% Reliability)	
			Rutting mm in.	Cracking m/m^2 ft/ft^2
,* 4d. *CalME*—pulverized with 2% cement as PAB and RHMA-G overlay over new HMA.	• 0.10 ft (30 mm) RHMA-G overlay • 0.40 ft (120 mm) PG 64-16 HMA • 0.35 ft (105 mm) pulverized 2% cement • 0.5 ft (150 mm) existing AB • SG	-0.15 ft (-50 mm)	4.26 0.17	0.0 0.00
,* 4e. *CalME*—pulverized with 3% lime as PAB and RHMA-G overlay over new HMA.	• 0.10 ft (30 mm) RHMA-G overlay • 0.40 ft (120 mm) PG 64-16 HMA • 0.35 ft (105 mm) pulverized 3% lime • 0.65 ft (195 mm) existing AB • SG	-0.00 ft (-5 mm)	2.4 0.09	0.0 0.0

* Caltrans design methods used but performance simulated with *CalME.*

** ASTM Standard Test Method for Determining Stabilization Ability of Lime (MDSAL) or British Standard Initial Consumption of Lime (Cement) test (ICL/ICC) should be performed on subgrade material to determine exact lime/cement percentage required to reach desired stiffness and strength.

*** Designs 4c, 4d, and 4e do not appear in the list of *CalME* pulverization options. They were hypothesized by altering the depth of the PG 64-16 HMA layer in Designs 4, 4a, and 4b. That HMA layer thickness of 150 mm was replaced by 120 mm of PG 64-16 HMA overlaid with 30 mm of RHMA-G.

**** Grade changes for pulverization designs include the presence of existing open-graded surfacing since this layer will be part of the pulverization process. Grade changes do not include potential bulking effects of the pulverization process, which can add approximately 0.05 ft to 0.15 ft grade elevation depending on the thickness of the pulverized layer.

Note: At the time this analysis was performed, the *CalME* Standard Materials Library database did not include the material characteristics for pulverized aggregate base (PAB) stabilized with 2% cement or 3% lime. The values used for the lime-stabilized or cement-stabilized PAB in Designs 4a, 4b, 4d, and 4e were based on aggregate base materials listed in the *CalME* Standard Materials Library database that had stiffness values similar to a cement- or lime-stabilized PAB.

SUMMARY

The recommendations presented here are based on the results of office and site investigations, analysis of materials with *CalBack*, and design with *CalME (ver. 1.02, 03-07-2011)* mechanistic-empirical methods, R-value method, and the Caltrans tolerable deflection-based method. In the rehabilitation, it is important to address the primary distresses exhibited on State Route 53, namely transverse and fatigue cracking. Three general rehabilitation types were considered in the design alternatives: (1) overlay, (2) mill and fill and overlay, and (3) pulverization and overlay. Each of these designs was evaluated with *CalME* for expected performance. Detailed economic analysis was not performed as part of this work, but relative cost rankings can be estimated from past experience. The design recommendations are specific to certain sections of this project, based upon their existing structural section and potential grade constraints. The Caltrans 356 design (Design 1 for all sections) indicates that a 0.15-ft structural overlay is required. However, in order to address the likely reflection of fatigue and low-temperature cracking into the overlay, a 0.25-ft overlay is required for Sections A and E&F, and a 0.2-ft overlay for Section B&C. With proper binder selection, this cracking can be minimized. Currently, *CalME* only considers reflective cracking due to traffic loading and not that attributable to low-temperature expansion and contraction; this is the likely reason that the analysis did not show early failure for this design, i.e., the cracking was attributed to low-temperature expansion and contraction.

The mill-and-fill alternatives (Designs 2, 2a, and 2b) compared the performance of three overlay materials: PG 64-16 binder recommended for the Low Mountain/North Coast region, RHMA-G, and terminal blend with more than 15 percent rubber (MB-15). The latter two materials were calibrated for *CalME* from HVS studies conducted by the UCPRC. Overall, most alternatives showed good permanent deformation and cracking performance, although several failed: Sections A and E&F—Alternative 2a (RHMA-G) and Alternative 2b (terminal blend with more than 15 percent rubber)—and Section B&C Alternative 2b (terminal blend with more than 15 percent rubber).

The pulverization and overlay alternatives (Designs 3, 4, 4a, 4b, 4c, 4d, and 4e) show good rutting and cracking performance. With the removal of the existing cracked HMA, reflection cracking has been essentially eliminated. Design 3 raises the average section grade 0.55 ft whereas Designs 4 and 4c raise the average section grade 0.05 ft. Designs 4a and 4d lower the existing grade 0.15 ft (50 mm), and Designs 4b and 4e lower the existing grade 0.05 ft. Since no grade restrictions were encountered along the project, these alternatives can be considered. More investigation is needed at the beginning of the project (PM 3.2 to PM 3.4) to assess whether the culvert pipe is deep enough to safely allow milling or pulverization to the design depth.

FINAL RECOMMENDATIONS

The recommendations for this project follow, based upon structural and geometric considerations. The final selection should be based on a life-cycle cost analysis performed by the Caltrans District.

The current pavement structure for the project has an open-graded surface that has to be milled off before any overlay is placed.

Transverse and fatigue cracking are the predominant distresses at the project site.

A solution that could better address the issue of reflective cracking in the future is mill and fill.

The HMA mill-and-fill design option analyzed with *CalME* showed good performance for all sections. The suggested solution below considers the entire project area (PM 3.2 to PM 7.00).

1. Mill 0.15 ft (0.1 ft OGAC and 0.05 ft old HMA) on Sections A and E&F and replace with 0.2 and 0.25 ft PG 64-16 HMA overlay, respectively. Mill 0.35 ft (0.1 ft OGAC and 0.25 ft old HMA) on Section B&C and replace with 0.25 ft PG 64-16 HMA overlay. This solution offers good rutting and fatigue cracking performance, passing the design life for Sections A and B&C and reaching the cracking limit at the end of the design life for Section E&F. These results are based on *CalME* performance prediction models.
2. Mill 0.15 ft (0.1 ft OGAC and 0.05 ft old HMA) over the entire project length and replace with 0.25 ft PG 64-16 HMA overlay. This alternative may present an advantage in terms of a more uniform pavement grade and production speed since equipment is only set once. The downside of this solution is that it may increase the materials cost. A life-cycle analysis will reflect the benefits of this solution over that described in Item 1, above.

Alternatively, the viable pulverization options would eliminate the poor bonding between the existing HMA lifts that will continue to contribute to the reflection cracking of overlays, as well as the existing cracking. Life-cycle cost analysis should be used to evaluate the best option.

RECOMMENDATIONS FOR *CALME* AND MECHANISTIC DESIGN PROCESS

It is recommended that a method for calculating reflection cracking due to temperature changes be included in *CalME.* It is also recommended that the library of standard materials continue to be expanded and include rich bottom mixes for each of the four PG binder types currently in the library (fatigue and stiffness only) and further refinements on the pulverized asphalt binder mix (PAB) models.

Recommendations for Further Monitoring and Analysis of This Project

It is recommended that UCPRC staff be present during construction to take loose material samples, perform slab and/or core extractions, and make thickness measurements. These materials would be tested in the laboratory to develop in-situ material parameters for *CalME,* which would then be run again to validate or assess initial analysis. Future performance monitoring of the project over the next five to ten years would add to performance modeling for *CalME.*

Caution is to be exercised in considering these recommendations—which are based on a site investigation performed in December 2007—as they may be outdated. This is in keeping with the warning included in the *Highway Design Manual,* Section 635.1, Subsection 3, which essentially states that deflection data older than 18 months prior to the start of construction are considered unreliable in rehabilitation design.

ENGINEERING DOCUMENTATION

Relevant Design Calculations and Procedures

R-Value with Pulverization: Entire Project—Design Options with TI 9

- Pulverize max existing HMA + 0.15ft AB
- TI 9
- R-value SG = 21
- Max in situ HMA thickness = 0.69 ft
- Average HMA thickness = 0.5 ft
- Average existing AB thickness = 1.08 ft
- GE total req = 0.0032(TI)(100-R) = 2.27 ft
- PAB thickness 0.69 + 0.15 = 0.85 ft
- GE(PAB) = 1.02 (Table 2 "Flexible Pavement Rehabilitation using Pulverization")
- AB thickness 0.5 + 1.08 - 0.85 = 0.75 ft
- GE(AB) = 0.75*1.1 = 0.85 mm
- GE for HMA
- GE(HMA) = 0.0032(TI)(100-78) = 0.65 ft
    - Add 0.2 ft FoS = 0.85 ft
- GE(HMA) + GE(PAB) + GE(AB)
- 0.85 + 1.02 + 0.85 = 2.72>2.27 ft

Required Design

- 0.45 ft HMA
- 0.85 ft PAB
- 0.74 ft AB

APPENDIX A: ME SUPPLEMENTARY DATA AND PROCEDURAL INFORMATION

This appendix contains detailed information on the ME design process from which the pavement designs in this memorandum were developed. The information, which is outlined in the list below, is not intended to be a "how-to guide" for ME, but to document the information derived during the field and office study.

1. Benefits of Mechanistic-Empirical (ME) Design Using Caltrans New Design Tools *CalME* and *CalBack*
2. ME Procedure Overview
3. Traffic Data
4. Climate
5. Material Parameters
   a. Backcalculation with *CalBack*
   b. ME analysis and design with *CalME*

Benefits of Mechanistic-Empirical (ME) Design Using Caltrans New Design Tools *CalME* and *CalBack*

The following list shows the benefits to Caltrans of using the new ME design approach taken for these projects:

General and Specific Benefits for the 01-LAK-53 Case Study

1. ME designs are based upon an analysis of three fundamental factors: material behavior, traffic loading, and climate. With ME, a library of statewide material, climate, and traffic data is accessible that allows the designer to tailor designs to very specific local needs. This information has been developed from rigorous laboratory testing, field testing, and analysis over the past decade.
   A. ME allows for design with specific binder and mix types. Both rutting and cracking levels can be reviewed during the design process, and tradeoffs can be made with regard to rutting and cracking performance. For this project, test data from RHMA-G, terminal blend with more than 15 percent rubber (MB-15), and PG 64-16 binder were used in the analysis. Rubberized mix performance for reflective cracking was assessed analytically rather than with generalized tables. A fatigue shift factor is required in *CalME* to calibrate the material properties. For the old in-situ HMA, the fatigue shift factor was determined using a back-casting analysis that included condition survey and traffic data from 1978 through 1996, a year in which a new overlay was placed and fatigue material parameters were determined from flexural bending beam tests.
   B. ME can examine the impact of different additives to mixes, for example the use of lime or cement as a modifier to pulverized base material. For this project, the use of either lime or cement with the pulverized base was evaluated. The analyses included stiffnesses for the two types of stabilizer based on laboratory testing from previous projects.
   C. ME uses detailed traffic information from WIM stations throughout the state. Axle counts and weights for each truck type are input into the design program. Typical axle-load spectra are used instead of ESALs.

D. ME uses climate data from weather stations throughout the state. In *CalME*, cracking and rutting performance are analyzed using detailed "Master Curves" of stiffness versus temperature for each binder and mix type produced in the state. Surface temperature data selected from the *Enhanced Integrated Climate Model* database (also referred to as the "climate region database") is used to calculate temperatures at different depths of the pavement structure. These calculated temperatures and load spectrum data read from the WIM database are the inputs needed in the *CalME* Incremental-Recursive analysis to calculate the elastic modulus changes from the "Master Curves." For this project, the North Coast climate region was used for HMA performance calculations.

2. Three types of pavement designs can be performed: traditional Caltrans designs (R-value and deflection-based overlay designs), Classical ME designs based upon Asphalt Institute performance curves, and newly developed Recursive ME designs that take into account the decreased capabilities of HMA over time. ME analysis of Caltrans designs can be performed to show whether a particular Caltrans design is conservative or non-conservative.
3. The designer can pre-set failure criteria (cracking and rutting) and design life, and tailor the design to these factors. The level of reflective cracking and rutting is specified up front.
4. Deflection testing with the Falling Weight Deflectometer allowed the characterization of the existing base stiffness, base variability, subgrade stiffness, and subgrade variability to be taken into account in the design process. Specific designs were developed depending upon the existing structural section thickness and deflection performance.
5. "Reliability" of the design, meaning the probability of failure before the design life, can be considered, and higher reliabilities can be used for more critical projects. Variability in material/construction and traffic may be taken into account. The user can input the range of layer thicknesses and traffic levels expected in the project. Variability of stiffnesses backcalculated from FWD deflections for existing subgrade and aggregate base materials were included as part of the pavement design.
6. In *CalME*, the in-place cost of materials is included in the Materials Library. The cost of each design is calculated.
7. Users can rerun analyses with as-built information (thicknesses, stiffnesses) to estimate the expected life of the as-built pavement, if desired. This information can be used in the pavement management system to estimate when future maintenance may be needed compared with original design assumptions.
8. *CalME* and *CalBack* can output all design information to Microsoft *Excel* for further analysis.

ME Procedure Overview

ME design and analysis is a multistep process that uses detailed information about traffic loading, material performance, and climate. Many of the field data–gathering procedures are similar to what Caltrans performs currently. The major difference between traditional Caltrans design and new ME design is in how materials, climate, and traffic data can be uniquely selected and analyzed for a given project. Generalized design tables based upon broad average behavior for generic materials are not used.

The process performed for 01-LAK-53 is summarized below.

An initial meeting was held with District 1 staff to discuss the project. As with standard Caltrans procedures, the design process began with analysis of structural section thicknesses (cores) and deflection measurements from Falling Weight Deflectometer (FWD) testing. The ME process then diverged from traditional methods. *CalBack* was used to estimate pavement layer stiffnesses through backcalculation. Using *CalBack* the designer separated the project into distinct sections based upon layer thickness and/or estimated material stiffness. This offered more flexibility than sectioning by D_{80} deflection values alone. The designer now had detailed information on the performance of all layers within the pavement and could analyze designs for each specific section as needed.

CalME ver. 1.02 (03-07-2011) was used to perform deflection-based overlay designs and ME-based rehabilitation designs. The ME designs were verified with the Incremental-Recursive method which took into account how pavement materials change in behavior (cracking, aging) over the lifetime of a project.

The *CalME* analysis process started with the importation of thicknesses, backcalculated stiffnesses, and standard deviation factors of backcalculated stiffnesses for each layer from *CalBack*. Variability of thickness was determined from field cores, and the coefficient of variation for each layer/section was manually entered into *CalME*. The two variability measures (stiffness and thickness) were used to describe the construction variability in the Incremental-Recursive method.

Design options were developed based upon engineering judgment and were evaluated with *CalME*. Structural sections were adjusted as necessary to make the most efficient designs that met the failure criteria specified (user chosen) within *CalME*.

Traffic Data

ME Weigh-in-Motion (WIM) data has been created from years of traffic-counting from WIM stations distributed across the state. Traditional Caltrans designs used a Traffic Index, based upon expected cumulative lifetime ESAL counts. ME WIM data consists of detailed vehicle counts by classification, axle counts, and axle-weight loading. ME takes this specific data and computes performance estimates based upon damage from the individual axle loads.

Table A.1 shows the raw data from the Caltrans traffic log on 01-LAK-53, and Table A.2 shows the calculated traffic by axle count for 01-LAK-53. Figure A.1 shows a plot of the calculated traffic for 01-LAK-53. The twenty year TI for this project is 9.0.

