Partnered Pavement Research Center

Update for DME Meeting

30 November, 2006

Caltrans

UC PRC
Pavement Research Center
UNIVERSITY OF CALIFORNIA • DAVIS • BERKELEY

Outline for today

- Contract status
- Current Strategic Plan
- Status
  - Recently completed projects
  - Projects nearing completion
  - Projects underway and monitoring
- Detailed results from a few selected projects
- New projects – strategic plan status and discussion

Contract status

- Contract:
  - Partnered Pavement Research Center
  - Managed by Division of Research and Innovation
  - Technical Advisory Panel: Pavement Standard Team
- Contract period: July 2004 – June 2008
- $ 5 million per year
- Perform research following Strategic Plan
  - Operate two Heavy Vehicle Simulators
  - Laboratory work
  - Analysis
  - Field work

Current Strategic Plan

- Updated two years ago
- Projects support:
  - Pavement Program Steering Committee objectives
  - Program Level Action Plan (PLAP)
- Currently nearing completion on most projects in the plan
- Take a look at the strategic plan summary list
  - Each item has a PST technical lead, DRI Pavement Research Group technical contact, UCPRC lead
  - Quarterly updates to PST

PPSC Objectives and Pavement Research Road Map

PPSC Objectives

1. Pavement Management System
2. Smoothness
3. Preservation
4. Quiet Pavements
5. Construction Practices
6. Mechanistic-Empirical
7. Long Life Pavements
8. Recycling

Take a look at the Pavement Research Road Map

DRI handout version of Pavement Research Road Map

- Same information as in the big sheet
- All current projects are listed under each PPSC objective in the Road Map

Recently Completed Projects

- (3.2.4) Development of Integrated Databases to Make Pavement Preservation Decisions
- (3.2.9) Development of Guidelines for Effective Maint. Treatment Evaluation Test Sections
- (3.2.12) PG Binder Specification development and training
- (4.2) Evaluation of Rigid Pavement Long-Life Rehabilitation Strategies (LLPRS-Rigid
- (4.5) Calibration of PMS Performance Models
- (4.7) Verification of Asphalt Concrete Long-Life Pavement Strategies
- (4.9) Investigation of Asphalt Concrete Moisture Damage

Development of Integrated Databases to Make Pavement Preservation Decisions

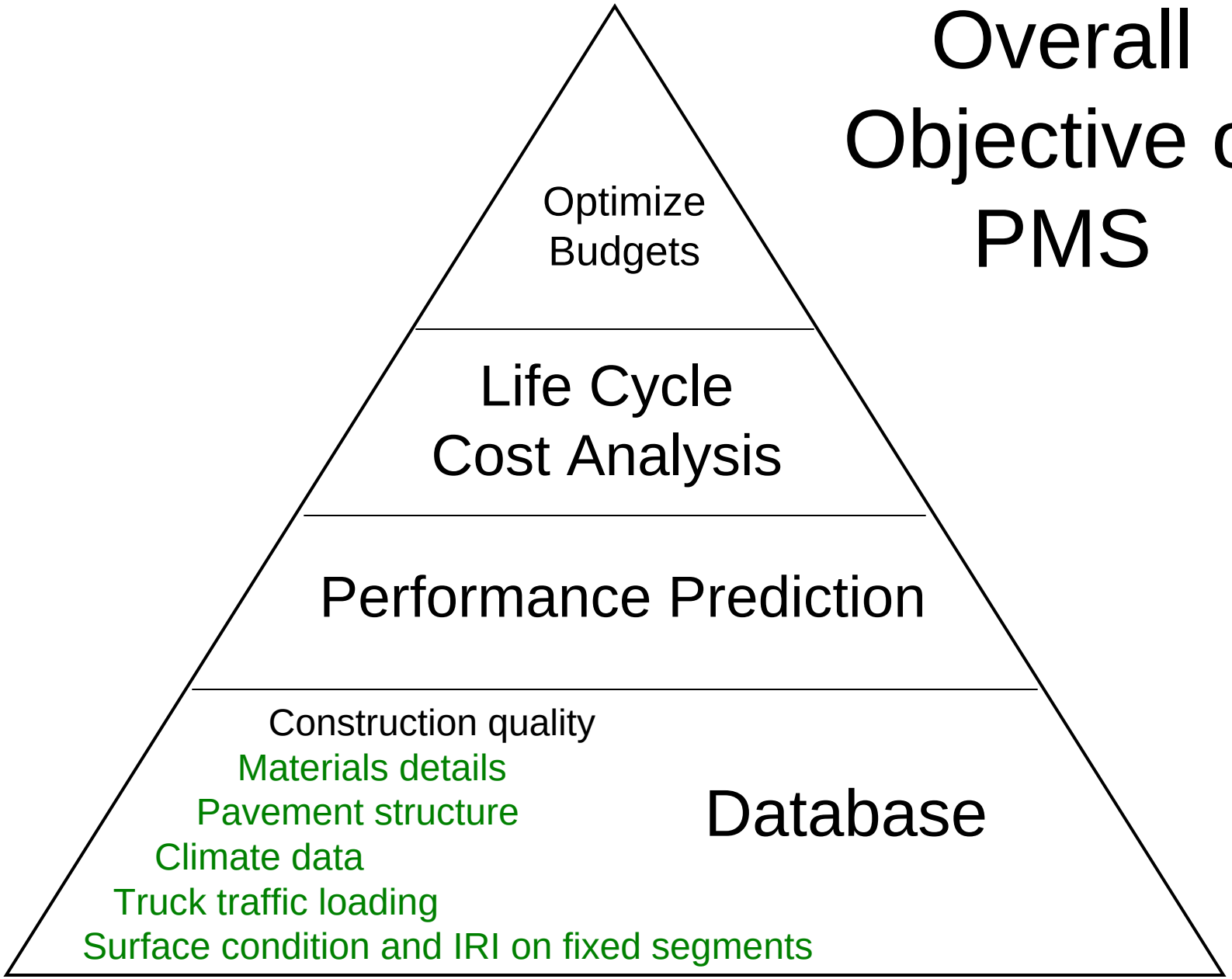
PPRC Strategic Plan Element 3.2.4

supports PPSC PMS objective

Objectives

- Develop recommendations for PMS database
- Develop additional empirical performance models beyond those of PPRC SPE 4.5
- Perform pilot project for network segmentation and PMS database development
  - Study a small sample of Caltrans pavement network to determine the feasibility of expanding approach to the entire network
  - Included evaluation of Ground Penetrating Radar to check underlying pavement structure for network segmentation

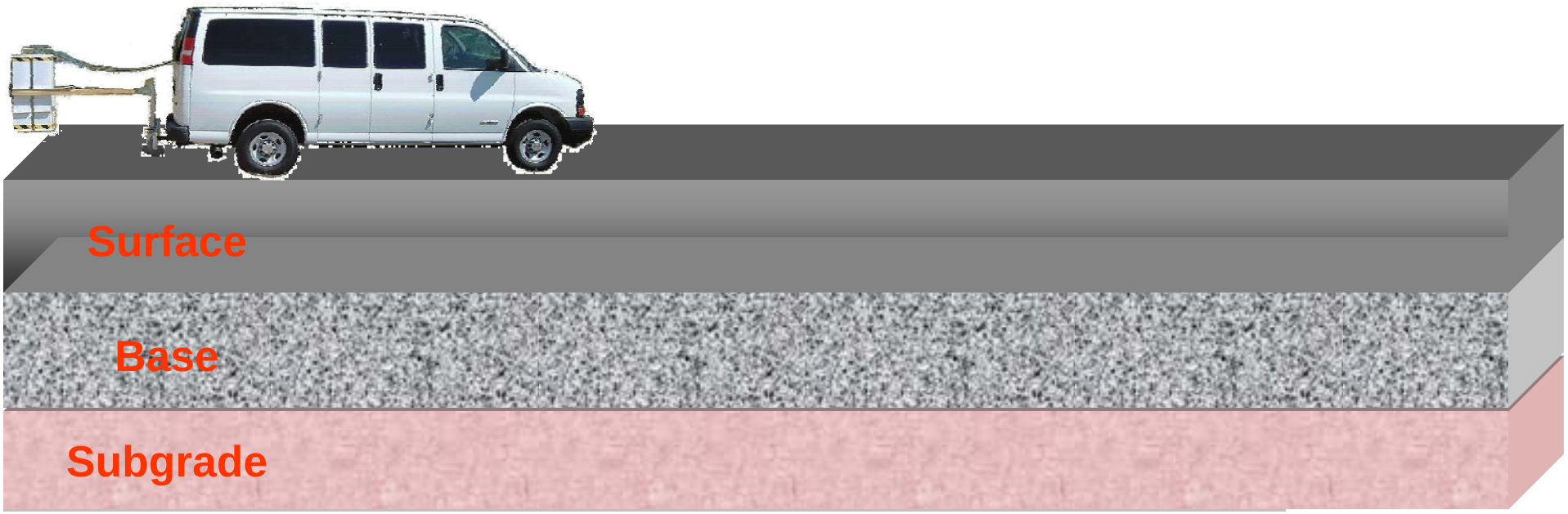
Overall Objective of PMS



Performance modeling

- Optimize M&R by predicting future pavement condition
- Current challenges to pavement performance modeling
  a) *dynamic segmentation*
  b) *database lacks subsurface pavement structure data*
  c) *quantification (severity and/or extent) for some pavement distresses*

GPR Technology



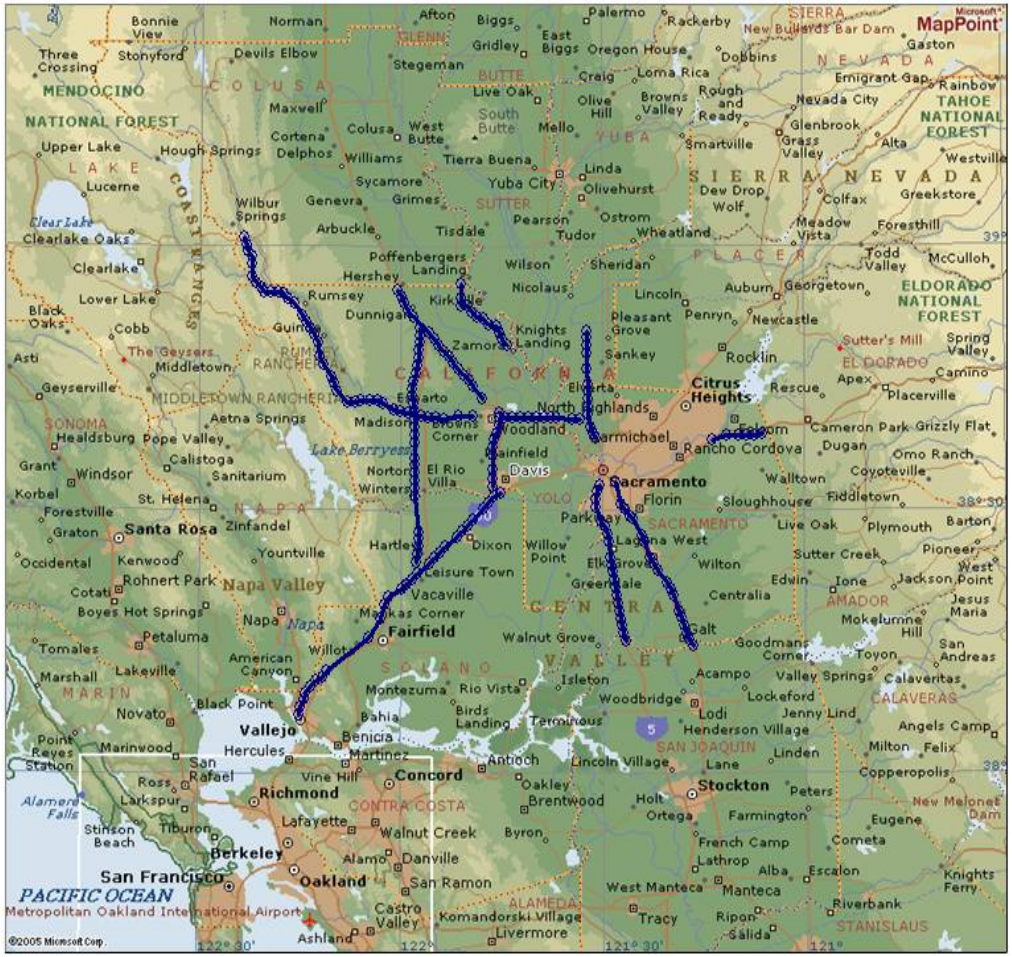
Draft segmentation

Small network to evaluate:

1. Use of GPR for thickness and materials
2. Feasibility of establishing static, well-defined (fixed) network segments
3. costs of collecting data and performing the segmentation (and extrapolation)

Pilot network

305 lane-miles



8 Roadways:

I-5,I-80,I-505,
SR-16, SR-45, SR-99, SR-113,
US-50

2 Districts:

D3, D4

5 Counties:

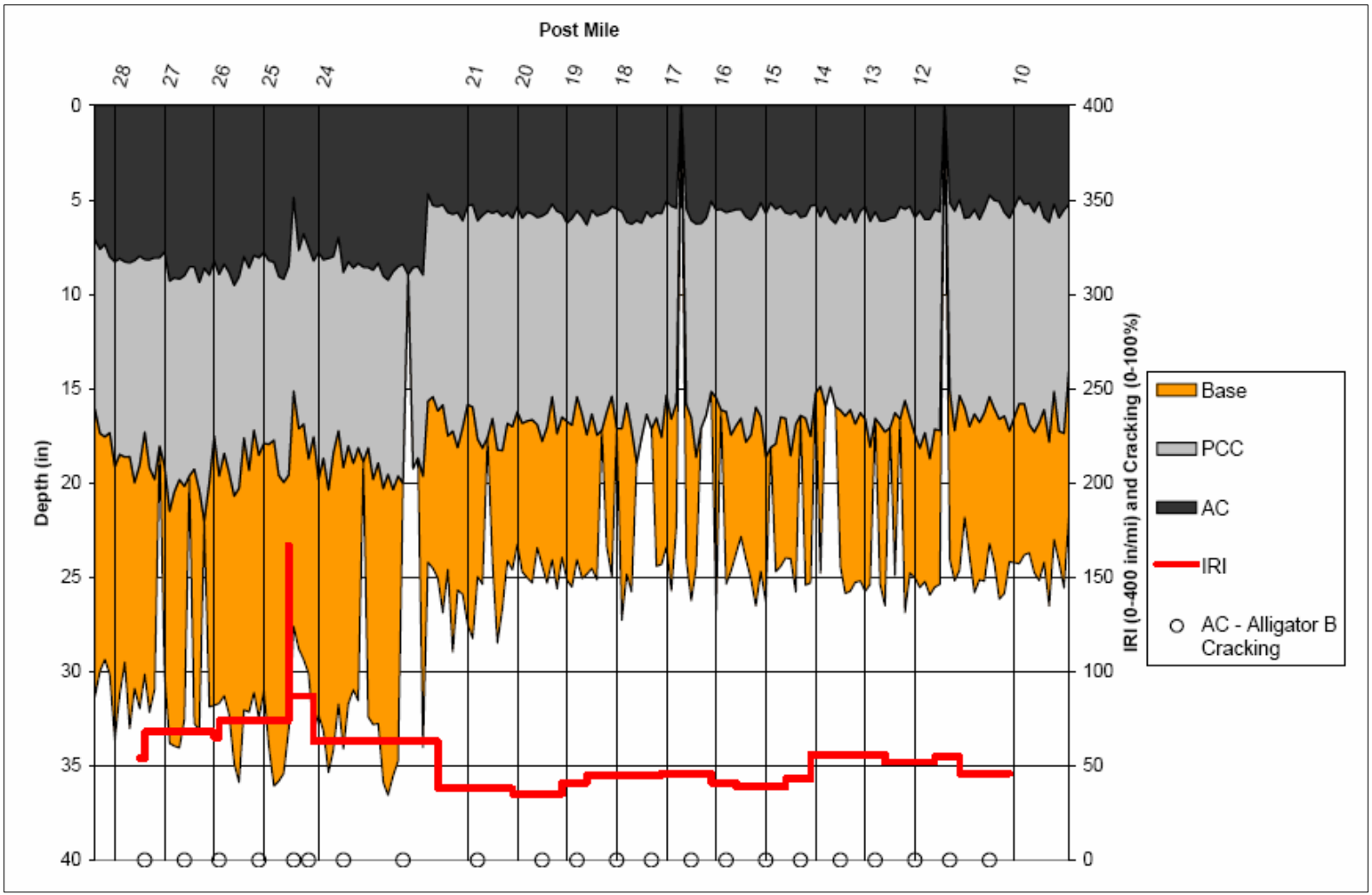
Sacramento, Sutter, Colusa,
Solano, Yolo

Segmentation process

Dividing the network into homogeneous segments, based on:

1. Administrative boundaries
2. Traffic load
3. Pavement structure
4. Climate
5. Pavement condition

Pavement structure from GPR



Utilization of Coring Data

- Total of 43 cores from 13 sites
- Cores from 7 sites were given to GPR contractor for verification/calibration
- They were used to correct pcc thickness (12% reduction) in two sites

- GPR technology <u>is effective</u> for determining layer thicknesses <u>for all layers</u>

Conclusions and Recommendations

Conclusions

1. Fixed segments would allow for the development of performance models
2. → administrative boundaries → traffic load → pavement structure → climate region → pavement condition (if needed)
3. Whole network: $7 million of contracted field work, plus 12.3 PY.
4. GPR has been found to be reliable (by Caltrans and by other DOTs)
5. GPR testing (& limited coring and DCP) seems feasible option to populate inventory database

Recommendations

1. A condition survey for PMS purposes needs to be implemented
   - Minor changes to the current Pavement Condition Surveys, OR
   - parallel data collection for PMS
2. Segmentation can be staged (spread costs)
3. It will be important to keep database updated

Pavement preservation studies technical advisory guide PPSTAG

PPRC SPE 3.2.9

Supports PPSC Pavement Preservation objective

Objectives

- Improve the quality of data and analysis obtained from Pavement Preservation and Innovative Product Experiments in California
  - How to get scientifically based answers from field test sections
- Status: currently being reviewed by PST and FHWA task group
- Will likely be used on Pavement Preservation Task Group (PPTG), UCPRC and Chico State field projects

PPSTAG Guidelines Include

- Management and responsibilities
- Project fundamentals
- Experiment work plan
- Site selection
- Experiment construction
- Experiment monitoring
- Forensic investigations
- Laboratory testing
- Data analysis and reports
- Data management and documentation
- Example experiment work plans, checklists and forms

PG Binder Asphalt Specs

PPRC SPE 3.2.12
supports PPSC Construction Practices objective

- Assistance with development of PG binder grade map
  - Used LTPPBind v. 2.1 software to identify PG grades (98% reliability) for weather stations across state
  - Map also serves for Mechanistic-Empirical design climate regions
- Developed training material
- Performed training

Evaluation of Rigid Pavement Long-Life Pavement Rehabilitation Strategies (LLPRS-Rigid)

PPRC SPE 4.2

Supports PPSC Long-Life Pavement objective

Specific objectives

- Evaluate adequacy of structural design options
  - tied concrete shoulders, doweled joints, and widened truck lanes
  - primarily with respect to joint distress, fatigue cracking and corner cracking.
- Assess durability of concrete slabs made with cements for early opening to traffic,
- Measure effects of construction and mix design variables on durability and structural performance of pavements.

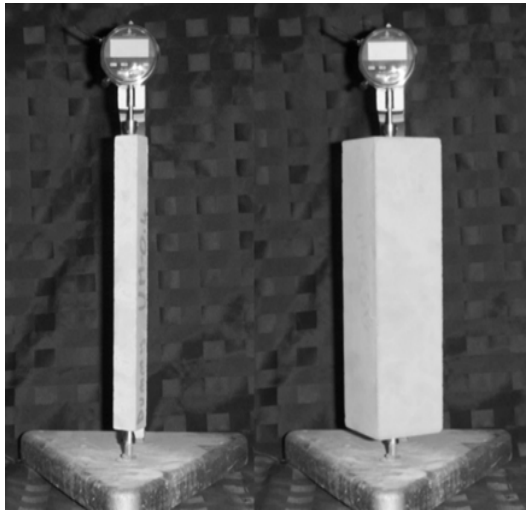
Status

- Various investigations between 1998 and 2005
- 19 reports written, plus a summary showing implementation

- DESKTOP STUDIES
  - Pavement Distress
  - Design Methods
  - Concrete Construction Productivity
- LABORATORY TESTING
  - Concrete Durability: ASR & Sulfate Attack
  - Strength, Stiffness, Thermal Expansion and Shrinkage of FSHCC
  - Flexural Fatigue
  - Base Carbonation
- HEAVY VEHICLE SIMULATOR TESTING
  - Pilot Study
  - Full-scale Experiments at Palmdale

List of reports

February, 2000	Investigation of Design and Construction Issues for Long Life Concrete Pavement Strategies
April 1999	CAL/APT Goal LLPRS – Rigid Phase III: Concrete Test Section 516CT Report
April 1999	Analysis of Durability of Advanced Cementitious Materials for Rigid Pavement Construction in California
December 1999	Shrinkage and Thermal Cracking of Fast Setting Hydraulic Cement Concrete Pavements in Palmdale, California
April 2000	Accelerated Test for Measuring Sulfate Resistance of Hydraulic Cements for Caltrans LLPRS Program
April 2000	Construction, Instrumentation, and Testing of Fast-Setting Hydraulic Cement Concrete in Palmdale, California
May 2000	Preliminary Evaluation of Proposed LLPRS Rigid Pavement Structures and Design Inputs
July 2001	Accelerated Laboratory Testing for High Early Strength Concrete for Alkali Aggregate Reaction
July 2002	HVS Test Results on Fast-Setting Hydraulic Cement Concrete Palmdale, California Test Sections, South Tangent
June 2003	Environmental Influences on the Curling of Concrete Slabs at the Palmdale HVS Test Site
February 2004	Goal 4 Long Life Pavement Rehabilitation Strategies—Rigid: Laboratory Strength, Shrinkage, and Thermal Expansion of Hydraulic Cement Concrete Mixes
May 2004	Analysis and Estimation of Effective Built-In Temperature Difference for North Tangent Slabs Data analysis from the Palmdale, California Rigid Pavement Test Site
May 2004	Palmdale South Tangent Slab Built-In Curling and Cracking: Preliminary Analysis Report
November 2004	Accelerated Laboratory Testing for Alkali-Silica Reaction Using ASTM 1293 and Comparison with ASTM 1260
May 2005	Characterization of Effective Built-in Curling and Concrete Pavement Cracking on the Palmdale Test Sections
August 2005	Summary Report of HVS Testing of the Palmdale Test Site, North Tangent Sections: Evaluation of Long Life Pavement Rehabilitation Strategies—Rigid
August, 2005	Goal 4 Long Life Pavement Rehabilitation Strategies—Rigid: Flexural Fatigue Life of Hydraulic Cement Concrete Beams
May 2003	Durability Testing of LCB and CTB Materials Supplied by Caltrans
March 2006	Summary Report on the Evaluation of Rigid Pavement Long-life Strategies



MTS

Calibration of Mechanistic-Empirical Models
(should be named
Calibration of PMS Performance Models)

PPRC SPE 4.5
supports PPSC PMS objective

Objectives

- Model for predicting the initiation of overlay cracking in asphalt concrete (AC) pavements
- Model for predicting the progression of roughness for AC pavements
- Model for predicting the initiation of cracking in Portland Cement Concrete (PCC) pavements
- Model for predicting the progression of roughness for Portland Cement Concrete pavements

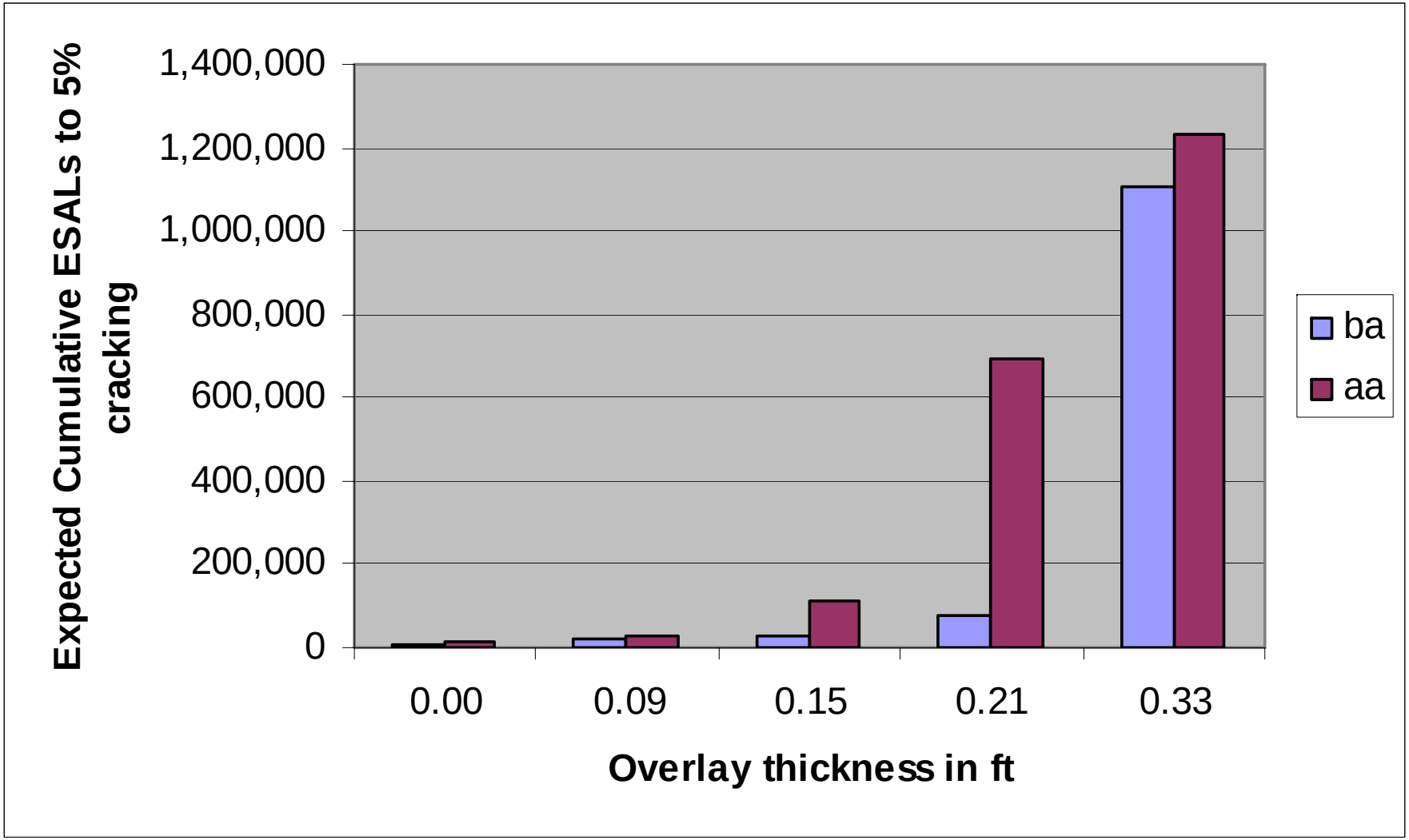
Tasks to Achieve Objectives

- Mine the WSDOT PMS databases
  - Pavement section structure
  - Traffic
  - Condition
  - Resurfacing activities
  - Climate data from CDIM program
- Select appropriate functional forms for the empirical models
- Calibrate parameters with statistical modeling tools
- Perform classical statistical tests on all models to confirm the statistical significance of the various parameters and of the models as a whole
- Predict performance using the various models to confirm that they produce realistic results

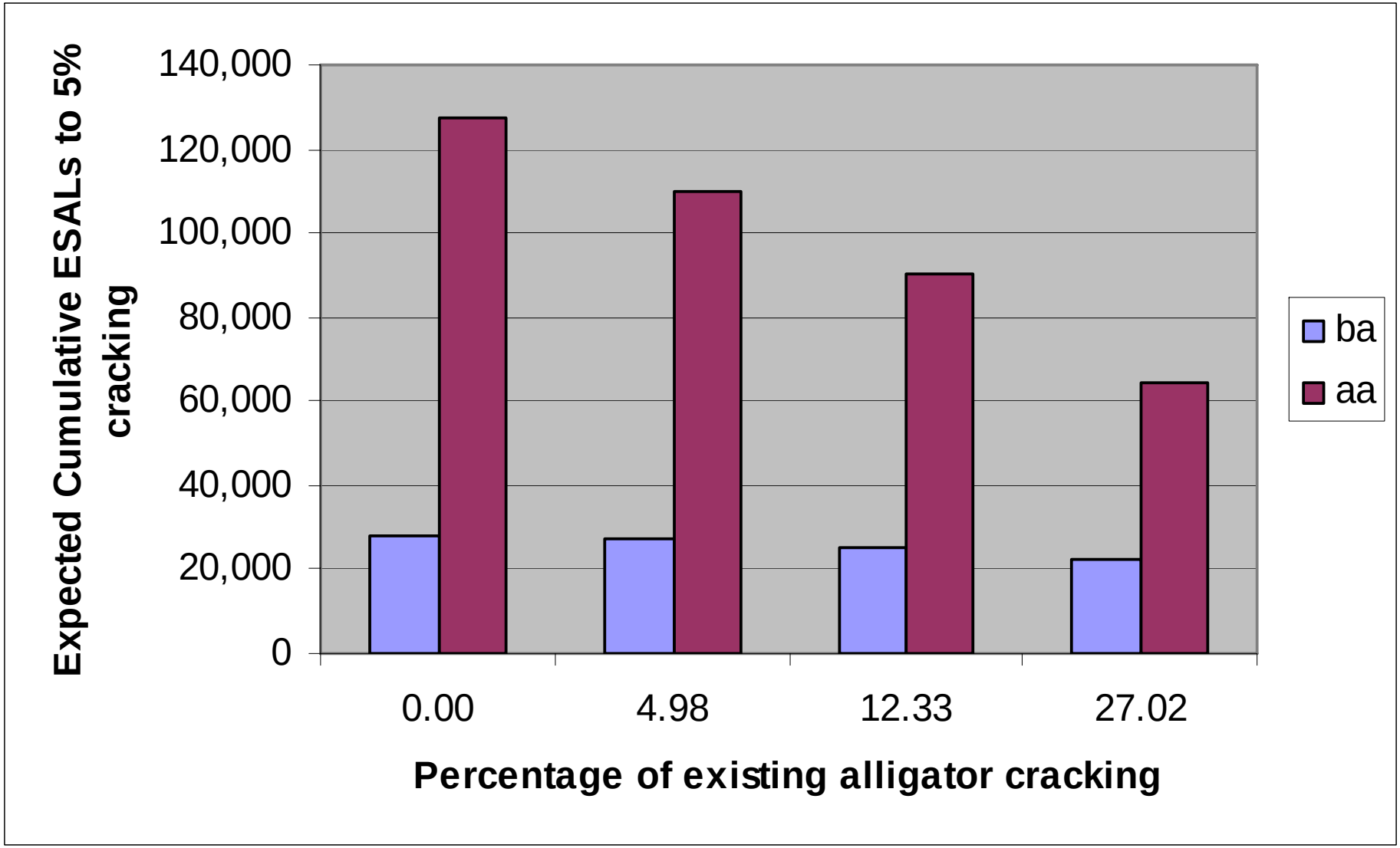
AC Overlay Crack Initiation Model

- Failure defined as 5 % of wheelpaths with alligator cracking (Type A or B)
- Duration/Hazard Rate model, not linear regression model
  - Same used for medical studies
  - Probability of how long you will survive, given you've survived this long as function of variables (Bayesian)
- Handled various types of censoring that can bias models using PMS data
- Accounted for correlation between ESALs and
  - overlay thickness design
  - two AC mix specs (aa and ba)