Table A.1: Traffic Log Data for 01-LAK-53 (1998, 2000-2007)

County	PM	Leg	AADT Total	Total Trucks	Total Truck %	2 Axle Volume	2 Axle Percent	3 Axle Volume	3 Axle Percent	4 Axle Volume	4 Axle Percent	5 Axle Volume	5 Axle Percent	Description	Yr	Verify/ Estimate
LAK	0	A	13,800	690	5	345	50	76	11	7	1	262	38	Lower Lake, Jct. Rte. 29	93	E
LAK	7.45	B	6,500	410	6.3	200	48.8	47	11.4	4	0.9	159	38.9	Jct. Rte. 20	95	E
LAK	0	A	14,000	700	5	350	50	77	11	7	1	266	38	Lower Lake, Jct. Rte. 29	93	E
LAK	7.45	B	7,000	441	6.3	215	48.8	50	11.4	4	0.9	172	38.9	Jct. Rte. 20	95	E
LAK	0	A	14,000	690	5	345	50	76	11	7	1	262	38	Lower Lake, Jct. Rte. 29	93	E
LAK	7.45	B	7,000	410	6.3	200	48.8	47	11.4	4	0.9	159	38.9	Jct. Rte. 20	95	E
LAK	0	A	14,000	700	5	350	50	77	11	7	1	266	38	Lower Lake, Jct. Rte. 29	93	E
LAK	7.45	B	7,000	441	6.3	215.208	48.8	50.274	11.4	3.969	0.9	171.549	38.9	Jct. Rte. 20	95	E
LAK	0	A	14,000	700	5	350	50	77	11	7	1	266	38	Lower Lake, Jct. Rte. 29	93	E
LAK	7.45	B	7,000	441	6.3	215	48.8	50	11.4	4	0.9	172	38.9	Jct. Rte. 20	95	E
LAK	0	A	14,200	710	5	355	50	78.1	11	7.1	1	269.8	38	Lower Lake, Jct. Rte. 29	93	E
LAK	7.45	B	7,200	453.6	6.3	221.357	48.8	51.7104	11.4	4.0824	0.9	176.45	38.9	Jct. Rte. 20	95	E
LAK	0	A	13,800	690	5	345	50	76	11	7	1	262	38	Lower Lake, Jct. Rte. 29	93	E
LAK	7.45	B	5,300	334	6.3	163	48.8	38	11.4	3	0.9	130	38.9	Jct. Rte. 20	95	E
LAK	0	A	17,000	850	5	425	50	94	11	9	1	323	38	Lower Lake, Jct. Rte. 29	93	E
LAK	7.45	B	7,000	441	6.3	215	48.8	50	11.4	4	0.9	172	38.9	Jct. Rte. 20	95	E
LAK	0	A	17,000	850	5	425	50	94	11	9	1	323	38	Lower Lake, Jct. Rte. 29	93	E
LAK	7.45	B	7,400	466	6.3	227	48.8	53	11.4	4	0.9	181	38.9	Jct. Rte. 20	95	E

Table A.2: Traffic Calculations for 01-LAK-53

Year	AADT Total	Total Trucks	2 Axle Volume	3 Axle Volume	4 Axle Volume	5 Axle Volume	Total # Axles	# Axles/ truck
1998	13,800	690	345	76	7	262	2,256	3.27
2000	14,000	700	350	77	7	266	2,289	3.27
2001	14,000	690	345	76	7	262	2,256	3.27
2002	14,000	700	350	77	7	266	2,289	3.27
2003	14,000	700	350	77	7	266	2,289	3.27
2004	14,200	710	355	78.1	7.1	269.8	2,322	3.27
2005	13,800	690	345	76	7	262	2,256	3.27
2006	17,000	850	425	94	9	323	2,783	3.27
2007	17,000	850	425	94	9	323	2,783	3.27

Estimated traffic growth rate	1.40%
Estimated # trucks in 2009	802
Estimated # axles/truck	3.27
Estimated # axles 2009 (first yr)	478,456

Calculations:

1. Estimated #axles per truck was determined based on data in Table A.2, columns "2 Axle Volume" to "5 Axle Volume" and the column "Total Trucks":

$$Estimated\ \#axles\ per\ truck = \sum (2 * 2\ axle\ Volume + 3 * 3\ Axle\ Volume + 4 * 4\ Axle\ Volume + 5 * 5\ Axle\ Volume)/(Total\ trucks)$$

2. Estimated traffic growth rate was calculated from the total truck traffic from 1998 to 2007 (Table A.2). The following equation form was used to determine the estimated truck traffic:

$$\ln(y) = \ln(y0) + n * \ln(1 + r)$$

   where:

   ln(y) = natural logarithm of estimated truck traffic
   ln(y0) = natural logarithm of truck traffic in the base year of traffic analysis period (1998); ln(y0) = ln(690)
   N = number of years from the base year considered in traffic analysis (1998)
   r = traffic growth rate

   The Solver function in Microsoft *Excel* was used to determine ln(1+r) for which the sum of the root mean square error between the measured and calculated truck traffic was minimum. From this analysis ln(1+r) = 0.013644 and r = 0.013737 or r(%) = 1.37 roundup to r = 1.4%.

3. Estimated trucks in 2009 both directions = exp(ln(690)+(2009-1998*ln(1+r)) = exp(6.53669 + 11*0.013644) = 802
4. Estimated no. of axles in 2009 design direction = (802/2)*3.27*365 = 478,456

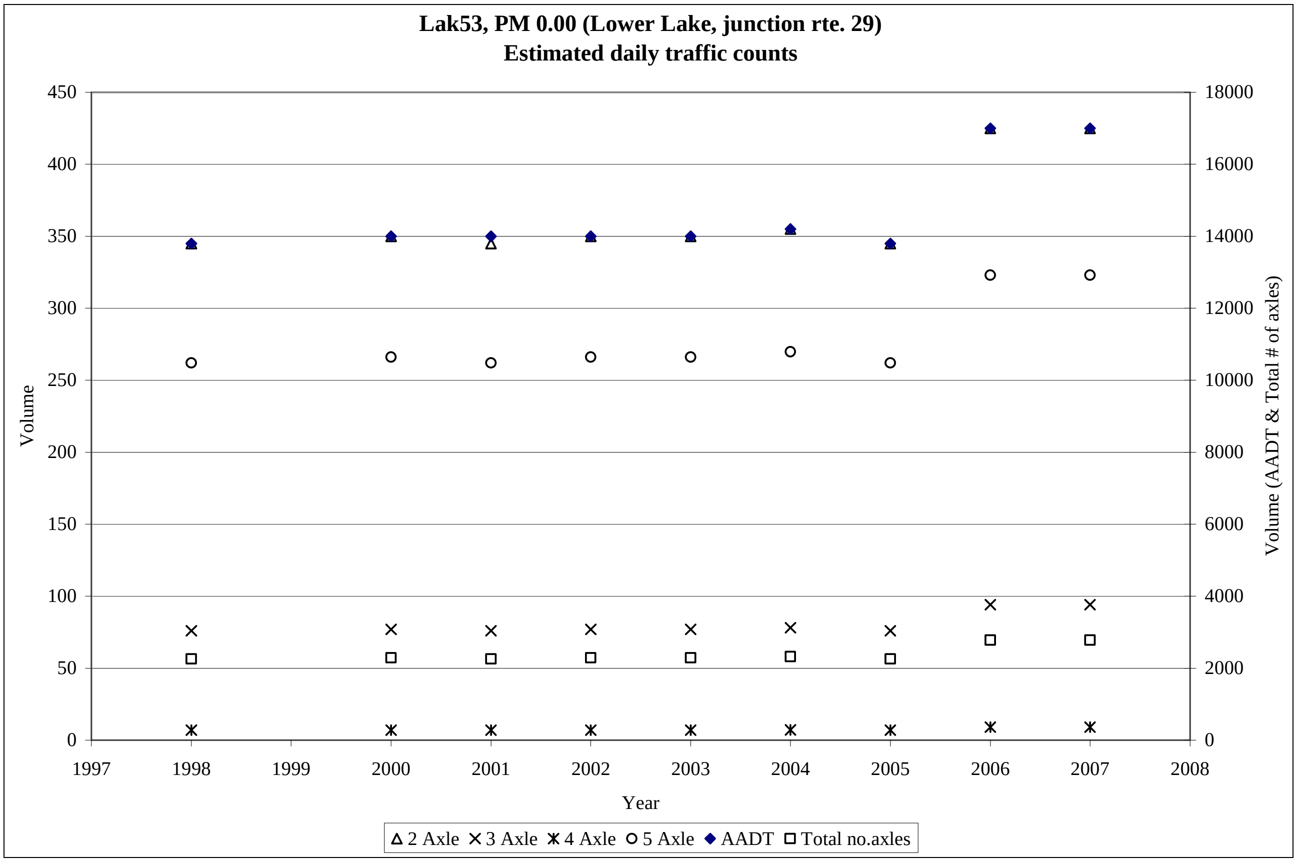

Figure A.1: Plot of traffic data for 01-LAK-53.

Climate

HMA rutting and cracking performance is highly dependent upon air and mix temperature over the pavement life. *CalME* designs take that into account by analyzing HMA performance using climatic conditions at the project site. Figure A.2 shows the Caltrans Pavement Climate Regions map. The arrow points to the project location, which is situated in the Low Mountain climate region. *CalME* contains a climate database to access hourly air temperatures and uses the Bell's Equation to convert air temperature (based upon current and recent historical air temperatures) to HMA temperature at one-third depth. See the *CalME* help file for further details about this topic.

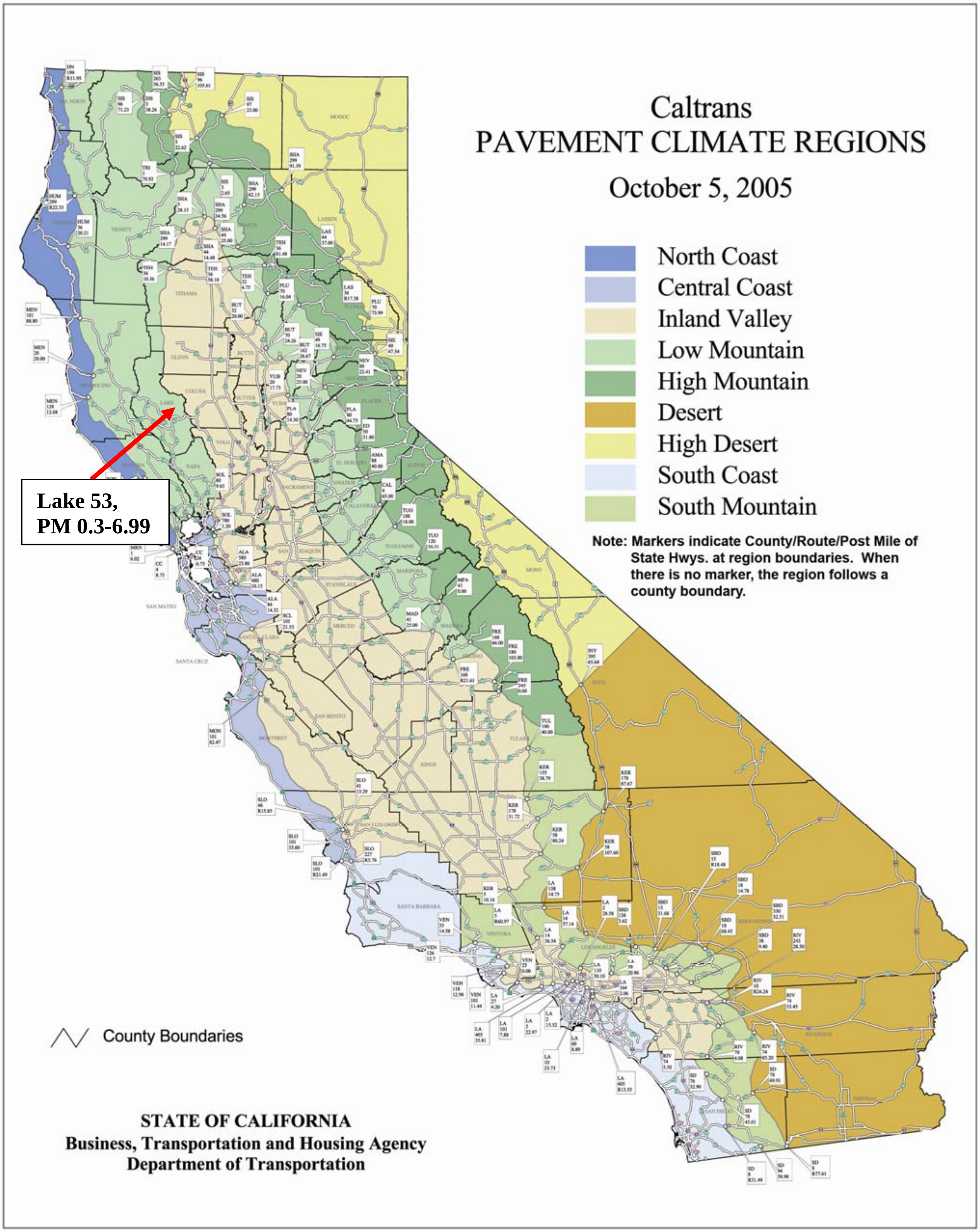

Figure A.2: Caltrans Pavement Climate Regions map.

Material Parameters

<u>*Backcalculation with* CalBack</u>

This project was broken up into six sections according to their pavement structure and alignment: A North, B South, C North and South, D South, E North, and F North and South. Following FWD data analysis and for design purposes, the six sections were gathered into three "design groups" according to their structural similarities as follows:

- A North: 0.33 to 0.38 ft HMA/0.98 ft AB nominal
- B South: 0.58 to 0.69 ft HMA/0.98 ft AB nominal
- C North and South: 0.53 to 0.58 ft HMA/0.98 ft AB nominal
- D South: 0.56 to 0.58 ft HMA/1.31 ft AB nominal
- E North: 0.38 ft to 0.48 ft HMA/1.15 ft AB nominal
- F North and South: 0.38 ft to 0.48 ft HMA/0.98 ft AB nominal

For reference, these are the PM limits for each section:

- A North: 3.2 to 3.4
- B South: 3.4 to 3.2
- C North and South: 3.6 to 4.0
- D South: 4.925 to 4.9
- E North: 4.9 to 5.2
- F North and South: 6.5 to 6.9

The backcalculation process began with the use of initial seed moduli from the Materials Library. From there, the *CalBack* program's basin-fitting algorithm attempted to match the actual deflection values with deflections based on calculated moduli. When the error levels reached were sufficiently low, typically under 2 to 3 percent, the stiffness values presented were considered layer moduli.

Figure A.3 shows the Falling Weight Deflectometer deflection data for the inner sensor (D1) and HMA surface temperature versus post mile. Figure A.4 shows the Falling Weight Deflectometer deflection data for the outer sensor (D8) and HMA surface temperature versus post mile. Deflection testing started in the morning at Section A North, and proceeded generally to the adjacent section as indicated by increasing surface temperatures with post mile. Figure A.5 shows the temperature-adjusted layer moduli from *CalBack* for the entire project.

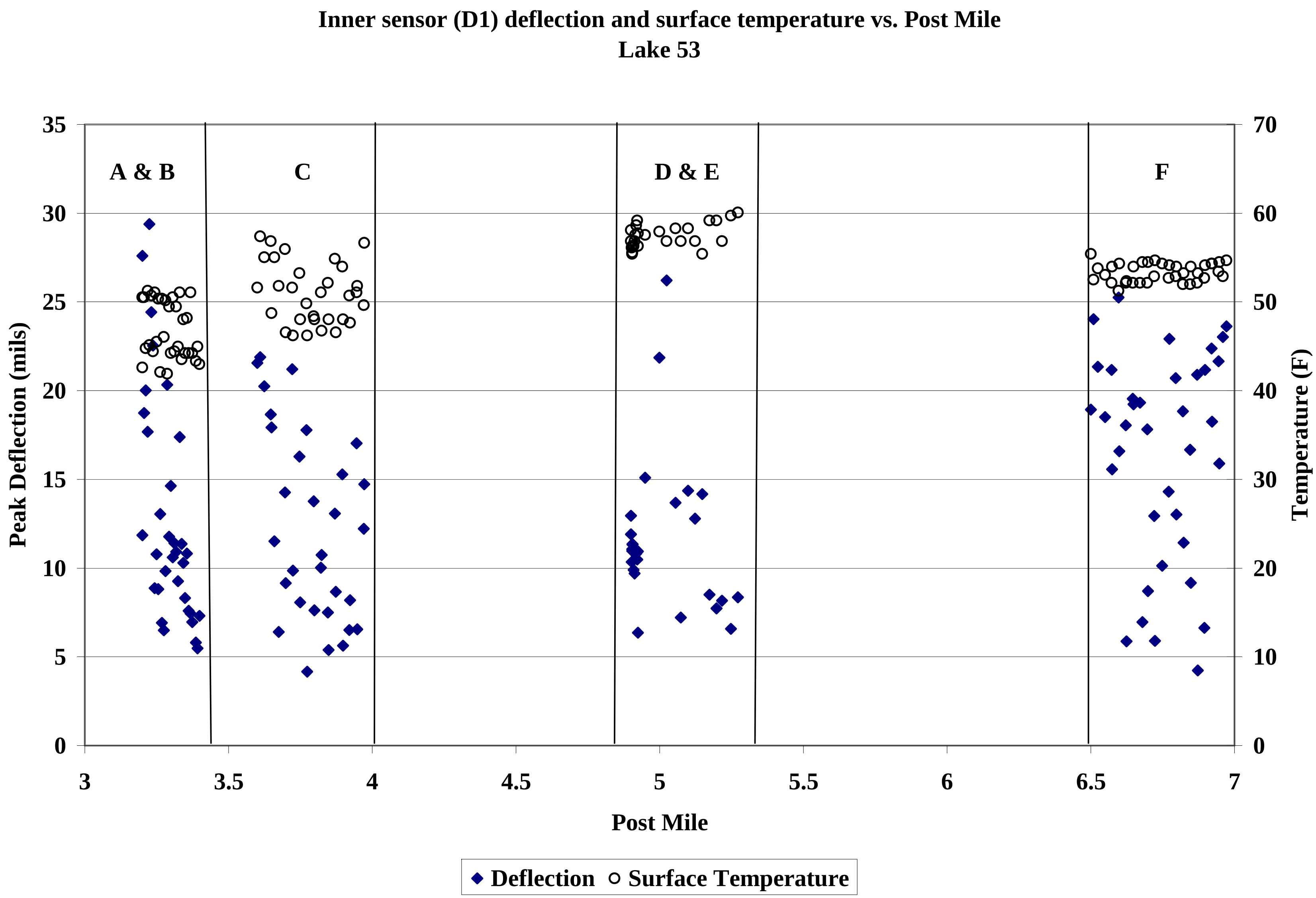

Figure A.3: FWD inner sensor (D1) peak deflection and surface temperature versus post mile.

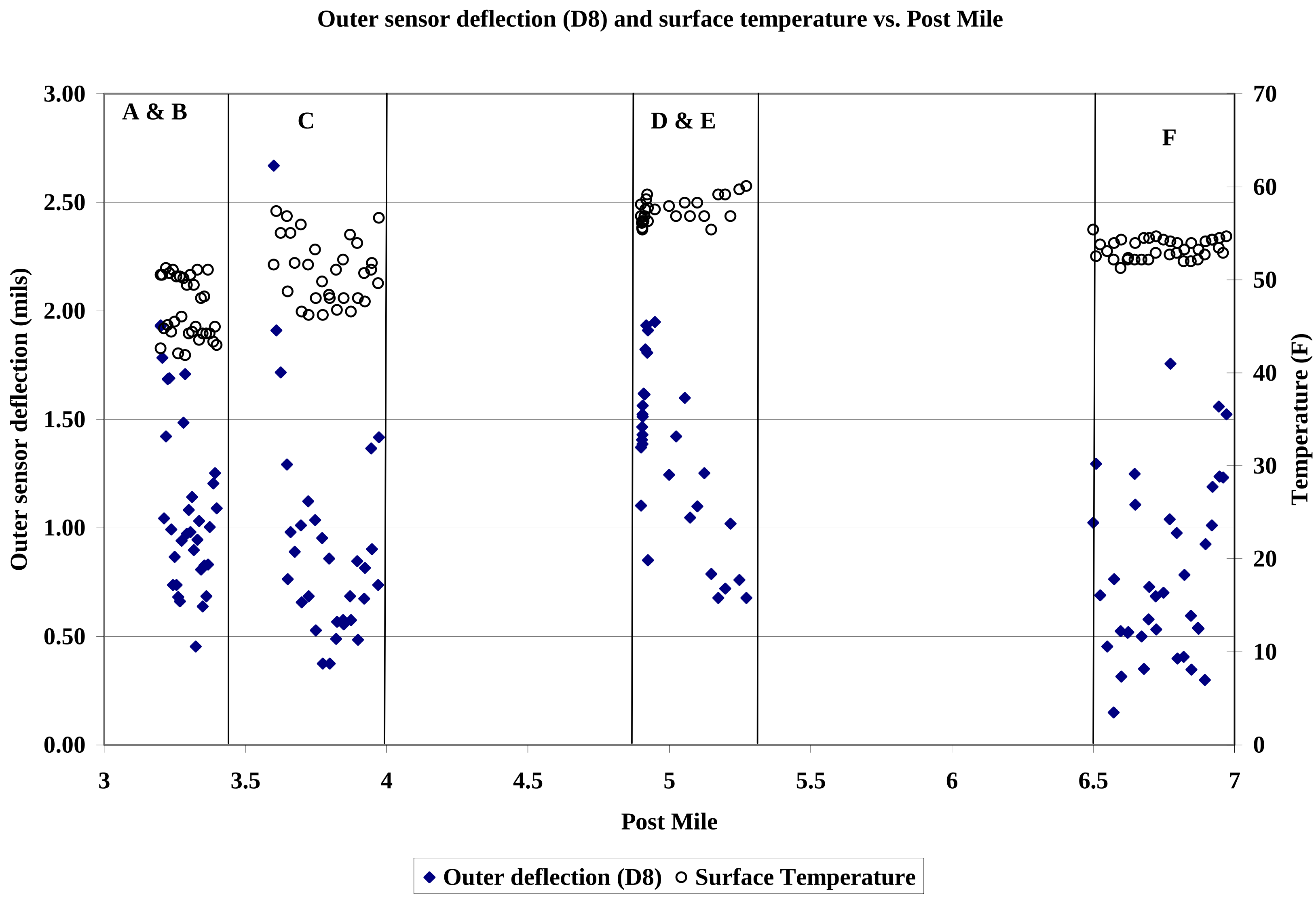

Figure A.4: FWD outer sensor (D8) peak deflection and surface temperature versus post mile.

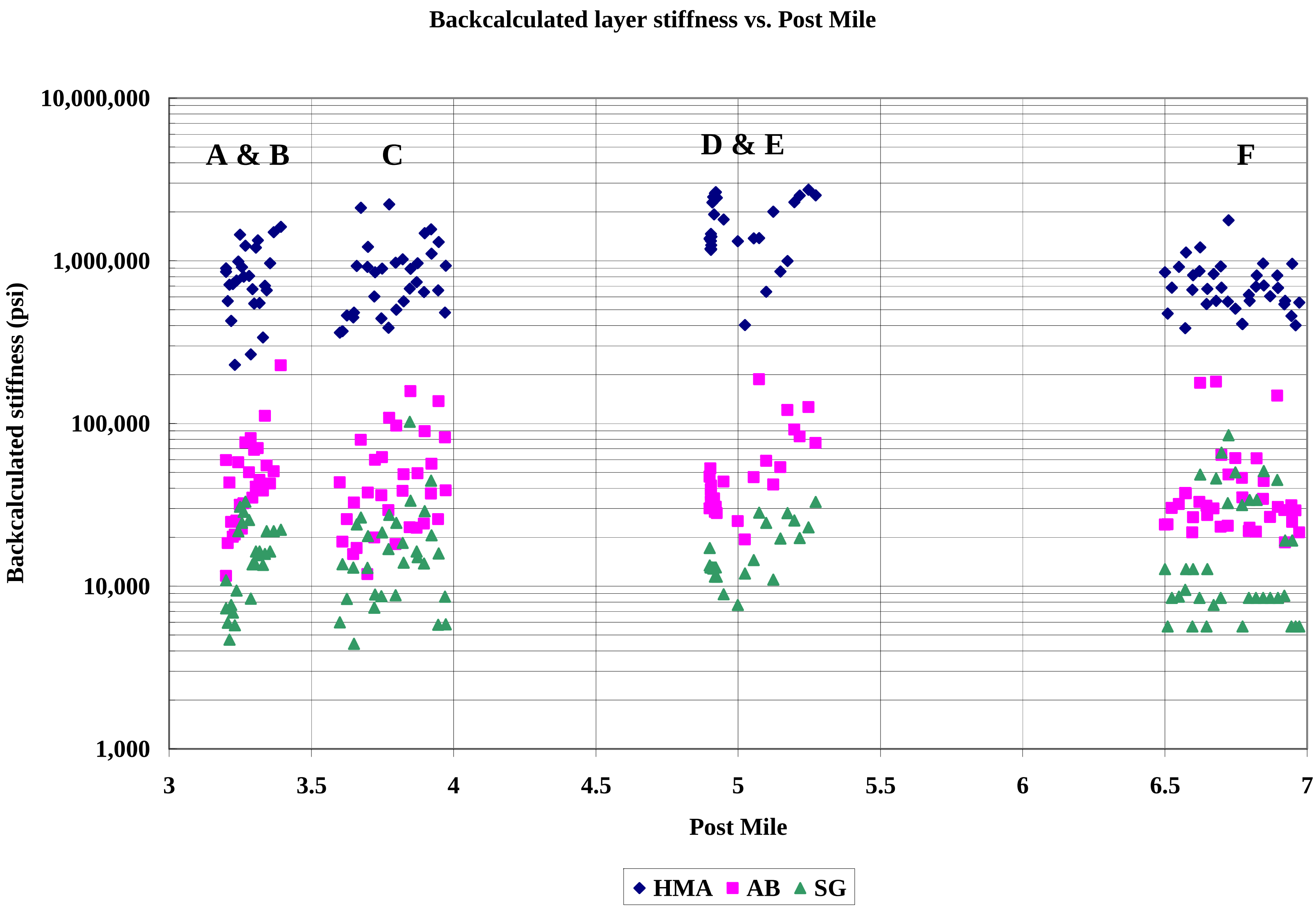

Figure A.5: Backcalculated layer stiffness (temperature adjusted to 68° F) versus post mile.

ME Analysis and Design with CalME

Following *CalBack* analysis of the deflection and thickness data, *CalME version 1.02 (3-07-2011)* was run with the various design alternatives. Standard Caltrans designs were run. For ME-based designs, layer thicknesses were adjusted to produce the most efficient designs that still met the limiting criteria for HMA rutting (10 mm) and cracking (0.5 m/m^2) as predicted by *CalME*. Important *CalME* screens are presented below.

Monte Carlo simulations were run to produce designs with 90 percent reliability, using the imported distributions for backcalculated stiffnesses.

When values for thickness and stiffness variability are input into *CalME*, a single run determines one of many possible outcomes. *CalME* can also perform a Monte Carlo simulation of several runs to obtain a range of possible performance outcomes over the design life, including cumulative rutting and cracking after 20 years. The average and standard deviation of this distribution of estimates are used to determine the reliability of performance. To obtain the 90 percent reliability provided in this memo, the average value of 30 Monte Carlo runs at the end of the design life (Year 20) was added to 1.28 times the corresponding standard deviation.

Figure A.6 shows a typical rutting-versus-age plot for this project. Note the progression in rut depth (blue/dark line) and the established limiting criteria (blue/light line). The light red and green lines on the plot show the plus and minus one standard deviation performance from the Monte Carlo simulations. The pavement performs well, reaching on average a quarter of the desired 20-year life. Figure A.7 shows a typical cracking-versus-age plot for this project. The pavement almost reaches the 90 percent reliability cracking limit at the end of 20-year design life.

Figure A.8 shows a typical structural section input screen for *CalME*, with material type, average layer thickness, and backcalculated moduli imported from *CalBack* as primary inputs. In Figure A.8, note the button "Edit Material Parameters" that allows a user to specifically tailor a given material behavior in *CalME*. Most of these parameters have been preset for the user. Figure A.9(a), Figure A.10, Figure A.11, and Figure A.12 show the recursive material parameters for the surface materials used in this project: PG 64-16 HMA, existing DGAC, RHMA-G, and terminal blend (MB-15), respectively. These factors were generally left unchanged throughout the analysis procedure except for those of the existing DGAC, which was calibrated from fatigue and permanent deformation tests on in-situ cores. For example purposes, Figures A.9(b), A.9(c), and A.9(d) illustrate the Environment, Classical, and Modulus material parameters, respectively, for PG 64-16 HMA.

Note: For the Environment *material parameters, a "reference rest period" of 10 seconds and a "power phi" coefficient of 0.4 were considered for all surface materials.*

Figure A.13 shows the recursive material parameters for the aggregate base. These parameters were left unchanged throughout the analysis.

Figure A.14 is an example of the initial condition inputs for the Incremental-Recursive (I-R) analysis.

Figure A.15 shows the construction variability inputs for Incremental-Recursive analysis specific to the project.

Table A.4 lists the material names used in the *CalME* Material Library corresponding to the PAB, PAB stabilized with 2 percent cement, PAB stabilized with 3 percent lime, and for the new surface materials used in the designs for the project.

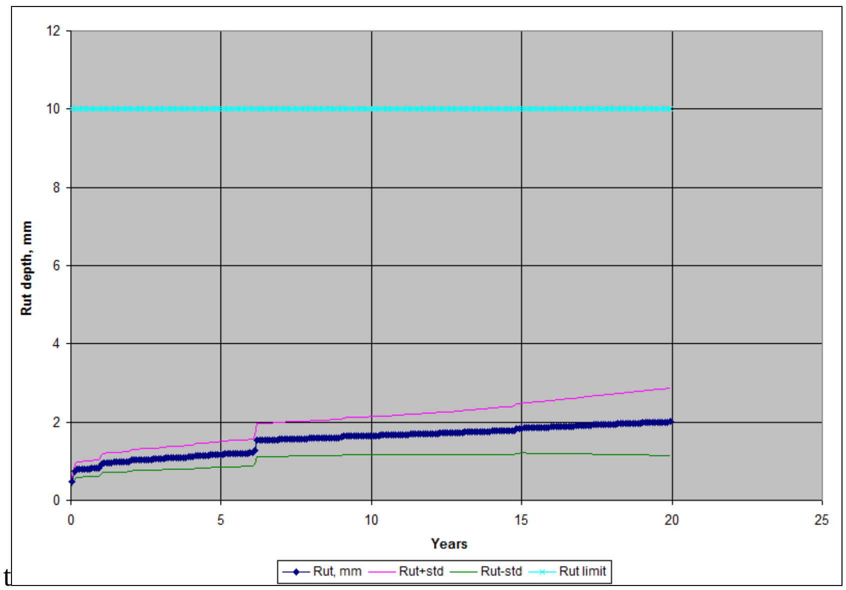

Figure A.6: Typical rutting-versus-age plot from *CalME* (Table 8, Design Option 2, PG 64-16 HMA mill and fill).

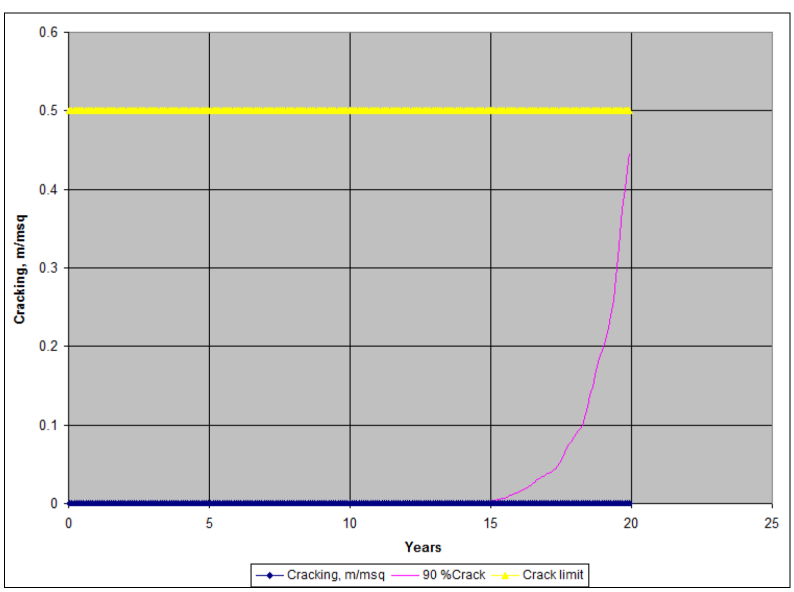

Figure A.7: Typical cracking-versus-age plot from *CalME* (Table 8, Design Option 2, PG 64-16 HMA mill and fill).