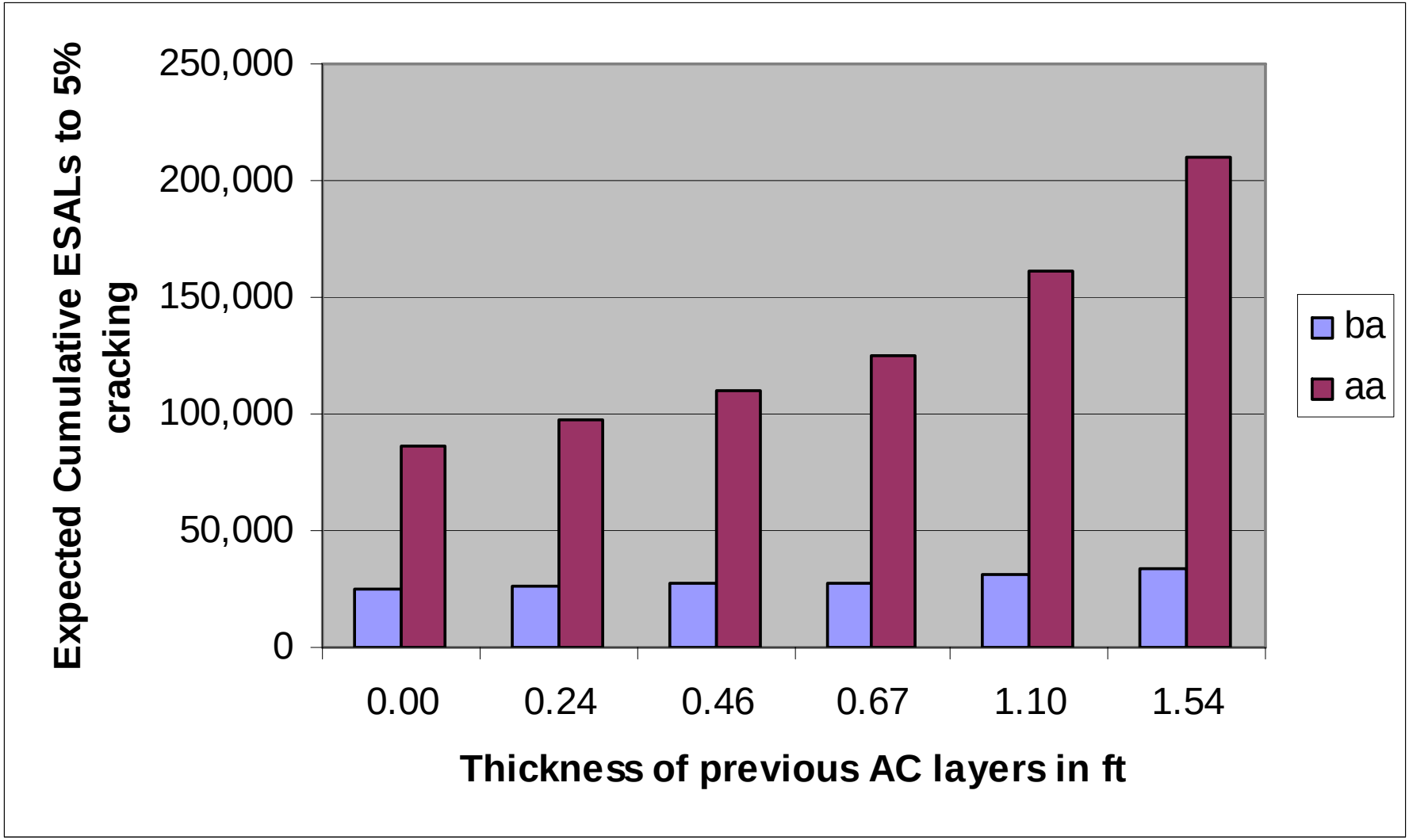
Effect of Overlay Thickness



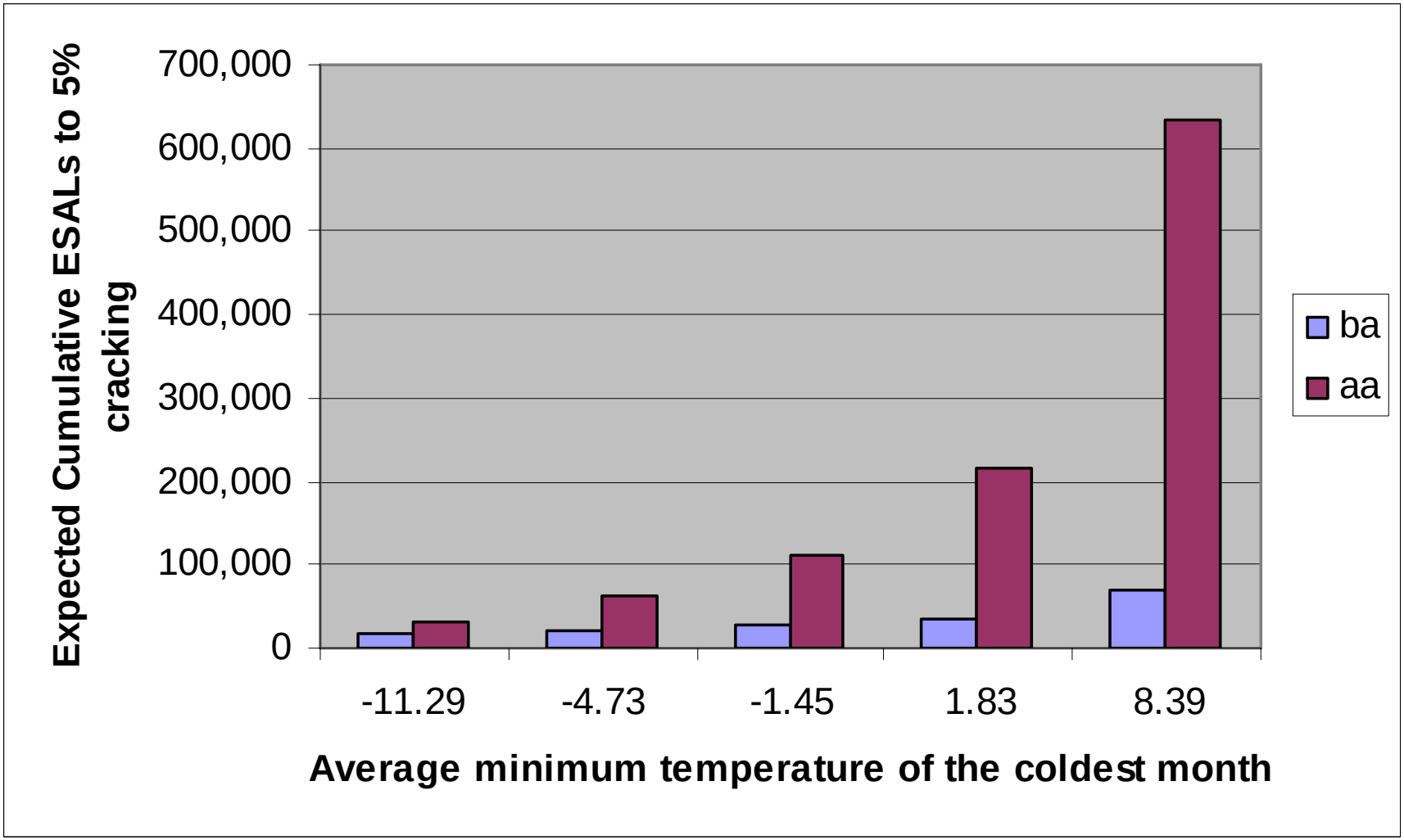
Effect of existing alligator cracking (Type B for CT)



Effect of existing AC thickness



Effect of cold temperatures



Verification of Asphalt Concrete Long-Life Pavement Strategies

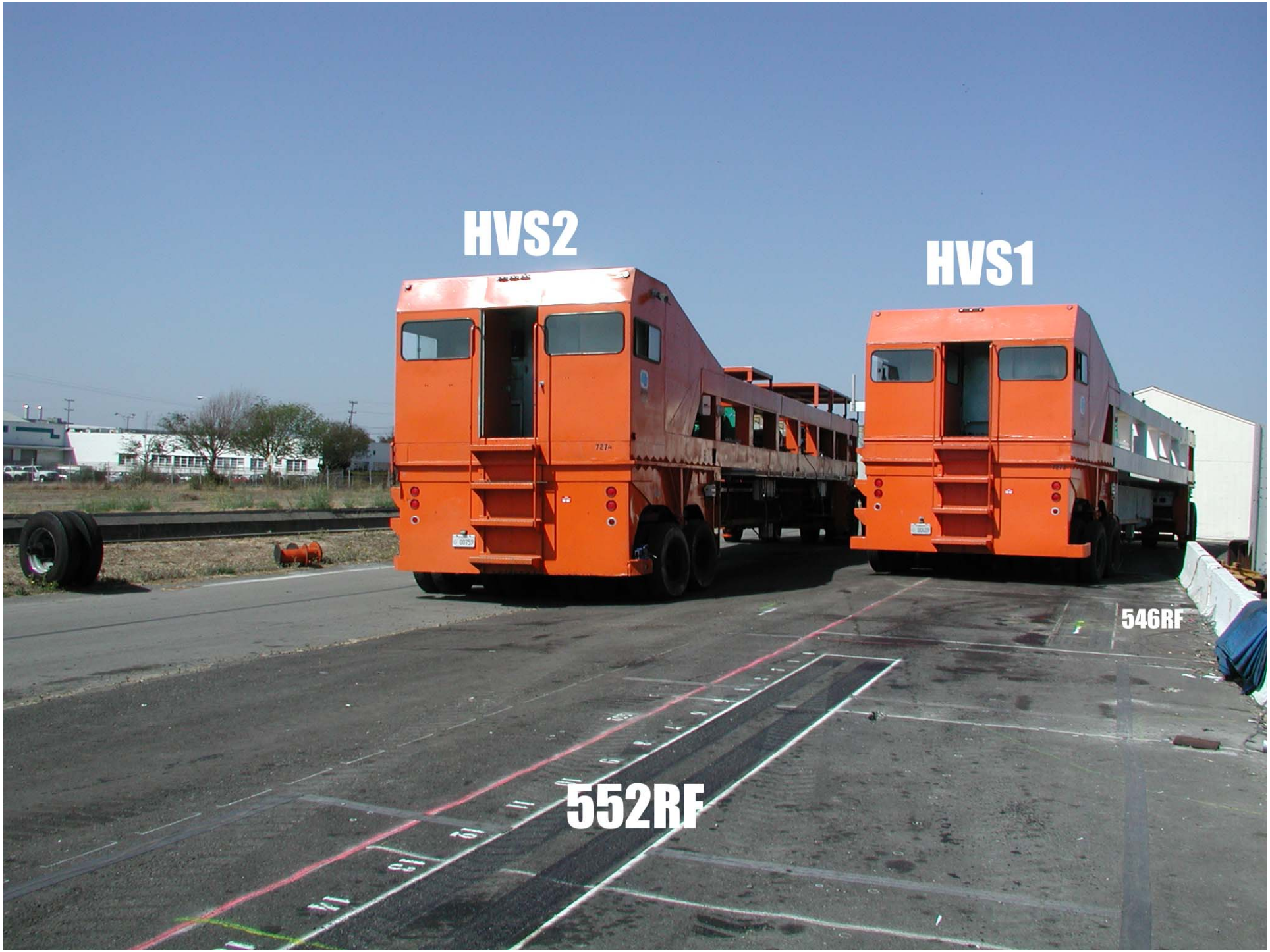
PPRC SPE 4.7

supports PPSC Long-Life Pavement objective

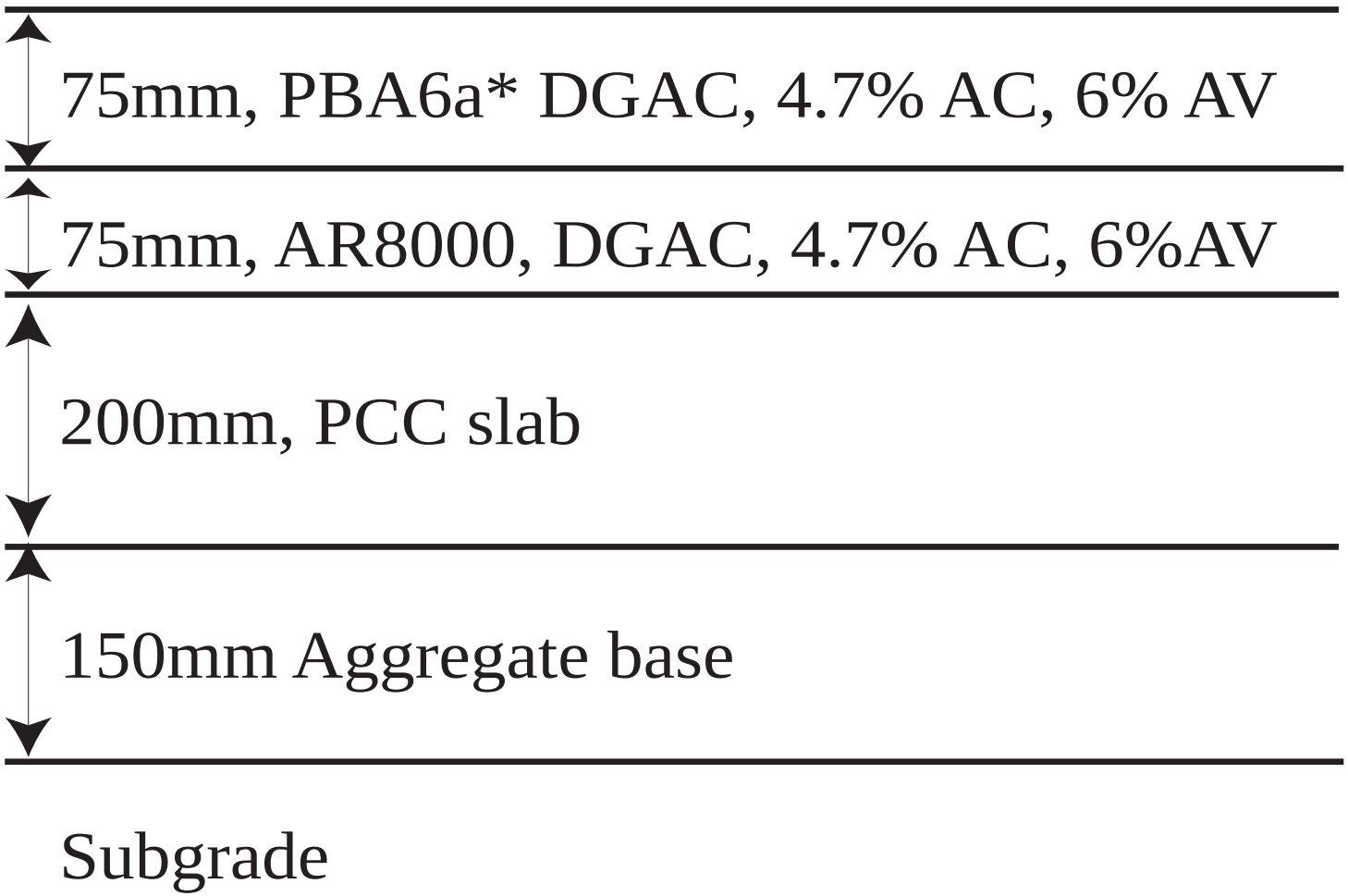
- Heavy Vehicle Simulator testing of scaled-down I-710 overlay on PCC pavement
  - Rutting tests at 55 C (128 F)
  - Reflection cracking tests at 20 C (67 F)
- Draft report delivery in December, 2006

Purpose of the Test Program

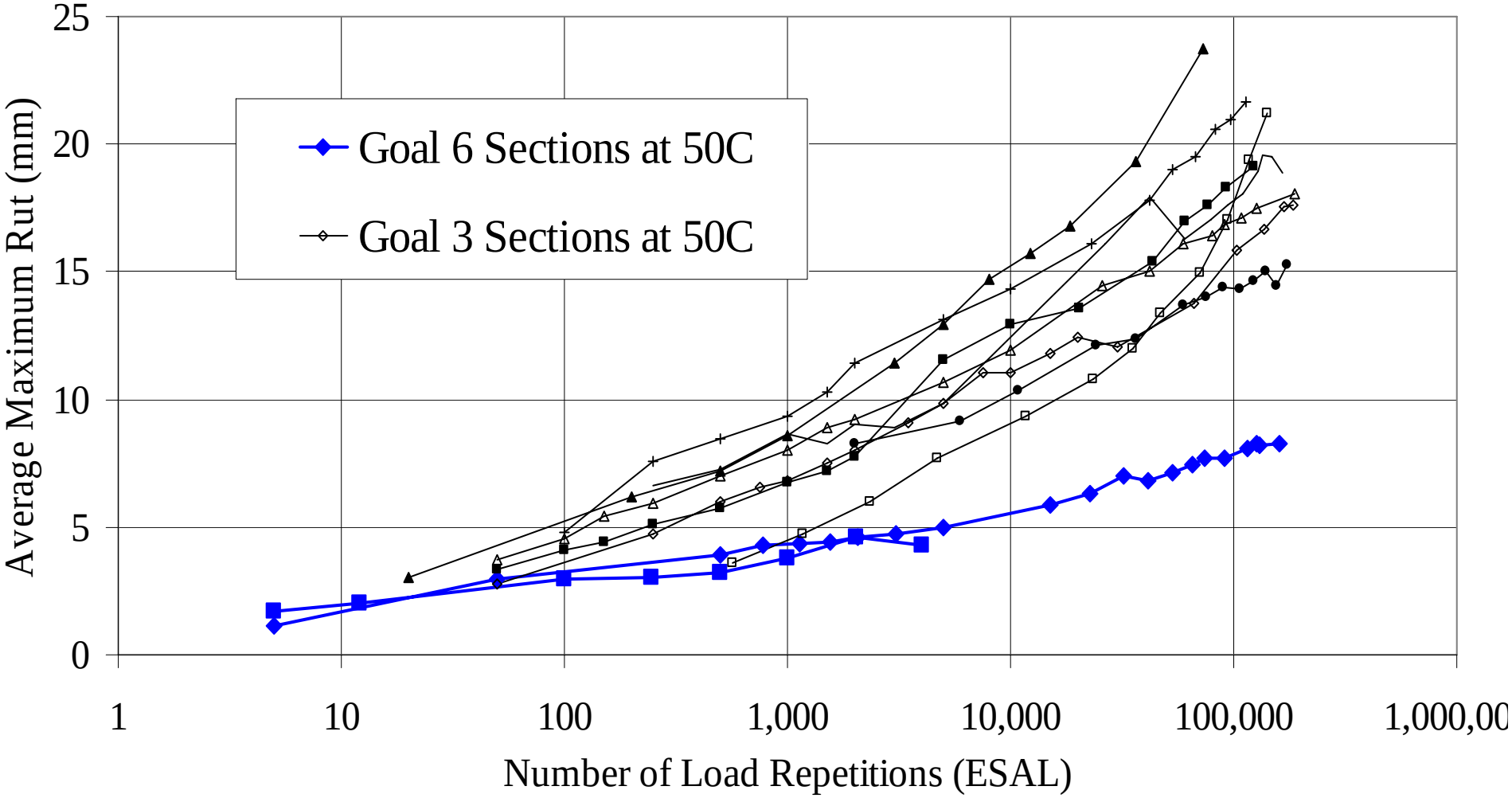
- To compare performance with other HVS tests
- To validate the asphalt concrete mix design provided for the overlay of I-710 in Long Beach
- To compare rutting performance between the AR-8000 and PBA-6a* asphalt concrete mixes.
- To provide data to validate mechanistic-empirical procedures for predicting mix rutting and reflection cracking.


HVS2
HVS1
546RF
552RF

Design Cross Section



Rutting Performance Comparison



A Simple Approach for Design against Reflective Cracking in AC Overlays

A Simple ME Approach for Reflective Cracking

- Initial conditions
  - Layer thickness and stiffness
  - Crack/joint geometry, opening and spacing
  - Crack resistance index of AC mix
  - Crack initiation time calculated with fatigue equation (continue on next slide)

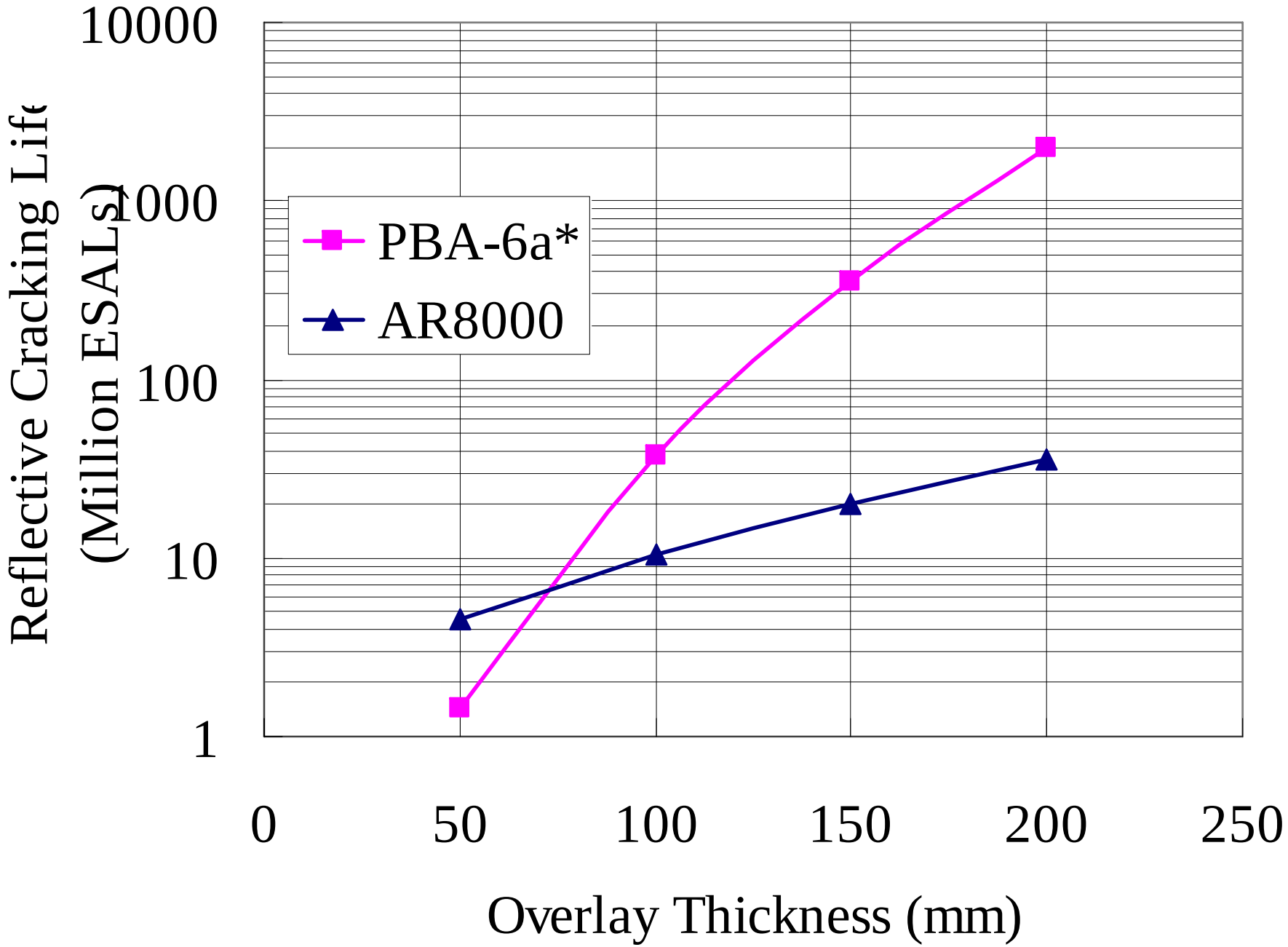
Simple ME Approach for Reflective Cracking

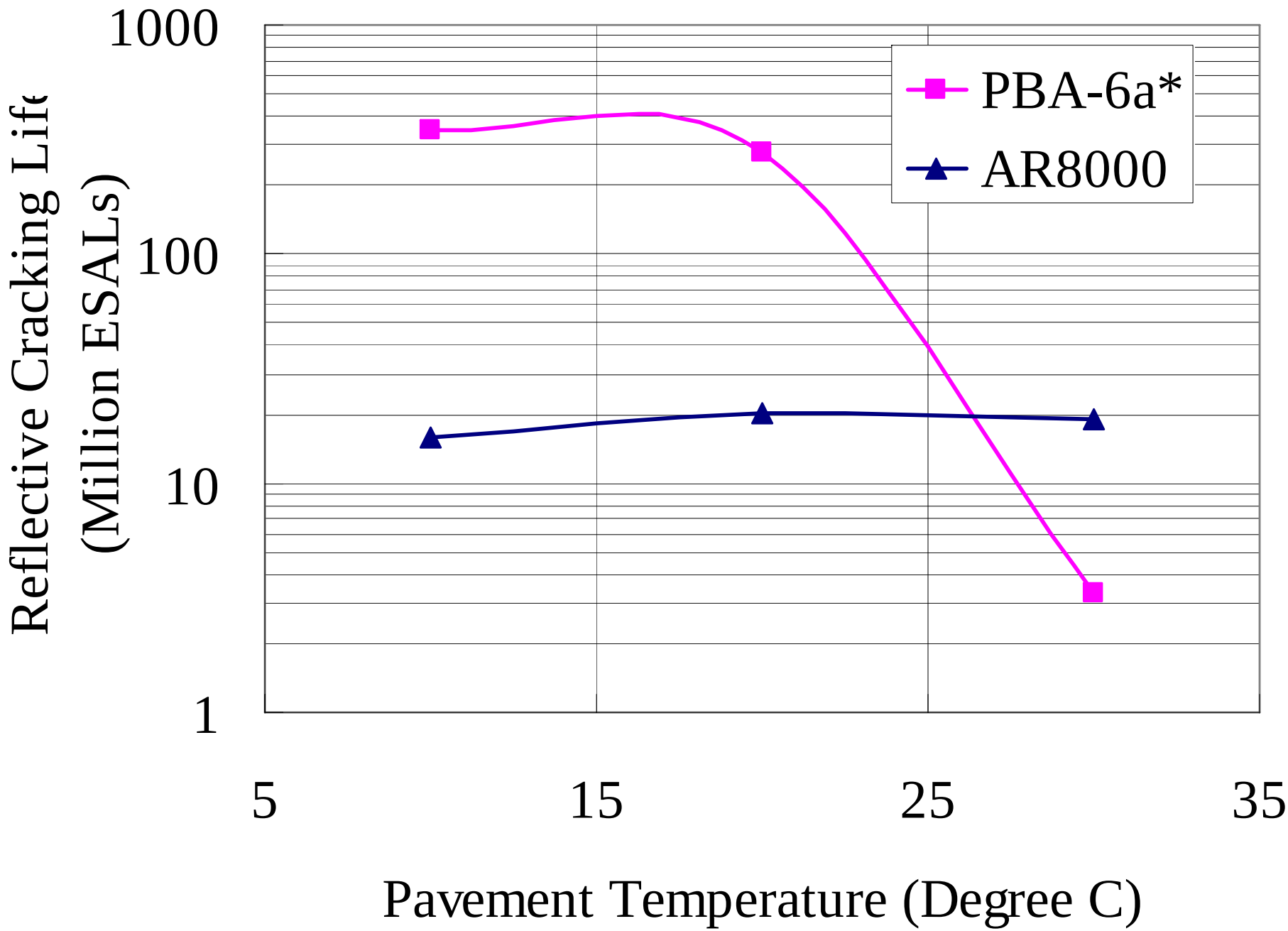
- Strain calculation
  - Averaged strain at crack/joint tip
  - Use empirical equations based on pre-run finite element analyses results
- Fatigue equation
  - Beam bending fatigue tests
  - Establish database for typical mixes

Some observations from sensitivity check of model

- Based on PBA-6a* and AR8000 overlay on PCC pavement
- Reflective cracking life increase exponentially with thickness of overlay
- Relative mix performance is temperature dependent
- Better compaction always helps

- Model of this type now in CalME, being validated with the HVS tests, field data


10000
1000
100
10
1
Reflective Cracking Life
(Million ESALs)
PBA-6a*
AR8000
0
50
100
150
200
250
Overlay Thickness (mm)


1000
100
10
1
Reflective Cracking Life
(Million ESALs)
PBA-6a*
AR8000
5
15
25
35
Pavement Temperature (Degree C)

Investigation of Asphalt Concrete Moisture Damage

PPRC SPE 4.9

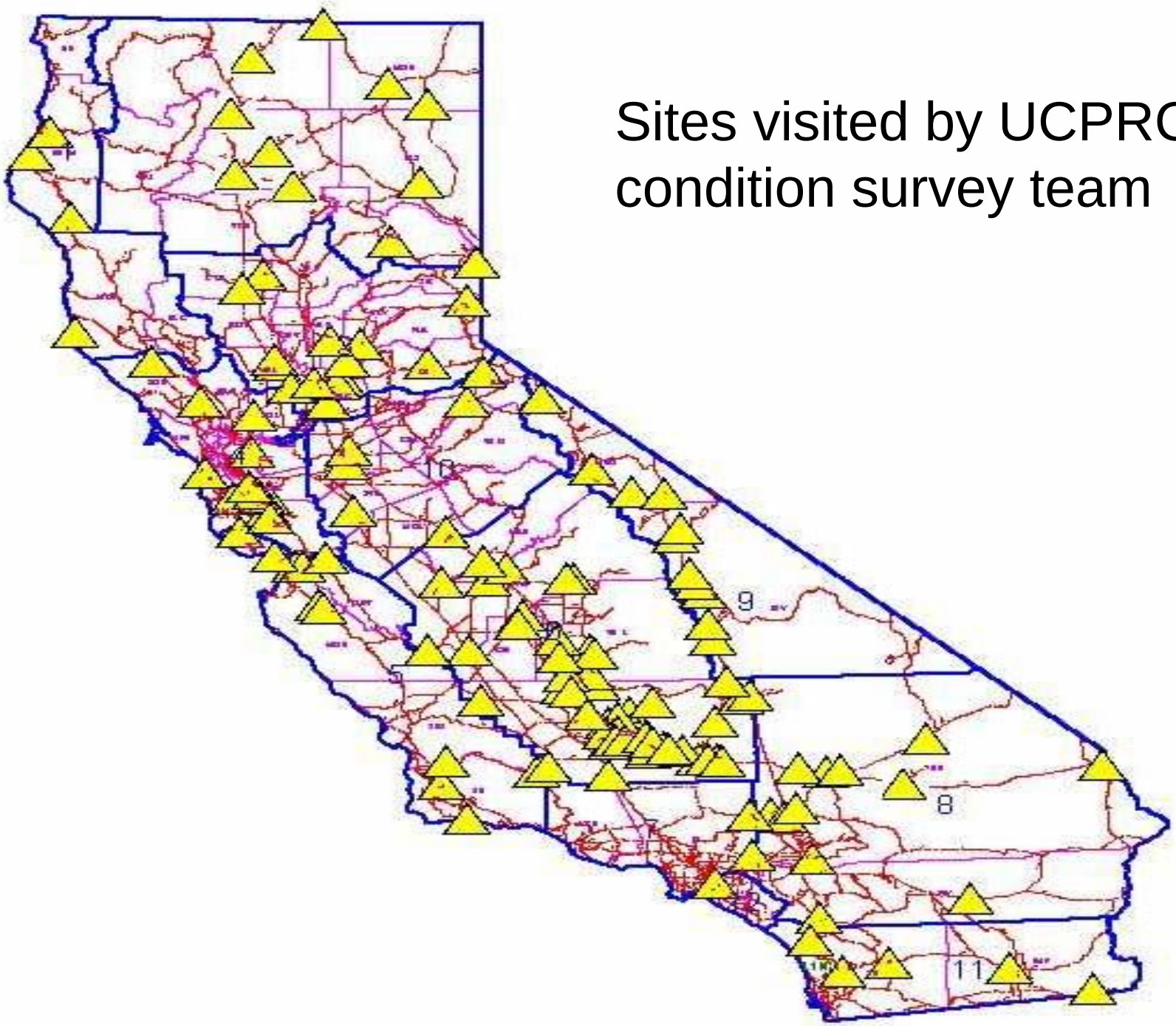
supports PPSC Long-Life Pavement objective

AC Moisture Damage (Goals)

- State-wide field investigation into effect of different variables on occurrence and severity of moisture damage
- Determine major factors associated with moisture damage in the field.
- Analyze the extent of moisture damage in California with available data
- Laboratory testing to compare test methods; evaluate effects of anti-stripping methods and other variables on moisture damage performance

Field Investigation

- General Condition Survey
  - Site selection (total of 194 sections)
    - Performance unknown prior to selection:
      - QC/QA data available: 122
      - Additional DME office data mining: 44
    - Identified as having potential problems:
      - Identified by industry or DME: 18
      - Discovered on road during field survey: 10
- Not a random sample
  - biased for evaluation of extent across state



Sites visited by UCPRC condition survey team

Field Investigation

- Intensive Condition Survey
  - 63 sections (14 control sections)
  - Take cores: Dry / Wet, Wheelpath / Lane Center
  - Permeability Measurement

Sites cored and permeability tested

Green sites: damage identified from initial visit

Yellow sites: random sites with no visible distress in initial visit

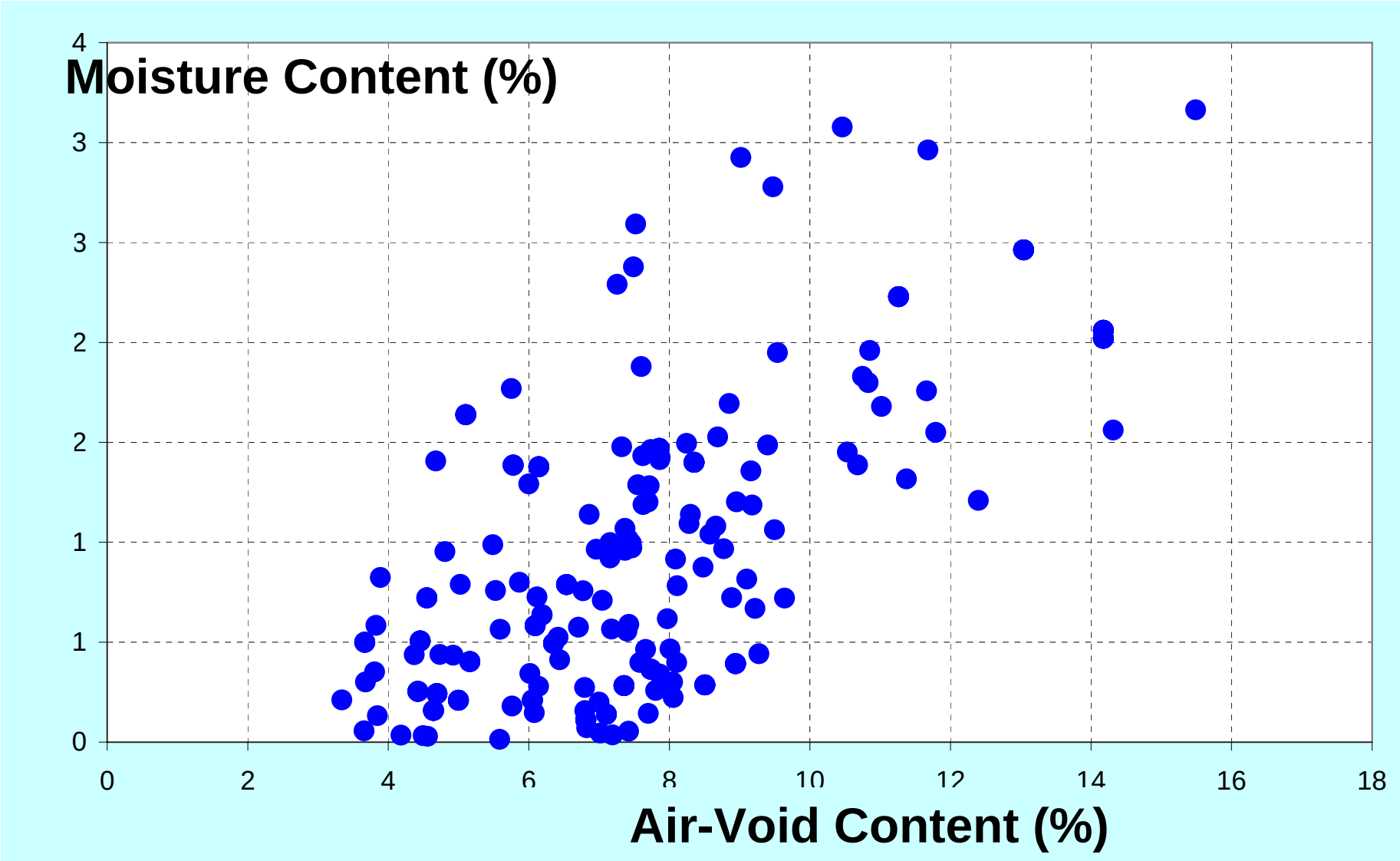
Field Investigation

- Factors Affecting Moisture Content

Factors	Degrees of Freedom	SS	Mean SS	F Value	P-value
In Wheel Path or Not	1	0.69	0.69	2.69	0.1029
Air-void Content	1	19.07	19.07	74.58	0.0000
Days since Last Rain	1	5.64	5.64	22.08	0.0000
Distance from Distresses	1	1.17	1.17	4.58	0.0335
QC/QA or not	2	0.21	0.10	0.41	0.6642
Rainfall	1	0.14	0.14	0.55	0.4593
Degree Days >30degree C	1	0.92	0.92	3.61	0.0590
Residuals	190	48.58	0.26		

Field Investigation

- Moisture Content versus Air-void Content



Field Investigation

- Estimate of moisture damage based on Core Data (63 sections)

Variable	Value	P-value
Air-void Content	0.142	0.001
Polymer Modified Binder?	-0.209	0.259
Use of Additive?	-0.134	0.578
PCC or CTB underneath?	-0.885	0.001
In the Wheel Path?	0.234	0.172
Cumulative Truck Traffic* all truck lanes	-0.002	0.877
Cumulative Rainfall?	0.008	0.047
Cumulative Degree Days>30C	0.003	0.647
Cumulative Freeze-thaw Cycles	-0.024	0.378
Pavement Age	0.136	0.080
Interlayer (PRF, SAMI) exists?	-0.188	0.397
DGAC or RAC?	-0.580	0.031