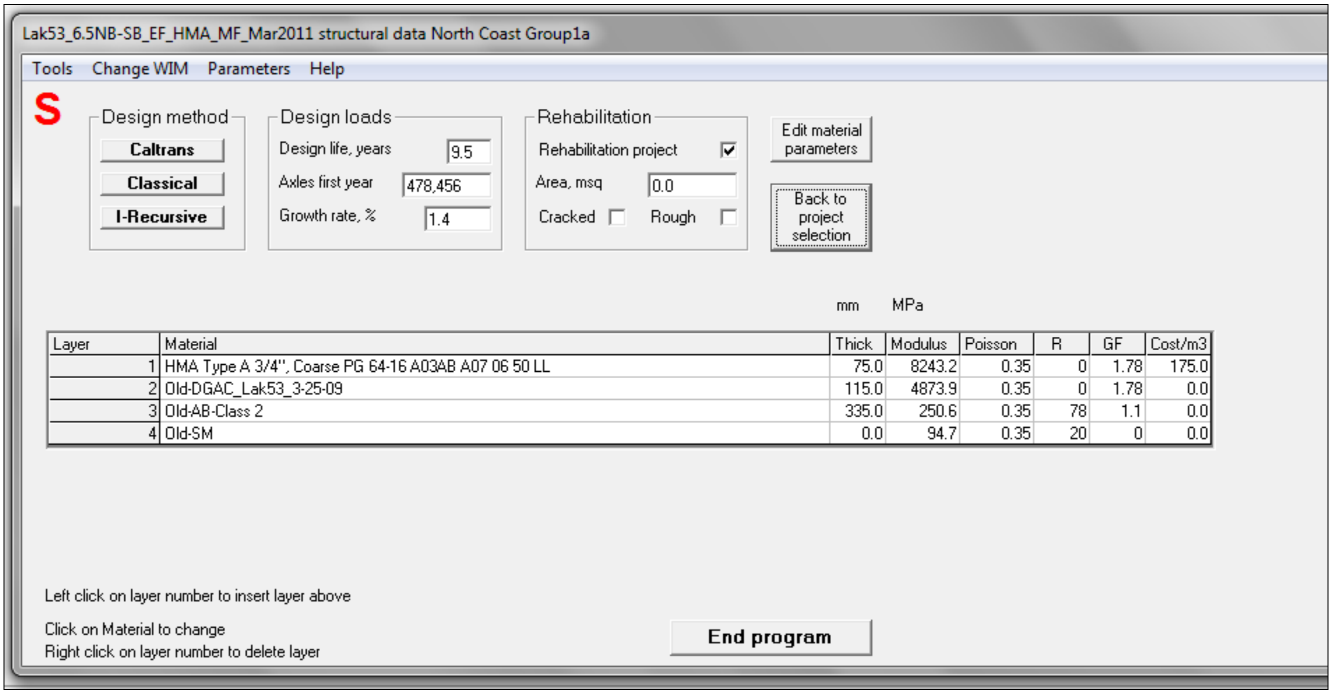

Figure A.8: Example structural input screen from *CalME* (Table 8, Design Option 2, PG 64-16 HMA mill and fill).

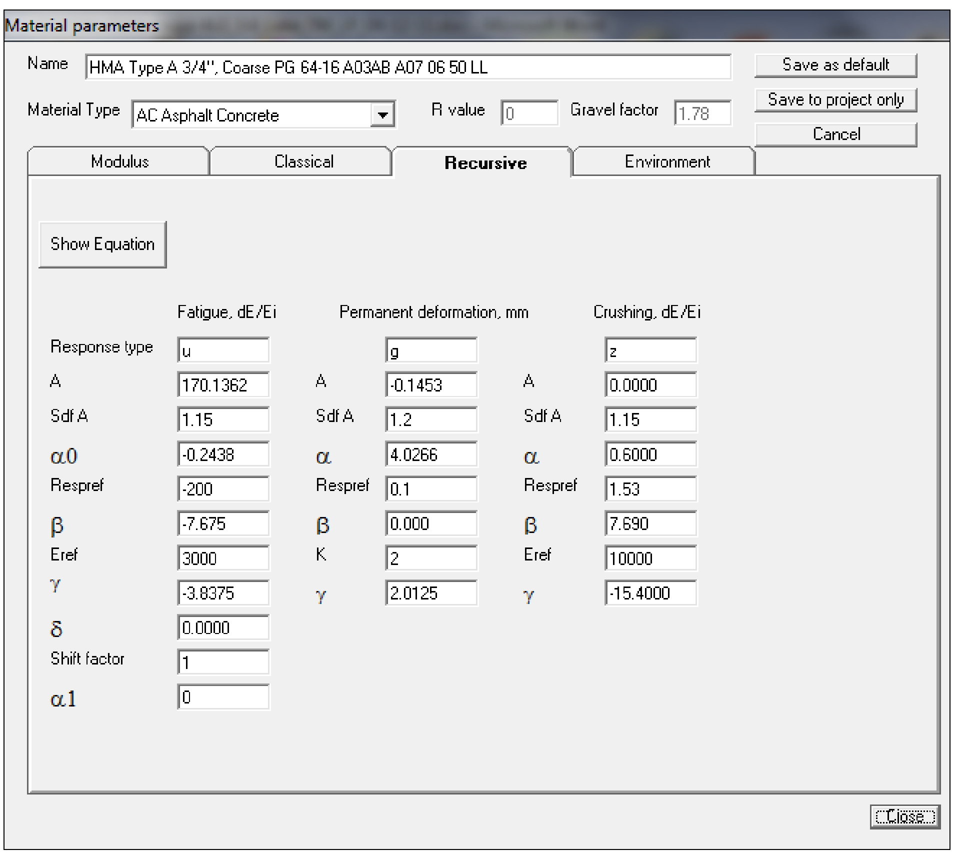

Figure A.9(a): Material parameter inputs for PG 64-16 HMA used in *CalME* analysis—Recursive.

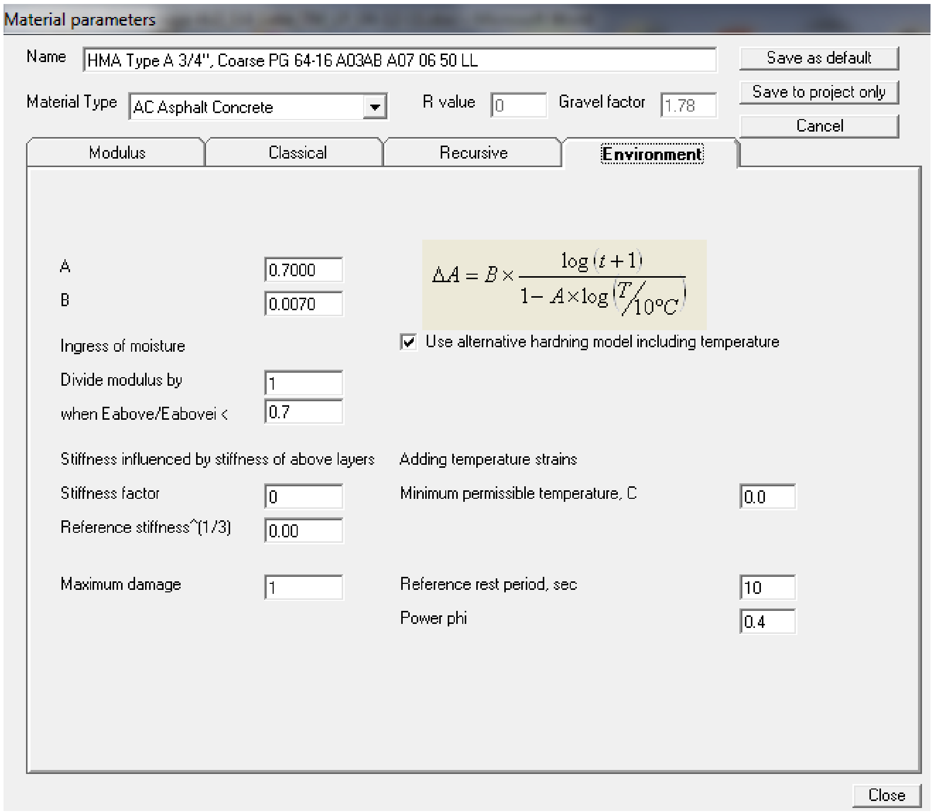

Figure A.9(b): Material parameter inputs for PG 64-16 HMA used in *CalME* analysis—Environment.

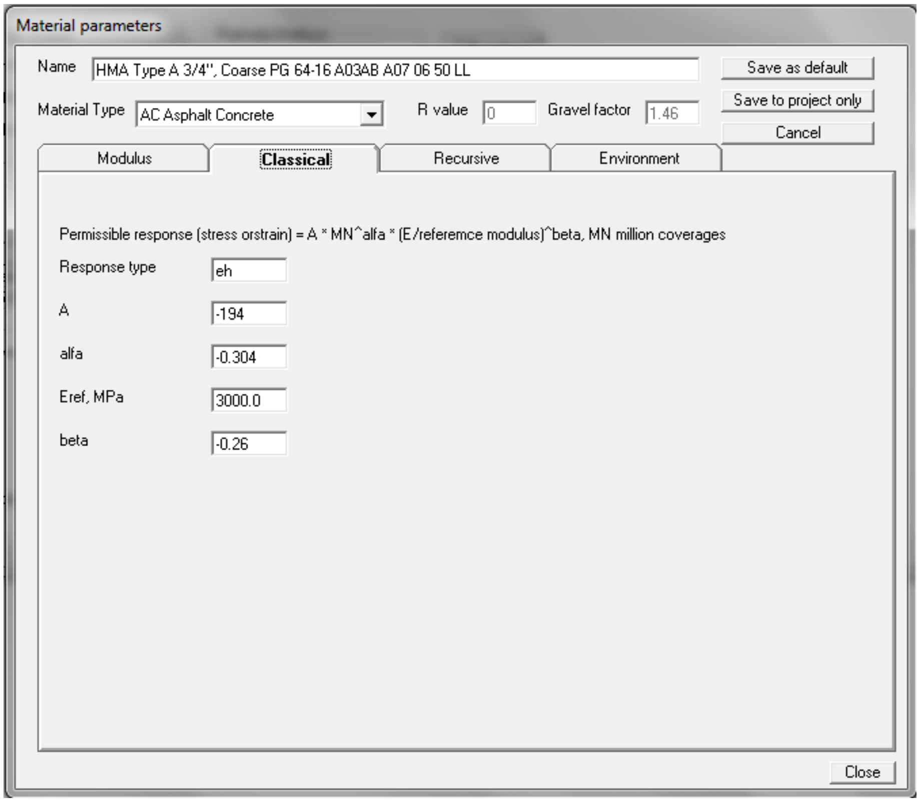

Figure A.9(c): Material parameter inputs for PG 64-16 HMA used in *CalME* analysis—Classical.

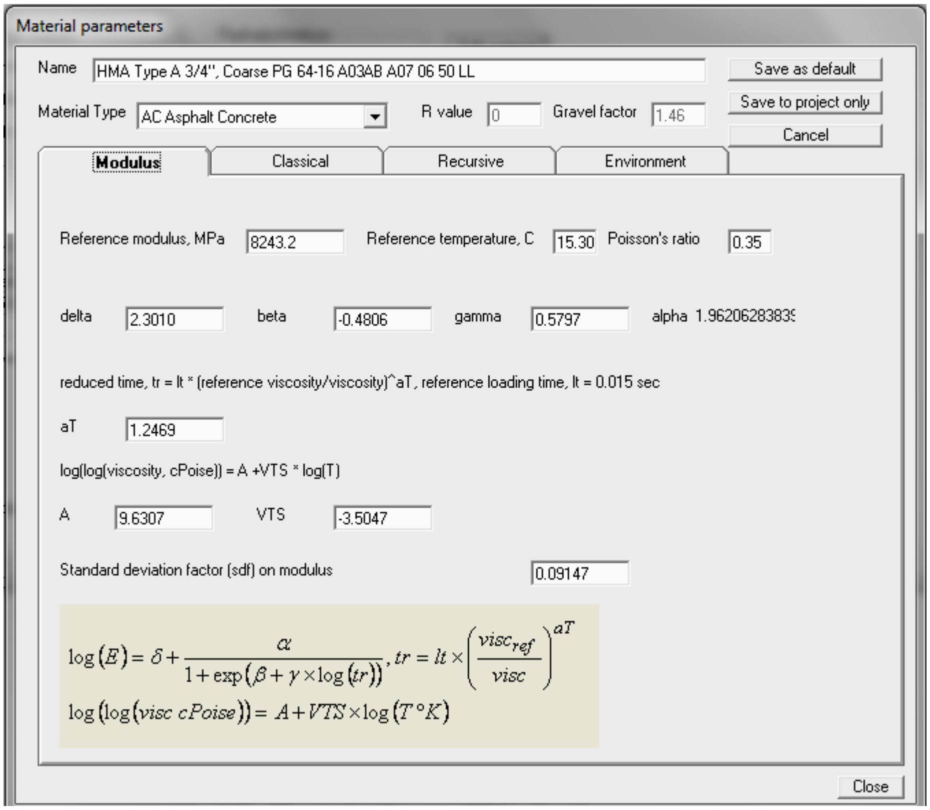

Figure A.9(d): Material parameter inputs for PG 64-16 HMA used in *CalME* analysis—Modulus.

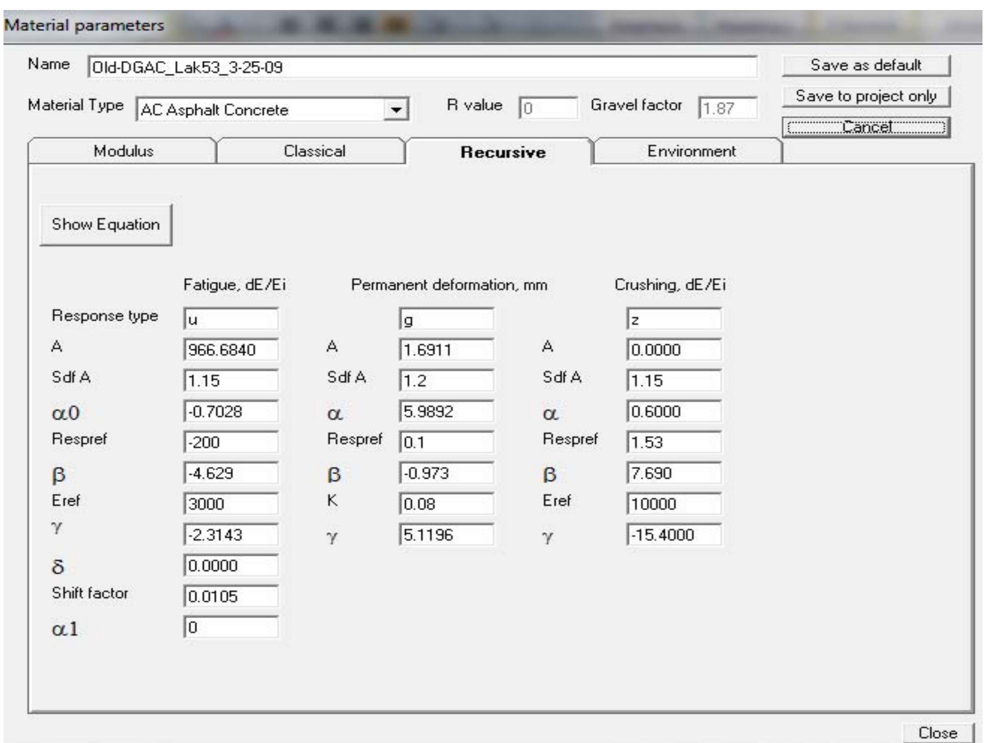

Figure A.10: Material parameter inputs for existing DGAC used in *CalME* analysis.

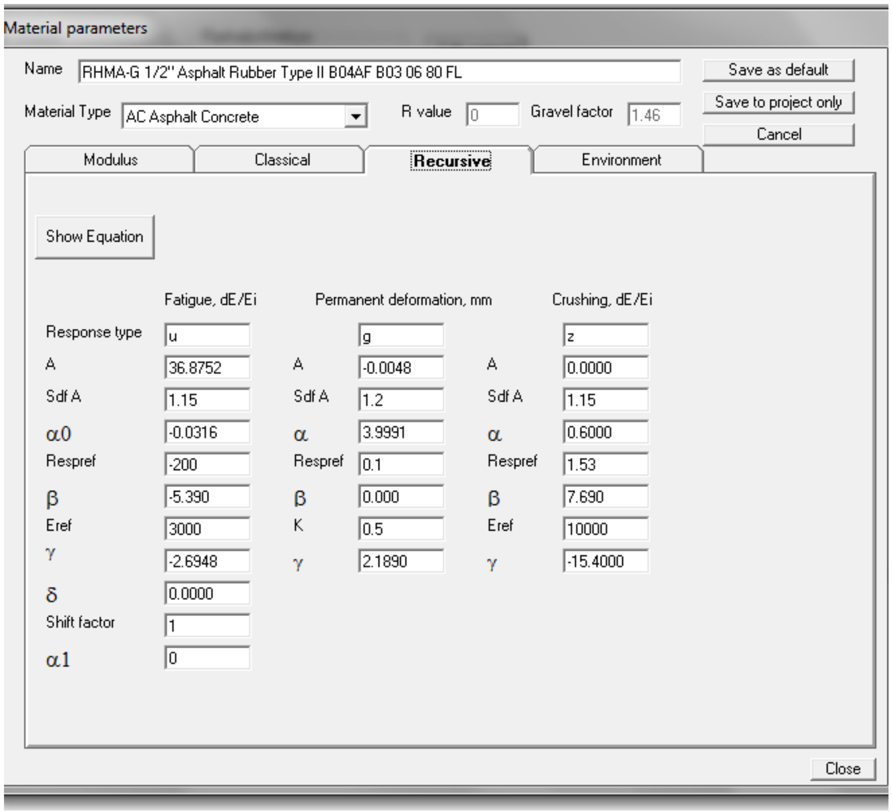

Figure A.11: Material parameter inputs for RHMA-G used in *CalME* analysis.

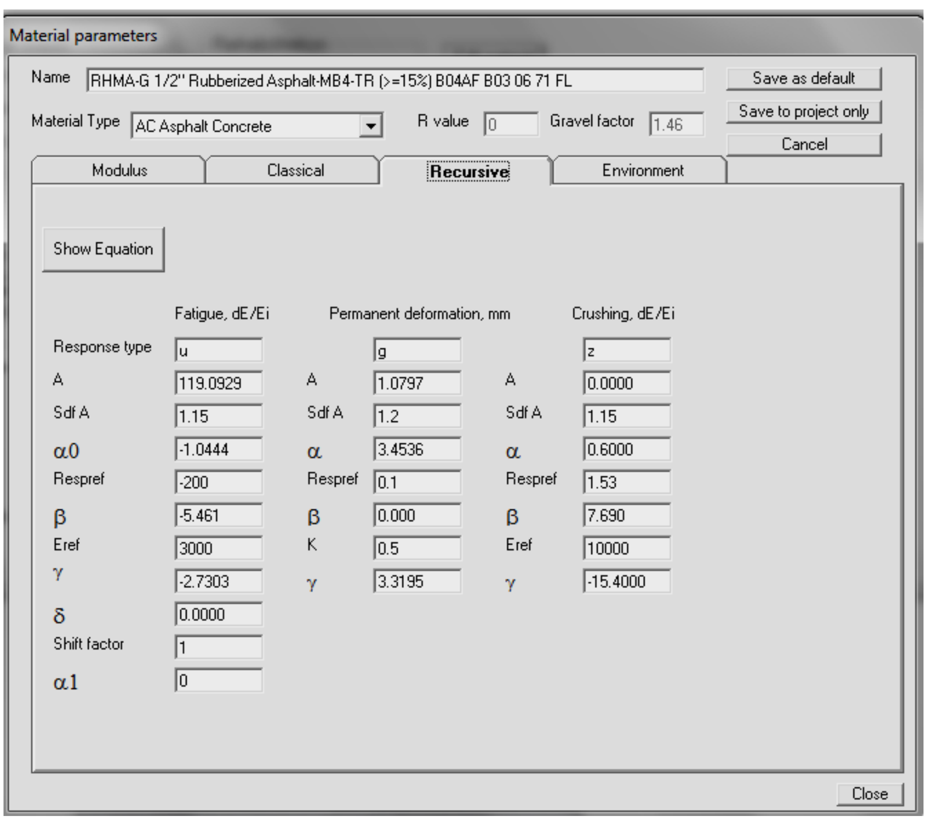

Figure A.12: Material parameter inputs for RHMA-G terminal blend (>15% rubber [MB-15]) used in *CalME* analysis.

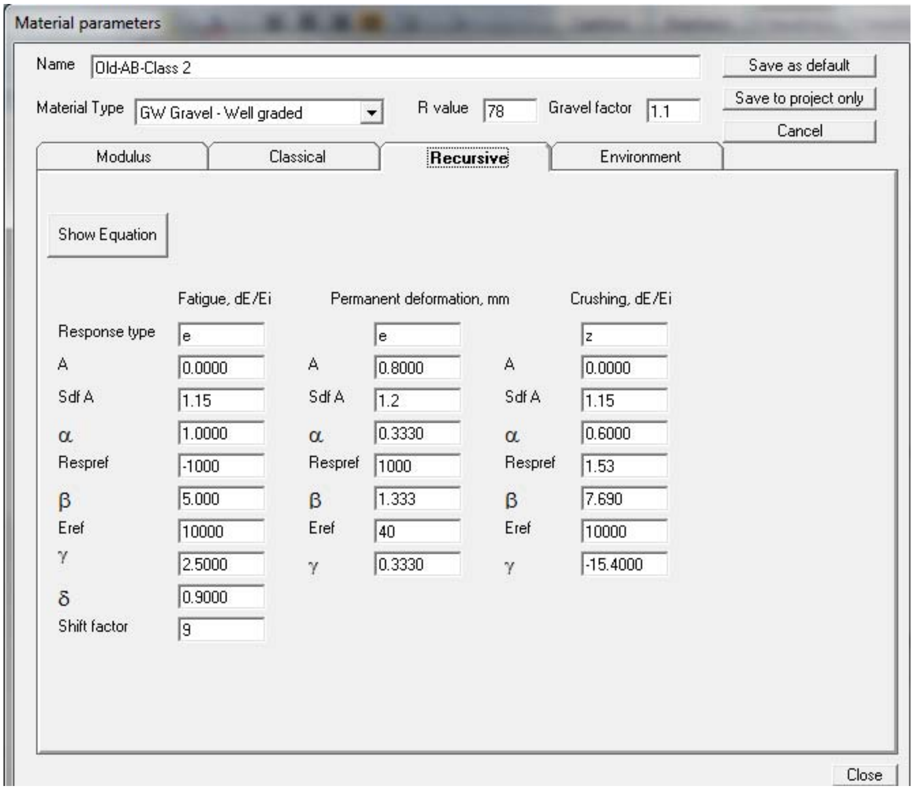

Figure A.13: Material parameter inputs for calibrated aggregate base used in *CalME* analysis.

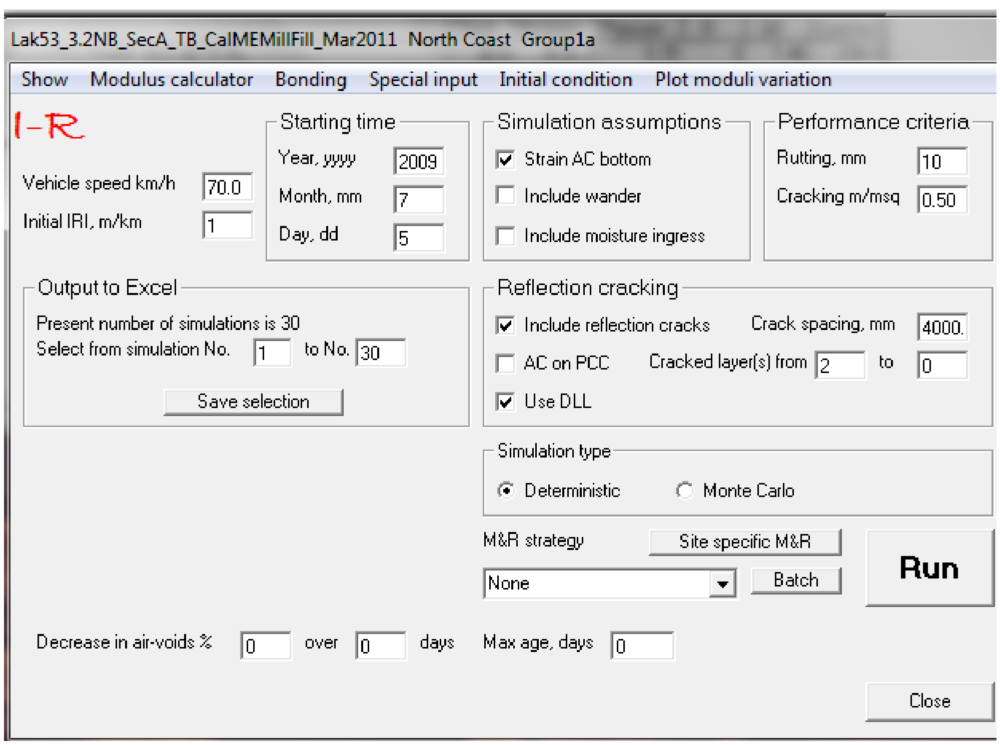

Figure A.14: Setup Incremental Recursive initial conditions window.

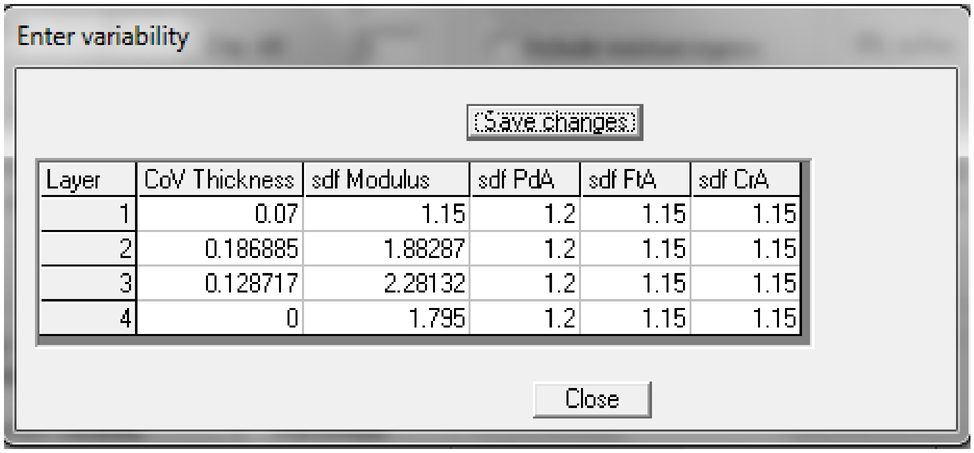

Figure A.15: Construction variability inputs for the Incremental Recursive analysis.

Table A.3: *CalME* Results: Rut Depth and Cracking Avg and Stdev at End of Design Life (20 Years)

SI Units			US Units			z-Factor (90% Reliability)	Design Option
Rut at the end of design life (mm)	Stdev Rut at the end of design life (mm)	90% Cracking at the end of the design life (m/sqm)	Rut at the end of design life (in.)	Stdev Rut at the end of design life (in.)	90% Cracking at the end of the design life (ft/sq ft)		
1.455	0.437	0.000	0.057	0.017	0.000	1.28	Sect. A, Design 1a
1.285	0.637	0.062	0.051	0.025	0.019	1.28	Sect. A, Design 1b
1.609	0.584	0.007	0.063	0.023	0.002	1.28	Sect. A, Design 2
1.953	1.213	9.978	0.077	0.048	3.041	1.28	Sect. A, Design 2a
2.574	1.363	2.919	0.101	0.054	0.890	1.28	Sect. A, Design 2b
0.880	0.237	0.017	0.035	0.009	0.005	1.28	Sect B&C, Design 1a
0.491	0.210	0.001	0.019	0.008	0.000	1.28	Sect B&C, Design 1b
1.473	2.707	0.001	0.058	0.107	0.000	1.28	Sect B&C, Design 2
1.457	1.521	0.258	0.057	0.060	0.079	1.28	Sect B&C, Design 2a
2.336	1.706	0.764	0.092	0.067	0.233	1.28	Sect B&C, Design 2b
1.824	0.687	0.001	0.072	0.027	0.000	1.28	Sect. E&F, Design 1a
1.992	1.606	8.781	0.078	0.063	2.676	1.28	Sect. E&F, Design 1b
2.006	0.863	0.446	0.079	0.034	0.136	1.28	Sect. E&F, Design 2
2.331	1.677	9.163	0.092	0.066	2.793	1.28	Sect. E&F, Design 2a
2.991	1.742	6.491	0.118	0.069	1.978	1.28	Sect. E&F, Design 2b
0.800	0.169	0.030	0.031	0.007	0.009	1.28	Design #3
2.253	0.410	0.000	0.089	0.016	0.000	1.28	Design #4
1.879	0.281	0.000	0.074	0.011	0.000	1.28	Design #4a
2.444	0.552	0.000	0.096	0.022	0.000	1.28	Design #4b
2.102	0.244	0.000	0.083	0.010	0.000	1.28	Design #4c
1.816	0.364	0.000	0.071	0.014	0.000	1.28	Design #4d
2.102	2.440	0.000	0.083	0.096	0.000	1.28	Design #4e

Table A.4: *CalME* Material Library—List of Materials Selected

CalME Material Library – Material Name	Material Description
AB-Class 2, FDR-Pulverization, Various California Highways, E=300MPa(44ksi), SDF=1.20	Non-stabilized PAB
AB-Class 2, UCPRC Test Track, RCA, E=650MPa(94ksi), SDF=1.20	Stabilized PAB (2% cement)
AB-Class 2, UCPRC Test Track, E=400MPa(58ksi), SDF=1.20	Stabilized PAB (3% lime)
HMA Type A 3/4", Coarse PG 64-16 A03AB A07 06 50 LL	PG 64-16 HMA
RHMA-G 1/2" Asphalt Rubber Type II B04AF B03 06 80 FL	RHMA-G
RHMA-G 1/2" Rubberized Asphalt-MB4-TR (>=15%) B04AF B03 06 71 FL	RHMA-G terminal blend with >15% rubber (MB-15)