Field Investigation

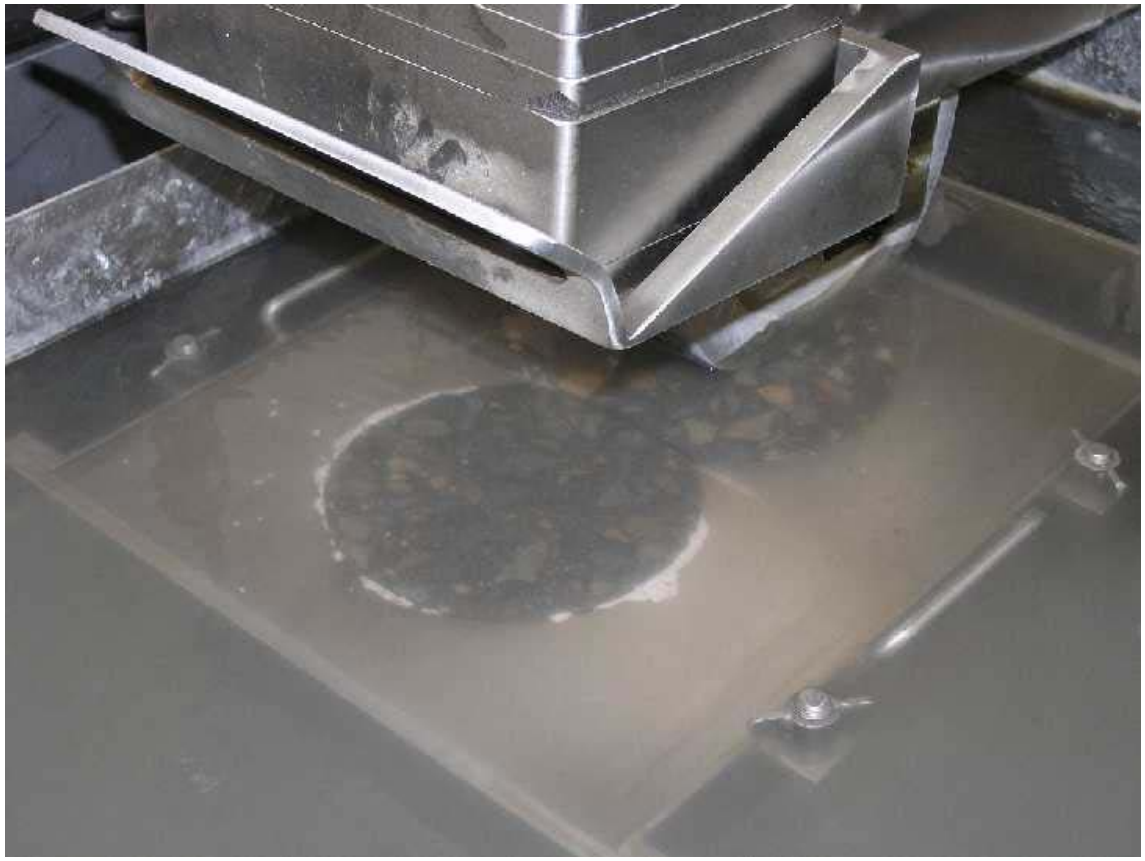
- Estimate of moisture damage on all Surveyed Sections (139 sections)
  - Extent of damage was estimated from artificial neural network

μ_1

Variable	Value	P-value
Polymer Modified Binder?	-0.103	0.813
Use of Additive (liquid or lime)?	-0.861	0.016
PCC or CTB underneath?	0.395	0.221
Cumulative Truck Traffic	-0.013	0.271
Cumulative Rainfall?	0.001	0.884
Pavement Age	0.112	0.034
QC/QA Project?	-0.302	0.370
Interlayer Exist?	0.023	0.945
DGAC?	-0.064	0.885

HWTD Test on Field Cores

- One pair of cores for one test
- Two tests for one site

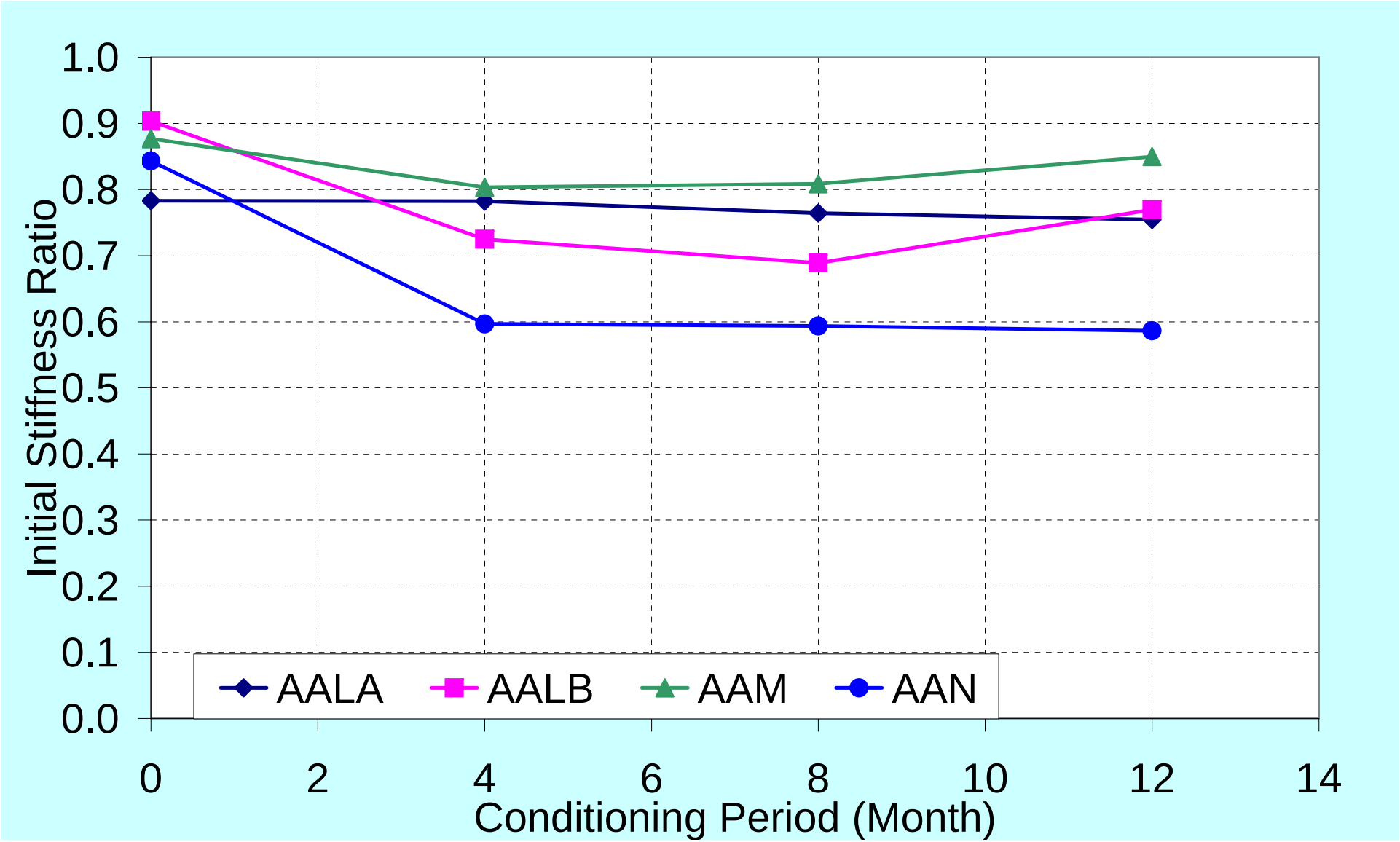


Potential Improvement to HWTD Test

- Pre-saturate and pre-condition specimens
- Use different test temperatures for mixes with different binders
- Rut test in both dry and wet conditions, use ratio as performance indicator

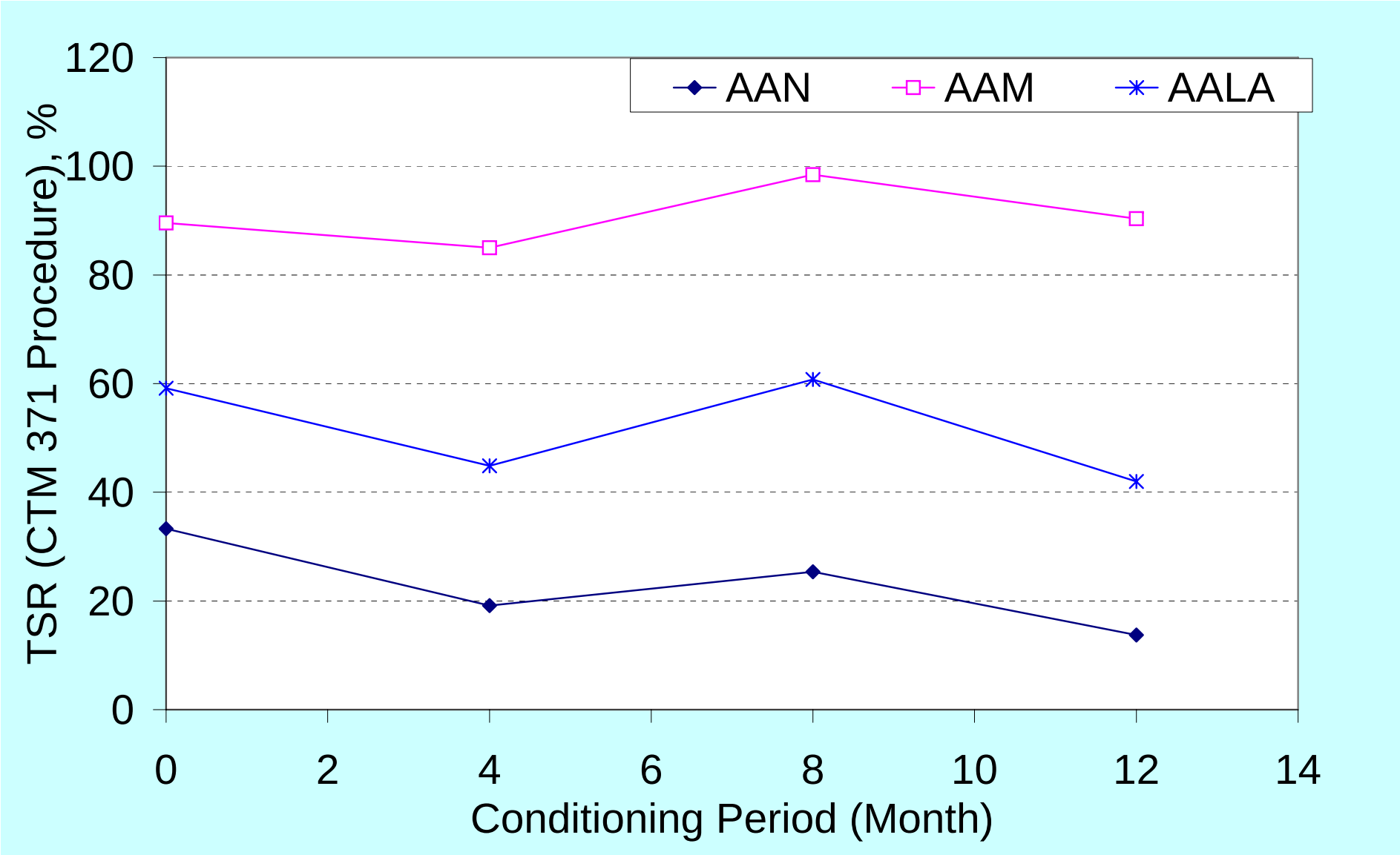
Evaluation of long-term effectiveness of additives

Fatigue Test - Initial Stiffness Ratio (LA, LB=liquid antistrips; M=lime; N=nothing)



Evaluation of long-term effectiveness of additives

TSR Test (after 25 °C + CTM 371 conditioning)



Conclusions

- 8-13% pavements with unknown performance before survey may have moisture-related damage
- Moisture commonly exists in pavements
  - Positively correlated to air-void content
  - Higher in distressed areas
- In-place air-void content has high mean and variance
  - DGAC: 6.8% (2-14%)
  - RAC: 9.8% (2-23%)

Conclusions (Cont'd)

- Case studies revealed that soft aggregate, poor pavement drainage design, inappropriate structural design may also lead to moisture damage
- Laboratory testing showed that high air-void content (>7%) and low binder content (0.5% less than OBC) significantly aggravate moisture effect on pavement fatigue resistance

AC Moisture Damage (Findings-2)

- Additives (hydrated lime or liquid anti-stripping agents) both reduced severity of moisture damage
  - Difference between anti-stripping agents over one year of soaking in laboratory
- Case studies on a few severely distressed pavements revealed in specific cases, that one/few factor(s) dominate moisture-related damage
  - Susceptible aggregate
  - High air-void content combined with ample source of water
  - Poor pavement drainage design
  - Inappropriate structural design, and others.
- In most cases, high air-void content was found in the severely distressed pavements.

Projects Nearing Completion

- (2.4.2) Deep In-Situ Recycling Using Recycled AC as Unbound Base
- (3.2.5) Documentation of Pavement Performance Data for Pavement Preservation Strategies and Evaluation of Cost-Effectiveness of Such Strategies
- (3.2.8) Pilot Projects for Chip Seal Specifications
- (4.1) Development of First Version of Mechanistic-Empirical Pavement Rehab., Reconstr., & New Pavement Des. Procedure for Rigid & Flexible Pavements
- (4.4) Development of Asphalt Concrete Rutting Performance Tests and Analysis Procedures
- (4.8) Dowel Bar Retrofit of Rigid Pavements
- (4.10) Development of Improved Rehabilitation Designs for Reflection Cracking
- (4.17) HVS testing of pre-cast concrete slabs

“Pulverization” -- Deep in-situ recycling (DISR) using recycled AC as unbound base: field and laboratory testing

SPE 2.4.2

Supports PPSC Recycling objective

Objective

- Recommend Gravel Factor (G_f) for rehabilitation by pulverization of existing base
  - Field monitoring of four projects built with Pulverized DISR
  - Laboratory testing of pulverized base
  - Mechanistic analysis of field and laboratory data to determine Gravel Factor

WARNING
NOT
DRINKING
WATER
Caltrans

383722
Heavy Weight Deflectometer
1035636

Fieldwork

- Ongoing biannual monitoring (FWD, visual condition) of three recently built projects in District 2:
  - MOD395, PLU70, LAS44
- Just completed construction monitoring of final project SHA89
- Backcalculation of FWD data to determine stiffness of each layer

Laboratory

- Gradation, compaction, classification tests
- Triaxial shear and repeated load tests on pulverized base material and virgin Class 2 aggregate
  - Including lime treatment
- Determining variability along project (typically 5-10 miles long)

Current status

- Lab testing of material from last project (SHA89)
- Ongoing field monitoring
- Mechanistic analysis to compare pulverized base and virgin aggregate pavements in order to determine gravel factors
  - Calculations due in December, 2006

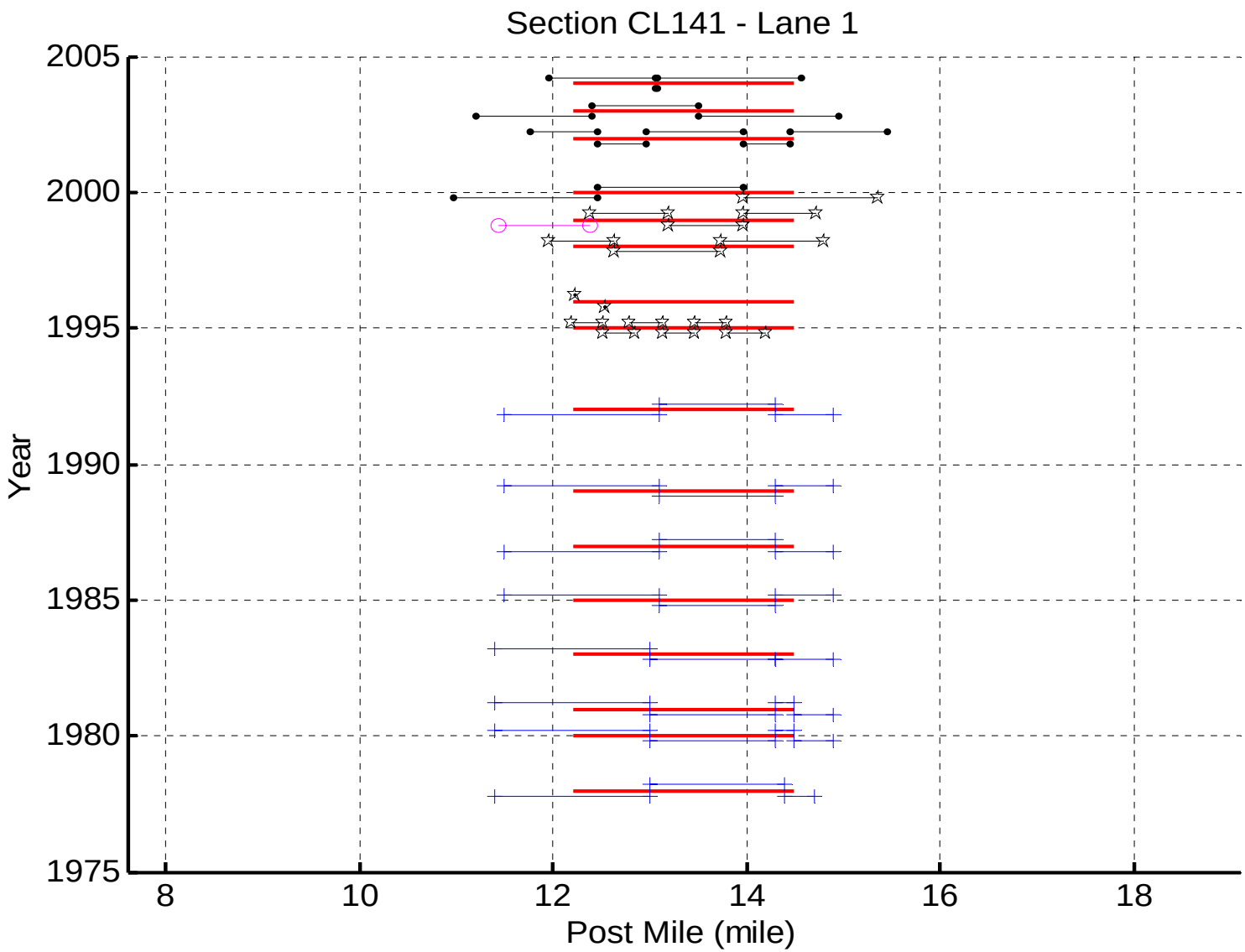
Documentation of pavement performance data for pavement preservation strategies and evaluation of cost-effectiveness of such strategies

PPRC SPE 3.2.5
supports PPSC PMS and Pavement Preservation objectives

Objectives

- Use Caltrans PMS data
  - Algorithm to correct for dynamic segmentation
  - Get smooth performance curves for alligator cracking
  - Compare asphalt overlays with and without pavement preservation
  - Develop simple performance estimates for both
  - Perform first cut life cycle cost analysis comparing them

Dynamic Segmentation in PMS



Previous Attempts

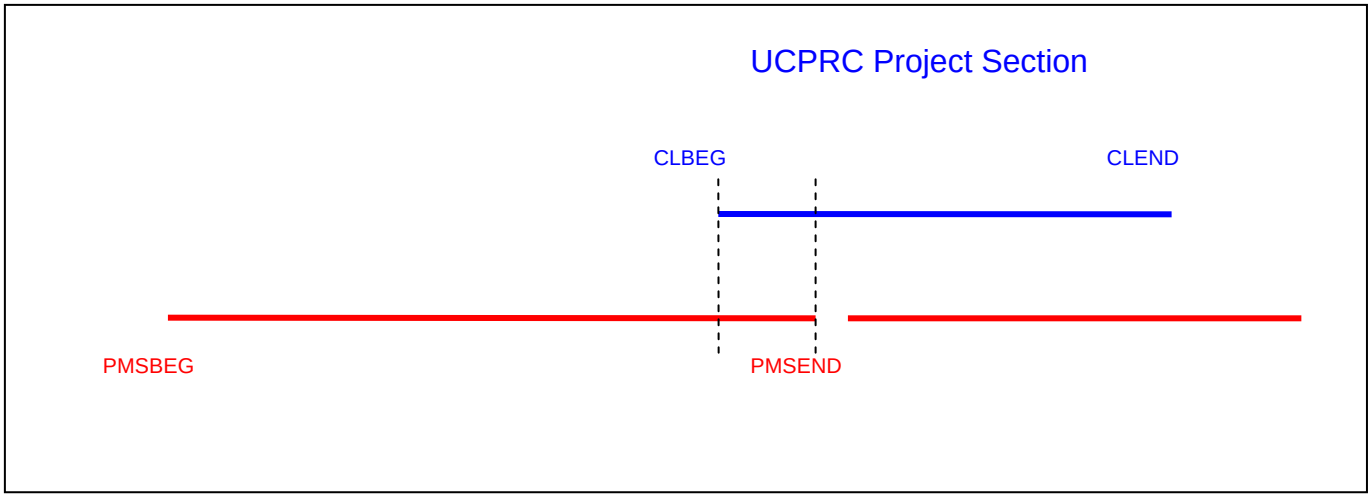
- Top-down approach
  - Identify fixed segments in the network
  - Did not work very well
  - Report on UCPRC webpage (Lea & Harvey, 2002)

Bottom-up approach

- Track fixed segments through the PMS
- These fixed segments have structural data from GPR and/or field work
- Used weighing algorithm to deal with dynamic segmentation

The Algorithm

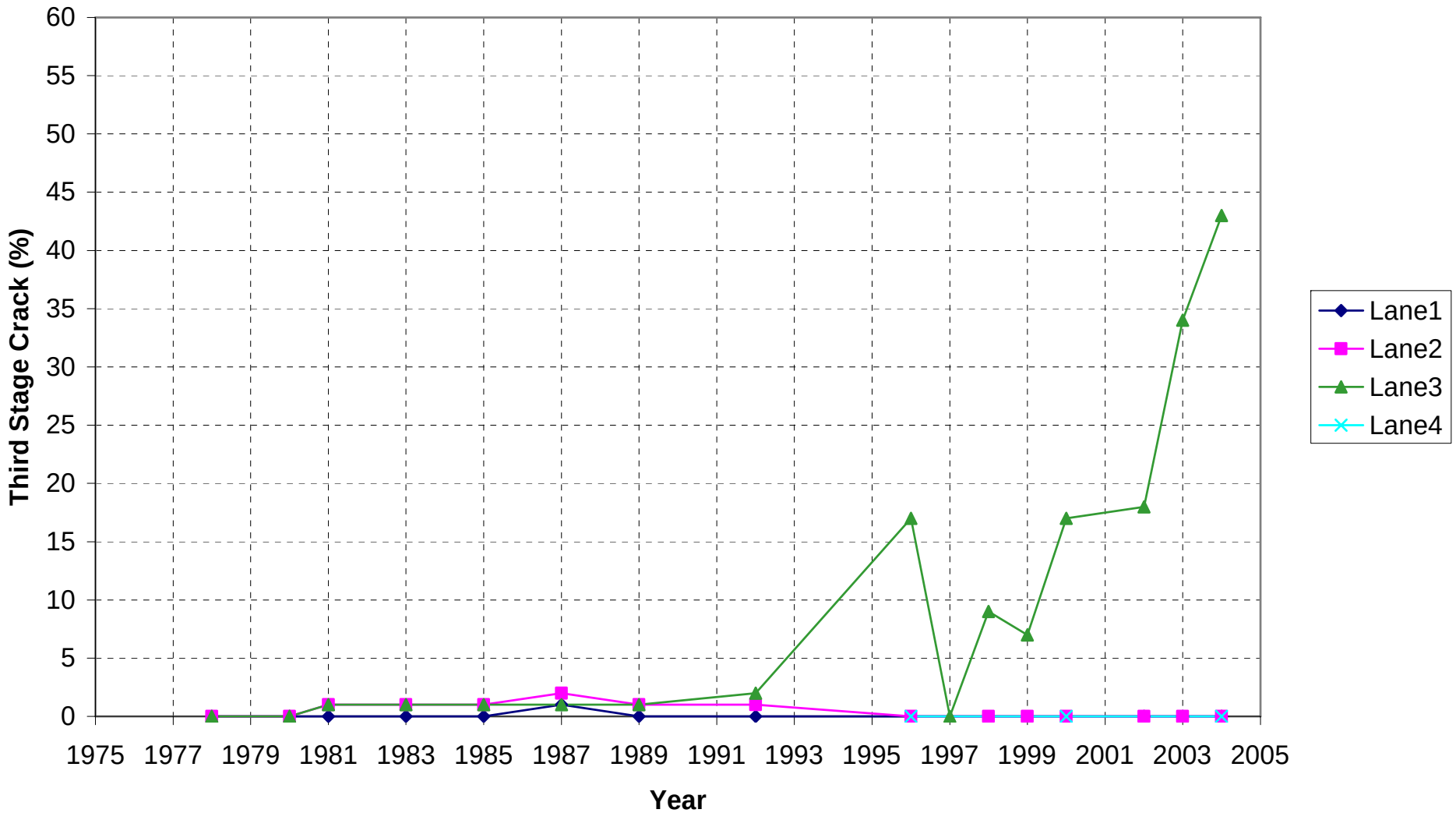
$$\left(\sum_{i}^{n}(distressi * CTsegmi_length)\right) / \left(\sum_{i}^{n} CTsegmi_length\right)$$

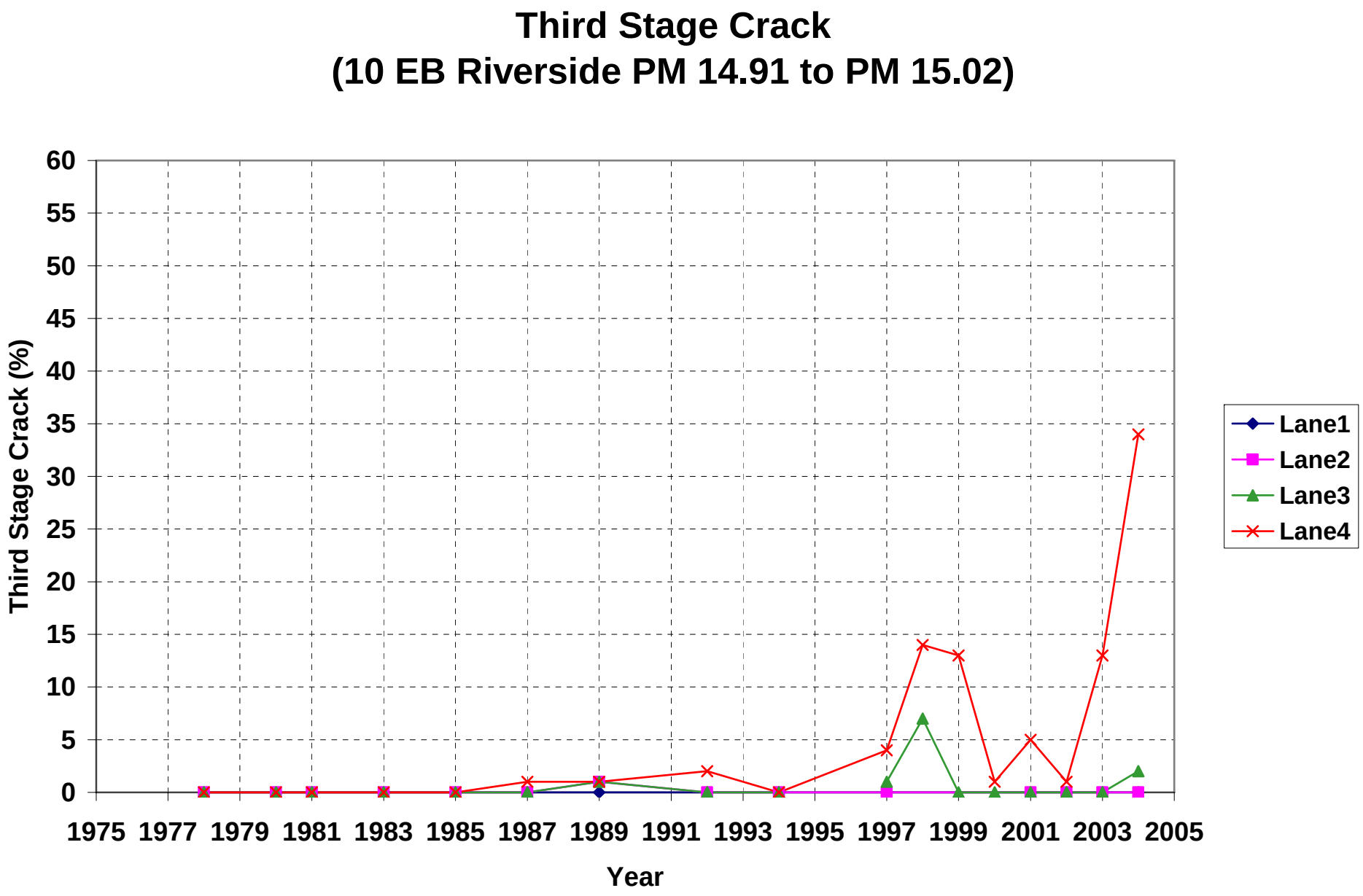


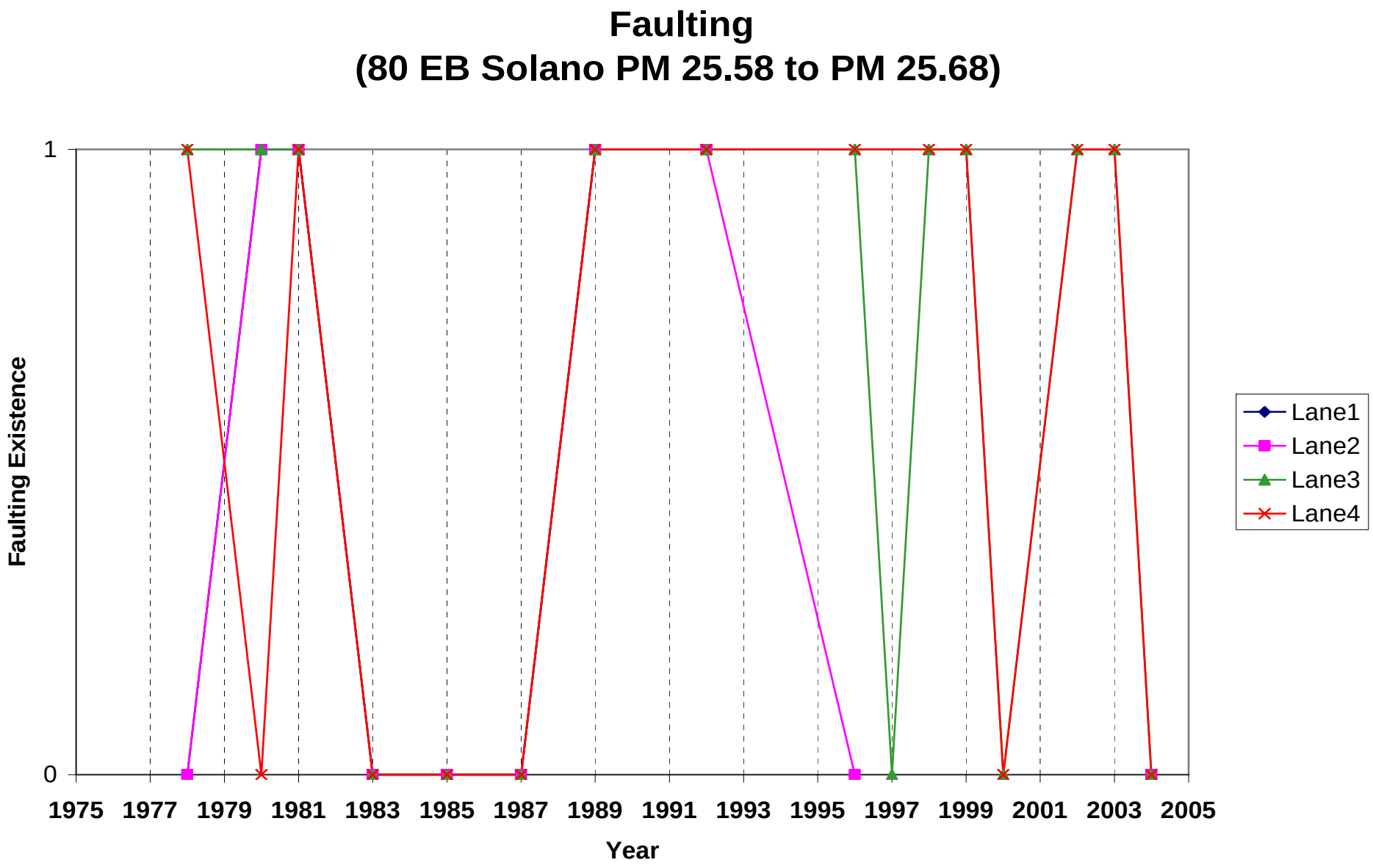
Steps involved

- Identify sections
- Extract PMS data from 1978 to 2004
- Use the algorithm
- Plot the distresses
- Analyze the plots
- Prepare a list of site specific M & R questions

Third Stage Crack
(80EB Solano PM 30.83 to PM 30.93)




Third Stage Crack
(10 EB Riverside PM 14.91 to PM 15.02)
Third Stage Crack (%)
60
55
50
45
40
35
30
25
20
15
10
5
0
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Year
Lane1
Lane2
Lane3
Lane4

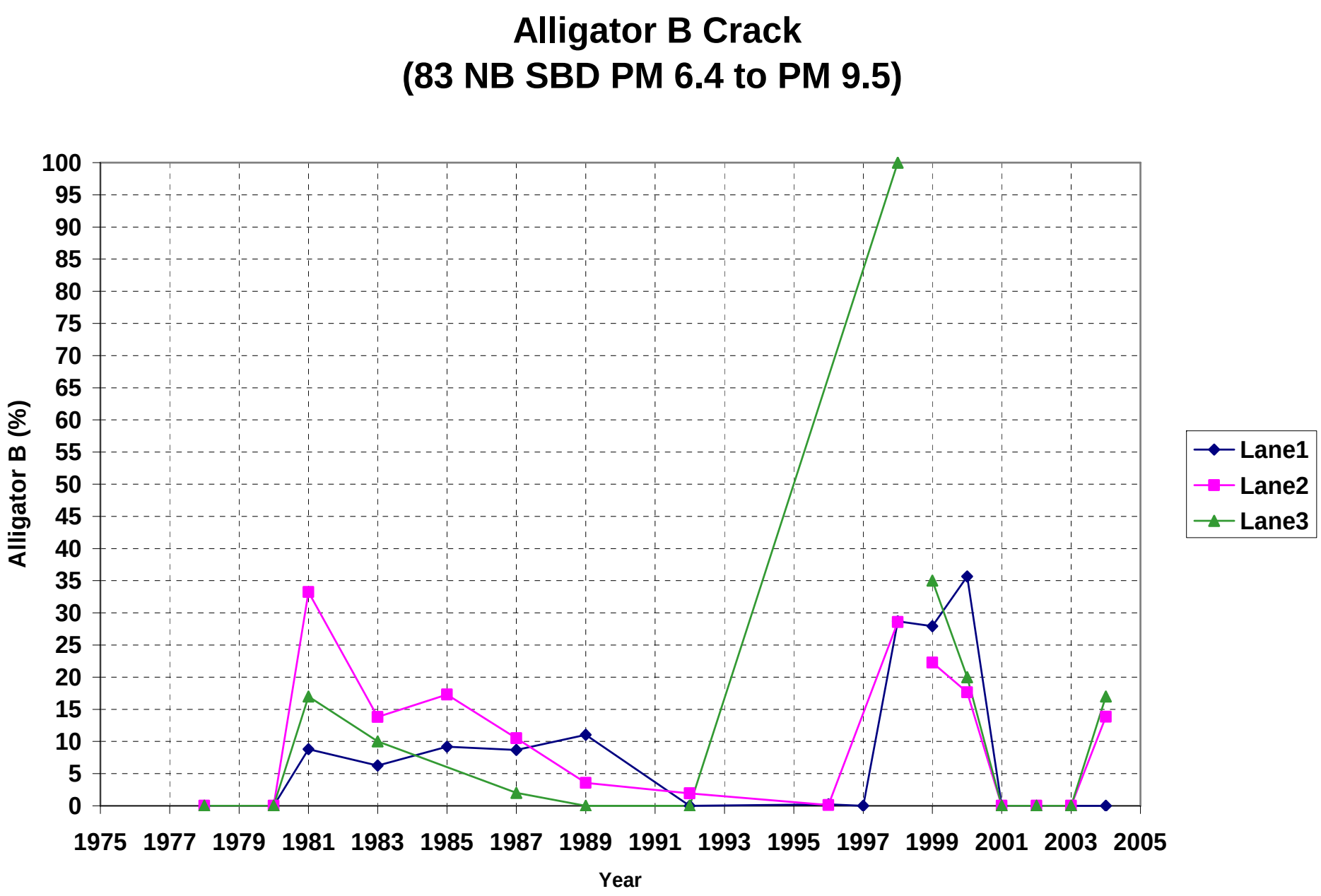

Faulting
(80 EB Solano PM 25.58 to PM 25.68)
Faulting Existence
1
0
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Year
Lane1
Lane2
Lane3
Lane4

Observations from the rigid distresses

- Good data for cracking (1st stage, 3rd stage and corner cracking)
- Faulting data cannot be used
- Spalling data cannot be used
- Questions
  - What is the construction year
  - 1997 data questionable
  - Site specific questions (year and amount of slab replacement)

Flexible Distresses

- Alligator Cracking A
- Alligator Cracking B
- Rutting: binary variable and hence not analyzed.