APPENDIX B: FALLING WEIGHT DEFLECTOMETER MEASURED DATA

Table B.1: FWD Data SR 53 North, Lake County, PM 3.2–PM 3.4

Station (m)	T Surface (C)	T Air (C)	Time	Stress (kPa)	Force (kN)	D1 (μ)	D2 (μ)	D3 (μ)	D4 (μ)	D5 (μ)	D6 (μ)	D7 (μ)	D8 (μ)
0	5.6	8.6	9:17	410	28.95	423.1	346.5	283.4	191.7	137.6	64.4	29.1	22.1
0	5.6	8.6	9:17	603	42.61	551.8	459.6	382.1	265.5	198.5	97.1	43.5	39.2
0	5.6	8.6	9:17	837	59.13	700.8	583.7	490.6	348	268.1	135.1	61.4	49.1
20	7.6	8.2	9:18	401	28.33	287.8	219.4	187.1	136.4	100.7	52	17.5	11.2
20	7.6	8.2	9:18	584	41.28	390.7	306.5	263.4	196.1	146	78.1	27.7	18.4
20	7.6	8.2	9:18	810	57.22	508.4	405.4	351.1	264.4	200.4	109.6	38.9	26.5
40	7.9	8.7	9:19	405	28.61	449.8	338.2	277.7	185.2	116.5	58.5	25.7	15.4
40	7.9	8.7	9:19	596	42.09	591.8	457.6	382.6	265.7	174.4	90.8	43.2	28.7
40	7.9	8.7	9:19	830	58.67	746.4	585.2	494.4	353	237.1	128.3	60.4	42.8
60	7.3	8.9	9:20	412	29.14	344.1	272	195.4	130.1	90.3	44.2	15.7	12.6
60	7.3	8.9	9:20	595	42.04	451.5	363.2	268.7	184.4	131	66.1	24.7	17.2
60	7.3	8.9	9:20	827	58.48	572.3	464.7	351	246.2	178.9	93.6	35.2	25.2
80	8.2	8.3	9:21	420	29.67	145.1	111.2	89.2	60.9	43.2	23.8	13.3	12.2
80	8.2	8.3	9:21	618	43.68	203.4	159.1	129.6	90	64.8	36.9	19	17.9
80	8.2	8.3	9:21	854	60.37	274	214.9	176.4	124.5	91.4	52.7	27.8	22
100	5.2	8.1	9:22	443	31.28	196.9	142.1	104.1	65.7	43.2	21.3	10.4	8.5
100	5.2	8.1	9:22	634	44.78	258	189.3	141.3	91.6	62.3	32.2	16.8	12.5
100	5.2	8.1	9:22	877	61.96	331.4	244.7	185.9	123.5	85.5	46.2	23.5	17.3
120	8.7	8.5	9:23	416	29.37	84.7	69.6	61.3	48.2	40.2	27.8	14.3	12.7
120	8.7	8.5	9:23	617	43.63	122.2	101.5	90.4	73.3	60.5	42.5	22.4	16.8
120	8.7	8.5	9:23	849	60	165	137.2	122.8	100.1	83.5	59.1	31.1	23.9
140	5	9	9:23	402	28.4	274.6	201.7	170.8	130.7	103.8	67.1	28.6	19.6
140	5	9	9:23	593	41.94	385.9	290.7	248.6	192.3	153.2	101.4	45	29.8
140	5	9	9:23	824	58.23	516.2	392	336.8	261.7	209.4	140.7	64.6	43.4
160	7.1	8.5	9:24	414	29.26	205.2	151.6	121.4	86	64.4	38.6	18	13
160	7.1	8.5	9:24	603	42.62	280.4	210.8	171.4	125.7	94.6	57.8	28.4	20
160	7.1	8.5	9:24	836	59.11	371.6	281.8	231.5	170.9	131.3	81.7	38.4	27.5
180	7.2	8.6	9:25	419	29.58	156	126.3	103	79.6	61.7	41.7	19.4	13.1
180	7.2	8.6	9:25	605	42.79	215.6	178.3	148.3	115.8	90.6	61.3	29.2	21
180	7.2	8.6	9:25	832	58.83	289.6	241.4	203.1	160.3	126.6	86	41.6	29
200	7.7	8.8	9:27	417	29.48	119.1	107.1	96.9	75.6	59.7	35.3	6.4	5.1
200	7.7	8.8	9:27	609	43.01	172	155.3	141.3	111.1	88.4	53	10.3	7.7
200	7.7	8.8	9:27	847	59.87	235.4	212.9	194.2	153.4	122.8	74	13.6	11.5
220	6.5	9.1	9:28	414	29.25	153.5	115.5	97.2	71.4	57.1	36.7	16.7	13.5
220	6.5	9.1	9:28	605	42.73	215.7	165.9	140.7	106	84.5	55.3	26	18.2
220	6.5	9.1	9:28	839	59.33	288.8	224.4	191.8	146.1	118.4	78	36.8	26.2
240	7	9	9:28	419	29.58	108.8	86.6	73.5	54.6	41.2	23.1	9.4	7.8
240	7	9	9:28	617	43.61	157.6	127.2	108.7	81.5	61.9	36	16	11.4
240	7	9	9:28	847	59.86	211	171.4	148	112.5	86.4	51.3	22.6	16.2
260	7.1	9.2	9:29	417	29.46	98	79.1	70	55	44.5	29.4	13.7	9.7
260	7.1	9.2	9:29	602	42.54	141.4	114.9	101.4	80.8	65.3	44	19.9	13.6
260	7.1	9.2	9:29	832	58.78	192.9	157.7	140	112	91.4	61.4	27.3	17.4
280	7	9.2	9:30	415	29.3	85.4	77.6	73.4	64.2	57.3	42.2	16.1	12.9
280	7	9.2	9:30	603	42.62	124.6	115.9	108.8	96.8	84.9	63.7	26	17.2
280	7	9.2	9:30	840	59.36	176.6	163.9	154.2	138.6	121.3	91.3	37.1	25.5
300	6.3	9.2	9:32	414	29.25	71.2	60.9	56	48.1	42.4	31.6	19.8	14.3
300	6.3	9.2	9:32	609	43.03	104.8	89.9	82.7	72.2	63.4	48	29.5	23.2
300	6.3	9.2	9:32	844	59.62	147.3	127.2	117.9	102.8	90.4	68.9	42.3	30.6
320	5.9	9.2	9:33	425	30.04	94.8	88.9	82.2	69.6	58.6	42.2	21.2	13.7
320	5.9	9.2	9:33	616	43.54	135.6	127	118	100	85.1	61.9	31.9	19.8
320	5.9	9.2	9:33	850	60.05	185.8	174.7	162	138.6	118.9	86.5	45	27.7

Table B.2: FWD Data SR 53 South, Lake County, PM 3.4–PM 3.2

Station (m)	T Surface (C)	T Air (C)	Time	Stress (kPa)	Force (kN)	D1 (μ)	D2 (μ)	D3 (μ)	D4 (μ)	D5 (μ)	D6 (μ)	D7 (μ)	D8 (μ)
310	7.7	10	10:14	445	31.44	71.6	61.2	56.8	49.6	43.4	33.9	22.4	15.9
310	7.7	10	10:14	644	45.49	100.9	88.7	82.1	72	64.5	50.1	31.3	23
310	7.7	10	10:14	889	62.83	139.3	122.4	114	100.8	89.2	70	44.1	31.8
290	8.9	9.7	10:15	430	30.42	167.9	181.9	187.7	42.9	37.9	32.3	20.1	15.3
290	8.9	9.7	10:15	627	44.34	239	260.4	267.2	62.8	56	47.5	29.5	23.1
290	8.9	9.7	10:15	867	61.31	329.3	355.5	364.6	86.6	77.7	65.2	41.8	30.2
270	12.9	9.8	10:16	429	30.31	91.8	79.4	71.5	58.2	48	32.3	14.7	9.5
270	12.9	9.8	10:16	651	46.02	139	121.2	109.6	90.1	75.6	50.4	23.4	15.8
270	12.9	9.8	10:16	894	63.16	189.2	165.9	150.4	124.1	103.1	70.6	32.9	21.1
250	10.4	10	10:17	434	30.68	140.1	115.4	97.9	73.5	56.4	35.4	16	10.1
250	10.4	10	10:17	628	44.39	202.5	165.6	141.9	107.2	83	52.5	23.5	14.6
250	10.4	10	10:17	872	61.62	274.8	226.4	194.8	149.7	115.7	73.6	32.6	21
230	10.2	9.9	10:18	433	30.63	142.1	112	92.2	65.6	46.8	25.6	12	9.3
230	10.2	9.9	10:18	631	44.6	197	156.3	129.6	94.1	68	38.1	18.5	14.6
230	10.2	9.9	10:18	884	62.45	261.4	208	173	127.4	93.6	53.6	27.3	20.5
210	12.9	10.1	10:19	447	31.62	255.1	182.1	142.4	96.2	67.6	36.2	15.5	11.8
210	12.9	10.1	10:19	645	45.56	339.8	250.7	200.4	140	100.4	55.2	24.3	17.3
210	12.9	10.1	10:19	896	63.32	441.7	330.5	267.7	191.2	140.5	79.3	34.3	24
190	11.4	10.3	10:19	435	30.75	149.2	118.1	100.6	74.6	56.3	34.1	14.9	12.6
190	11.4	10.3	10:19	636	44.94	209.4	167.7	144.2	108	83.1	51.2	22.2	16
190	11.4	10.3	10:19	876	61.94	277.4	223.6	193.2	146.4	113.8	70.8	31.1	22.8
170	12.4	10.3	10:20	428	30.22	143.4	120.7	104.7	80.9	60.9	37	16.9	11.1
170	12.4	10.3	10:20	629	44.46	203.3	172	150.5	117.4	90.5	56.3	26.8	16.5
170	12.4	10.3	10:20	878	62.08	269.2	229.4	202.4	159.8	125.8	79.6	37.6	24.9
150	11.4	10.3	10:21	420	29.71	156.5	135.1	120	92.5	69.9	42.7	17.4	11.7
150	11.4	10.3	10:21	620	43.83	223.5	195.5	172.6	133.5	104.1	63.8	27.3	17.6
150	11.4	10.3	10:21	862	60.92	298.9	262.5	233.1	181.8	144.3	90	38.9	24.7
130	12.1	10.4	10:23	439	31	139.8	115.4	99.4	72.6	56	40	25.1	15
130	12.1	10.4	10:23	646	45.63	190.4	159	138.6	104.6	82.8	59.9	36.9	27.7
130	12.1	10.4	10:23	910	64.31	249.8	213.1	188.6	146.5	116.7	85.4	52	37.7
110	12.3	10.5	10:24	436	30.8	94.3	74.4	62.7	45.9	34.8	20.8	10.5	8.4
110	12.3	10.5	10:24	642	45.4	130.8	105.6	90.3	67.6	51.3	31.5	15.8	11.2
110	12.3	10.5	10:24	895	63.28	175.6	142.3	122.4	93.2	71.8	45.2	22	16.8
90	12.2	10.4	10:24	438	30.96	116.5	97.3	84.1	63	47.7	26.5	12.1	11.5
90	12.2	10.4	10:24	640	45.2	165.6	138.2	119.6	90.2	68.9	39.2	17.8	11
90	12.2	10.4	10:24	893	63.11	224	187.1	162.3	124.2	95.3	55.7	23.9	18.7
70	12.8	10.3	10:25	429	30.32	119.3	96.2	81.7	59.2	44.1	23.5	10.2	8.8
70	12.8	10.3	10:25	634	44.8	169.2	137.8	117.1	87.5	63.7	34.4	17.8	14.8
70	12.8	10.3	10:25	879	62.13	225.3	184.7	157.4	119	87.7	48.5	24.1	18.7
50	12.6	10.6	10:26	411	29.04	361.2	278.8	231.9	160.1	114.1	57.7	24.7	21.4
50	12.6	10.6	10:26	606	42.8	483.8	382.6	322	230.1	167.5	90.2	40.1	31.7
50	12.6	10.6	10:26	844	59.68	620.3	496.3	422	308	226.5	126.9	56.8	42.9
30	13	10.4	10:27	424	29.96	254.2	210.9	183.1	138.7	103.8	57	23.8	16.9
30	13	10.4	10:27	627	44.34	346.7	290.8	254.2	195.8	148.7	84	36.7	26.2
30	13	10.4	10:27	873	61.69	449.3	378.4	331.8	258.8	198.5	114.7	50	36.1
10	12.4	10.8	10:28	413	29.16	252.9	222.4	199.7	161.7	130.9	81.9	31.3	20.2
10	12.4	10.8	10:28	603	42.64	355.7	313.8	282.4	231.2	187.2	118.3	47.4	31.2
10	12.4	10.8	10:28	834	58.94	476	421	379.5	312.7	254.4	162.9	65.5	45.3
0	12.3	10.6	10:29	434	30.64	150.7	129.4	118.7	101.8	86.6	65.4	37.6	24.6
0	12.3	10.6	10:29	636	44.96	218	191.8	175.6	150.2	128.5	96.4	54.9	34.5
0	12.3	10.6	10:29	880	62.2	301.1	265.4	243.3	208.8	178.7	134.6	75.4	49

Table B 3: FWD Data SR 53 North, Lake County, PM 3.6–PM 4.0

Station (m)	T Surface (C)	T Air (C)	Time	Stress (kPa)	Force (kN)	D1 (μ)	D2 (μ)	D3 (μ)	D4 (μ)	D5 (μ)	D6 (μ)	D7 (μ)	D8 (μ)
0	13.2	11.4	11:34	414	29.23	302.5	254.1	224.9	186.2	155.1	104.6	51.6	36.3
0	13.2	11.4	11:34	602	42.57	419.1	351.4	313.4	260.9	218.7	148.6	77.6	49.6
0	13.2	11.4	11:34	837	59.15	547.8	458.9	409.9	342.5	287.9	198.9	103.7	67.8
40	16.1	12.2	11:35	424	29.99	295.1	242.2	208.2	155.5	122	77	37.4	20.4
40	16.1	12.2	11:35	615	43.49	398.7	329.8	286.7	219.4	174.5	112.2	53.9	32.6
40	16.1	12.2	11:35	853	60.26	514.2	430.6	377.2	293.5	236.1	154.4	74.5	43.6
80	10.8	12	11:36	414	29.25	256.1	209.6	177.1	134.7	101.7	56.3	16.2	8.8
80	10.8	12	11:36	600	42.41	348.7	288.5	246.4	189.1	144.8	81.8	25.1	13.7
80	10.8	12	11:36	834	58.97	455.3	378.6	326.4	252.5	194.3	112.1	35.2	19.4
120	13.3	11.4	11:42	462	32.66	82.9	72	64.2	53.1	44.8	26.8	15.5	12.7
120	13.3	11.4	11:42	678	47.95	121.3	102.6	91.7	76.8	64.7	39.9	22.3	16.2
120	13.3	11.4	11:42	947	66.94	162.5	139.4	125.2	104.7	88.9	55.3	31.3	22.6
160	8.8	11.8	11:44	429	30.35	123.6	99.7	85.8	63.4	47.1	26.9	10.9	8.5
160	8.8	11.8	11:44	626	44.24	172.7	142	123.2	92.3	69.4	40.4	17.4	12
160	8.8	11.8	11:44	865	61.14	232.4	192.5	168	127.7	97.4	57.7	24.6	16.7
200	8.5	12.2	11:45	419	29.64	134.1	112.4	95.1	70.6	54.5	33.3	12	7.3
200	8.5	12.2	11:45	612	43.26	187	157.8	136.4	102.7	79.7	50.5	16.8	12.5
200	8.5	12.2	11:45	850	60.07	250.4	211.7	183.5	140.8	110.8	71.4	24.6	17.4
240	10	11.7	11:46	438	30.95	108.3	86	72.7	54.4	40.8	24.4	10.6	7.5
240	10	11.7	11:46	636	44.92	152.6	121.9	104.2	78	58.3	35.4	15.1	9.3
240	10	11.7	11:46	887	62.66	205	164.7	140.8	106.6	80.7	49.5	21.7	13.4
280	8.5	11.1	11:46	427	30.18	53.2	44.3	37.7	28.7	22.5	13.5	5.3	4.1
280	8.5	11.1	11:46	626	44.21	77.5	65.3	55.9	42.7	34.1	21.1	8.4	6.6
280	8.5	11.1	11:46	870	61.46	105.7	90.5	78	60.2	48.2	30.4	12	9.5
320	10.1	11.3	11:48	421	29.78	100.2	68.4	54.8	37.4	26.3	15.4	6.1	4.4
320	10.1	11.3	11:48	616	43.56	142.4	99.8	81	56.1	40	23.4	9.3	6.7
320	10.1	11.3	11:48	857	60.54	193.5	137.4	112.8	79.3	57.6	34	13.4	9.5
360	8.7	11	11:49	413	29.21	141.1	116.2	102.4	82.3	26.6	16.8	9.7	5.5
360	8.7	11	11:49	613	43.35	197.7	164.9	147.3	119.8	42	26.9	13.4	10.4
360	8.7	11	11:49	853	60.32	263	221.2	198.1	162.3	61	39.6	18.5	15.9
361	8.9	10.9	11:50	423	29.89	151.7	112.3	91.9	65.5	46.2	23.2	9.9	6.2
361	8.9	10.9	11:50	619	43.75	207.3	157.9	131.2	96.6	69.2	36.8	14.9	10.1
361	8.9	10.9	11:50	861	60.88	272.7	210.4	176.6	131.9	96.6	52.6	20.7	14.4
400	10	11.1	11:52	438	30.93	74.9	54	45.2	34.1	27.1	17.4	7.7	8.9
400	10	11.1	11:52	628	44.36	101.3	76	64.6	49.6	39.1	25.4	12.1	11.7
400	10	11.1	11:52	870	61.52	136.6	104.3	89.8	69	54.7	36	16.8	14.1
440	8.8	10.9	11:53	424	29.99	112.8	92.3	79.9	59.2	45.1	26.7	11.8	9.2
440	8.8	10.9	11:53	614	43.4	161.2	132.1	114.4	87.3	66.3	38.6	15	10.5
440	8.8	10.9	11:53	851	60.17	220.1	180.4	157.1	120.3	92.7	55.2	22.2	14.6
480	10.1	10.5	11:54	435	30.75	73.3	59.5	50	38	29.1	18.1	7.6	7.6
480	10.1	10.5	11:54	640	45.2	104.8	86.3	73.9	56.9	44.1	27.8	13.1	8.1
480	10.1	10.5	11:54	897	63.39	143.1	118.3	102	79.4	62.5	39.8	18.1	12.3
520	9.7	11.3	11:55	425	30.06	104.5	84.8	74.6	59.2	46.2	29	14.4	10.6
520	9.7	11.3	11:55	614	43.4	151.2	123.9	109.3	87	68.7	43.6	21.7	14.8
520	9.7	11.3	11:55	853	60.26	208	171.7	152.6	122.6	97.2	62.3	31.2	20.7
560	13.3	11.4	11:56	424	29.94	83.6	69.7	62.4	50.8	41.7	28	13.3	10.3
560	13.3	11.4	11:56	628	44.39	120.7	102.1	91.4	75	61.7	42.7	19.5	16.1
560	13.3	11.4	11:56	871	61.59	166.4	139.8	126	103.6	85.6	59.8	27.3	22.9
600	17.4	12.1	11:58	417	29.46	202.5	179.3	161.3	131	105.9	67.5	26.2	16
600	17.4	12.1	11:58	614	43.37	281.9	251.9	227.5	186.8	152.7	99.4	40	24.9
600	17.4	12.1	11:58	854	60.37	374.1	335.5	304.4	251.2	206.8	136.5	57.7	36