Alligator B Crack
(83 NB SBD PM 6.4 to PM 9.5)
Alligator B (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Year
Lane1
Lane2
Lane3

Observations from flexible distresses

- Usefulness of the data is variable but still good
  - Of 85 sections first analyzed
  - 54 have some form of useful cracking data
  - 26 might be useful
  - 5 bad sections
- Data very sparse between 1992 and 1997

Observations from the Composite Pavements

- Good cracking data for PCC part
- Plots tell the approximate year of OL and give an idea of the performance of OL
- Overlay life 5 to 15 years. Based on limited data
- Summary Statistics
  - 50 first analyzed
  - All 50 have data that can be used

ROUGHNESS

- Roughness recorded as
  - Ride score from 1978 to 1992
  - IRI from 1997
- Tracked for all the sections (GPR flexible, ME rigid & composite)
- Need for validation of IRI model in 1-37a
- Ridescore cannot be used for validation

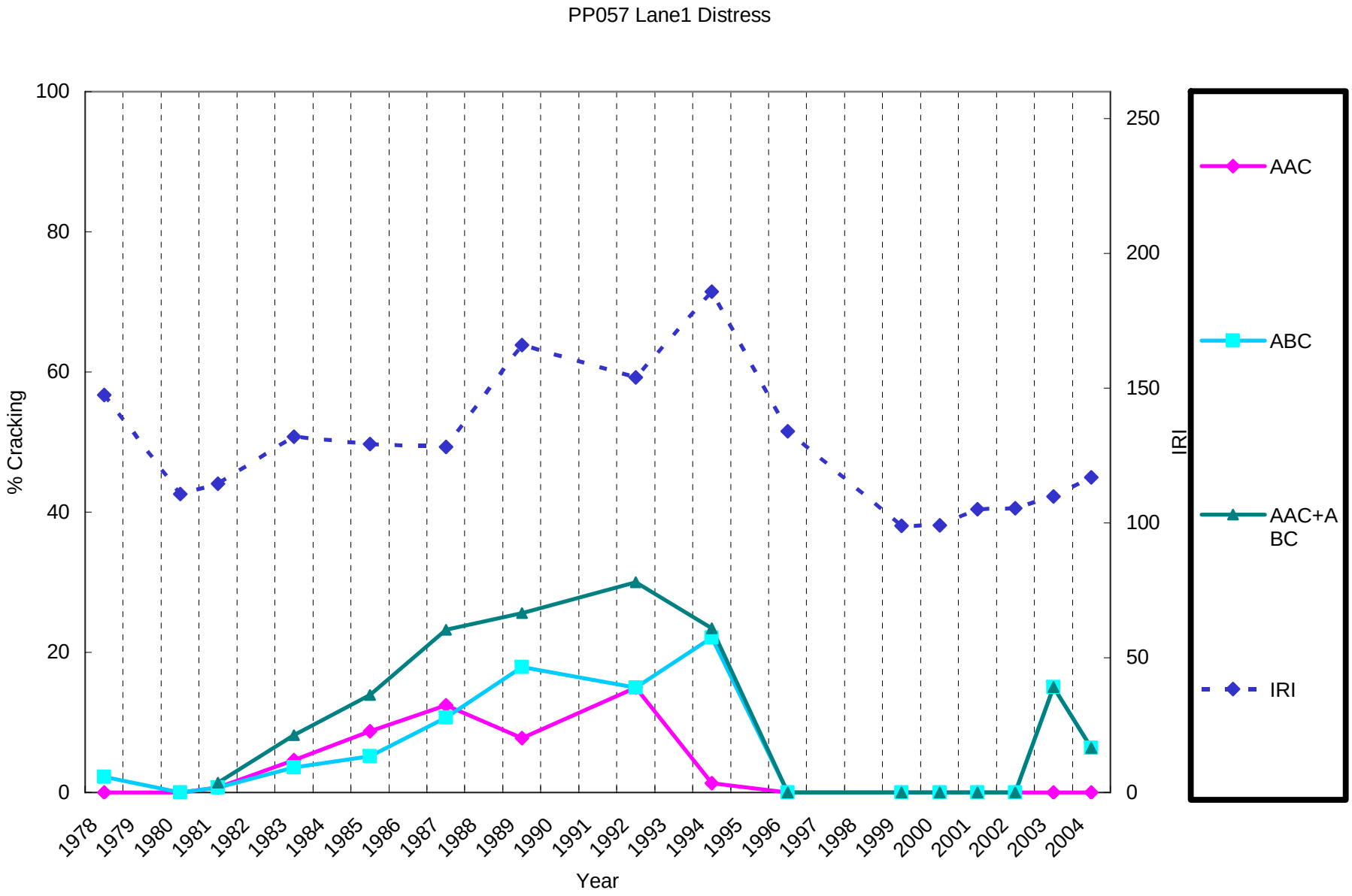
Status

- Have collected more than 1,500 sections of data
  - Maintenance regional coordinators databases
  - District Maintenance databases:
    - Have: D2, D8, D9
    - Promised: D4, D7, D10, D11
- Preparing performance plots

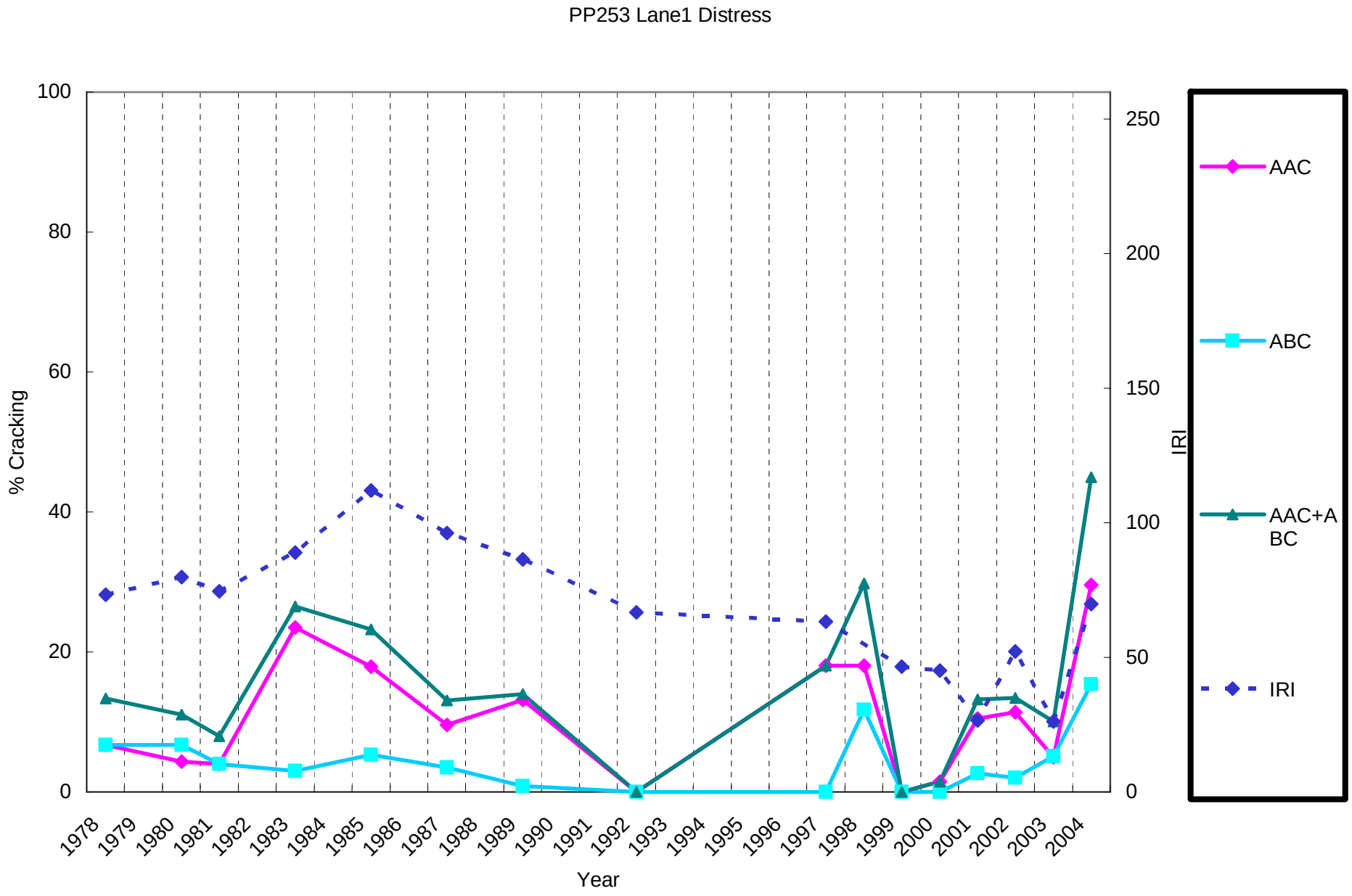
Summary of projects to date

Action Category	District												
	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total
ACOL-DG	24	33	10	8	69	24	2	165	27	35	8	21	426
ACOL-GG								1					1
ACOL-OG	19	5	2	19	3	6	3	35	4	2	1	3	102
ACOL-RAC	2	11	6	9		14	30	17	1	11	2	1	104
ACOL-RACG				5	2	12	7	27	2		6	6	67
ACOL-RACO					1	12	1	18	2	7	2		43
BWC			2		1	3	1						7
ChipSeal-AC								31					31
ChipSeal-AR	4	5	1	1	7	4	2	10	11	7	3		55
ChipSeal-PMA	3			2	1				1	2			9
ChipSeal-PME	3	39	11	1	5	45		10	12	18	10		154
Cont-DGAC									1				1
CrackSeal	1	2	4		1	9				8			25
DigOut	8	48	16	30	2	16	1	13			1	13	148
FogSeal								1			2	1	4
Microsurfacing		1	2	1		3	1				2	1	11
SlurrySeal	1	9	1		4	15	1		2	3	4		40
Grand Total	65	153	55	76	96	163	49	328	63	93	41	46	1228

ACOL + OGAC Rt. 20, Dist 1, not sure when done, looks like 1994.



OGAC Rt.40, Westbound, Dist-8, built in 2000.



Pilot Projects for Chip Seal Specifications based on South African Design Practice

PPRC SPE 3.2.8
supports PPSC Pavement Preservation objective

Draft Single-Size Aggregate Chip Seal Design Manual

- Based on most recent South Africa National Roads Authority manual
  - Similar to Australia and New Zealand practice
  - Volumetric design of binder content based on aggregate shape “flakiness index” and size
  - Strict limits on aggregate gradation
- Scheduled to deliver draft to Maintenance in December, 2006

Development of the First Version of a Mechanistic-Empirical Pavement Rehabilitation, Reconstruction and New Pavement Design Procedure for Rigid and Flexible Pavements

PPRC Strategic Plan
Element 4.1

Supporting PPSC ME Design objective

Mechanistic-Empirical (Goals)

- Improve Caltrans pavement performance by implementation of mechanistic design, integration of structure, materials, traffic and construction
- Evaluate MEPDG (JPCP, CRCP & AC designs)
- Develop seasonal change curves
- Create traffic and climate databases
- Develop library of typical CT materials mechanistic properties
- Develop and adapt design algorithms (CRCP)
- Develop, verify and calibrate additional models and tools
  - CalME flexible new and rehab design models
  - RadiCal rigid cracking models
  - CalBack FWD back-calculation software

Caltrans ME Implementation Status

- ME is not to be used in practice at this time without permission from HQ Design
- Work plan developed for Caltrans implementation*
- National status:
  - Continual updating of software by ARA
    - Difficult to evaluate because keeps changing, v 0.91 in Sept 06
  - NCHRP 1-40 reports due this month
    - Critical evaluation of models by experts
  - Balloting of MEPDG by AASHTO states this summer
    - Would transfer from MEPDG from NCHRP to AASHTO
    - Major concerns about rehab
  - Various states evaluating software & models
    - Caltrans has done more evaluation than most other states
    - Working closely with 5 States group (CA, FL, MN, TX, WA)
    - Access to code is a major issue being investigated
    - CalME, RadiCal and models developed by other states may be used in a more open AASHTO software in the future; software is currently to be used for model development (research tool)

Caltrans ME research and development process:

- Evaluate MEPDG
- Develop alternative models and procedures where needed
- Sensitivity studies
- Calibration
- Gap identification and filling
  - Field and lab testing
  - Databases
  - Tools
  - Training
- Implementation
  - Simple tools
  - Software

Rigid Pavement Progress since last mtg with DMEs in May 06

- Finished Sensitivity Analysis (v.0.8), redone with (v.0.91)
  - JPCP module of MEPDG reasonable
  - CRCP module of MEPDG required thicknesses not reasonable
- Developed design catalog for JPCP
- Field Calibration
  - Completed field data collection from 50 JPCP
  - Have California sections database used to calibrate MEPDG
    - Undoweled faulting underpredicted by models
  - Data being analyzed for comparison with MEPDG predictions
- Measuring CTE, strength, elastic modulus from cores from sites
- RadiCal longitudinal cracking model being calibrated against MEPDG

State in Transition: Empirical Designs to Long Life Designs Based on ME Procedures in California

Presented by: Bill Farnbach & Venkata Kannekanti

Co-authors: John Harvey, Erwin Kohler & Arron Rambach

International Society for Concrete Pavements: Long-Life Concrete Conference, Chicago, Oct 06

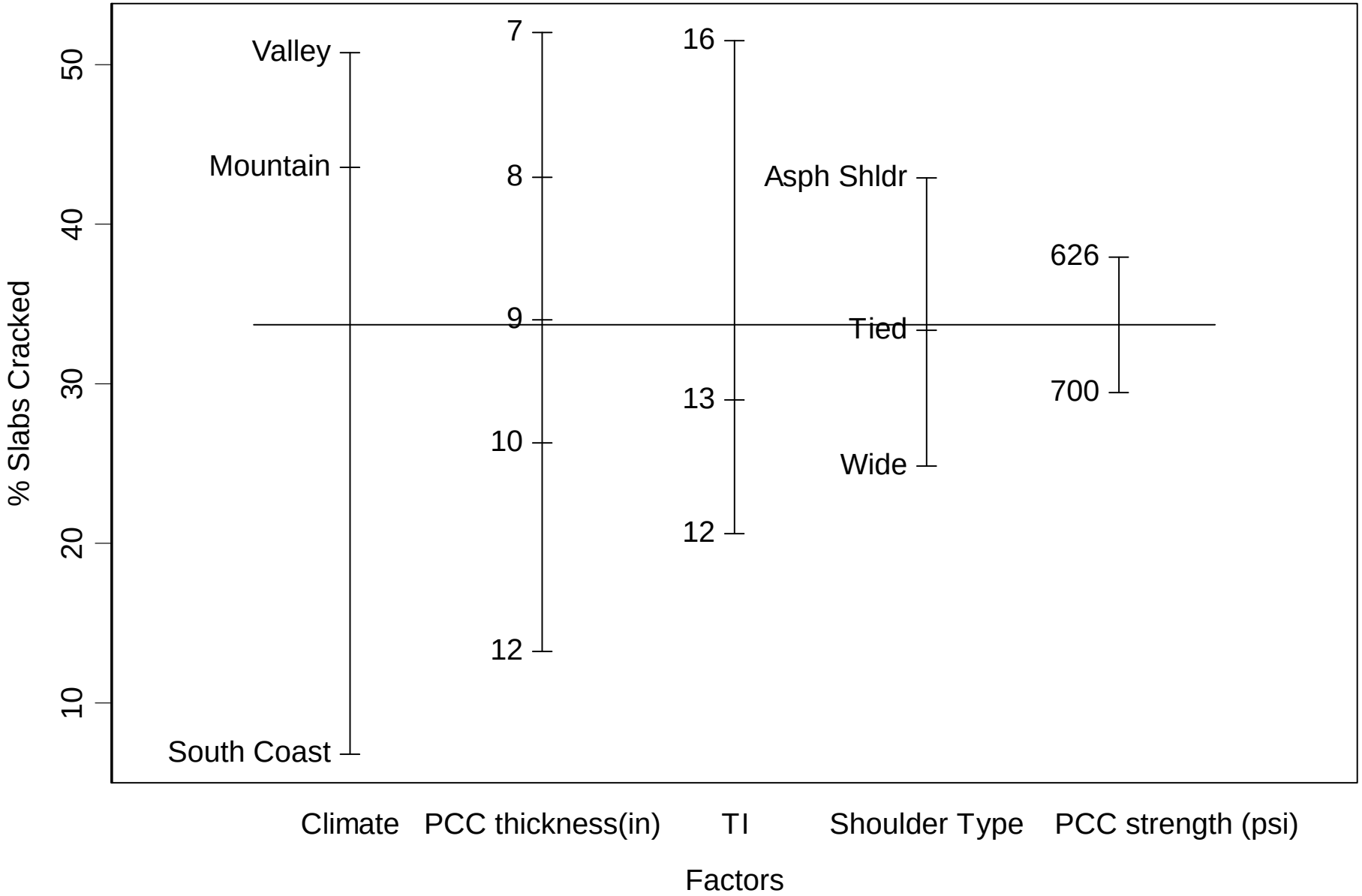
Caltrans

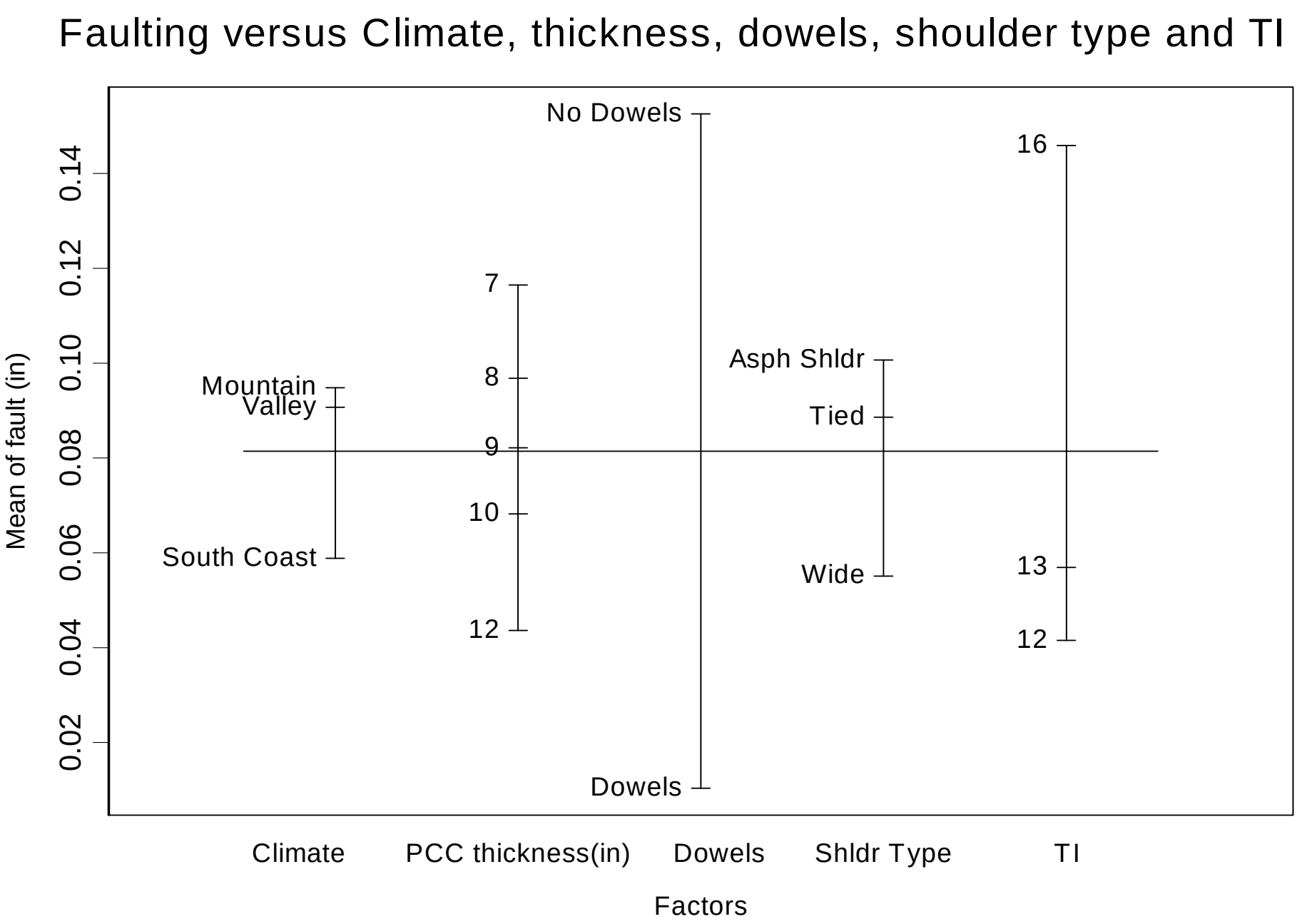
UC PRC
Pavement Research Center
UNIVERSITY OF CALIFORNIA • DAVIS • BERKELEY

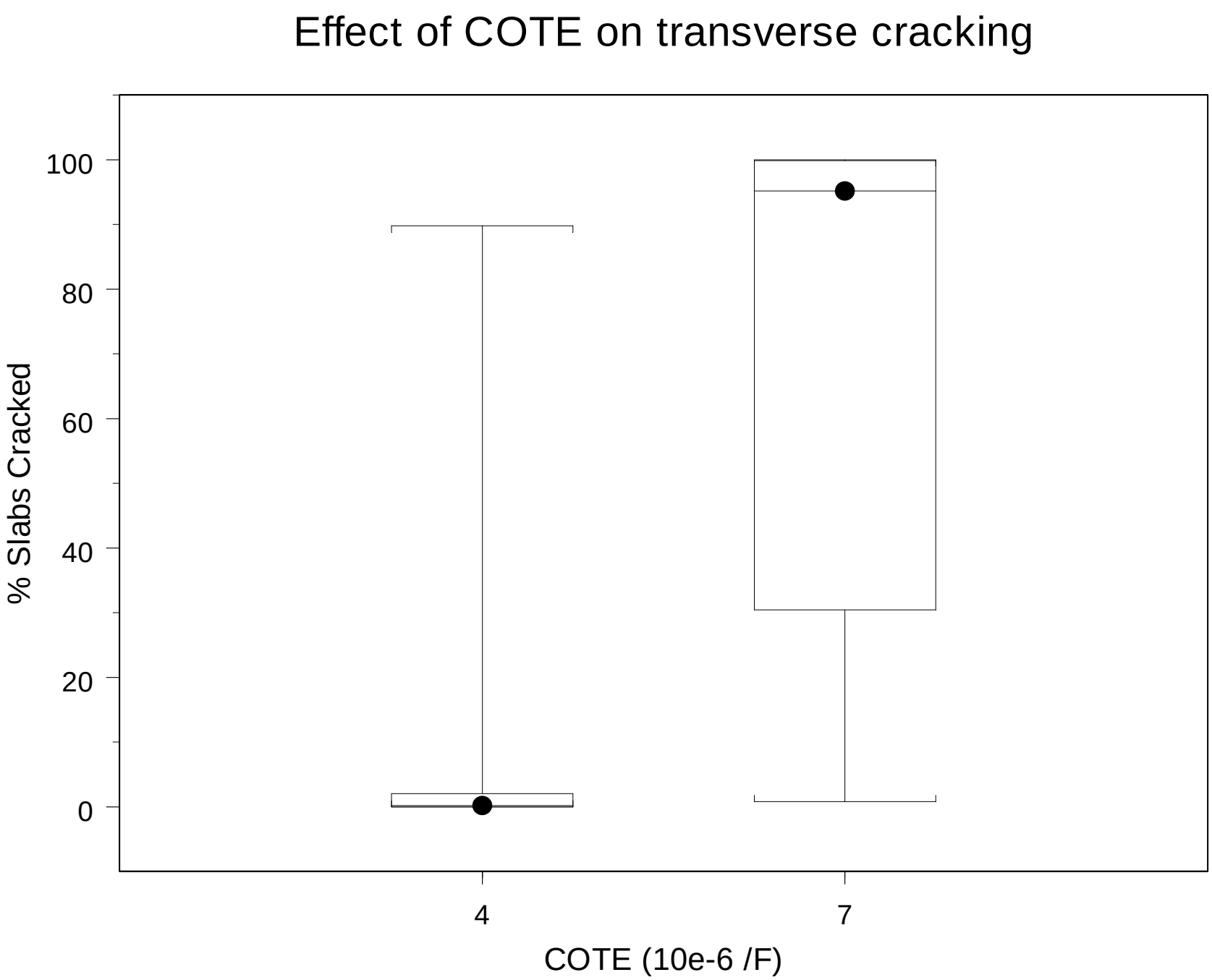
Sensitivity Analysis

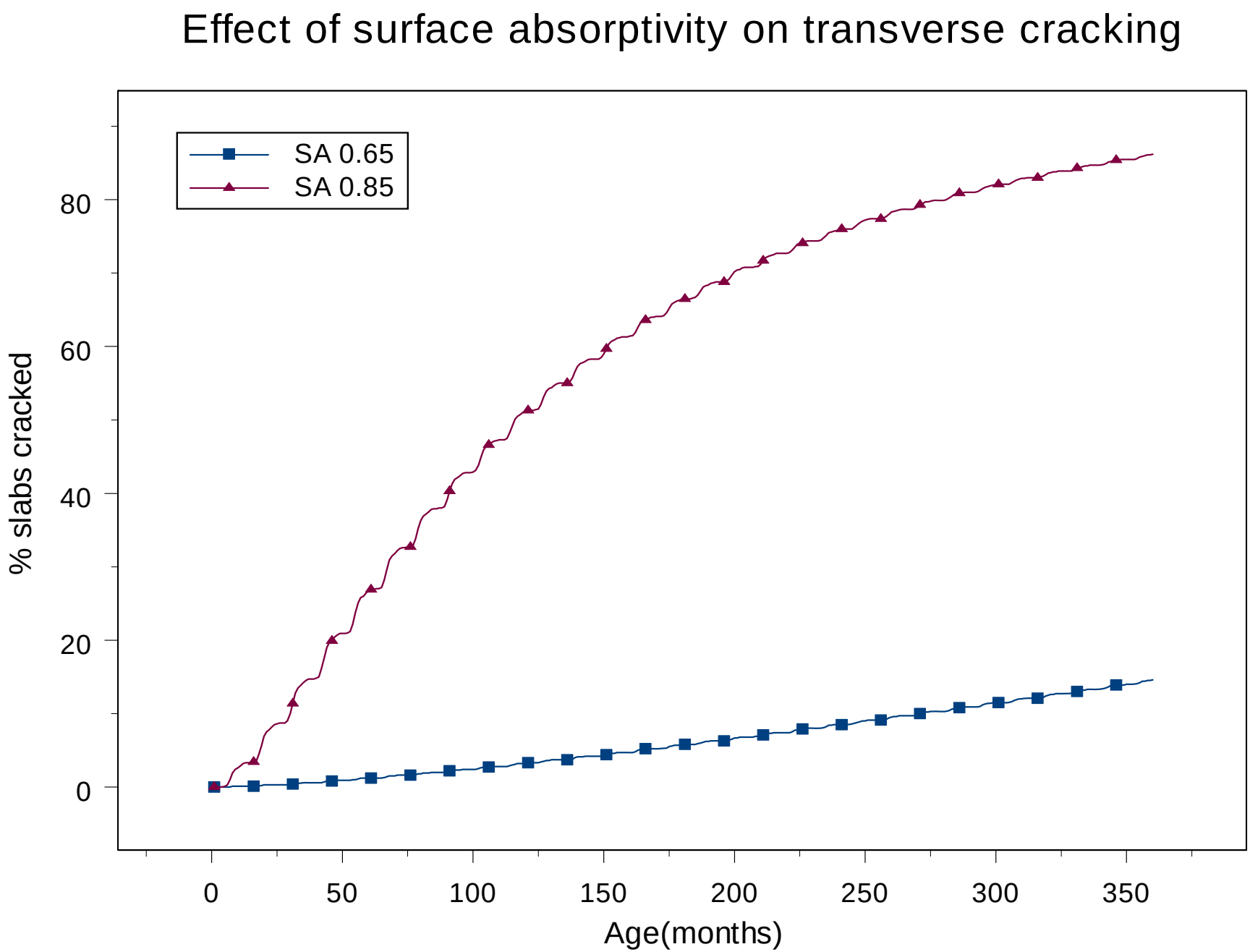
- 10,000 cases run with 0.8 version
  - Varied all the key variables
- Generally results are reasonable
- Some issues with the models
  - SG effect counter-intuitive
  - Subbase thickness has no effect
  - CTE & surface absorptivity extremely sensitive

Effect of Climate, thickness, TI, shoulder type, strength on cracking



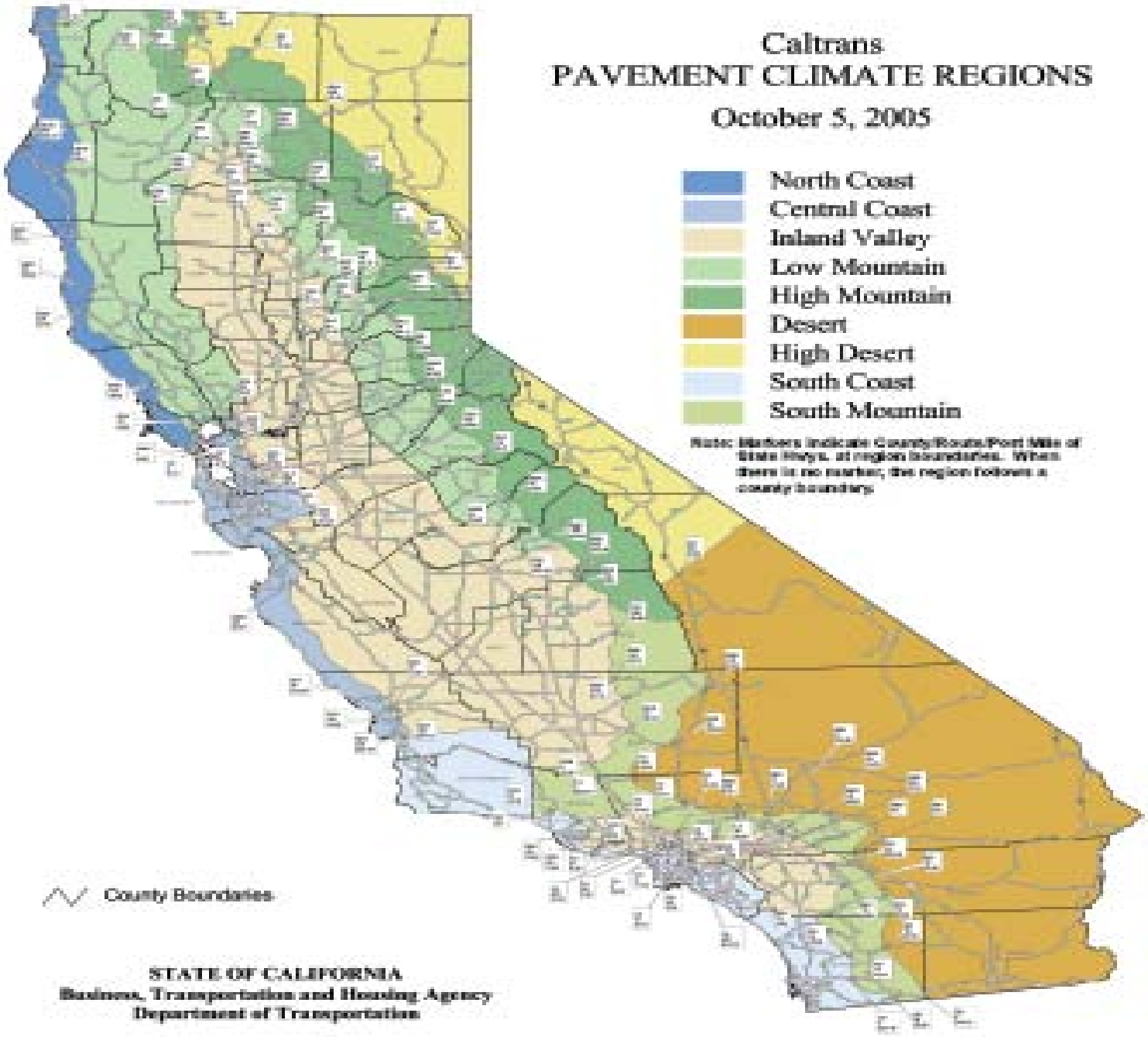

Faulting versus Climate, thickness, dowels, shoulder type and TI
Mean of fault (in)
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Mountain
Valley
South Coast
7
8
9
10
12
No Dowels
Dowels
Asph Shldr
Tied
Wide
16
13
12
Climate
PCC thickness(in)
Dowels
Shldr Type
TI
Factors


Effect of COTE on transverse cracking
% Slabs Cracked
100
80
60
40
20
0
4
7
COTE (10e-6 /F)


Effect of surface absorptivity on transverse cracking
SA 0.65
SA 0.85
% slabs cracked
0
20
40
60
80
0
50
100
150
200
250
300
350
Age(months)

New Criteria for the Catalog

- Failure Criteria
  - Transverse cracking: 10% slabs
  - Faulting: 0.1 inch
  - IRI: 160 in/mile
- Reliability: 90 %
- Design life
  - 40 years
  - End of 40 yrs do either 1-2% slab replacement or grinding or both
- Climate Regions


Caltrans
PAVEMENT CLIMATE REGIONS
October 5, 2005
North Coast
Central Coast
Inland Valley
Low Mountain
High Mountain
Desert
High Desert
South Coast
South Mountain
Note: Markers indicate County/Route/Post Mile of State Hwys. at region boundaries. When there is no marker, the region follows a county boundary.
County Boundaries
STATE OF CALIFORNIA
Business, Transportation and Housing Agency
Department of Transportation

Climate Regions (contd..)