Table B.4: FWD Data SR 53 South, Lake County, PM 4.0–PM 3.6

Station (m)	T Surface (C)	T Air (C)	Time	Stress (kPa)	Force (kN)	D1 (μ)	D2 (μ)	D3 (μ)	D4 (μ)	D5 (μ)	D6 (μ)	D7 (μ)	D8 (μ)
580	11.3	11.8	12:10	450	31.81	184.4	143	119.7	89.4	69.6	42.6	13.9	9.8
580	11.3	11.8	12:10	655	46.26	243.5	193.3	163.5	124.2	98.5	61.9	22	14.1
580	11.3	11.8	12:10	902	63.78	310.2	247.8	211.1	163.8	129.1	83.8	30.3	18.7
540	12.5	12.2	12:11	422	29.79	245	206.1	180.2	139.2	109	65.6	24.6	16.9
540	12.5	12.2	12:11	609	43.01	332	285.3	250.8	196.1	155.2	95.9	38.5	24.8
540	12.5	12.2	12:11	841	59.43	432.7	374.7	331.2	260.9	208.4	130.7	52.8	34.7
500	12.2	11.4	12:12	439	31.03	87	68.1	57.3	45.6	36.3	23.1	10.6	8.2
500	12.2	11.4	12:12	644	45.52	123.5	99.1	85	68.6	54.4	35.4	17.2	12.6
500	12.2	11.4	12:12	890	62.88	165.4	133.8	116.2	93.9	75.3	49.5	23.9	17.1
460	14.9	11	12:13	430	30.39	219.9	173.8	142.5	102.3	77	42.1	13.3	9.7
460	14.9	11	12:13	626	44.27	296.2	237.4	197.2	144.7	109.4	62.4	22	15.7
460	14.9	11	12:13	878	62.03	388.2	313.4	263.9	197.1	151.2	88.1	33.3	21.5
419	15.7	11.3	12:15	428	30.25	186.2	140	119.6	87.8	64.8	34	12	8.2
419	15.7	11.3	12:15	625	44.2	253.3	194.3	166.3	124.5	93.7	50.6	18.7	12.6
419	15.7	11.3	12:15	871	61.57	332	259.7	223.6	169.2	129.1	71.9	27.2	17.4
380	13.3	12.3	12:20	434	30.68	101.1	73.2	55.7	36.3	24.1	13	6.5	5.9
380	13.3	12.3	12:20	658	46.48	143.9	107.6	84.3	56	38.1	21	14.2	10.4
380	13.3	12.3	12:20	908	64.2	190.6	144.6	114.6	77.3	53.3	29.7	16.8	14.6
340	12.4	11.5	12:21	430	30.39	129.1	104.7	88.6	64.1	45.9	23.7	7.9	5.1
340	12.4	11.5	12:21	624	44.13	185.6	151.6	129.5	94.3	69.3	37.2	12.5	8.9
340	12.4	11.5	12:21	866	61.24	254.4	206.5	177.3	130.8	97.2	53.2	18.5	12.4
300	10.2	11.4	12:22	408	28.83	187.7	151.3	130.2	97.5	71.5	35.6	9.2	9.9
300	10.2	11.4	12:22	595	42.08	262.4	216.4	188.1	143	106.3	55.5	18.1	15.7
300	10.2	11.4	12:22	821	58	349.5	289.7	252.9	195.8	146.6	78.8	25.8	21.8
260	11.4	11.4	12:23	415	29.32	265.7	198.3	167	124.9	93.9	52.9	17.4	10.4
260	11.4	11.4	12:23	608	42.98	350.7	267.4	228.4	172.6	131.7	76.8	26.5	17.4
260	11.4	11.4	12:23	846	59.8	451.5	346.6	297.2	227	176	103.7	36.9	24.2
220	14.2	11.1	12:24	421	29.74	239.2	188.4	155.7	111.6	84.6	51.2	18.6	13.5
220	14.2	11.1	12:24	612	43.28	320	258.7	216.8	159.3	122.6	75.6	29.1	18
220	14.2	11.1	12:24	853	60.28	413.8	337	285	213.4	166.2	105.2	41.8	26.3
180	12.9	11.2	12:25	411	29.02	321.3	262.4	218.1	158.1	117.3	61.1	16.6	15.1
180	12.9	11.2	12:25	603	42.61	422.1	354	298.6	222.2	167.4	91.3	26.9	18.9
180	12.9	11.2	12:25	835	59.02	538.8	455.3	388	293.3	225.5	128.3	41.1	28.5
140	16.5	11.7	12:26	425	30.03	202.6	171.6	151	118.1	89.2	52.1	20.4	14.1
140	16.5	11.7	12:26	616	43.54	276.2	234.6	206.7	162.7	126.4	75	28.1	18.3
140	16.5	11.7	12:26	861	60.83	362.3	308.6	273.3	216.7	171.4	105.6	41.6	25.7
80	15.7	12.4	12:27	438	30.96	163.1	134.5	111.3	87.1	67.1	41.5	19.8	5.3
80	15.7	12.4	12:27	642	45.34	224.7	187.9	158.9	125.2	97.5	61.1	26.5	17.9
80	15.7	12.4	12:27	898	63.48	292.5	246.6	211.1	167.8	131.9	84.6	38.8	24.9
60	17.2	12	12:28	408	28.8	274.2	208.2	172.8	122.6	88.9	45.4	19.9	12.6
60	17.2	12	12:28	619	43.74	377.5	294.4	248.6	179.3	132.4	71	30.8	23.5
60	17.2	12	12:28	855	60.4	474	376	320.3	235	176.2	96.3	43.6	32.8
20	17.6	12.2	12:32	423	29.92	333.6	254.3	208.4	153.5	114	65.8	30.3	23.4
20	17.6	12.2	12:32	618	43.65	437.6	342.8	285.3	213.9	162	97.4	46.5	34.3
20	17.6	12.2	12:32	869	61.39	556	440.7	370.4	282.4	216.7	134.3	65.9	48.5

Table B.5: FWD Data SR 53 North, Lake County, PM 4.9–PM 5.27

Station (m)	T Surface (C)	T Air (C)	Time	Stress (kPa)	Force (kN)	D1 (μ)	D2 (μ)	D3 (μ)	D4 (μ)	D5 (μ)	D6 (μ)	D7 (μ)	D8 (μ)
0	17.2	12.5	13:52	445	31.48	187.1	151.7	130.1	98.7	75.3	45.2	18.3	15.1
0	17.2	12.5	13:52	645	45.61	254.7	207.9	179.4	138.4	108.2	66.7	29.3	19.7
0	17.2	12.5	13:52	889	62.86	329	269.4	234.7	183.1	144.9	91.3	39.7	28
40	15.7	12.7	13:53	446	31.53	82	70.6	64.6	54.8	47.1	33.8	18.1	11.2
40	15.7	12.7	13:53	653	46.16	118.1	102.4	93.3	79.7	68.7	49.6	24.9	15.6
40	15.7	12.7	13:53	902	63.76	161.5	139.8	127.9	108.8	94	68.7	35.7	21.6
80	16.8	12.5	13:54	433	30.61	220.5	185.5	166.6	137	113.9	75.4	36.7	25.7
80	16.8	12.5	13:54	635	44.87	295.5	255.1	229.7	192.1	160.1	108.5	53.1	35.4
80	16.8	12.5	13:54	881	62.3	383.2	333.6	301.1	253.7	213.8	147.4	73.4	49.5
120	17.2	13	13:55	440	31.07	327.7	266.7	220.8	99.7	76.6	43.6	17.7	14.2
120	17.2	13	13:55	643	45.44	411.5	337.4	280.9	136.5	106.6	63.5	28.9	19.8
120	17.2	13	13:55	895	63.26	506.3	416.4	347.7	178.4	139.5	85.1	41.8	27.8
160	16.9	13.3	14:00	431	30.49	342.8	275.4	230.4	168.9	115.9	61.7	21.2	14.1
160	16.9	13.3	14:00	640	45.2	448.2	366.2	310.8	234.2	165.4	93.8	33.8	23.2
160	16.9	13.3	14:00	890	62.91	555.3	455.6	390.1	298.5	214.7	126.5	46.3	31.6
200	16.1	13	14:01	428	30.27	421.1	295.7	228.7	150.7	98.3	46.7	19.9	15.4
200	16.1	13	14:01	626	44.27	534.4	389.9	308.5	207.6	141.7	71	31.8	24.7
200	16.1	13	14:01	879	62.13	665.7	494.3	396.5	272.7	191	101.9	46.9	36.1
250	17.2	13.3	14:02	435	30.73	199.1	164	138.8	106.3	83.6	52.3	25.5	19.8
250	17.2	13.3	14:02	647	45.72	269.1	224.7	192.5	149.8	120.6	75.9	41.8	29
250	17.2	13.3	14:02	900	63.58	347.7	292.1	251.7	198.8	160.8	103.9	54.3	40.6
280	16.1	13.3	14:04	440	31.09	97.4	75.3	65.8	53.1	43.7	31.4	17.7	12.2
280	16.1	13.3	14:04	647	45.73	136.7	108.4	95.5	77.9	64.8	46.7	26.7	20.8
280	16.1	13.3	14:04	901	63.67	183.4	148.1	130.8	109.4	90.7	65.4	36.7	26.6
320	17.2	13.3	14:04	439	31	209.9	149.1	118.7	79.1	55.8	33.2	18.1	16.9
320	17.2	13.3	14:04	649	45.84	282.4	205.8	166	113.4	82.3	48.4	27	19.3
320	17.2	13.3	14:04	900	63.6	364.8	268.6	218.5	152.4	112.8	68	37.8	27.9
360	16.1	13.4	14:05	435	30.71	177.3	146	131	105.1	85.3	52.2	22.7	18
360	16.1	13.4	14:05	638	45.12	245.9	205.7	185.4	151.7	122.1	77.8	35.7	22.5
360	16.1	13.4	14:05	879	62.12	324.9	274.8	248.1	204.5	166.6	107.6	48.5	31.8
400	14.9	13	14:07	442	31.21	195.7	137.1	110.8	78.5	55.7	29.4	12.7	10.3
400	14.9	13	14:07	651	46.04	271.8	193.9	159.9	114.7	83.5	45.8	18.6	14.1
400	14.9	13	14:07	903	63.79	359.9	260	217.1	158.6	117.1	65.9	26.3	20
440	17.9	13.6	14:08	446	31.51	109.7	82.5	68.5	50.7	40.4	26.7	15	10.6
440	17.9	13.6	14:08	654	46.21	158.6	120.3	100.1	75	59.1	38.5	19.8	12.8
440	17.9	13.6	14:08	907	64.08	216	164.1	137.5	103.7	83.5	54.9	26.4	17.2
480	17.9	13.3	14:09	453	32.02	105.1	84.6	73.7	57.2	45.2	30	12.4	9.8
480	17.9	13.3	14:09	662	46.79	146.5	119.4	105.1	81.6	65.3	43.6	20.7	13.7
480	17.9	13.3	14:09	915	64.64	196.3	161.2	142	111.4	89.4	59.8	28.3	18.3
510	16	13	14:10	434	30.68	105.8	86.9	77.1	61.1	49.5	32.2	16	13.4
510	16	13	14:10	658	46.5	155.2	129.8	115.1	92.9	76	49.9	25.2	18.7
510	16	13	14:10	900	63.64	207.4	174.7	155.8	126.6	104	68.7	33.9	25.9
560	18.3	13.6	14:12	430	30.42	87.2	69.7	61.2	48.2	40.6	27.3	14.7	9.5
560	18.3	13.6	14:12	628	44.41	121.3	102	89.5	72.9	59.5	41.1	20.7	14.3
560	18.3	13.6	14:12	878	62.05	166.9	140.9	124.3	101.8	83.8	57.7	28.7	19.3
600	18.5	13.9	14:13	442	31.21	110.1	87.3	75	56.3	44.7	27.6	13.2	10.7
600	18.5	13.9	14:13	647	45.7	155.8	124.8	107.8	81.9	65.3	40.6	18.4	15.4
600	18.5	13.9	14:13	902	63.76	212.2	170.8	148.4	114.2	91	57.2	25.5	17.2

Table B.6: FWD Data SR 53 South, Lake County, PM 5.27–PM 4.9

Station (m)	T Surface (C)	T Air (C)	Time	Stress (kPa)	Force (kN)	D1 (μ)	D2 (μ)	D3 (μ)	D4 (μ)	D5 (μ)	D6 (μ)	D7 (μ)	D8 (μ)
40	16.3	11.8	14:47	425	30.03	143.7	131	122.1	106.8	92	66.7	32.7	22.4
40	16.3	11.8	14:47	636	44.98	206.8	190	178.9	156.4	136.2	99.8	52.2	32.2
40	16.3	11.8	14:47	882	62.33	277.8	257.1	241.3	212.3	184.2	136.1	71.9	48.5
35	17.4	11.6	14:48	442	31.26	144.8	130.9	121.9	107	92.3	67.8	34.1	23
35	17.4	11.6	14:48	644	45.49	197.7	181.4	170.8	150.7	131.2	96.4	50.4	33.8
35	17.4	11.6	14:48	893	63.11	266.4	245.1	231.3	206.1	178.3	132.1	70	45.9
30	16.9	11.8	14:49	437	30.91	149.4	136.4	127.7	111.8	96.1	69.7	34.5	25.6
30	16.9	11.8	14:49	643	45.45	207.2	188.3	176.7	154.8	134.5	98.7	52.4	37.5
30	16.9	11.8	14:49	888	62.73	274.7	250.7	235.7	208.1	181.7	134.7	71.9	49.1
25	16	12	14:50	420	29.67	144.5	127.7	117.2	98.5	84.3	60.3	31.8	22.1
25	16	12	14:50	631	44.62	205.9	183.7	169.5	145.3	124.3	89.5	48.5	33.1
25	16	12	14:50	874	61.78	274.2	245.6	227.3	195.9	169.3	123.5	68.1	46.3
20	15.5	11.8	14:50	432	30.52	131	114.9	106.5	91.9	79	56.5	27.5	20.6
20	15.5	11.8	14:50	635	44.91	184	163.1	152.4	132.2	114.7	83.3	43.1	29.3
20	15.5	11.8	14:50	884	62.49	246.4	220.2	205.2	180.3	156.5	114.8	60.6	41
15	15	11.6	14:51	429	30.32	135.7	120	111.2	95.4	79.7	56.2	28.4	18.7
15	15	11.6	14:51	639	45.13	190.5	170.5	158.8	136.5	115.9	83.7	44.4	30.7
15	15	11.6	14:51	887	62.72	251.6	226.2	210.9	182.8	156.1	113.3	60.7	41.1
10	15	11.5	14:52	423	29.92	156.8	135.9	122.2	100.1	82.7	54.9	26.8	18.2
10	15	11.5	14:52	643	45.45	221.2	192.8	173.9	144.9	121.2	82.1	40.5	28.6
10	15	11.5	14:52	888	62.75	288	252.1	227.9	191.9	162.4	111.2	56.4	38.4
9	15.1	11.5	14:53	428	30.27	161.9	138.4	123.1	98.7	81.7	54.7	25.7	18.2
9	15.1	11.5	14:53	630	44.55	220.1	192	171.1	139.3	115.8	79.3	41	27.8
9	15.1	11.5	14:53	883	62.44	287.9	251.7	225.7	185.6	156.5	109.5	57.2	39.7
8.5	15	11.9	14:54	423	29.86	160.8	139.1	124.1	100.3	81.5	54.7	30.2	19.8
8.5	15	11.9	14:54	622	43.95	220.4	192.7	172.7	141.3	115.7	78.7	41.3	27
8.5	15	11.9	14:54	867	61.31	288.4	252.6	228.1	188.1	155.6	108.1	57.4	38.7
8	14.4	11.8	14:55	413	29.19	158.8	135.8	121.5	97.6	80.3	54.4	24.7	16.5
8	14.4	11.8	14:55	615	43.49	218.8	189.8	170.1	138.6	115.3	79.5	41	26
8	14.4	11.8	14:55	860	60.81	287.9	250.5	225.6	186.5	158	109.6	57.1	35.2
7.5	14.3	11.1	14:55	418	29.55	155.3	132.8	119.4	100.4	82	55	26	16.3
7.5	14.3	11.1	14:55	622	43.97	215.7	187.7	170	142.3	119.3	82.4	38.6	22.1
7.5	14.3	11.1	14:55	866	61.24	281.2	246.2	224	190	160.2	112.1	54	36.3
7	14.5	11.6	14:56	407	28.77	149.3	128.7	115	94.1	77.6	52.3	25.8	16.6
7	14.5	11.6	14:56	621	43.86	211.9	186.2	167.5	137.4	114.2	78.9	39.8	26.3
7	14.5	11.6	14:56	865	61.13	278.7	244.7	221.5	182.7	153.1	107.4	54.8	37.2
5	14.9	11.1	14:57	425	30.01	145.6	123	109.6	90.2	74.5	51.6	24	16.1
5	14.9	11.1	14:57	626	44.25	200.3	172	153.9	127.4	106.8	75.2	37.7	24.7
5	14.9	11.1	14:57	870	61.5	262.7	226.5	204.1	170.5	144.2	102.9	53.1	35.7
0	15.4	11.5	14:58	423	29.9	166.8	143.3	128.2	103.7	84.4	57	27.7	16.1
0	15.4	11.5	14:58	616	43.51	230.8	199	178.2	145.3	120.2	81.5	39.4	23.8
0	15.4	11.5	14:58	853	60.28	302.5	263	235.4	194.1	164	111.3	55.1	34.8