- Ran a factorial of 1758 cases with all 9 climate zones
- Problems finding weather stations with good data in 0.8 software
- Grouped 9 zones into 3 for catalog based on factorial results

Catalog Factorial

- **Climate**: Coastal, Desert & Low Mountain
- **TI (MESALs)**: 9(1), 11(5.4), 13 (20) and 17 (210)
- **Spectra**: Urban and Rural
- **Base Type**: ACB, CTB, Granular Base
- **Subgrade**: CH and SP
- **Load Transfer**: Dowels and no dowels
- **Shoulder Type**: Asphalt, Tied & Widened lanes

Catalog Factorial (contd..)

- **Granular subbase**: Yes for CH and No for SP (current Caltrans practice)
- **PCC Thickness**:
  - 7 to 14 inches based on traffic levels
- Total Number of Cases: 2160

Key Assumptions

- CTE assumed to be 6x10-6 /^{o}F
- Surface absorptivity: Default value of 0.85
- No bonding between base & surface layer
- Joint Spacing: 13.5 ft
- Default values for unbound layers
- Erodibility Index of base
  - 3 for Granular bases, 2 for ACB, 1 for CTB

Findings from the runs

- Climate data was limited
- Faulting for un-doweled cases appeared under estimated
- There was little difference in results between urban and rural axle load spectra
- Granular base options had lower thicknesses at high Traffic Indices
- Additional consideration for California
  - Does not analyze longitudinal & corner cracking

Granular base at high traffic

Key Inputs	PCC with ACB (in)	PCC with CTB (in)	PCC with GB (in)
Tied, Dowels, High traffic, Desert.	13.31	12.98	12.81
Untied, Dowels, High traffic, Desert.	13.58	13.30	13.27

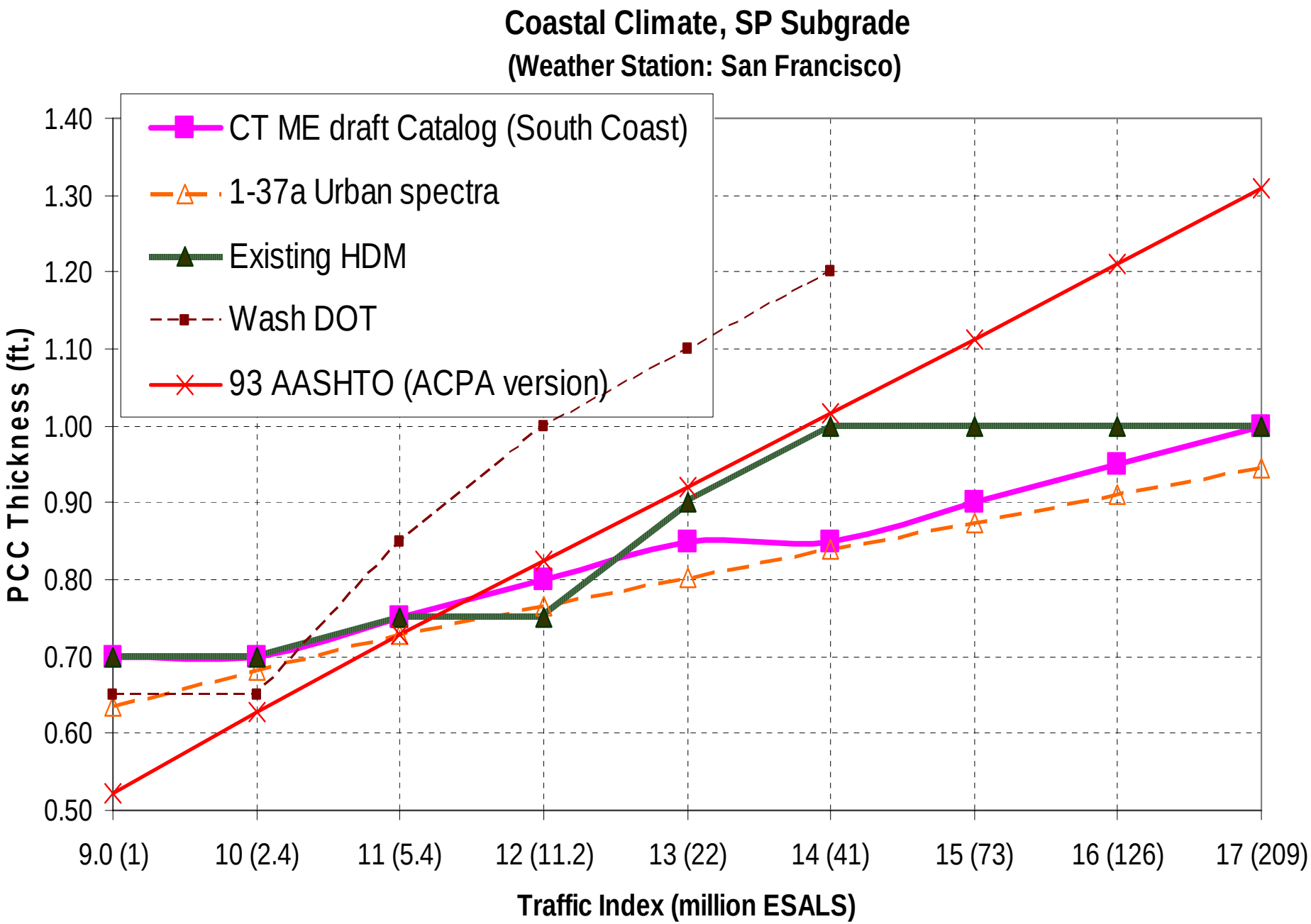
Catalog

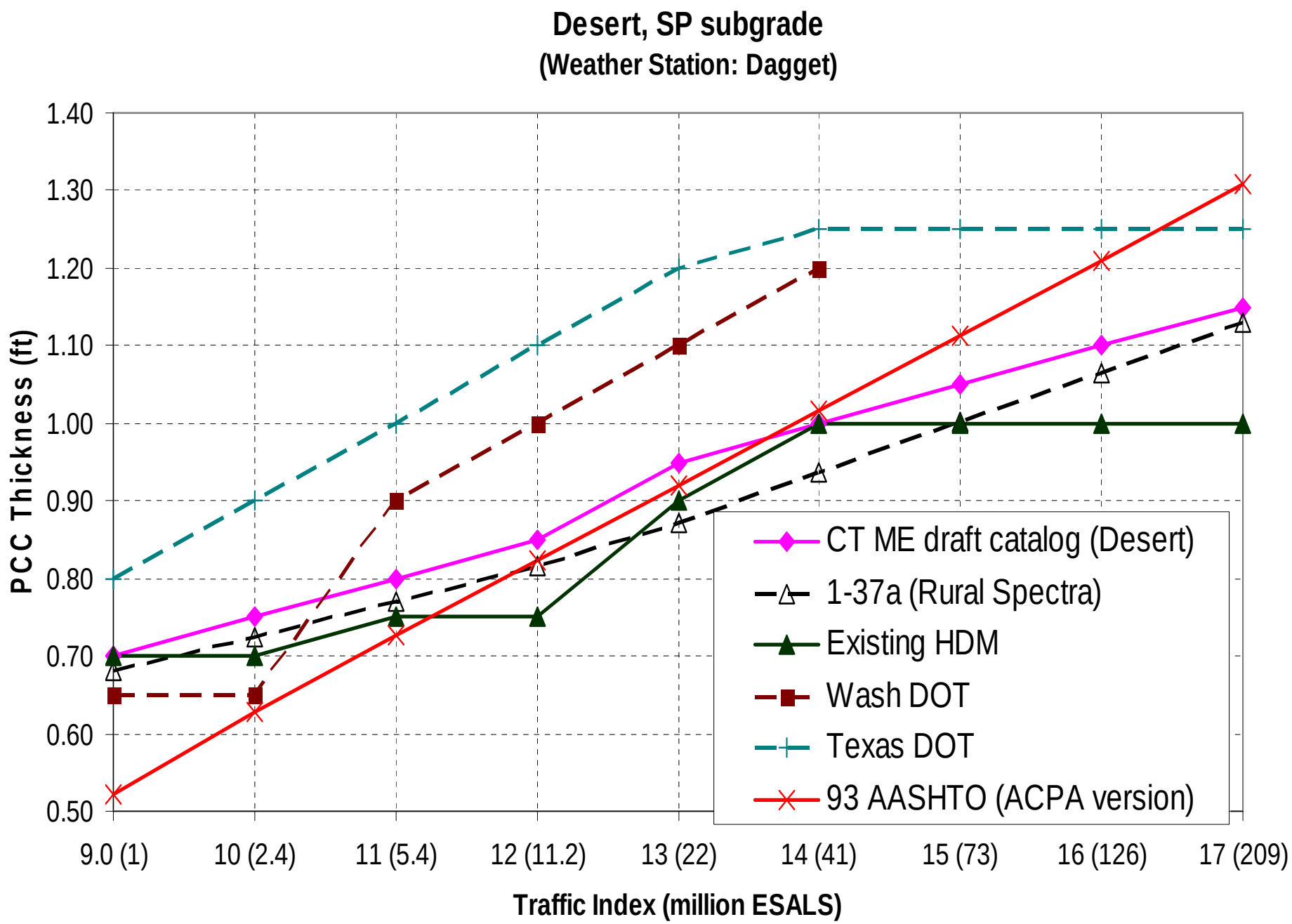
- Results from the factorial synthesized into design tables

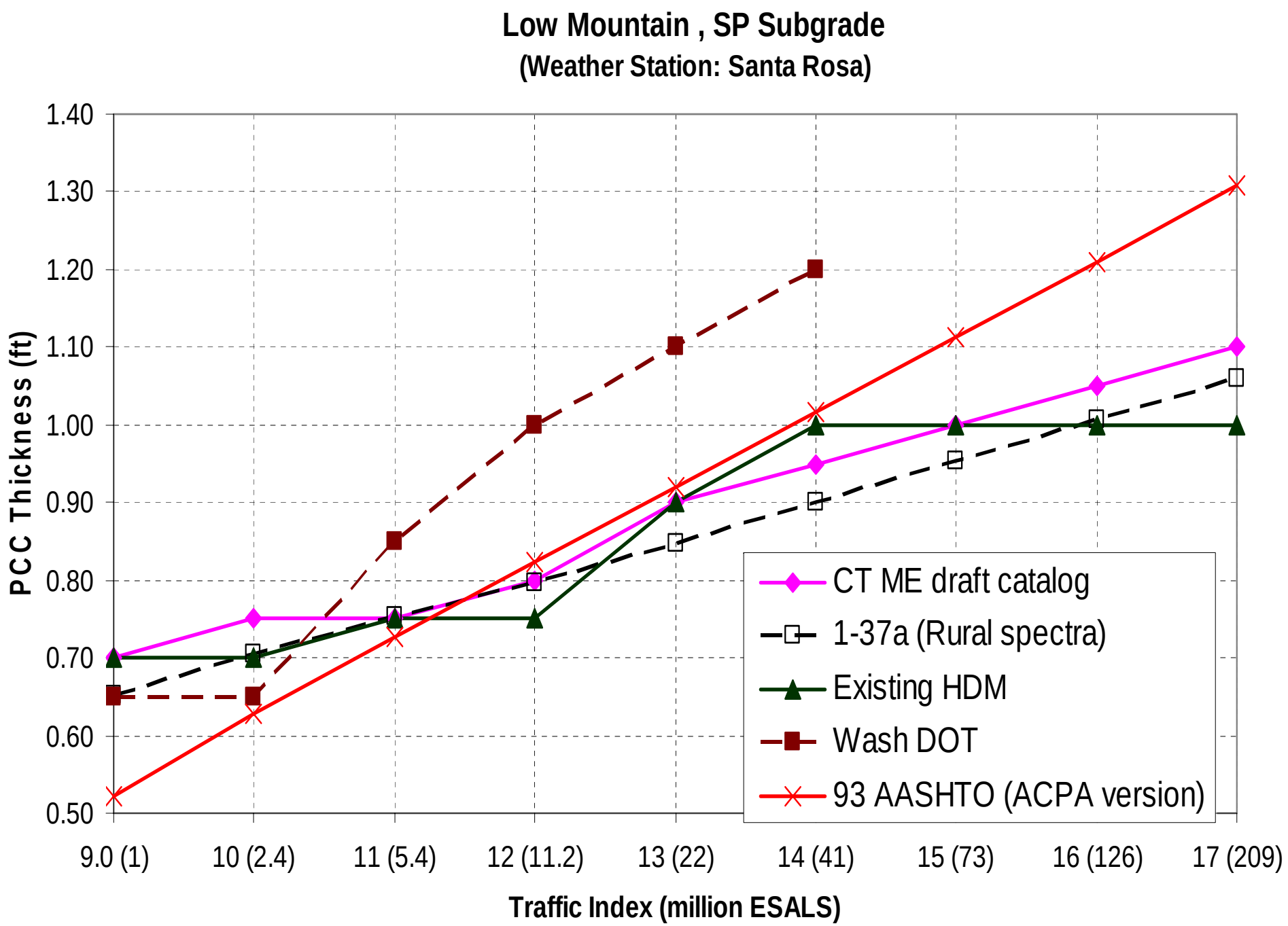
- Based on local experience design tables adjusted slightly by Caltrans where needed

Comparison Study

- In order to check the reasonableness of the catalog, it was compared to
  - Current Caltrans catalog
  - Washington and Texas designs for similar climate regions
  - Pavement Analysis software: ACPA version of AASHTO 93 guide (with adjusted k-value of the subgrades)
  - Historical performance of the pavements


Coastal Climate, SP Subgrade
(Weather Station: San Francisco)
CT ME draft Catalog (South Coast)
1-37a Urban spectra
Existing HDM
Wash DOT
93 AASHTO (ACPA version)
PCC Thickness (ft.)
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
9.0 (1)
10 (2.4)
11 (5.4)
12 (11.2)
13 (22)
14 (41)
15 (73)
16 (126)
17 (209)
Traffic Index (million ESALS)


Desert, SP subgrade
(Weather Station: Dagget)
PCC Thickness (ft)
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
9.0 (1)
10 (2.4)
11 (5.4)
12 (11.2)
13 (22)
14 (41)
15 (73)
16 (126)
17 (209)
Traffic Index (million ESALS)
CT ME draft catalog (Desert)
1-37a (Rural Spectra)
Existing HDM
Wash DOT
Texas DOT
93 AASHTO (ACPA version)


Low Mountain , SP Subgrade
(Weather Station: Santa Rosa)
PCC Thickness (ft)
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
9.0 (1)
10 (2.4)
11 (5.4)
12 (11.2)
13 (22)
14 (41)
15 (73)
16 (126)
17 (209)
Traffic Index (million ESALS)
CT ME draft catalog
1-37a (Rural spectra)
Existing HDM
Wash DOT
93 AASHTO (ACPA version)

Conclusions

- The results from MEPDG were reasonable based on our experience with our previous designs
  - Kept existing Caltrans base/ subbase design
  - Limited granular design to TI 11 & less
  - Did not adopt un-doweled pavement option
- Implement because new tables were an improvement to the old tables.

UCPRC Check on CRCP models in MEPDG

- Draft internal UCPRC report October 2005
- Performed small sensitivity study using results of earlier study by Texas A&M

	Variable	**Factor Levels**
Base cases	Axle Load Spectra (2)	Urban, Rural
	Traffic Volume (4)	Traffic Index : 9, 11 , 13 ,17
	Climate Regions (3)	Coastal (San Francisco), Low mountain (Santa Rosa), Valley/Desert (Dagget)
	Subgrade type (2)	High Plasticity Clay, Poorly graded sand
Design Features	CRCP Thickness (3 or 4 depending on TI)	7”,8”,9” for TI 9 8”,9”,10”,12” for TI 11 9”,10”,12”, 14”for TI 13 and 17
	Shoulder Type (2)	Asphalt Shoulders, Tied Shoulders
	Percent of longitudinal steel (2)	0.7%, 0.6%
	Depth of steel (2)	3.5-in, 4.0-in
	Rebar diameter (2)	#5 (0.625-in), #6(0.750-in)

CRCP Sensitivity, problems

- Subgrade issues
  - Thicker concrete (3 to 4 inches) required for CH (soft clay) than SP (sand) subgrade
  - ARA suggested some tricks in software didn’t work well
- Subbase issues
  - Use of granular subbase showed increased pavement distress. New version (0.9) was suggested to fix this. Software instability
- Insensitivity to percent of steel in particular cases
  - Didn’t make much sense.
- No change throughout the pavement life
  - In some cases, the program seemed to run normally, but the output showed flat results along the years, even with heavy traffic.
- Software version 0.700 and 0.800 had some crashing problems.

CRCP Sensitivity, what works

- MEPDG considers important variables in CRCP models:
  - Use of axle load spectrum and traffic data
  - Climatic effects on materials
- Sensitivity to depth of steel makes sense: reduction in punchouts when reinforcement is closer to surface
- Thickness: enhanced performance with thicker slabs
- Effect of shoulder type: generally seems reasonable for tied concrete vs asphalt shoulder
- Rebar diameter: better performance with smaller bars consistent with current knowledge
- Crack width model: may overpredict crack width. Unclear if this model was calibrated with real data.
- Zero-stress temperature: high sensitivity to this variable. Somewhat difficult to input, not sure if well calibrated
- Age related properties of concrete strength: works well

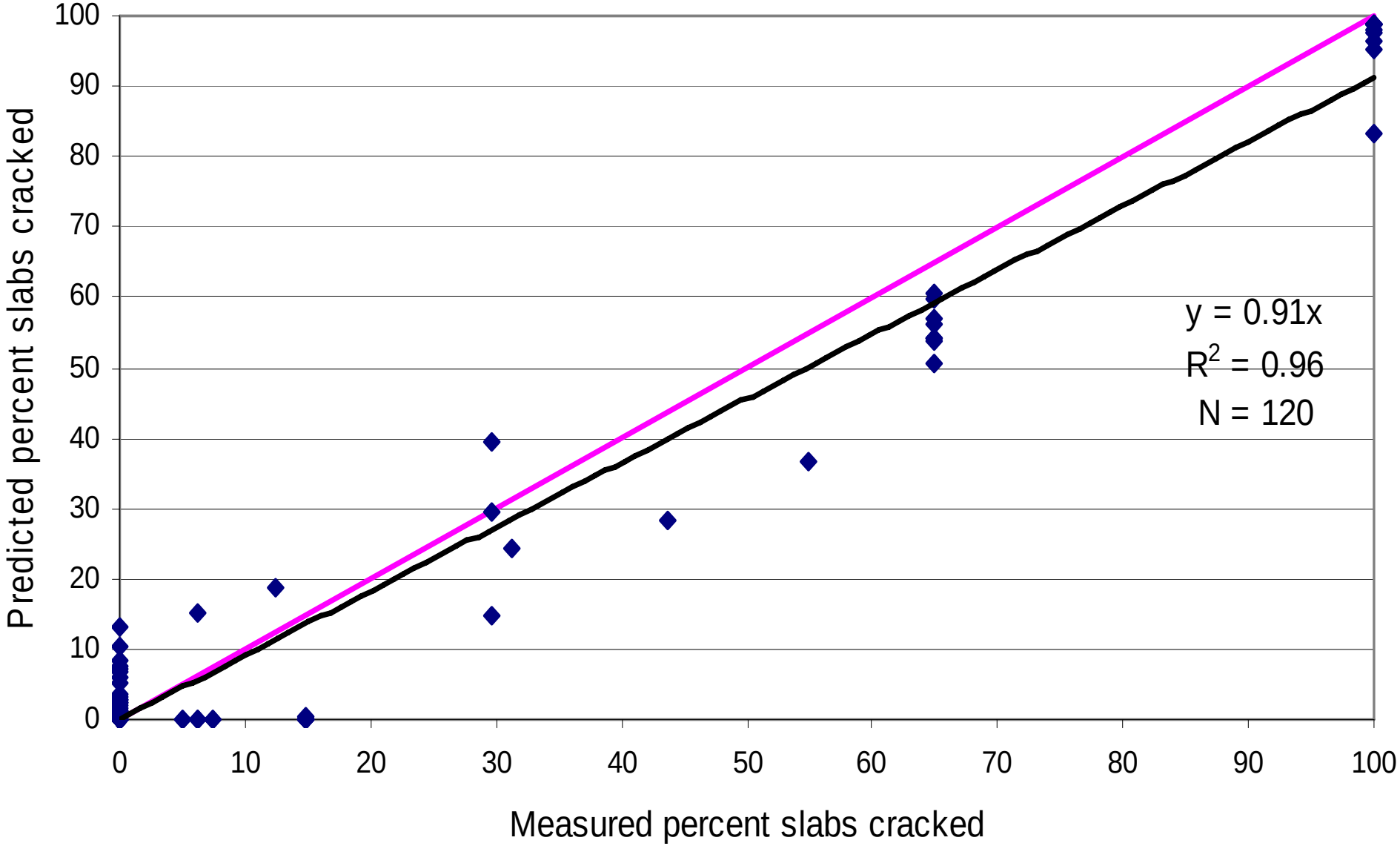
CRCP Design Catalog runs

- Similar factorial, smaller set
- Predicted thicker concrete needed for CRCP than JPCP
  - Doesn’t make sense
  - May be calibration problems??

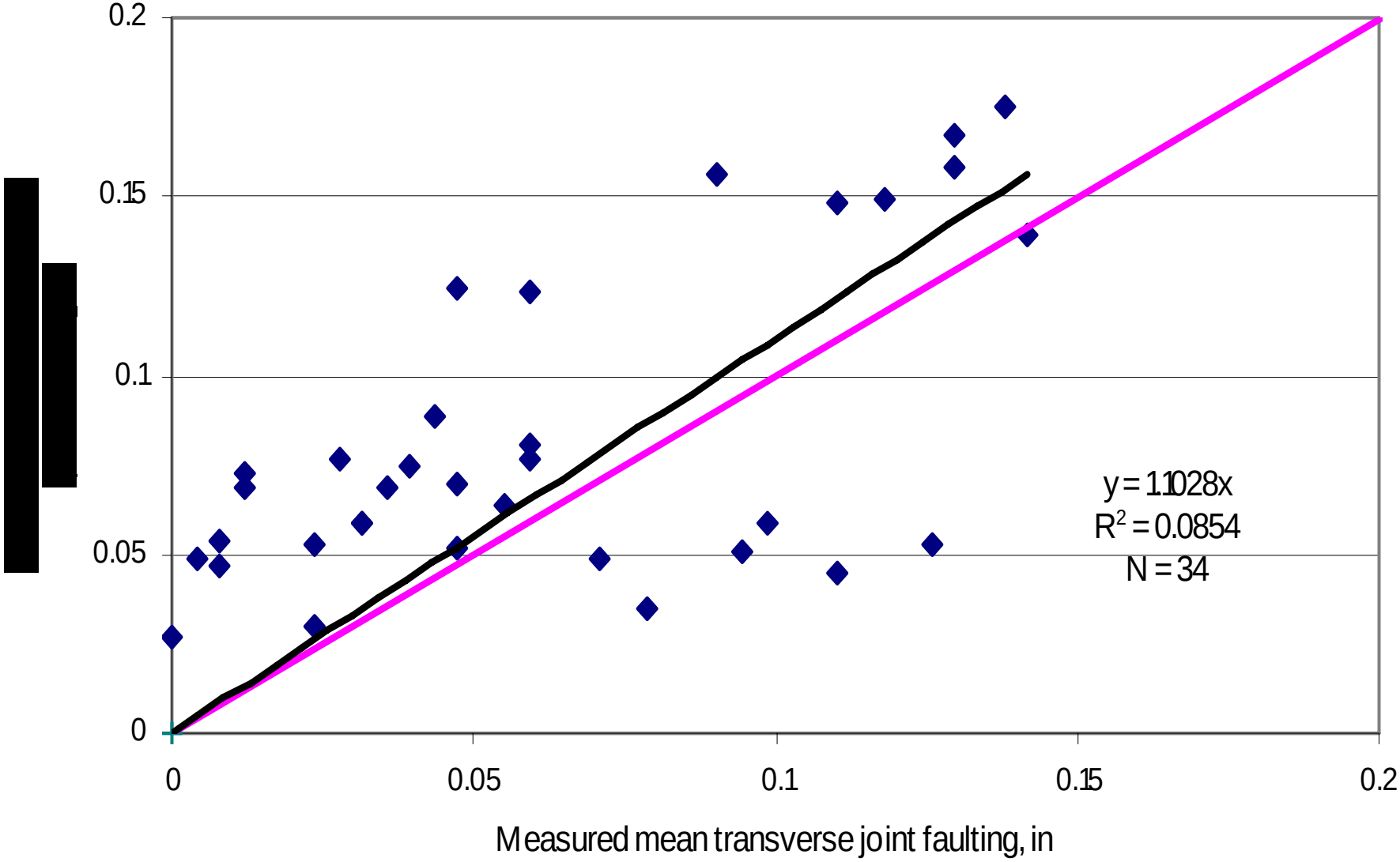
MEPDG JPCP Module Calibration

- Finished field work
  - JPCP: 53 sections
  - ACOL rigid: 44 sections (to calibrate rehab models)
  - Gathered historic traffic and performance data
    - Traffic: 1978 to current year
    - Performance history from PMS data: 1978-2004
- Obtained MEPDG calibration data set from ARA in Oct 06
  - Running just the California sections with current MEPDG software for comparison with national calibration

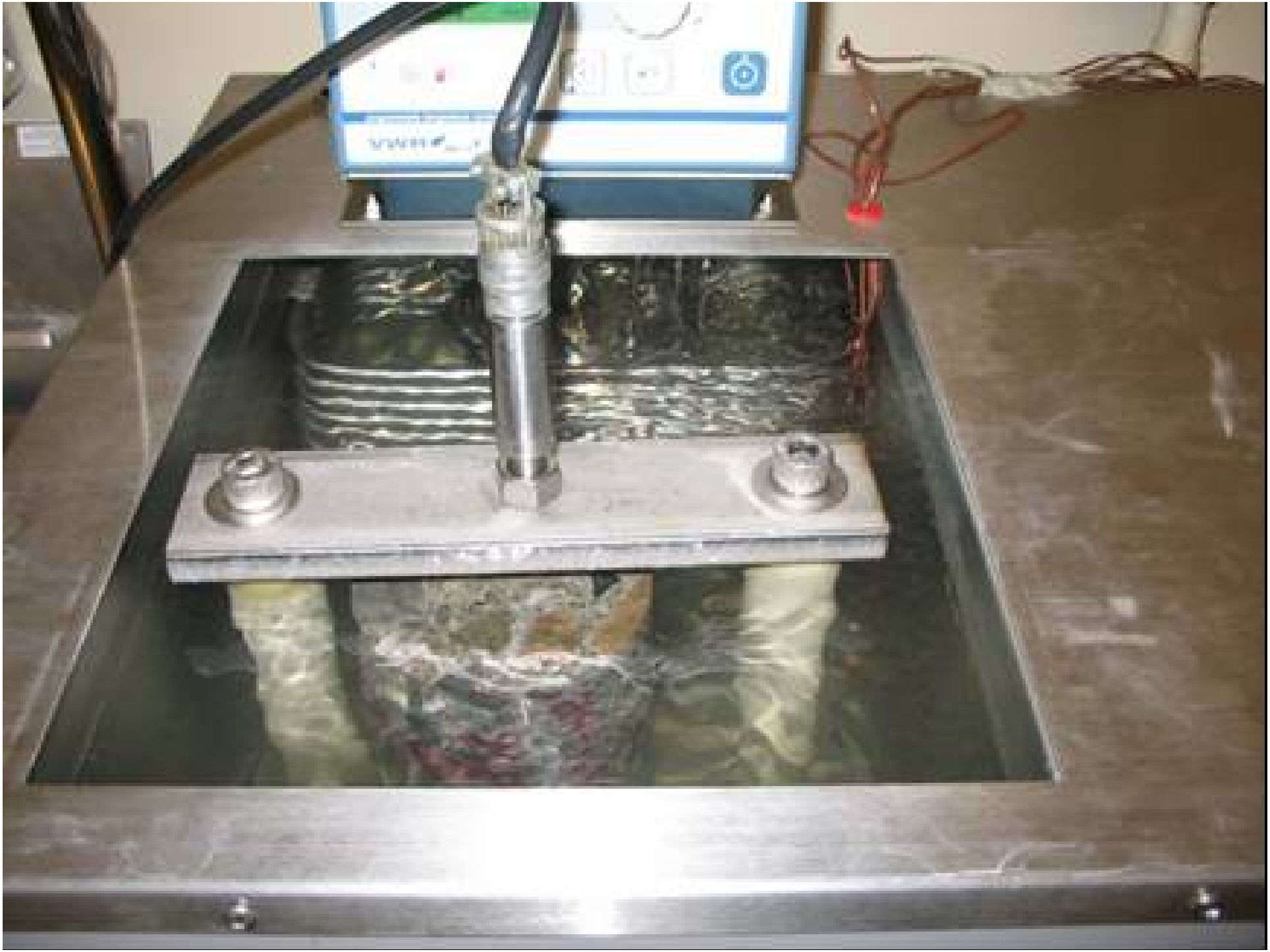
Transverse Cracking Model: ARA MEPDG calibration data for California

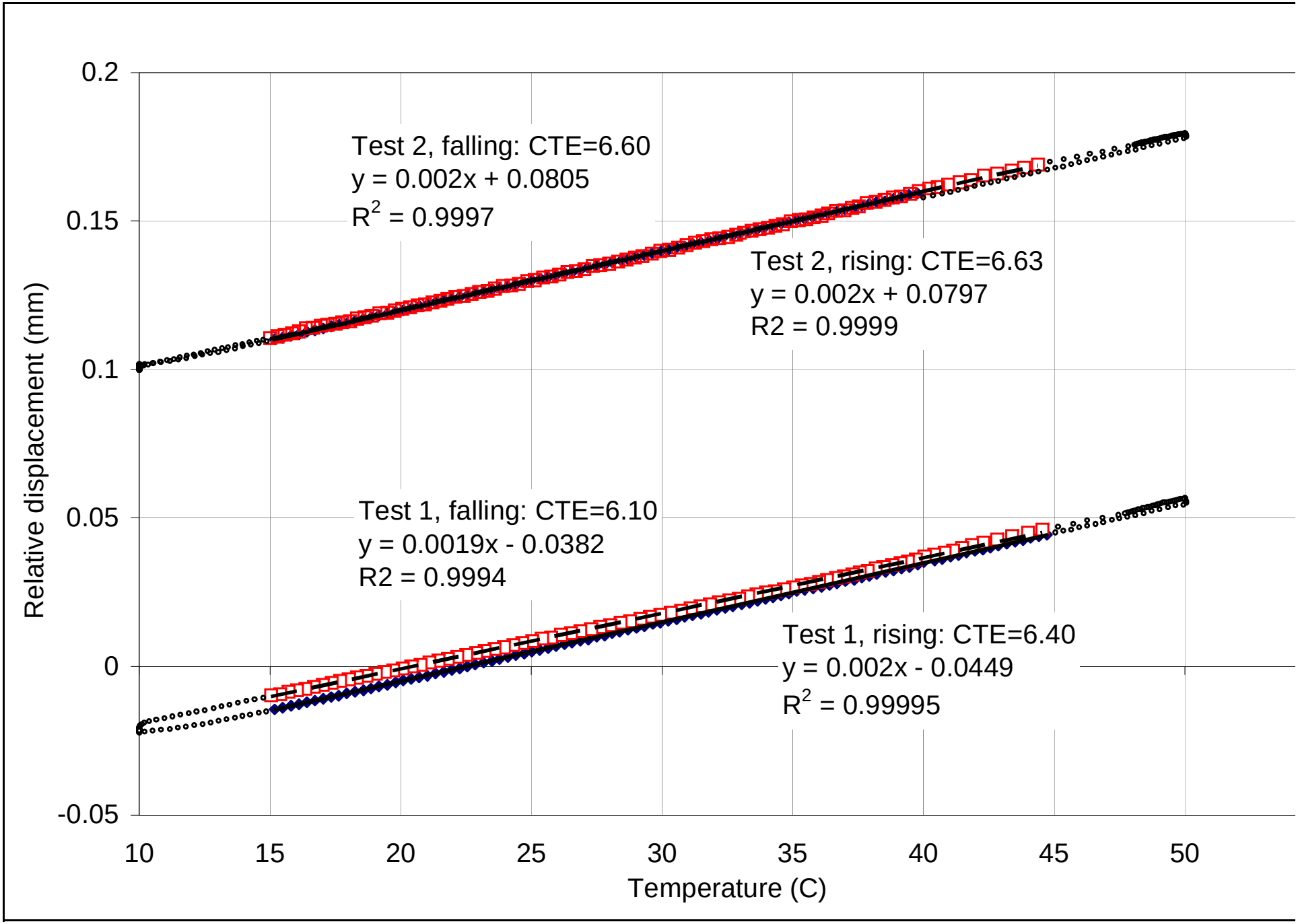


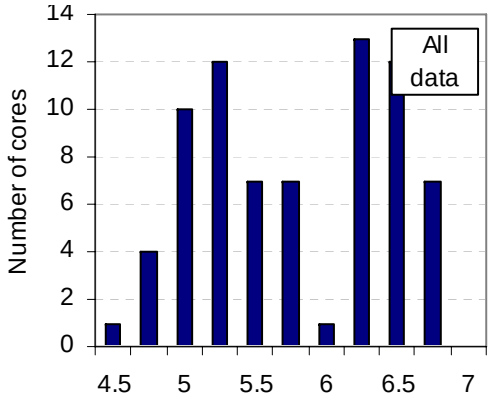
Faulting Model: ARA MEPDG Calibration data for California

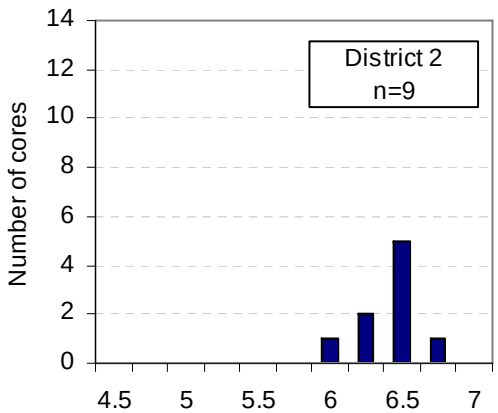


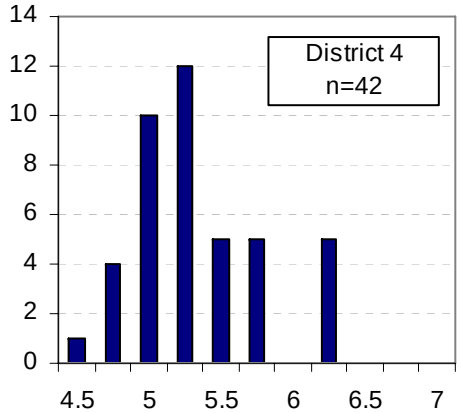
MEASUREMENT AND VARIABILITY OF COEFFICIENT OF THERMAL EXPANSION on Cores from PCC and ACOL Rigid Field Calibration Sections

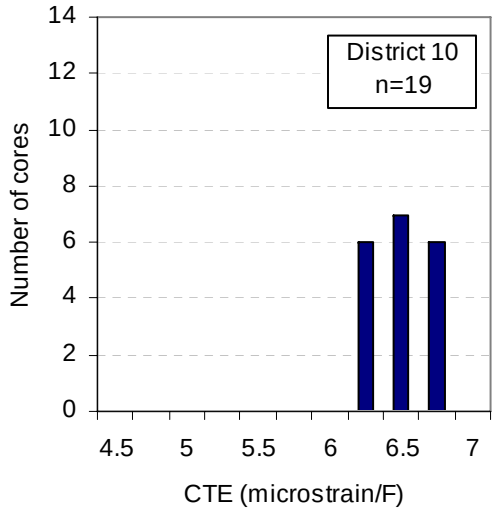


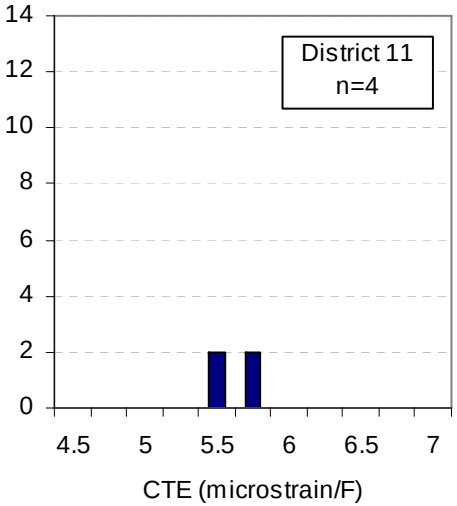

Test 2, falling: CTE=6.60
y = 0.002x + 0.0805
R2 = 0.9997
Test 2, rising: CTE=6.63
y = 0.002x + 0.0797
R2 = 0.9999
Test 1, falling: CTE=6.10
y = 0.0019x - 0.0382
R2 = 0.9994
Test 1, rising: CTE=6.40
y = 0.002x - 0.0449
R2 = 0.99995
Relative displacement (mm)
Temperature (C)
0.2
0.15
0.1
0.05
0
-0.05
10
15
20
25
30
35
40
45
50



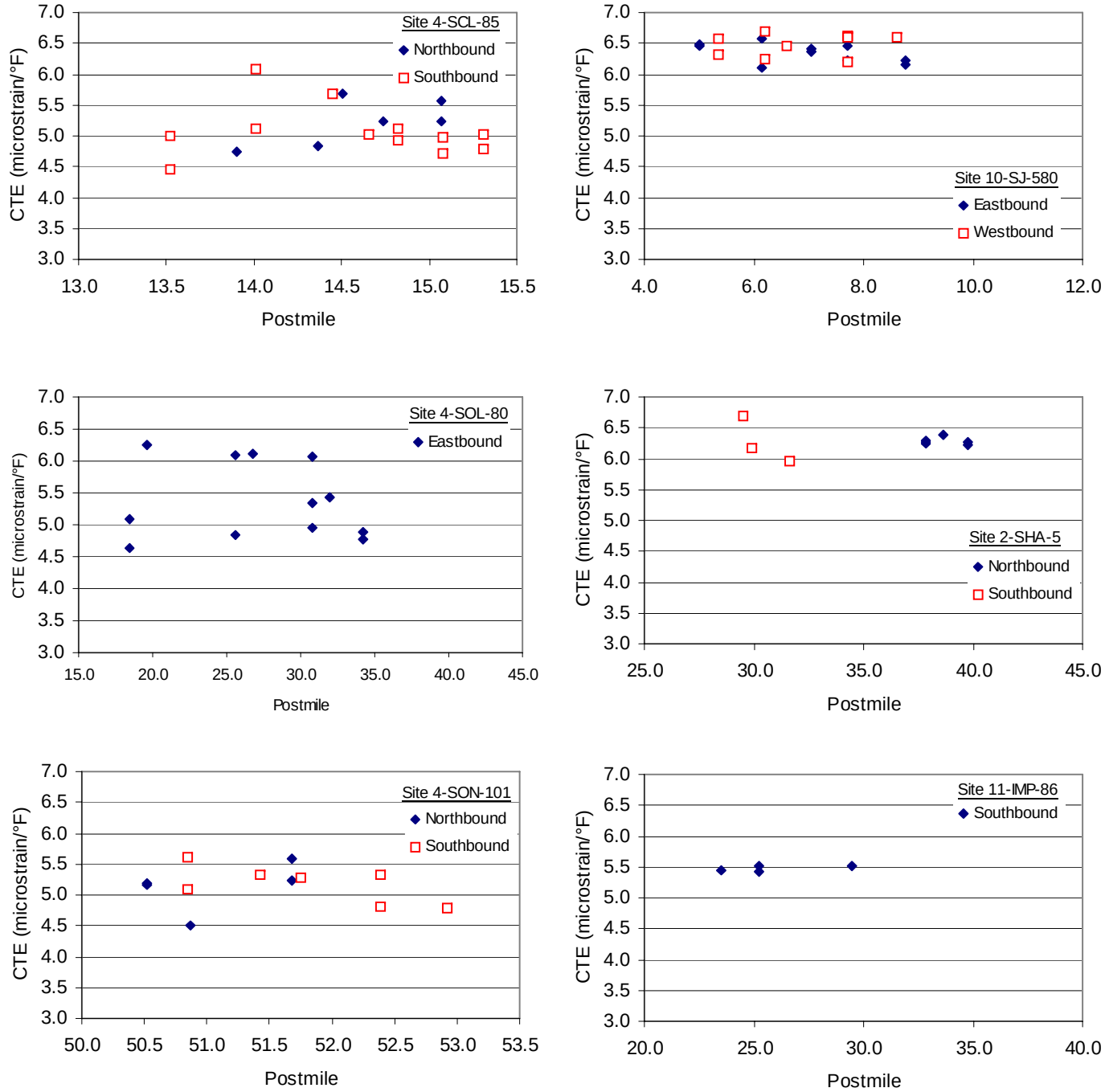








74 cores tested, 100 more to test (2 cores per Stantec section)


Site 4-SCL-85
Northbound
Southbound
CTE (microstrain/°F)
Postmile
Site 10-SJ-580
Eastbound
Westbound
Site 4-SOL-80
Eastbound
Site 2-SHA-5
Northbound
Southbound
Site 4-SON-101
Northbound
Southbound
Site 11-IMP-86
Southbound

Mechanistic-Empirical Flexible Pavement Progress

- MEPDG v. 0.91 software received Sept 2006
  - Sensitivity analysis underway, some difficulty getting asphalt master stiffness curve data
  - Previous version did not work (major bugs)
- CalME models for flexible pavement and rehab
  - Calibrated with HVS and WesTrack data (reports available)
  - MnRoad and NCAT materials gathering underway
- Field calibration
  - Flexible design: I-580 (D4), US101 (D1), need six more sites
  - 50 crack, seat and overlay sections tested and sampled, analysis to begin soon

Mechanistic-Empirical Back-calculation progress

- ME Technical Working Group established
  - Imad Basheer leader
  - HQ, D4 DME and UCPRC staff
- Detailed review of CalBack FWD back-calculation software and manuals
  - Changes being made based on Nov 06 mtg
- Will next review CalME models and MEPDG flexible sensitivity results

Flexible Gap Analysis Summary
Joint effort by Caltrans/UCPRC

- Key properties: stiffness, cracking or rutting performance
- Preliminary look:
  - Rehab: deflection testing with FWD and back-calculation of stiffnesses of all existing layers
  - Several levels of HMA characterization:
    - From PG binder tests and gradation
    - From lab mix tests: flex beams, shear, or triaxial or typical values from these tests
  - Lightly cemented layers: stiffnesses estimate from unconfined compression tests
  - Soils for new pavements: from classification or triaxial lab data or typical values from previous tests
- See handout for preliminary analysis

Flexible GAP analysis details

- Final versions of NCHRP 1-37a and CalME are not ready
  - “Final” inputs cannot be determined yet.
- Current GAP analysis based on generic flexible inputs required by 1-37a and CalME
  - Stiffness
  - Fatigue
  - Rutting
  - Thermal cracking
  - Unbound materials GAP analyses same for rigid & flexible

AC Properties Overview (Stiffness)

- Current CT : Does not collect
- 1-37a (Levels 1 and 2)
  - Time-temperature dependant dynamic modulus triaxial test (E*) :NCHRP 1-28A
  - Binder complex shear modulus: AASHTO T315
- 1-37A (Default level) handout
  - Use predictive equations for E* from typical asphalt properties values based on binder

Stiffness (contd..)

- CalME (Default level) handout
  - Default parameters from materials data base in CalME for the master curve
- CalME (Tests)
  - Flexural freq sweep (preferred) or shear frequency sweep
  - Standard Exp: 3 temps x 2 replicates x 1 strain level
  - AASHTO T321

Fatigue

- Caltrans Current: None
- 1-37a (Default level) handout
  - Default parameters built into the software (not dependant on binder type)
- 1-37a (Levels 1 & 2)
  - Flexural beam testing
  - Compaction method: Linear Kneading or Rolling wheel
  - 3 temps x 2 strain levels x 3 replicates
  - AASHTO T321

Fatigue (continued)

- CalME (Default level)
  - Default parameters built into the software (dependant on binder type) handout
- CalME (Levels using Test Values)
  - Flexural beam testing
  - Rolling wheel compaction
  - 3 temps x 2 strain levels x 3 replicates
  - AASHTO T321

Rutting

- Current Caltrans: Stabilometer
- 1-37a (Levels 2 and 3)
  - Default values built into the software (not dependant on binder type)
- 1-37a (Level 1)
  - Repeated loading Simple performance test triaxial (NCHRP 9-19)
  - Use gyratory compacted specimens (100 mm x 150mm)

Rutting (contd..)

- CalME (Default level)
  - Default parameters based on local testing.
- CalME (Levels 2 & 3)
  - Repeated simple shear test at Constant height (AASHTO T320-03)
  - Superpave shear tester
  - Rolling wheel compaction
  - Standard experiment: 2 temps x 3 stress levels x 3 replicates

Thermal Cracking

- Current Caltrans: None
- 1-37a (level 3)
  - Default values built into the software
  - Correlation with volumetric & binder properties
- 1-37a (level 1 and 2)
  - Creep compliance, tensile strength, Coeff of thermal contraction, albedo, thermal conductivity and heat capacity
  - AASHTO T322 (Indirect tensile test device)

Thermal Cracking (contd...)

- CalME
  - Not included in CalME
  - Rely on PG binder spec
  - Or could include 1-37A models in software, if needed

Rigid Gap Analysis – First look
Joint effort by Caltrans/UCPRC

- Key properties: stiffness, load transfer efficiency
- Preliminary look:
  - Rehab: deflection testing with FWD and back-calculation of stiffnesses and LTE
  - PCC properties:
    - Flexural stiffness and strength from testing
    - Coefficient of thermal expansion, from lab tests or typical values from previous tests
  - Soils for new pavements: from classification or triaxial lab data or typical values from previous tests
- See example handout
- Caltrans will use flexible and rigid gap analyses to update specifications and test methods for ME

Rigid Gap Analysis
Effect of MEPDG input values on results

- Variables Analyzing (underway now)
  - Cement Type
  - Cementitious material content
  - Water/Cement ratio
  - 28 day PCC Modulus of Rupture
- Finished Analyzed the effect of cement type
  - for different traffic conditions & climate regions
  - Absolutely no effect on cracking and faulting according to MEPDG
- Analyzing the rest of the variables

Expected UCPRC Results by Summer 07

- Sensitivity analysis of MEPDG completed
- CalME and CalBack 0.9 version completed available for review by Caltrans and other states
- California calibration completed for:
  - MEPDG flexible, rigid and rehab
  - CalME
  - RadiCal

Development of Asphalt Concrete Rutting Performance Tests and Analysis Procedures

PPRC SPE 4.4

Supports PPSC ME objective

Rutting Performance (Goals)

- Develop improved AC models to improve mix design and test methods
- Develop procedure for analysis of test data to predict AC rutting performance
- Determine relation between specimen size, sample size, and test variability for AC at high temperatures

Rutting Performance (Findings)

- Report with constitutive relations, recommended tests, and analysis completed
- Large scale test prototype machine developed
- One of two approaches developed is being coded and calibrated with existing data
- Analysis of MB and previous studies underway
- Relationship between specimen size, sample size, and test variability for AC at high temperatures to be performed

Dowel Bar Retrofit of Rigid Pavements

PPRC SPE 4.8

supports PPSC Pavement Preservation objective

- General objective: Evaluate DBR and best options for implementation
- Work components
  - HVS testing
  - Field Live Traffic Testing
  - Lab testing (corrosion, FRP)
  - Modeling (FEM, LCCA)

HVS testing, Ukiah

- Completed in 2001
- Epoxy coated steel, 4 per wheelpath
- No loss of Load Transfer Efficiency (LTE) under heavy HVS loading for DBR sections
- Severe loss of LTE on undoweled joints
- Live traffic sections monitoring to be summarized this winter

HVS testing, Palmdale

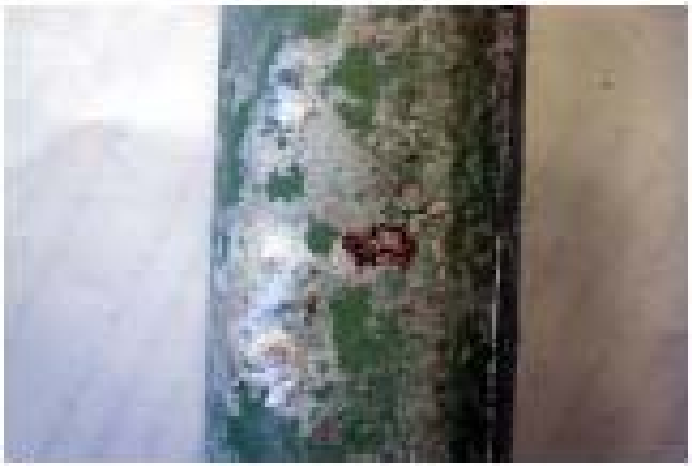
1. *Epoxy-coated steel, 3 and 4 per wheelpath*
2. *Hollow stainless steel dowel*
3. *Fiber-reinforced polymer*

Results:

- No damage to any of the DBR joints, or loss of LTE
- Fatigue cracking of the slab
- Draft report delivered to PST, being finalized

Lab testing: corrosion

Results compared with WSDOT field experience

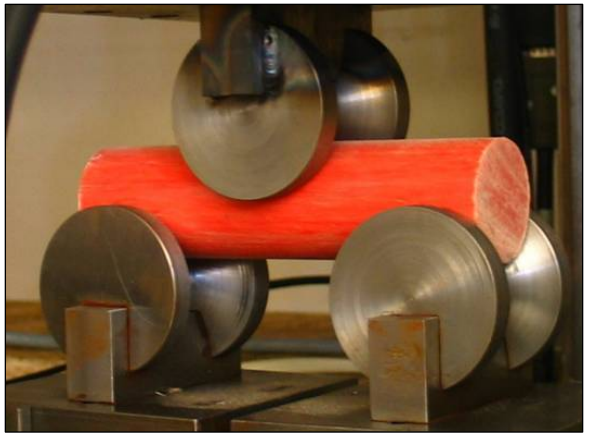


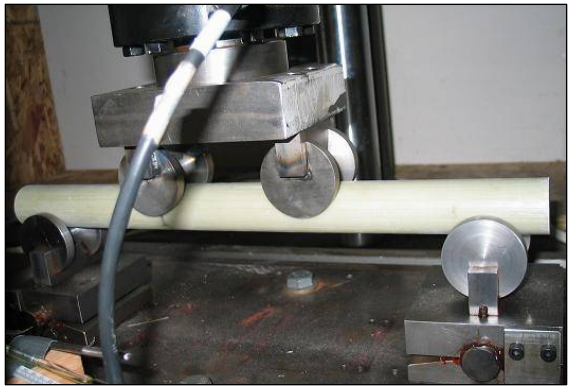
1. *bare carbon steel*
2. *stainless steel clad*
3. *grout-filled hollow stainless steel*
4. *microcomposite steel*
5. *carbon steel coated with flexible epoxy (green)*
6. *carbon steel coated with non-flexible epoxies (purple)*
7. *carbon steel coated with non-flexible epoxies (gray)*

Results:

1. Recommend that uncoated carbon steel dowels not be used
2. Epoxy dowels present risk of corrosion at holidays and the ends
3. Recommend use of stainless steel clad, hollow stainless steel, or microcomposite for locations with risk of high chloride exposure

Lab testing: Fiber Reinforced Polymer dowels





Results:

1. FRP dowel bars can perform well: measured strength, stiffness, fatigue life.
2. Water and UV conditioning can affect properties some, not a major concern
3. Alkali conditioning process significantly affected properties of one to two bar types tested

Analysis currently underway

- Summary of WSDOT field experience
  - Including time to open
- Finite element analysis of stresses between dowels and grout, grout and slab
- Life cycle cost analysis
- Expected completion: spring, 2007

Development of Improved Rehabilitation Designs for Reflection Cracking

PPRC SPE 4.10

Supports PPSC ME objective

Objectives

1. Develop improved mechanistic models of reflection cracking in California
2. Calibrate and verify these models using laboratory and HVS testing
3. Evaluate the most effective strategies for reflection cracking
4. Provide recommendations for reflection cracking strategies

HVS Testing

- Constructed new road
  - Compacted subgrade
  - 410mm Class 2 aggregate base
  - 90mm DGAC
- Cracked the road using HVS
- Overlaid with 6 different overlays
- Six HVS fatigue tests (low temperature)
- Six HVS rutting tests (high temperature)

HVS Testing (cont'd)

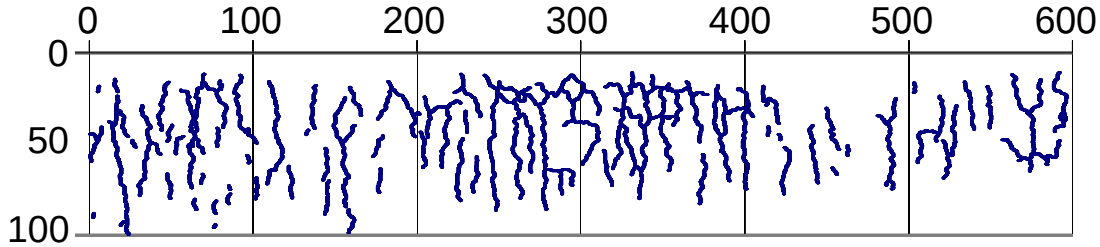
- Overlays
  - 90mm DGAC (control)
  - 45mm RAC-G (control)
  - 90mm MB4 (7% rubber)
  - 45mm MB4
  - 45mm MB15 (15% rubber)
  - 45mm MAC15 (15% rubber)

Laboratory

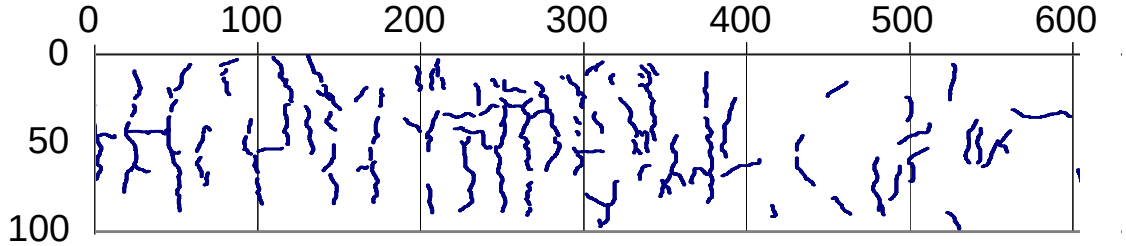
- Two part study
  - Fatigue – flexural beam test
  - Rutting – shear test
- Test material
  - Field mix, field compacted
  - Field mix, lab compacted
  - Lab mix, lab compacted

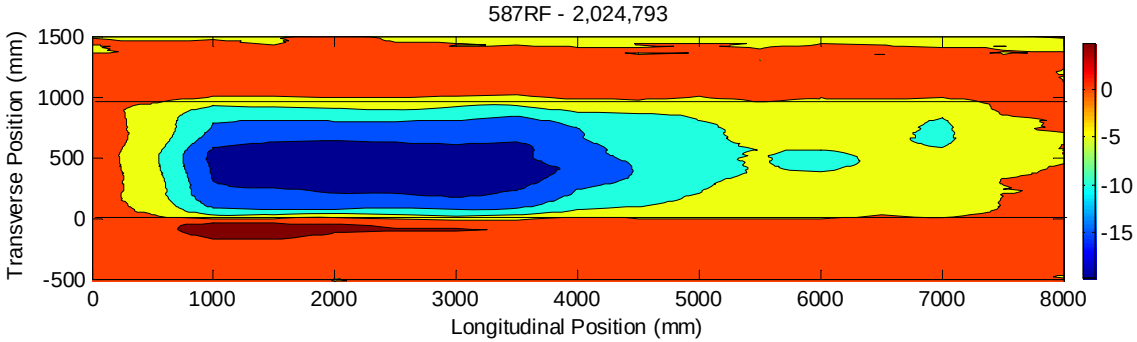
Section 587RF: RAC-G (45 mm)

Section 568RF - 273,992 Repetitions



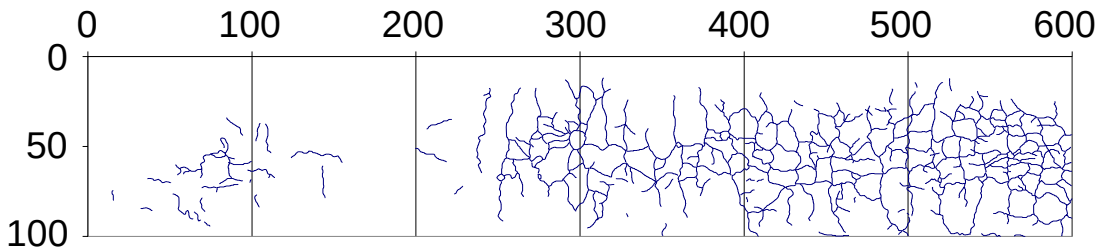
Section 587RF – 2,024,793 Repetitions



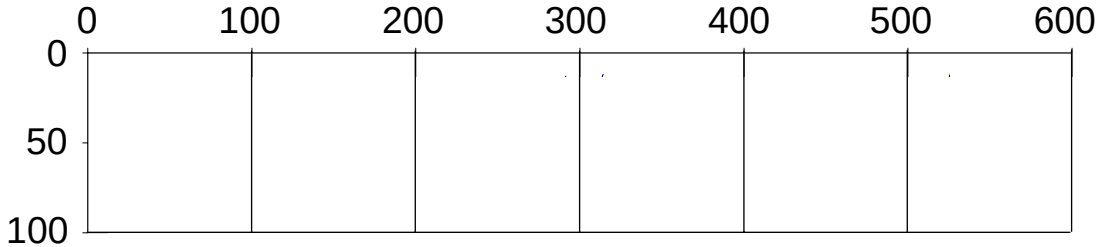


Section 590RF: MB4-G (90 mm)

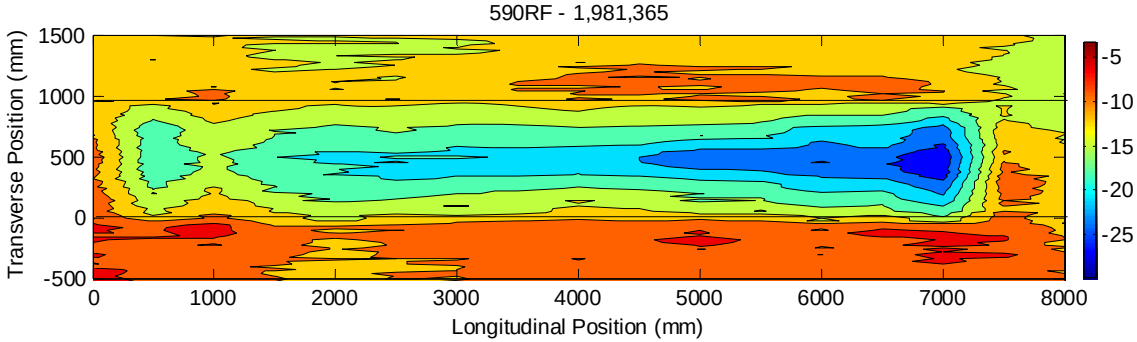
Section 572RF - 516,597 Repetitions



Section 590RF – 1,981,365 Repetitions



No Cracking



Status

- All laboratory testing completed
- Final HVS fatigue test should be done in March, 2007
- All reports expected to be completed by June, 2007

HVS testing pre-cast PCC panels in District 8

PPRC SPE 4.17

supports PPSC Long-Life Pavement objective

- Objectives:
  - Determine failure mechanisms of Super-Slab panels
  - Estimate expected service life
  - Compare to cast in place

Evaluation Plan

- Design and contract preparation requirements
- “Biddability” of the Super-Slab® Pavement pay item
- Constructability
- **Performance with HVS testing**

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Pre-cast slabs

- Intended as a rapid replacement option for damaged concrete pavements
- Individual slabs or a whole section of the pavement may be replaced
- The Super-Slab® System

Super-Slab® pavement system

- "Interconnecting series of precast concrete slabs that can be installed and placed into service **immediately"**

- "… achieving a perfectly smooth sub-grade to provide **full bedding** as well as the challenge of connecting adjacent slabs to **uniformly transfer load** from one slab to another"

Pre-cast concrete plant

April 2005

CTB construction

Slabs details

Epoxy coated dowel-bars cast into the transverse edge

Dowel-bar recesses and bedding grout confinement strip

Female end of the tie-bars cast into the longitudinal edge of the slab

Male to female connection

Placement

Lifting of the slab from the flat-bed

Precise placement of the slab

Fixing the tie-bars on the longitudinal edge

Placement of the slab on the adjacent lane

Placement (cont'd)

Spraying of the dowel-bars with a bond-breaker

Misalignment of adjacent slabs causing surface irregularities

Plastic spacers being driven into the joints between the un-grouted slabs

Expanding foam used for sealing of the outer edges of the joints

Grouting

Filling of the dowel and tie-bar cavities with grout

Removal of excess grout

Injection of the bedding grout

Excess bedding grout pouring from the exit hole

Shoulder, grinding and sealing

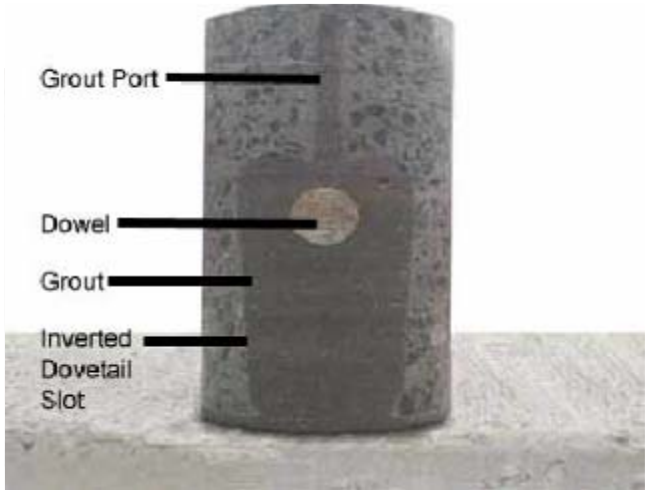
Shoulder filling

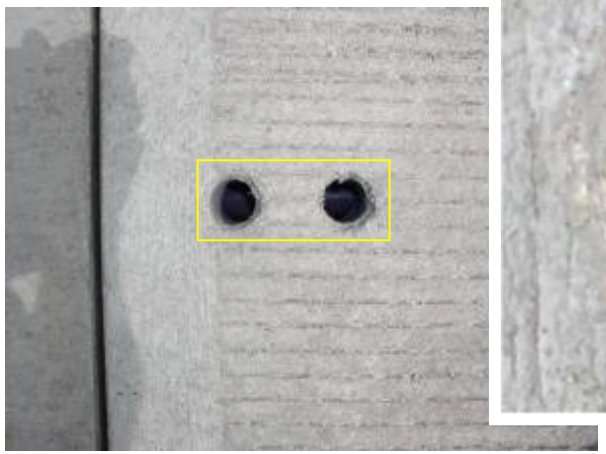
Shoulder compaction

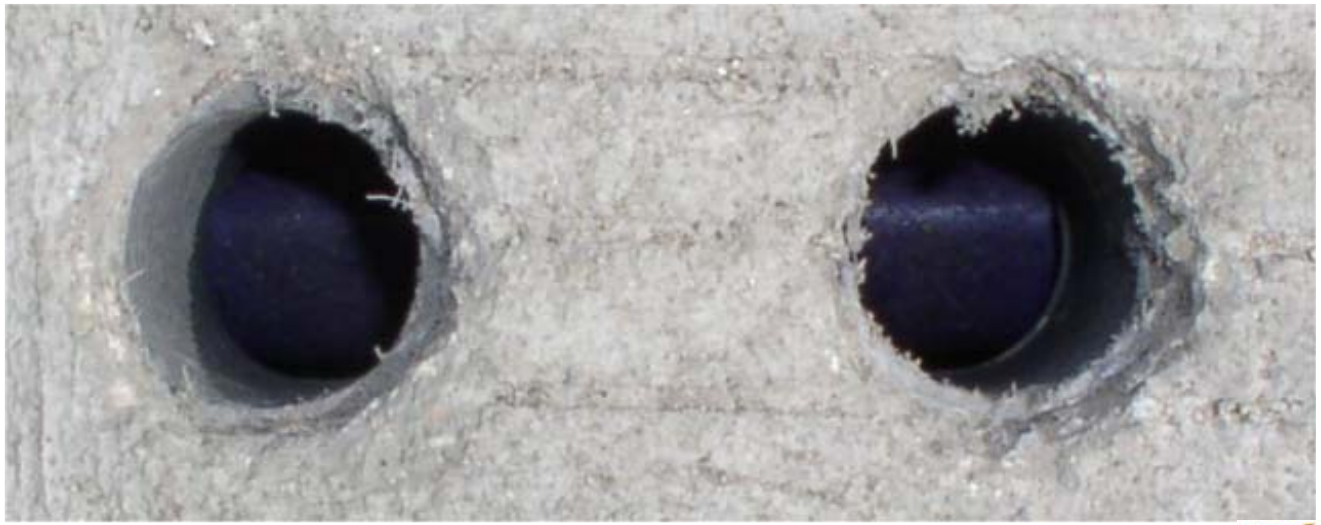
Level grinding of the surface

High density foam strip installed in the joints

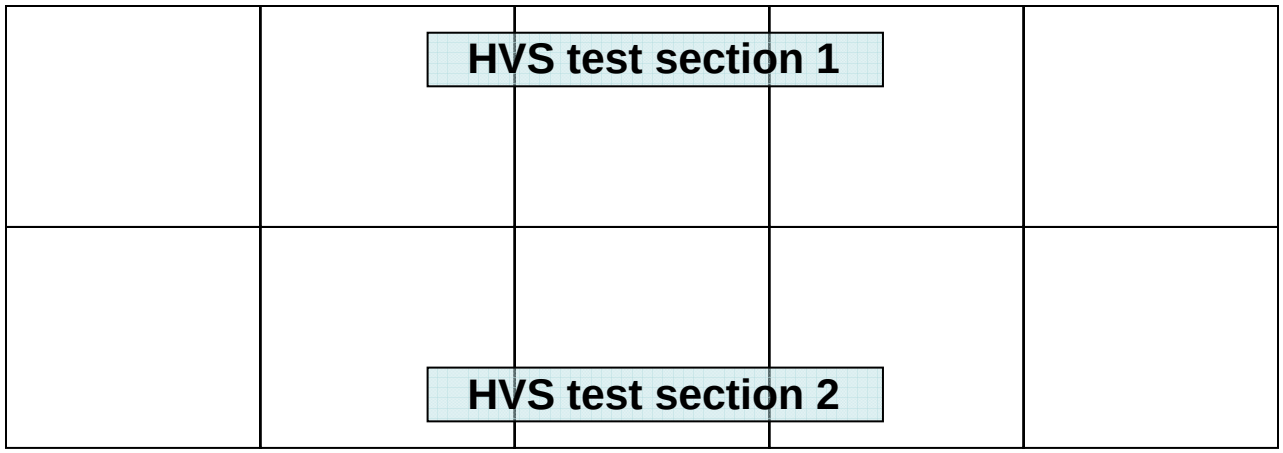
Dowel grout







Test Plan



- Ungrouted load test
- Thermal curl test

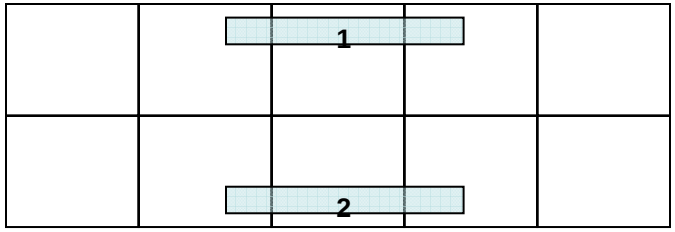
Preliminary tests

- Very high wheel-load test, dry
- High wheel-load test, dry
- High wheel-load test
- Very high wheel-load test, wet

Regular tests

Chronological order of tests

- Preliminary tests:
  - May 26th to June 8th, 2005



- Regular tests:
  - Section 1, dry: June - Sept, 2005
  - Section 2, dry: Sept - Feb, 2006
  - Section 2, wet: Feb - May, 2006
  - Section 1, wet: May - Aug, 2006

Section 1= very high load levels, aircraft tire

Section 2= high load levels, dual truck tires

Section 2, dry

- 100 million ESALs
- 2.3 million load reps (13 and 18 Kips)
- → no distresses

- Application of water at the joints

Section 2, wet

- 43 million ESALs
- 1.1 million reps (13, 18, 20, and 23 Kips)
- Dry+wet loading:
  - 143 millions ESALs
  - 3.46 million reps
- Results:

  → Pumping

  → **<u>No distresses</u>**

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Wet trafficking

Water application (look at loaded tires!)

Section 1, dry

- **165** million ESALs
- 1.1 million load reps (13 to 34 Kips)
- Cracks in one joint

- Application of water at the joints

Section 1, wet

- **79** million ESALs
- 0.5 million reps (13, to 34 Kips)
- Dry+wet loading section 1:
  - **244** millions ESALs
  - 1.6 million reps
- *Dry+wet loading section 2:*
  - *143 millions ESALs*
  - *3.46 million reps*

- Results:

  → **Cracks during dry testing**

  → **Joint failures during wet testing**

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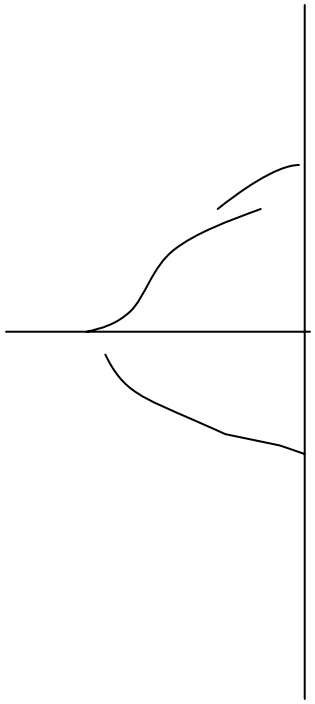
Corner cracks (dry testing)



Cracks on either side of the transverse joint fully developed and extending from the transverse joint to the shoulder joint.