Table B.7: FWD Data SR 53 North, Lake County, PM 6.5–PM 6.97

Station (m)	T Surface (C)	T Air (C)	Time	Stress (kPa)	Force (kN)	D1 (μ)	D2 (μ)	D3 (μ)	D4 (μ)	D5 (μ)	D6 (μ)	D7 (μ)	D8 (μ)
0	13.2	12.5	15:33	421	29.72	308.2	245.7	207.7	153.1	111.3	57	21.1	15
0	13.2	12.5	15:33	617	43.6	393.7	317.6	270.1	201.5	148.8	80.5	32	18.4
0	13.2	12.5	15:33	853	60.28	486.4	392.7	335.7	252.1	189.1	104.9	43	26.4
0	13.8	11.8	15:39	419	29.62	303.4	242.4	205.5	151.4	110.1	57.1	19.6	14.1
0	13.8	11.8	15:39	613	43.33	388.6	313.9	268	200.5	149.1	80.5	29.5	19.3
0	13.8	11.8	15:39	856	60.47	481	389.7	334	252.5	191.9	106	42.5	26
40	12.6	12	15:40	421	29.78	354.9	262.6	210.1	136	90.4	40.6	11.8	8
40	12.6	12	15:40	624	44.13	445.8	335.3	271.2	180.8	123.8	59.4	19.2	12.5
40	12.6	12	15:40	882	62.31	542.2	410.8	334.8	227	159.1	80.6	27.5	17.5
80	12	12.1	15:41	423	29.9	305.5	226.5	183.6	124.1	85.1	37.3	8.9	5.4
80	12	12.1	15:41	618	43.71	384.3	288.8	236.4	163.6	114.5	52.9	14.4	8.4
80	12	12.1	15:41	871	61.55	470	352.5	290.2	203	144.4	69.1	20.4	11.5
120	12.6	11.6	15:42	420	29.71	247	194.8	163.6	116.9	81.3	39.5	12.8	10.2
120	12.6	11.6	15:42	623	44	319.7	253.6	214.1	155.9	111.4	56.5	19.7	13
120	12.6	11.6	15:42	869	61.41	395.4	313.6	266.3	196.5	143.2	75.5	27.6	19.4
160	13	11.9	15:43	419	29.62	266.3	206	164.6	109.7	71.4	28	8	2.4
160	13	11.9	15:43	620	43.81	339.6	264.8	215.5	147.7	100.2	44.1	12.5	5.7
160	13	11.9	15:43	883	62.4	421.3	329.9	271.5	189.9	132.9	63.5	22.5	8
200	11.4	11.7	15:45	433	30.59	79.5	60.6	51.4	38.4	30	18.6	9.5	6.2
200	11.4	11.7	15:45	643	45.42	113.3	85.2	72.6	55.4	43.9	27.7	14.4	9.4
200	11.4	11.7	15:45	907	64.1	149	113.6	97.2	75.1	60.1	39.1	19.7	13.2
240	12.6	10.5	15:46	417	29.48	302.8	229.9	192.9	135.2	88	41.7	17.2	11.3
240	12.6	10.5	15:46	624	44.11	393.6	302.9	254.7	183.2	123.3	62.7	28.1	15.8
240	12.6	10.5	15:46	875	61.81	488.3	378.5	319.1	232.7	162.2	87.2	42.7	28.1
290	13	11	15:48	428	30.25	95.4	62.5	50.5	35.3	25.2	13.8	4.8	5.7
290	13	11	15:48	645	45.56	132.5	88.5	73.1	51	38.6	21.9	10.6	6.3
290	13	11	15:48	909	64.22	176.6	118.3	98.3	71.2	53.7	32.1	14.8	8.9
320	13	10.6	15:49	429	30.35	124.4	85.5	63.2	41	30.3	19.6	11.2	9
320	13	10.6	15:49	651	46.02	171.3	119.5	90.9	60.9	45.4	30	16.7	11.4
320	13	10.6	15:49	908	64.17	221.1	156.5	120.9	83.7	63.1	42.1	23.7	18.5
360	13.1	10.1	15:50	424	29.97	74.8	58.6	47.2	33	24.6	15.7	8.7	7.7
360	13.1	10.1	15:50	642	45.38	108.8	86.4	70.5	49.8	37.7	24.5	14.5	9.9
360	13.1	10.1	15:50	907	64.11	149.9	118.3	97.2	70.3	53	34.6	19.5	13.5
400	12.8	11	15:51	423	29.9	144.3	93.7	69.4	43.7	30.5	18.4	10.4	9.3
400	12.8	11	15:51	640	45.2	198.4	131.6	99.4	64.3	45.6	27.7	16.7	13.8
400	12.8	11	15:51	899	63.51	257.4	173.6	132.6	87.4	63.2	39.1	22.6	17.8
440	12.7	10.3	15:52	417	29.5	352.2	270.2	213.7	145.9	101.1	58.6	28.3	20
440	12.7	10.3	15:52	623	44.02	463.5	364.1	293.9	207.9	150.7	90.4	45.1	30.5
440	12.7	10.3	15:52	875	61.84	582.2	464.1	379.8	276.1	206.2	127.9	63.4	44.6
480	12.6	11.3	15:53	436	30.78	205.2	142.1	103.7	60.5	35.6	15.2	6.4	3.8
480	12.6	11.3	15:53	651	46.02	266.1	189.3	142	85.5	53.5	24	9.3	6.5
480	12.6	11.3	15:53	918	64.85	330.7	237.3	180.7	112.1	72.8	34.9	13.9	10.1
520	12	11.6	15:54	429	30.31	160.9	122.4	98	68.2	49.6	31	13.7	9.5
520	12	11.6	15:54	638	45.1	220.7	170.3	138.7	99.3	73.8	48	18.4	14.7
520	12	11.6	15:54	893	63.09	290.3	224.4	184.6	135.6	102.6	68.5	29.6	19.9
560	12.6	11.2	15:55	446	31.51	130.7	87.3	65	39	24	12.5	4.1	3.3
560	12.6	11.2	15:55	656	46.37	176.5	120.9	92.4	57.2	37.1	20.4	10.4	6.9
560	12.6	11.2	15:55	911	64.42	232.8	160.9	124.9	79.6	52.9	29.5	13.5	8.8
600	12	11	15:56	442	31.23	54.8	40.7	34.3	28	19.9	13.8	8.6	4.9
600	12	11	15:56	645	45.58	77.2	59.3	51.4	41.4	32.4	21.9	13.4	9.3
600	12	11	15:56	904	63.9	107.5	83	72.7	58.6	47.1	31.4	18.7	13.6
640	12.6	10.1	16:05	429	30.29	323.9	236.8	184.8	116.1	75.5	35.4	17.6	6.6
640	12.6	10.1	16:05	628	44.36	424.1	317.5	252.9	165.9	111.7	55	28.8	10.4
640	12.6	10.1	16:05	884	62.47	537.7	408.7	329.9	222.3	153.9	79.4	38	23.5
680	12.7	9.8	16:06	423	29.89	276.6	208.9	166.5	108.4	73.2	38.7	18.8	14.4
680	12.7	9.8	16:06	631	44.6	364.1	281.7	227.2	154.8	108.6	60	29	21.6
680	12.7	9.8	16:06	885	62.52	463.5	361.2	295.3	207	149.7	86.2	40.2	30.2
720	12.8	9.1	16:07	421	29.72	234.3	183.6	156.4	115.7	86.4	48.6	20.8	16.5
720	12.8	9.1	16:07	620	43.79	309.8	252.6	217.1	164	124.5	73.6	31.9	22.6
720	12.8	9.1	16:07	878	62.03	403.6	329.5	284.7	218.3	169.2	103.8	46.3	31.4
760	13	9.3	16:08	405	28.59	335.9	270.4	212.6	146.8	102.6	56.3	24.9	17.2
760	13	9.3	16:08	596	42.13	456.4	376.1	304.5	216	157.5	88.3	38.5	26.6
760	13	9.3	16:08	843	59.59	600	498.7	410.7	298.7	222.3	129.4	56.5	38.7

Table B.8: FWD Data SR 53 South, Lake County, PM 6.97–PM 6.5

Station (m)	T Surface (C)	T Air (C)	Time	Stress (kPa)	Force (kN)	D1 (μ)	D2 (μ)	D3 (μ)	D4 (μ)	D5 (μ)	D6 (μ)	D7 (μ)	D8 (μ)
740	11.5	9.7	16:13	419	29.64	352.8	262.7	207.3	138.9	97.4	49	20.1	14.7
740	11.5	9.7	16:13	611	43.21	463.4	357.2	287.1	199.7	142.3	74.7	30.6	21.9
740	11.5	9.7	16:13	857	60.54	585	456.6	373.9	266.3	194.1	104.1	45.2	31.3
700	12	10.2	16:14	408	28.83	316.5	241.6	194.9	135.7	92.6	44.9	19.8	17.5
700	12	10.2	16:14	619	43.75	436.8	339.6	278.2	199	139.9	71.8	32.5	28
700	12	10.2	16:14	858	60.63	550.1	432	357	260.4	187.5	100.5	47.4	39.6
660	12.6	9.7	16:18	409	28.88	324	235.2	185	121.5	84.1	38.8	14.1	12.1
660	12.6	9.7	16:18	600	42.43	439.9	324.8	259.6	174.5	122.5	58.7	23.8	18.3
660	12.6	9.7	16:18	839	59.33	568.3	425.4	344.6	235.7	167.5	83.5	34.5	25.7
620	11.4	9.9	16:19	426	30.11	88.1	59.8	48.7	34.9	26.3	15	6.1	4
620	11.4	9.9	16:19	623	44.02	121.5	87	71.5	52	39.9	23.8	9	6.9
620	11.4	9.9	16:19	875	61.87	168.3	121.4	100.8	74.5	57.6	35.3	13.8	7.6
580	10.9	9.5	16:20	407	28.73	322.3	238.1	185.9	116.7	74.7	30.2	8.9	6.7
580	10.9	9.5	16:20	604	42.66	422.7	322.5	255.5	166.8	109.9	46.4	13.3	9.3
580	10.9	9.5	16:20	850	60.1	530.9	410.2	329.9	221.7	150.3	67.4	20.6	13.7
540	10.8	9.6	16:21	417	29.5	245.9	190.7	144.6	90	56.7	21.3	8.1	3.8
540	10.8	9.6	16:21	618	43.71	328.5	259.1	201.2	128.8	84	33.8	8	11.5
540	10.8	9.6	16:21	867	61.27	423.3	337.1	265.2	173.7	116.9	49.9	15.4	15.1
500	10.8	9.7	16:22	406	28.72	297.2	221.6	175.3	108	66.2	23.3	7.7	4.5
500	10.8	9.7	16:22	607	42.89	384.4	293.1	237.2	150.3	95.9	36.5	9.6	7.6
500	10.8	9.7	16:22	855	60.4	478.6	367.8	300.7	195.9	128.1	53.8	16.3	10.3
460	11.4	9.8	16:23	404	28.56	329.2	246.9	194.6	123.6	77.8	30.2	14	10.6
460	11.4	9.8	16:23	602	42.54	425	327	263.1	172.2	112.2	47.9	20.4	17.7
460	11.4	9.8	16:23	847	59.86	526.1	408.5	332.1	223	149.4	68.1	32.3	24.8
420	11.3	10	16:24	423	29.89	214.4	144.9	110.5	73.9	50.4	29.2	14.1	7
420	11.3	10	16:24	622	43.95	282.4	195.4	152	104.9	73.2	43.4	23.1	18.7
420	11.3	10	16:24	879	62.13	363.4	255.1	201.6	142.2	101.1	61.2	32	26.4
380	11.5	9.7	16:25	427	30.17	167.3	127.4	95.4	48.2	31.5	17.5	8.1	6.9
380	11.5	9.7	16:25	637	45.05	220.5	172.1	130.5	71.1	46.6	24.8	12.1	11.5
380	11.5	9.7	16:25	901	63.67	285.1	224.1	170.7	97.4	65.2	36.5	20.7	15.3
340	11.4	10	16:26	422	29.85	198.6	136.7	101.4	62.3	38	17.2	10.9	3.1
340	11.4	10	16:26	630	44.5	258.8	183.7	140.2	87.4	55.5	26.2	14.1	12.6
340	11.4	10	16:26	892	63.02	328.6	235.8	182.6	116.4	75.6	37.3	19.1	17.4
300	10.8	9.7	16:27	403	28.47	270.4	208	170.5	114.7	73.5	29.5	10.1	6
300	10.8	9.7	16:27	603	42.59	362	282.2	235.2	162.7	107.5	46.2	14	10.1
300	10.8	9.7	16:27	844	59.66	452.6	355.9	299.2	210.9	142.3	64.3	21.2	14.7
260	10.8	9.6	16:28	404	28.52	305.9	223.5	179.9	119.7	77	27.4	5.3	5.3
260	10.8	9.6	16:28	597	42.16	392.6	295.1	240.7	164.4	108.3	41.7	10.7	9.1
260	10.8	9.6	16:28	845	59.73	490.7	372.5	306.7	212.7	142.9	58.6	15.9	12.7
220	10.8	9.7	16:29	397	28.08	291.6	225.7	184.5	126.1	88.8	44.9	21.1	10.9
220	10.8	9.7	16:29	586	41.39	390.4	308.9	256.5	180.2	129.4	68.3	30.1	20.5
220	10.8	9.7	16:29	830	58.69	496.2	395.2	331.5	237.5	173.9	95.2	42.7	31.7
180	10.8	9.7	16:30	409	28.91	290.7	210.6	170.3	109	70.3	29.6	6.9	5.2
180	10.8	9.7	16:30	612	43.28	371.8	276.7	226.4	149.4	99.6	44.1	11.3	9.9
180	10.8	9.7	16:30	868	61.38	458.4	343.7	283.1	190.4	130.1	60.4	16.5	13.1
140	10.1	10	16:31	393	27.8	411.6	311.2	251.7	172.5	113.8	44.4	6.9	6.2
140	10.1	10	16:31	579	40.91	521.4	404	330.9	231.7	156.2	64.1	11.6	8.9
140	10.1	10	16:31	813	57.47	641.3	500.1	414	293.8	203.1	89.2	16.3	13.3
100	10.8	9.6	16:33	415	29.33	338.9	227.3	166.2	101.2	61.8	22.9	3.4	0.2
100	10.8	9.6	16:33	623	44.06	438.3	300.9	224.3	139.3	86.2	32.1	4.1	2.7
100	10.8	9.6	16:33	880	62.17	537.8	375.9	282.5	178.5	110.9	42.7	6.8	3.8
60	10.8	9.5	16:34	405	28.61	332.6	225.3	168.5	100.2	60.9	18.5	0.1	0.1
60	10.8	9.5	16:34	598	42.26	434.5	303.4	232.7	142	88.4	28.1	1	2.2
60	10.8	9.5	16:34	845	59.69	544.2	384.9	299.3	186	118.9	39.7	2.9	2.5
20	11	10.1	16:35	395	27.91	374.1	293.4	240.4	172.3	124	66.5	22.6	13.9
20	11	10.1	16:35	587	41.46	488.6	391.4	325.7	238.1	175.8	96.6	37.5	22.7
20	11	10.1	16:35	828	58.49	610.2	493.9	414.6	307.7	231.9	131.6	51.7	32.9