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Section 1 wet, cracking

Void detection

- Considerable amount of material pumped from under the slab during wet trafficking

  → Void under the slab
- GPR (Ground Penetrating Radar) attempt
- Concrete segments removal

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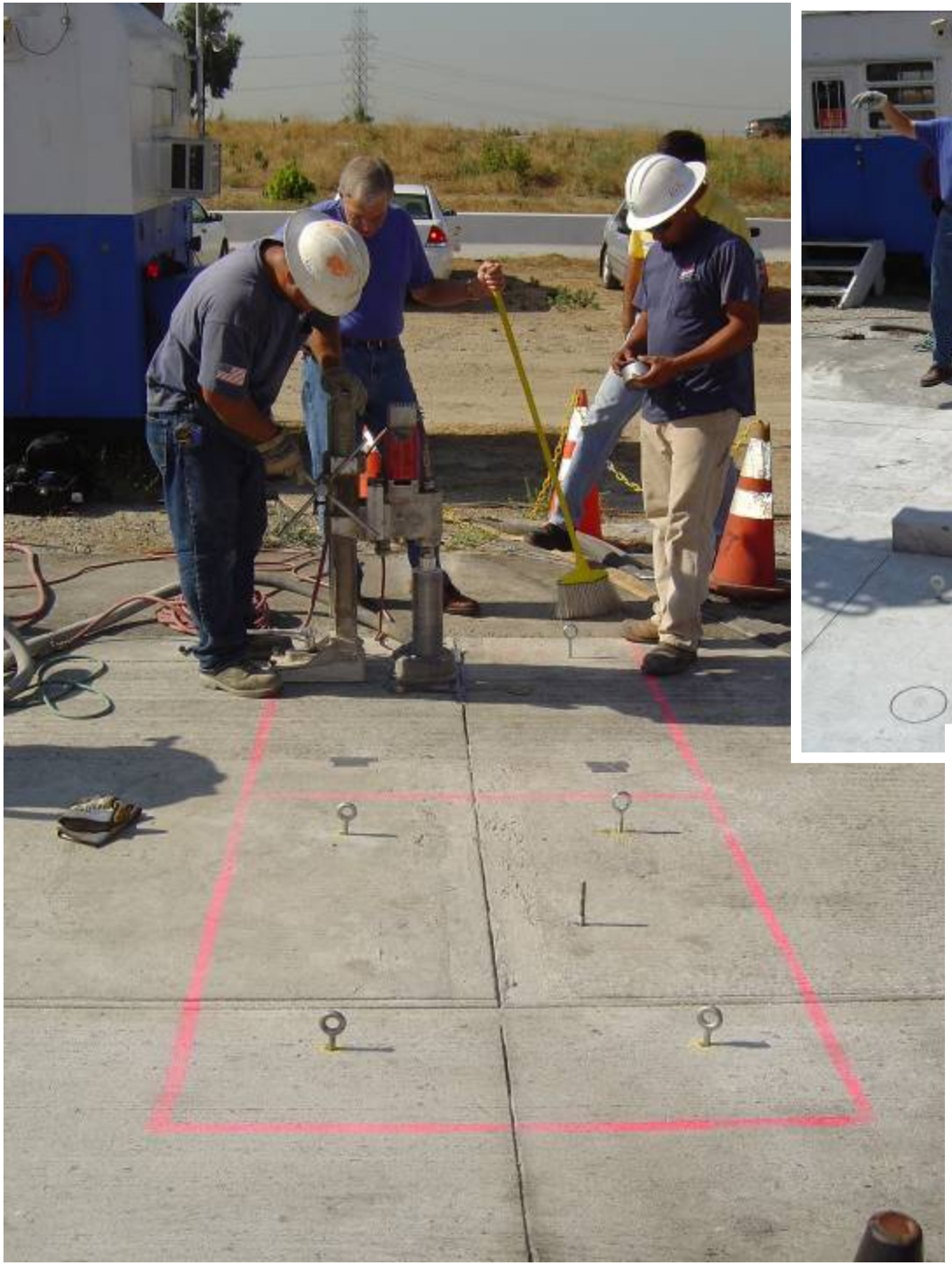

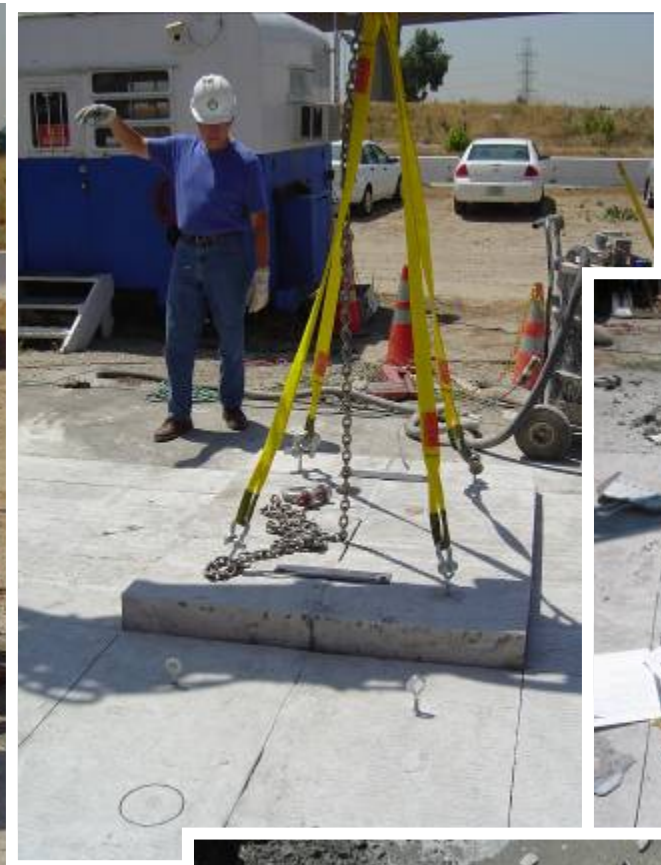

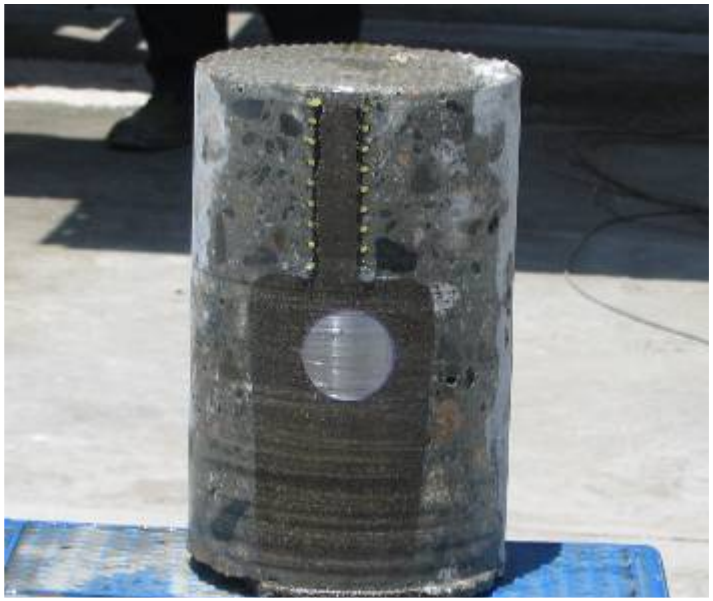

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Conclusions

1. The Super-slab system seems **capable to withstand 24-hr of highway traffic in the un-grouted condition** (at least 88,000 ESALs)

2. As expected, bedding and dowel grouts improved slabs responses considerably

3. At high loads (~21 kips), dry and wet, no cracking occurred. Pumping did no cause damage

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Conclusions (cont'd)

4. At very high loads (~27 kips), dry; **corner cracking occurred** (one joint). **No failure**.

5. At very high loads (~27 kips), wet, joint failure occurred

6. From the HVS tests there is **no evidence to believe the Super-slab system would fail before 140 millions ESALs**

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Projects Underway and Monitoring

Underway

- Assistance to Pavement Preservation Task Group
- (4.6) Development of Rehabilitation Construction Productivity Analysis Products
- (4.12) Development of Improved Mix and Structural Design and Construction Guidelines for Deep In-Situ Recycling (DISR) of Crack Asphalt Concrete as Stabilized or Unstabilized Bases “foamed asphalt”
- (4.14) A Framework for Implementing Innovative Contracting Methods for Transportation Infrastructure Rehabilitation/Reconstruction
- (4.15) Development of Integrated Pavement Strategy Decision Support System (Life Cycle Cost Analysis)
- (4.16) Investigation of Noise, Durability, Permeability and Friction Performance Trends for Asphaltic Pavement Surface Types

Monitoring

- (3.1.4) Quality Assurance Laboratory Testing for AC Long-Life Pavement Mix Designs (I-710)
- (3.2.11) Support for I-710 Phase 2

Assistance to Pavement Preservation Task Group

- Leading PPTG Research Committee with Division of Research and Innovation
- Participating in PPTG sub-committees
- Joint investigation with Chico State Pavement Preservation Center

Development of Rehabilitation Construction Productivity Analysis Products

PPRC SPE 4.6

Supports PPSC

CA4PRS

(Construction Analysis for Pavement Rehabilitation Strategies) software

- **Integrated pre-construction analysis tool: for longer lasting pavements; fast construction; tolerable traffic delays; and within agency budget and scope**
- **Software calculates construction duration and traffic delay for 'what-if scenarios': pavement structures, lane closures, construction logistics**
- **FHWA pooled-fund for CA, FA, MN, TX, and WA DOTs**
- **Implementation on I-10 Pomona, I-710 Long Beach and I-15 Devore I&II projects with work-zone traffic studies**
  - **Devore II currently being completed**

I-15 Devore I Pre-Construction Analysis with *CA4PRS:* Schedule-Traffic-Cost

Construction Scenario	*Schedule Comparison*		Cost Comparison ($M)			Max. Peak Delay (Min)
	Total Closures	Closure Hours	User Delay	Agency Cost	Total Cost	
One Roadbed Continuous (24/7)	2	400	5.0	15.0	20.0	80
72-Hour Weekday Continuous	8	512	5.0	16.0	21.0	50
55-Hour Weekend Continuous	10	550	10.0	17.0	27.0	80
10-Hour Night-time Closures	220	2,200	7.0	21.0	28.0	30

The I-15 Devore 'Rapid Rehab' proejct was completed in two 9-day continuous closures in 2004 with the estimated saving of $6M agency cost and $2M user cost (report delivered to PST)

Free download (CA4PRS at GOOGLE) for Caltrans at:

http://www.dot.ca.gov/hq/research/roadway/ca4prs/index.htm

2-day hands-on training workshop for district project teams is available (online course is in preperation)

Development of Improved Mix and Structural Design and Construction Guidelines for Deep In Situ Recycling with Foamed Asphalt

PPRC SPE 4.12

Supports PPSC Recycling objective

Objectives

1. Undertake literature survey and technology and research scan
2. Perform mechanistic sensitivity analysis
3. Undertake assessment of Caltrans projects built to date based on available data
4. Measure properties on Caltrans DISR-foamed asphalt projects to be built in the future.
5. Carry out laboratory testing to identify specimen preparation and test methods, and develop information for mix design, structural design and construction guidelines.
6. Prepare project selection guidelines
7. Prepare mix design recommendations.
8. Prepare structural design recommendations.
9. Prepare construction recommendations

California projects being monitored by UCPRC

- SR20 (Colusa)
- SR89 (Sierra)
- SR220 (Solano)
- SR132 (Modesto)
- SR33 (Santa Barbara/San Luis Obispo)
- SR33 (Ventura)

Field testing

- Biannual site visits (spring and fall)
  - Visual assessment
  - FWD testing
  - DCP testing
- Assess moisture and temperature sensitivity
- Identify cause of distress
- Build database of performance over time

Lab testing

- Comprehensive lab testing program to develop optimum mix design
- Assess influence of:
  - Binder foamability
  - Binder source and grade
  - RAP source and gradation
  - Compaction
  - Active filler
  - Curing
  - Mixing temperature
  - Test methods (fatigue, beam, strength)

DO NOT
PUSH
DO NOT
PUSH

WARNING
TEREX
RS-650B
DSI
3257
WOSS

WARNING

SAKAI

A Framework for Implementing Innovative Contracting Methods For Transportation Infrastructure Rehabilitation and Reconstruction

PPRC SPE 4.14
supports PPSC Construction Practices objective

Part A: Decision-supporting system for **Warranty Contracts**

- Completed case study on asphalt rubber chip seal project in Dist 11
- Engine for calculating probability of failure within warranty period developed
- Analyzing “classical” economic theory of warranties for application to pavement context
- Detailed work plan under development

Part B: Evaluation tool for **Incentives/Disincentive Contracts**

- Work plan under development

Development of Integrated Pavement Strategy Decision Support System (Life Cycle Cost Analysis)

PPRC SPE 4.15

Supports PPSC PMS and Long-Life objectives

Status

- Policy requirement by the state legislature (from Jan 2007)
- UCPRC and Caltrans customizing FHWA Realcost software and manual with state default inputs
  - Life cycles are based on district M&R practices, Maintenance regional coordinator review
- LCCA procedure user manual is completed and available at

  http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm
- Online and class training will be provided by HQ Design

Investigation of Improved Open Graded Mix Designs (incl. Quiet Pavement-AC)

PPRC Strategic Plan
Element 4.16

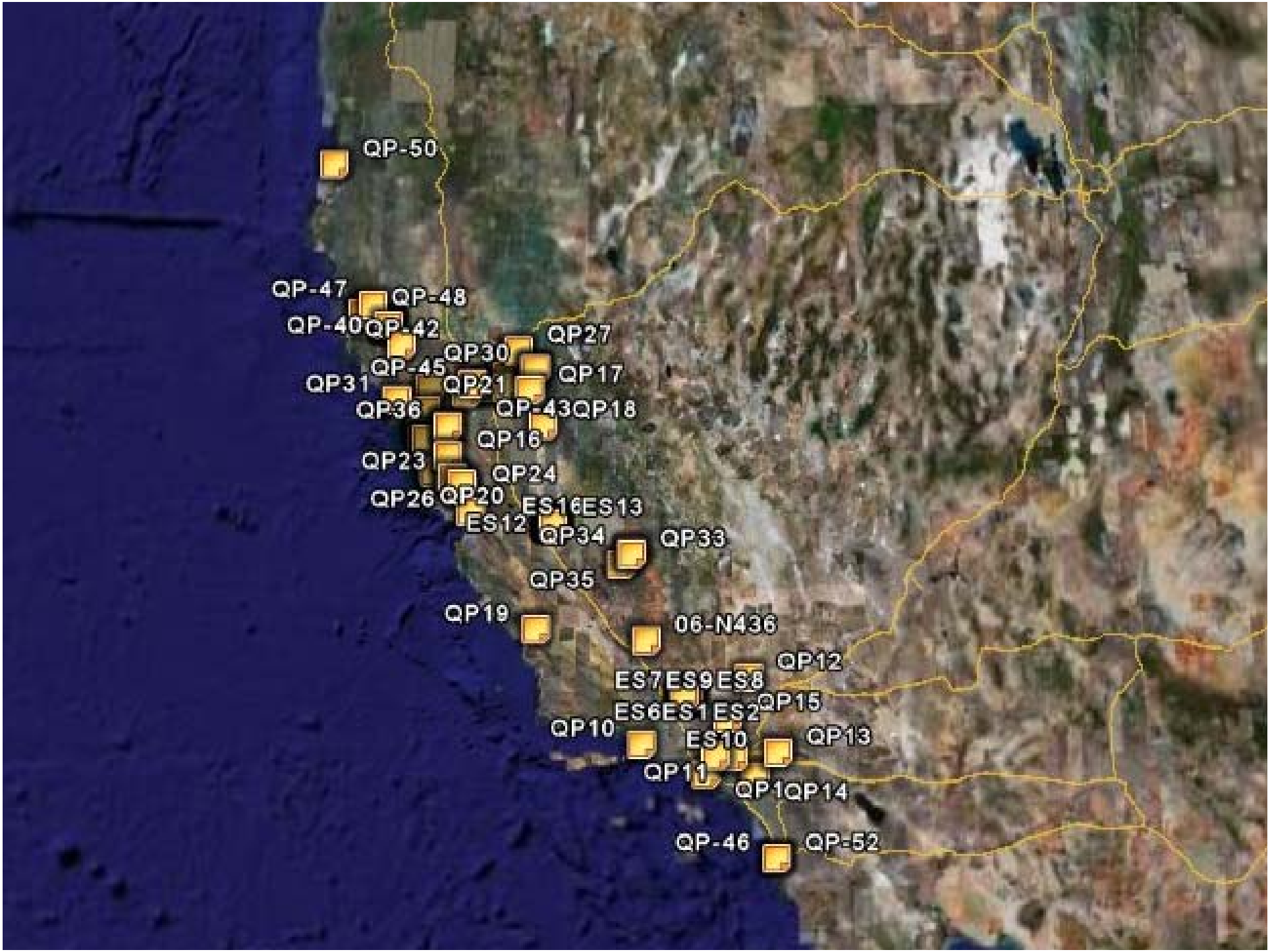
supports
PPSC Quiet Pavement, Pavement Preservation and Smoothness objectives

Open-Graded/QP (Goals)

- Identify best practice for selecting AC surfaces
  - based on noise, permeability, friction and durability
- Survey practice & research in US and Europe
- Develop database
- Field testing:
  - 23 Division of Environmental Analysis experimental sections (ES sections)
  - 51 Additional sections selected to fill factorial (QP sections)
- Determine relationships (if exist):
  - Sound intensity and pavement surface characteristics
  - Sound intensity and sound absorption
  - Longevity of surfaces and properties versus traffic, climate, underlying pavement, etc.

Factorial for QP sections

Pav. Type	OGAC												RAC-O												RAC-G												DGAC												F mixes		
Age	<1 year				1-4 years				5-8 years				<1 year				1-4 years				5-8 years				<1 year				1-4 years				5-8 years				<1 year				1-4 years				5-8 years				<1 year	4 year	8 year
Rainfall	H		L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	H	H
Traffic	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	L	H	H
DIST/CTY/RTE/KP	03-PLA-80-1.4/2.6	01-LAK-29-R37.3/R37.6	04-CC-680-23.9/24.9	05-SCR-152-7.6/8.0	04-Mrn-101-0.0/2.5(NB&SB)	04-Son-121-3.4/7.3(NB&SB)(+)	04-SCl-237-R3.8/7.10(+)	08-SBd-38-S0.0/R5.0	04-Mrn-37-12.1/14.4(EB&WB)(+)	01-MEN-1-0.1/15.2 (Stantec/cored)	04-SCl-237-R1.0/2.3	03-Sac-16-6.9/20.7	03-Pla-80-14.3/33.3	01-MEN-20-R37.9/43.0	06-TUL-99-42.0/47.0	06-TUL-63-19.8/R30.1	03-Sac-50-16.10/17.30	10-Ama-49-14.7/17.6	07-LA-710-6.8/9.7	06-Tul-65-21/29 (Stantec/cored)		04-Nap-128-5.1/7.4 (E.B. only)	04-SCl-85-1.9/4.7	08-SBD-58-R0.0/5.3		01-MEN-20-R37.9/43.0	04-SCl-280-R0.0/R2.7	06-TUL-63-19.8/R30.1	04-Mrn-101-18.9/23.1 (NB only)	04-Son-1-0.0/8.4 (NB&SB)(+)	08-Riv-15-33.8/38.4	05-SLO-46-R10.8/R22.0	04-Mrn-101-2.5/8.5 (as-buit)	10-Cal-4-0/18.8	07-LA-60-R25.4/R30.5(stantec)	07-Ven-34-4.3/6.3		01-MEN-20-R37.9/43.0	06-FRE-99-10.7/15.9	07-LA-138-60.2/61.6	03-ED-50-17.3/18.3	03-ED-50-18.5/20.3 (as-built)	06-KER-99-R29.5/R31.0 (only SB)	04-SOL-113-0.1/18.0	04-SM-280-9.6/10.8	01-Men-1-20.8/38.7 (Stantec/cored)	04-Ala-92-6.6/8.8	06-KER-65-R0.0/2.9 (Stantec/cored)	01-Lake-20-45.8/46.5	01-Men-101-37.4/38.8	01-Men-101-50.8/ 51.5	01-HUM-101-111.1/111.5	01-Men-20-21.19/21.69	01-Men-20-22.18 /22.68


QP-50
QP-47
QP-48
QP-40
QP-42
QP27
QP30
QP-45
QP17
QP31
QP21
QP36
QP-43
QP18
QP16
QP23
QP24
QP26
QP20
ES16
ES13
ES12
QP34
QP33
QP35
QP19
06-N436
QP12
ES7
ES9
ES8
QP15
ES6
ES1
ES2
QP10
ES10
QP13
QP11
QP1
QP14
QP-46
QP-52

Project Status

- Sections
  - 23 ES sections: all data collected for two years
  - 51 QP sections: all data collected for first year; 5 sections for second year

Data collection

Field data in closure

Type of Data	Specific Test
Condition Survey	Caltrans Condition Survey
Permeability	ASTM D 5042
Friction (microtexture)	British Pendulum
Cores	100 mm and 150 mm cores
Air Temperature	Thermocouple
Pavement Surface Temperature	Thermocouple

Field data with high speed car

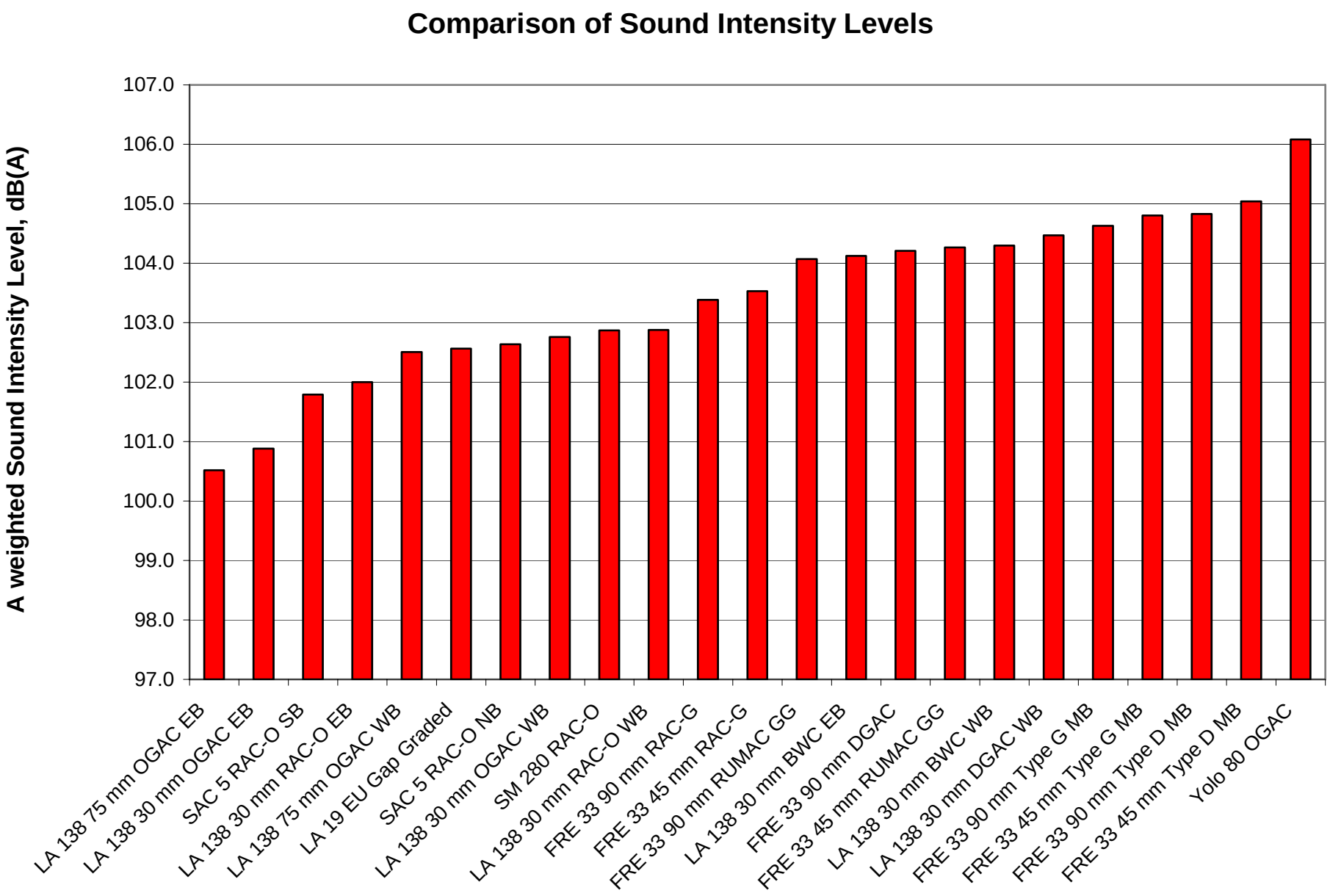
Type of Data	Specific Test
Pavement/ tire noise	On Board Sound Intensity
International Roughness Index (IRI)	Laser Profilometer
Macrotexture	Laser Profilometer
Air Temperature	Thermocouple
Pavement Surface Temperature	Thermocouple

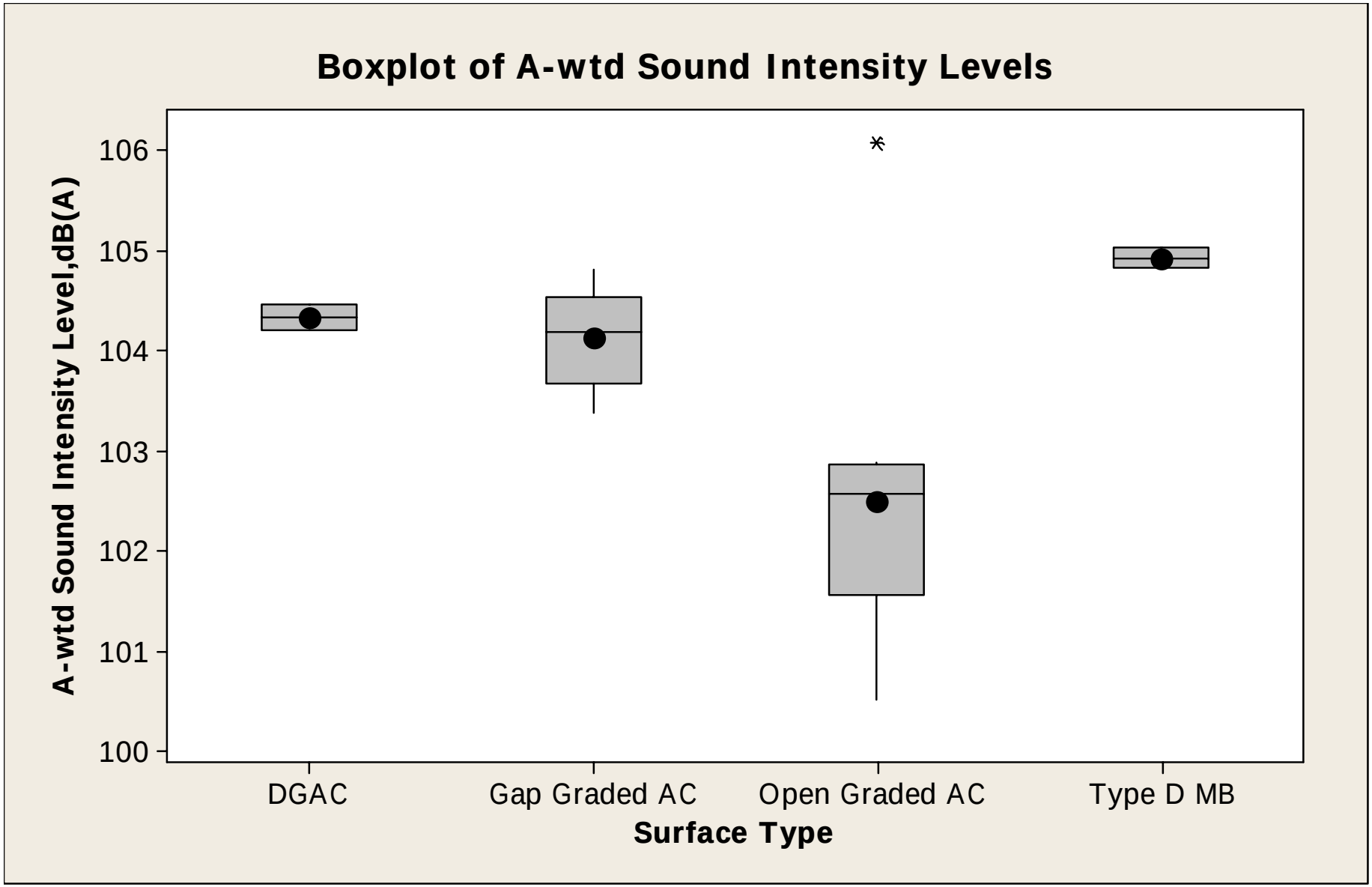
Lab data on cores from closures

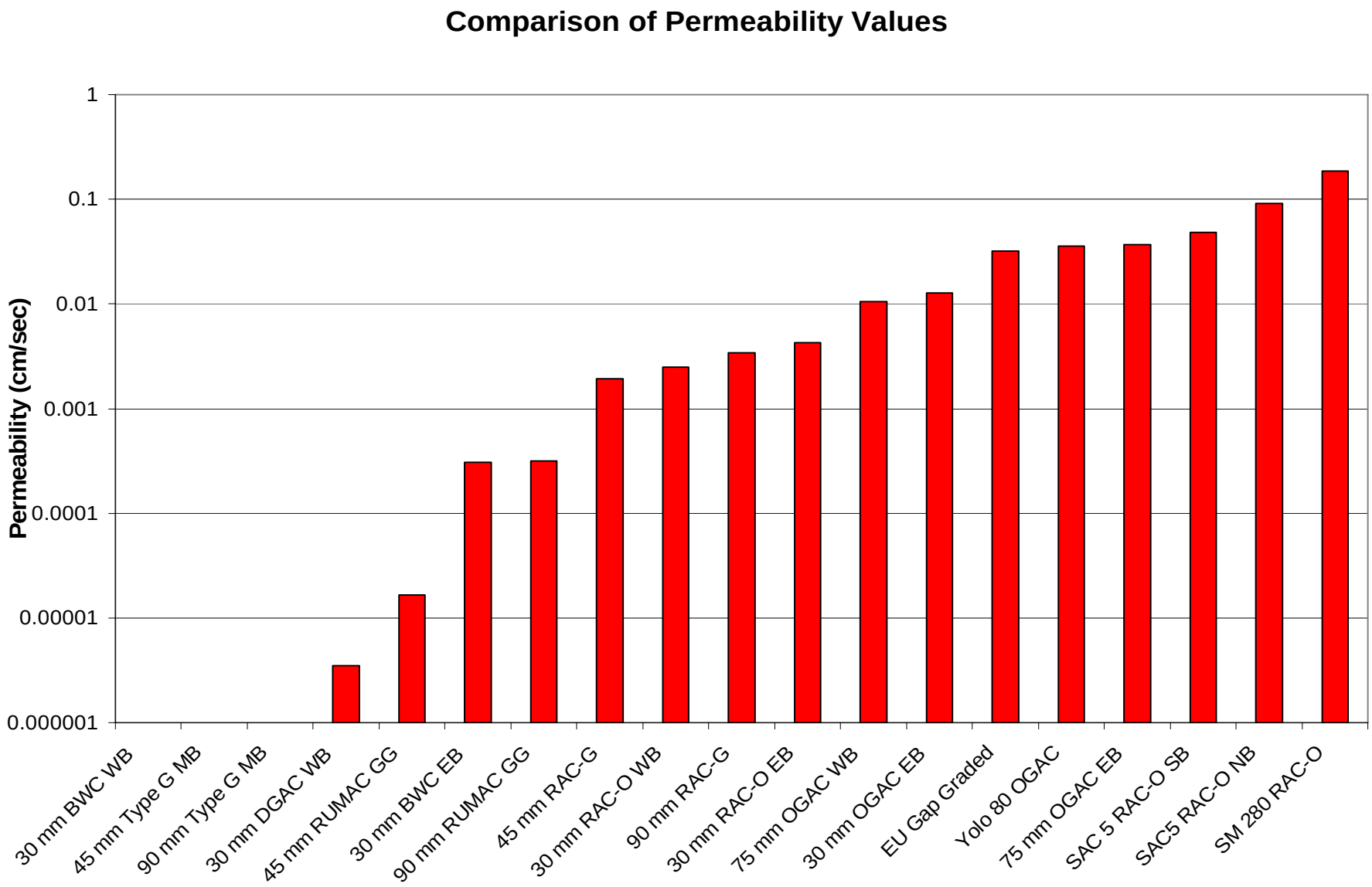
Type of Data	Specific Test
Thickness of Layers of Cores	visual
Bulk Specific Gravity	CoreLok® and Parafilm
Maximum Specific Gravity (Gmm)	CT 309
Air Void Content	Using Bulk Specific Gravity and Gmm
Removal of aggregate from binder	Ignition Oven
Aggregate Gradation	CT 202

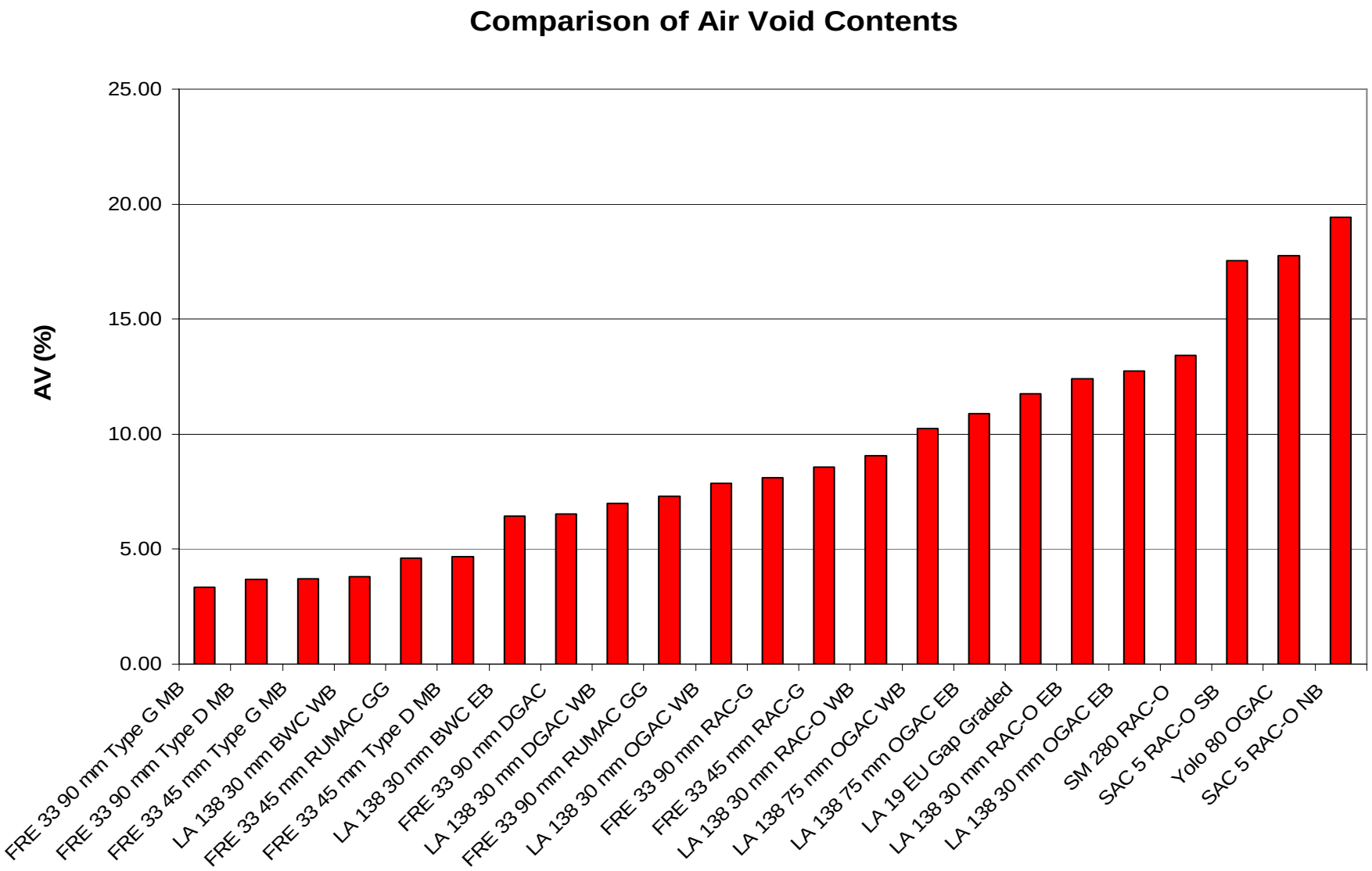
6 ES sites → 23 ES sections

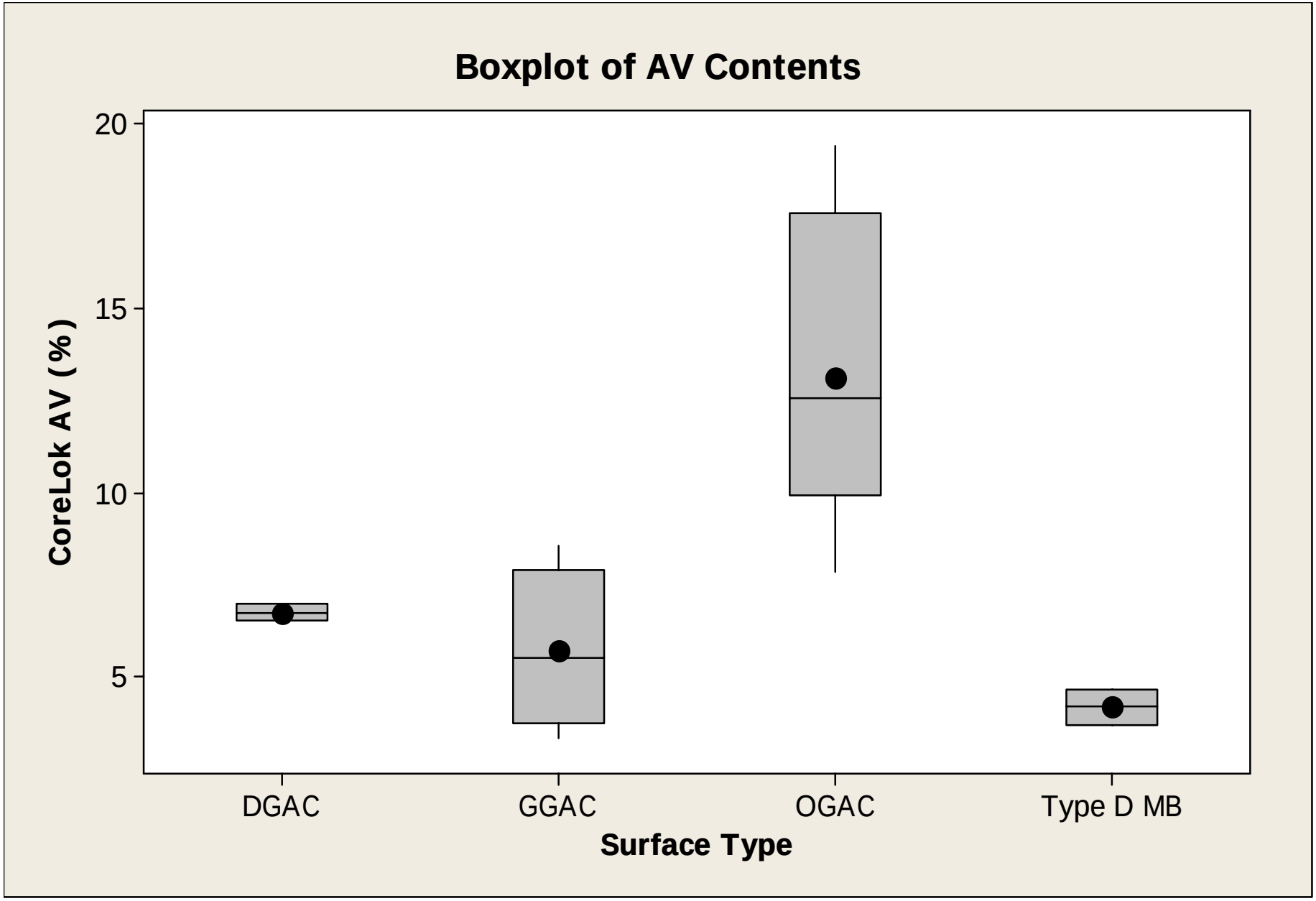
Section Name	Location	Surface Type	Construction Date
Yolo 80 (near Davis)	03-Yolo-80/PM 2.9-5.8	OGAC	Summer 1998
Sacramento 5 (near Florin Road)	03-Sac-5/PM 17.2-17.9	OGAC	Summer 2004
LA 138	07-LA-138/PM 16.0-21.0	30mm OGAC 75mm OGAC 30 mm RAC-O 30 mm BWC 30 mm DGAC	Spring 2002
Fresno 33 (near Firebaugh)	06-Fre-33/PM 70.9-75.08	RAC-G 45 mm RAC-G 90 mm RUMAC-GG 45 mm RUMAC-GG 90 mm Type-G MB 45 mm Type-G MB 90 mm Type-D MB 45 mm Type-D MB 90 mm DGAC 90 mm	Summer 2004
SM 280	04-SM-280/PM R0.0-R5.6	RAC-O	Fall 2002
LA 19 (Rosemead Blvd)	07-LA-19/ PM 3.4	European Gap Graded	May 2005

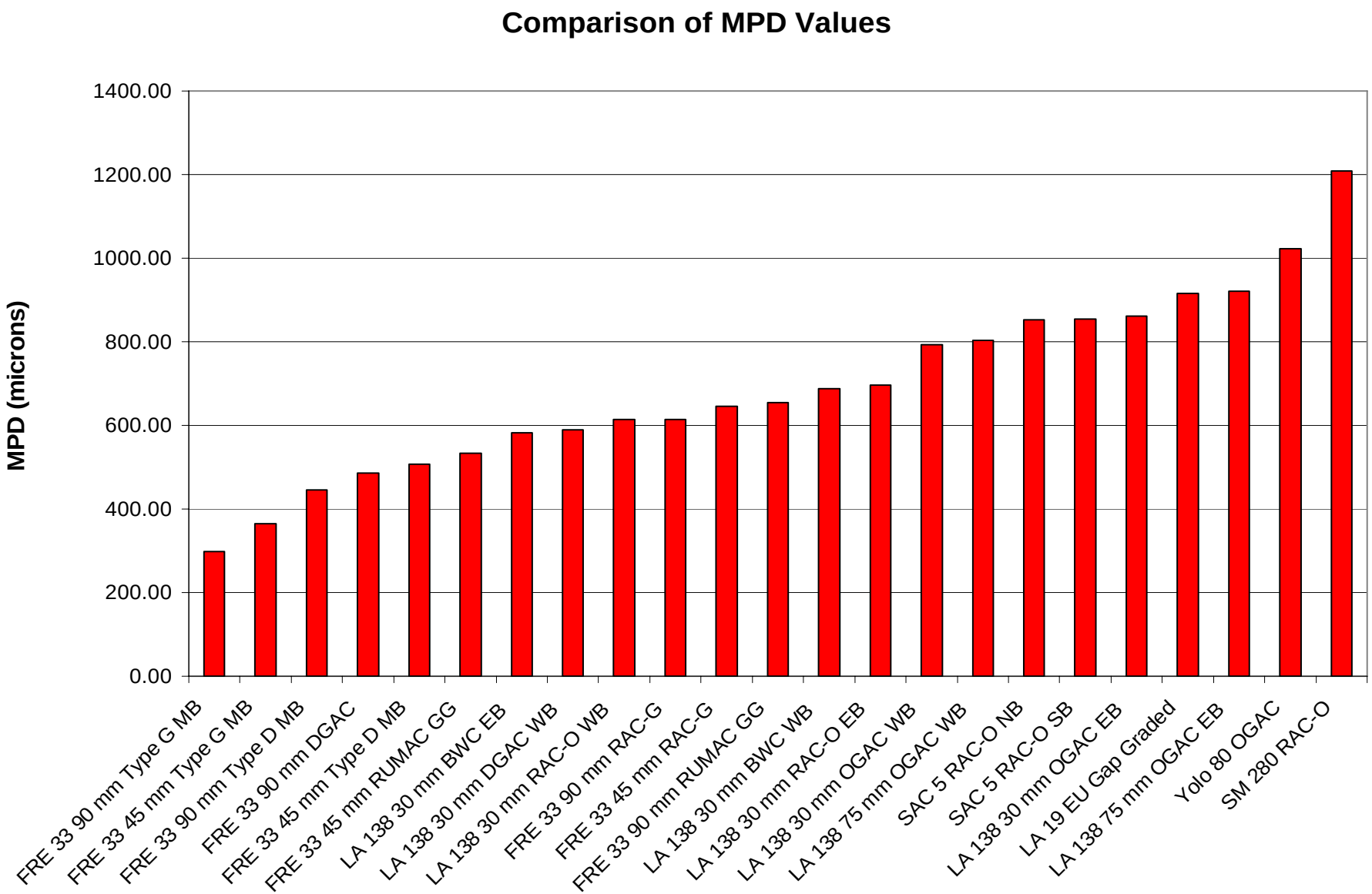

Comparison of Sound Intensity Levels
A weighted Sound Intensity Level, dB(A)
107.0
106.0
105.0
104.0
103.0
102.0
101.0
100.0
99.0
98.0
97.0
LA 138 75 mm OGAC EB
LA 138 30 mm OGAC EB
SAC 5 RAC-O SB
LA 138 30 mm RAC-O EB
LA 138 75 mm OGAC WB
LA 19 EU Gap Graded
SAC 5 RAC-O NB
LA 138 30 mm OGAC WB
SM 280 RAC-O
LA 138 30 mm RAC-O WB
FRE 33 90 mm RAC-G
FRE 33 45 mm RAC-G
FRE 33 90 mm RUMAC GG
LA 138 30 mm BWC EB
FRE 33 90 mm DGAC
FRE 33 45 mm RUMAC GG
LA 138 30 mm BWC WB
LA 138 30 mm DGAC WB
FRE 33 90 mm Type G MB
FRE 33 45 mm Type G MB
FRE 33 90 mm Type D MB
FRE 33 45 mm Type D MB
Yolo 80 OGAC

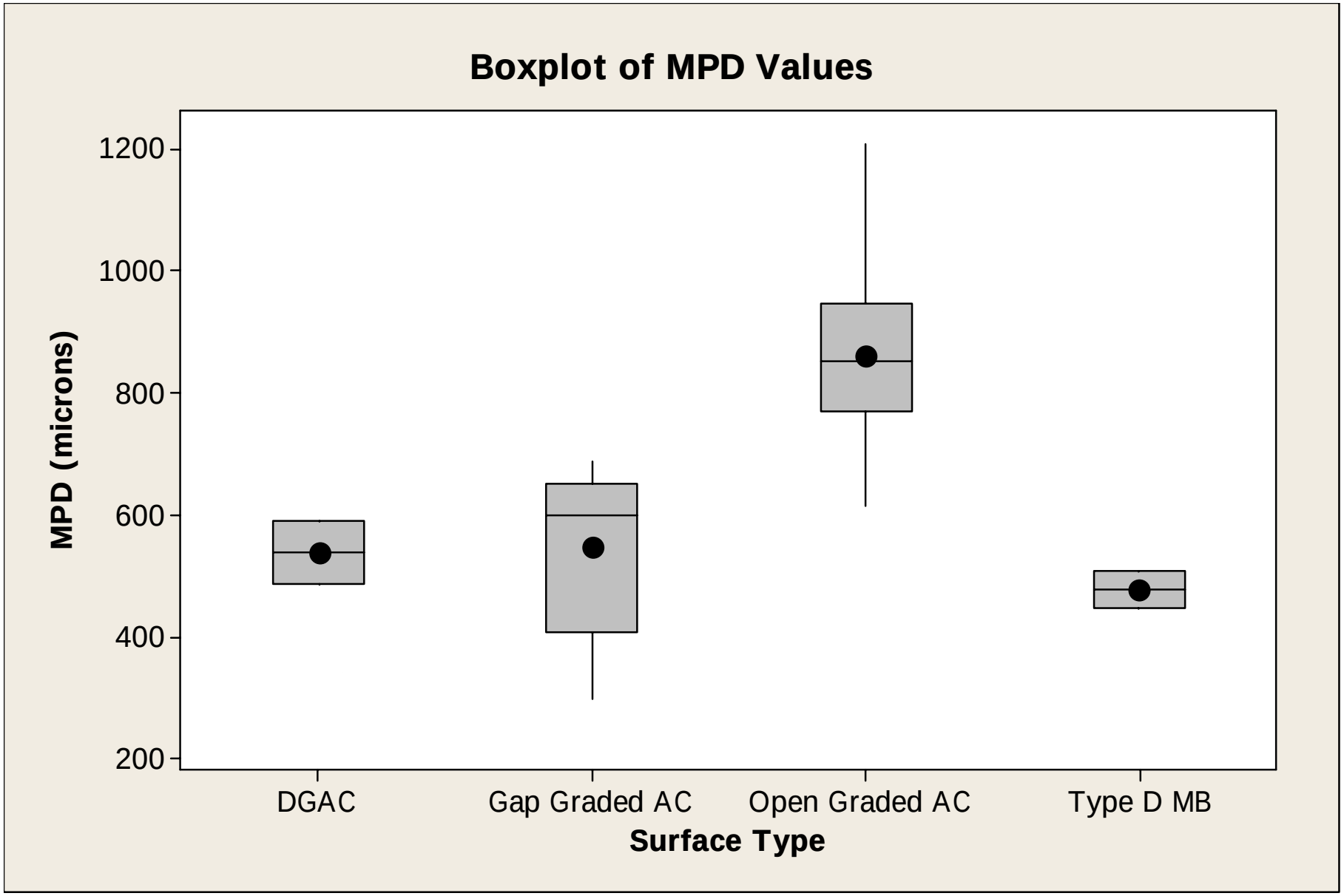

Boxplot of A-wtd Sound Intensity Levels
A-wtd Sound Intensity Level,dB(A)
106
105
104
103
102
101
100
DGAC
Gap Graded AC
Open Graded AC
Type D MB
Surface Type

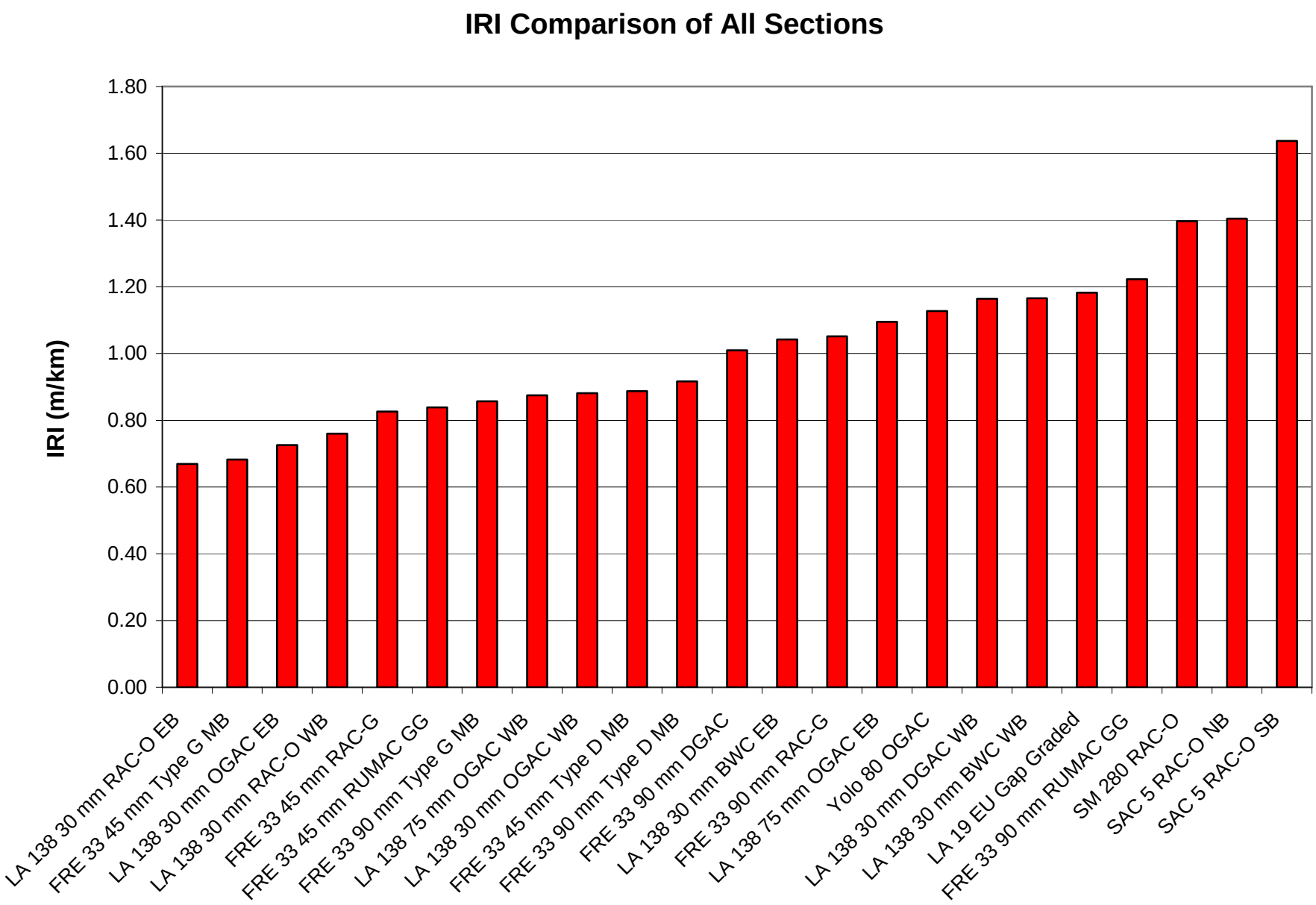

Comparison of Permeability Values
Permeability (cm/sec)
1
0.1
0.01
0.001
0.0001
0.00001
0.000001
30 mm BWC WB
45 mm Type G MB
90 mm Type G MB
30 mm DGAC WB
45 mm RUMAC GG
30 mm BWC EB
90 mm RUMAC GG
45 mm RAC-G
30 mm RAC-O WB
90 mm RAC-G
30 mm RAC-O EB
75 mm OGAC WB
30 mm OGAC EB
EU Gap Graded
Yolo 80 OGAC
75 mm OGAC EB
SAC 5 RAC-O SB
SAC5 RAC-O NB
SM 280 RAC-O

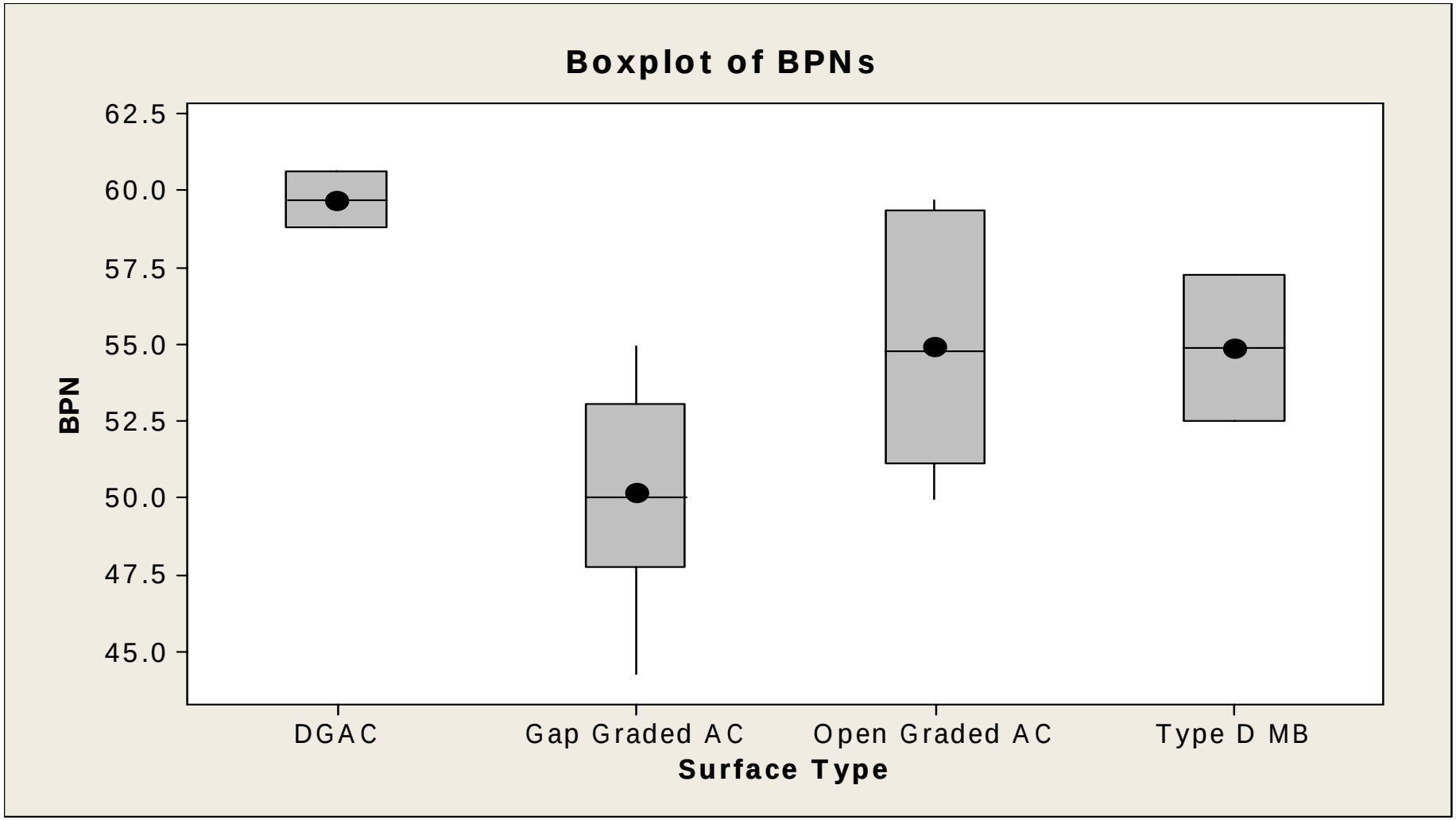

Comparison of Air Void Contents
AV (%)
25.00
20.00
15.00
10.00
5.00
0.00
FRE 33 90 mm Type G MB
FRE 33 90 mm Type D MB
FRE 33 45 mm Type G MB
LA 138 30 mm BWC WB
FRE 33 45 mm RUMAC GG
FRE 33 45 mm Type D MB
LA 138 30 mm BWC EB
FRE 33 90 mm DGAC
LA 138 30 mm DGAC WB
FRE 33 90 mm RUMAC GG
LA 138 30 mm OGAC WB
FRE 33 90 mm RAC-G
FRE 33 45 mm RAC-G
LA 138 30 mm RAC-O WB
LA 138 75 mm OGAC WB
LA 138 75 mm OGAC EB
LA 19 EU Gap Graded
LA 138 30 mm RAC-O EB
LA 138 30 mm OGAC EB
SM 280 RAC-O
SAC 5 RAC-O SB
Yolo 80 OGAC
SAC 5 RAC-O NB

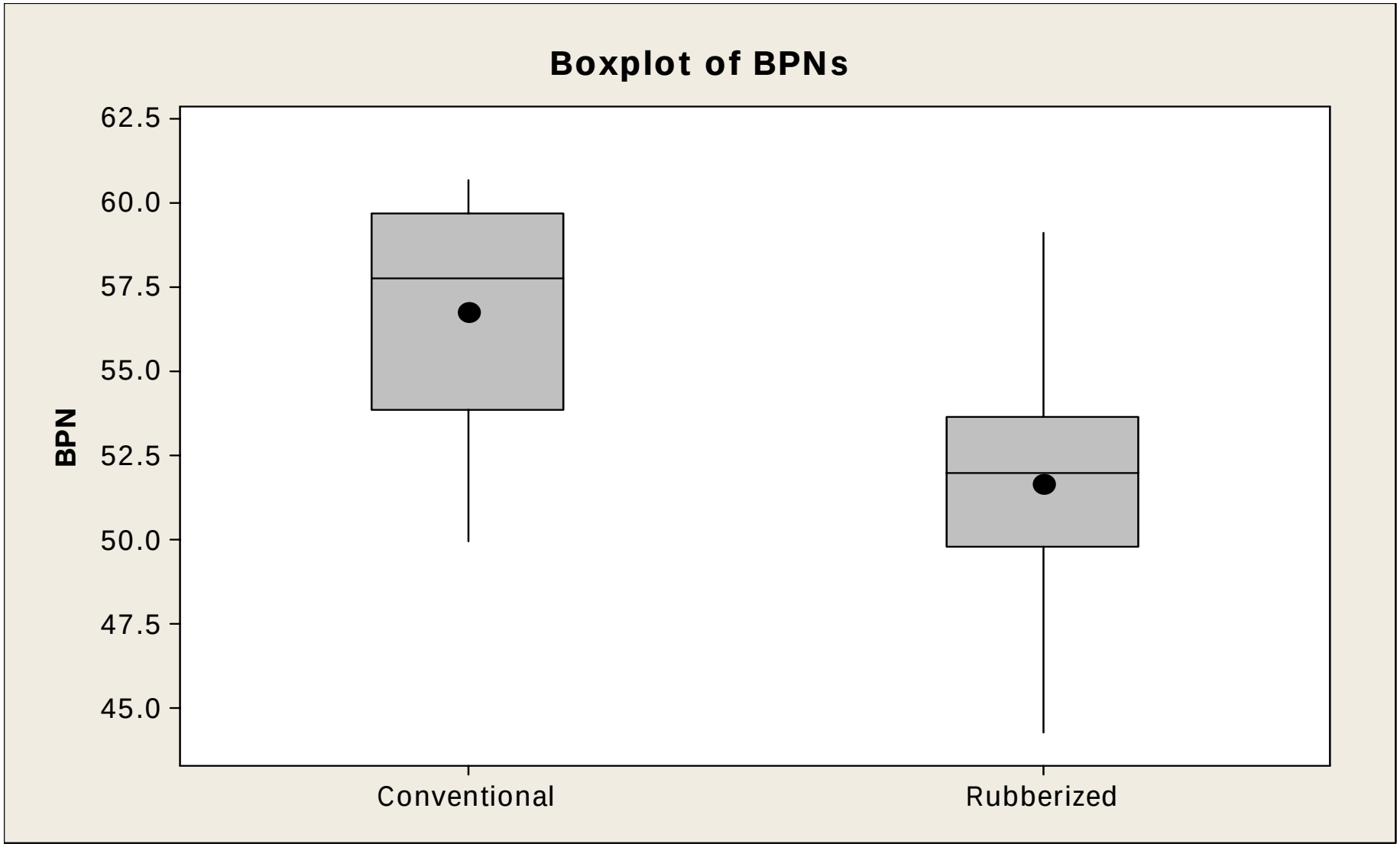

Boxplot of AV Contents
CoreLok AV (%)
20
15
10
5
DGAC
GGAC
OGAC
Type D MB
Surface Type


Comparison of MPD Values
MPD (microns)
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
FRE 33 90 mm Type G MB
FRE 33 45 mm Type G MB
FRE 33 90 mm Type D MB
FRE 33 90 mm DGAC
FRE 33 45 mm Type D MB
FRE 33 45 mm RUMAC GG
LA 138 30 mm BWC EB
LA 138 30 mm DGAC WB
LA 138 30 mm RAC-O WB
FRE 33 90 mm RAC-G
FRE 33 45 mm RAC-G
FRE 33 90 mm RUMAC GG
LA 138 30 mm BWC WB
LA 138 30 mm RAC-O EB
LA 138 30 mm OGAC WB
LA 138 75 mm OGAC WB
SAC 5 RAC-O NB
SAC 5 RAC-O SB
LA 138 30 mm OGAC EB
LA 19 EU Gap Graded
LA 138 75 mm OGAC EB
Yolo 80 OGAC
SM 280 RAC-O


Boxplot of MPD Values
MPD (microns)
1200
1000
800
600
400
200
DGAC
Gap Graded AC
Open Graded AC
Type D MB
Surface Type


IRI Comparison of All Sections
IRI (m/km)
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
LA 138 30 mm RAC-O EB
FRE 33 45 mm Type G MB
LA 138 30 mm OGAC EB
LA 138 30 mm RAC-O WB
FRE 33 45 mm RAC-G
FRE 33 45 mm RUMAC GG
FRE 33 90 mm Type G MB
LA 138 75 mm OGAC WB
LA 138 30 mm OGAC WB
FRE 33 45 mm Type D MB
FRE 33 90 mm Type D MB
FRE 33 90 mm DGAC
LA 138 30 mm BWC EB
FRE 33 90 mm RAC-G
LA 138 75 mm OGAC EB
Yolo 80 OGAC
LA 138 30 mm DGAC WB
LA 138 30 mm BWC WB
LA 19 EU Gap Graded
FRE 33 90 mm RUMAC GG
SM 280 RAC-O
SAC 5 RAC-O NB
SAC 5 RAC-O SB


Boxplot of BPNs
62.5
60.0
57.5
55.0
52.5
50.0
47.5
45.0
BPN
DGAC
Gap Graded AC
Open Graded AC
Type D MB
Surface Type


Boxplot of BPNs
BPN
62.5
60.0
57.5
55.0
52.5
50.0
47.5
45.0
Conventional
Rubberized

Correlations

1. Sound intensity levels are correlated with air void content and macrotexture values (MPD and RMS).
2. Increasing macrotexture and air void content reduce the sound intensity levels.
3. Air void is correlated with all variables except friction.
4. Increasing air void increases permeability, texture, and IRI.

All data in a relational database

Microsoft Access

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

QuietPavementStudy : Database (Access 2002 - 2003 file format)

Open Design New

Objects

- Tables
- Queries
- Forms
- Reports
- Pages
- Macros
- Modules

Groups

- Favorites

- Create table in Design view
- Create table by using wizard
- Create table by entering data
- BRITISH PENDULUM
- CALIBRATION RECORD
- CONDITION SURVEY
- CORE DESCRIPTION
- CORE DESCRIPTION old format
- CORE GRADATION
- CORE THICKNESS
- PERMEAMETER
- SECTION DESCRIPTION
- SECTION PHOTO
- SOUND INTENSITY DATA
- SOUND INTENSITY EQUIP
- WEATHER DATA

CORE DESCRIPTION : Table

Section Detail ID	Core ID	Core Diameter mn	Cross	Grade F	GPS Latitude	GPS Longitude
01MEN1N1.5	01-N103-1-R	100			N38-46.98'	W123-32.784'
01MEN1N1.5	01-N103-2-C	100			N38-46.496'	W123-32.283'
01MEN1N3.5	01-N104-1-R	100	9	1.9	N38-47.648'	W123-33.453'
01MEN1N3.5	01-N104-2-C	100	9	1.9	N38-47.688'	W123-33.963'
01MEN1N3.5	01-N104-3-R	150	9.7	2	N38-47.647'	W123-33.956'
01MEN1N3.5	01-N104-4-C	150	9.7	2	N38-47.645'	W123-33.956'
01MEN1N3.5	01-N104-5-R	150	11.2	1.2	N38-47.648'	W123-33.956'
01MEN1N3.5	01-N104-6-C	150	11.2	1.2	N38-47.648'	W123-33.956'
01MEN1N3.9	01-N105-1-R	150	8	-0.3	N38-47.841'	W123-34.200'
01MEN1N3.9	01-N105-2-C	150	8	-0.3	N38-47.841'	W123-34.200'
01MEN1N3.9	01-N105-3-R	100	1.6	-0.7	N38-47.856'	W123-34.222'
01MEN1N3.9	01-N105-4-C	100	1.6	-0.7	N38-47.856'	W123-34.223'
01MEN1N3.9	01-N105-5-R	100	2.9	-0.6	N38-47.851'	W123-34.217'
01MEN1N3.9	01-N105-6-C	100	2.9	-0.6	N38-47.851'	W123-34.217'
01MEN1N3.9	01-N105-7-R	150	5.3	-0.3	N38-47.856'	W123-34.222'
01MEN1N3.9	01-N105-8-C	100	5.3	-0.3	N38-47.856'	W123-34.223'
01MEN1N22.8	01-N114-1-R	100	3.9	2.8	N39-00.001'	W123-41.435'
01MEN1N22.8	01-N114-2-C	100	3.9	2.8	N39-00.000'	W123-41.345'
01MEN1N22.8	01-N114-3-R	150	4.5	3.4	N39-00.008'	W123-41.343'
01MEN1N22.8	01-N114-4-C	150	4.5	3.4	N39-00.007'	W123-41.342'
01MEN1N28.8	01-N121-1-R	150	-2.2	3.6	N39-04.364'	W123-41.583'
01MEN1N28.8	01-N121-2-C	150	-2.2	3.6	N39-04.364'	W123-41.585'
01MEN1N28.8	01-N121-3-R	100	-3.2	0.6	N39□04.371'	W123□41.585'
01MEN1N28.8	01-N121-4-C	100	-3.2	0.6	N39□04.370'	W123□41.586'

Record: 1 of 309

Monitoring and Support of LA-710 Projects support PPSC Long-Life objective

- 3.1.4 I-710 AC Long Life phase 1
  - Structural designs
  - Mix design support
  - Currently performing annual field testing
- 3.2.11 I-710 AC Long Life phase 2
  - Structural design advice
  - Help with FHWA pilot project monitoring plan
  - Annual field testing after construction

New project prioritization for strategic plan

- Strategic planning process
  - Research Problem Statement developed
  - PST adds additional items, prioritizes
  - DRI gathers additional items, priorities
  - UCPRC provides logistical information
  - DRI determines final strategic plan

Next steps

- PST prioritization on Nov 27, first cut:
  - Non-HVS: Quiet Pavements/Pavement Preservation; Pervious pavements (if DEA funded); PMS support; ME Design; 100 yr PCC pavement; Life Cycle Cost Analysis
  - HVS: Warm Asphalt; Pavement Preservation including OGAC, thin lift AC, dense graded terminal blend mixes
- This meeting

New Projects
Ideas and feedback from DMEs

Discussion