California Pavement Research in APT, Field Testing, Materials

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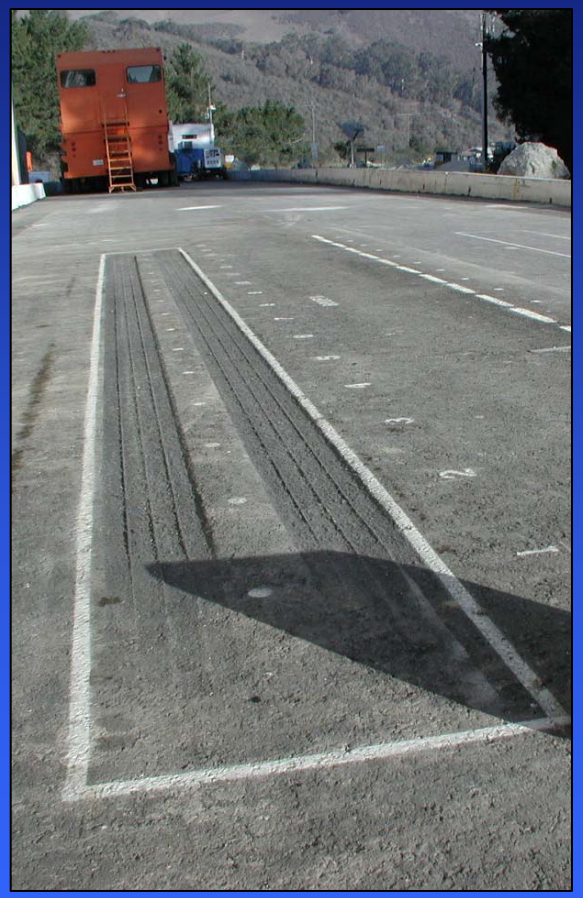
Presentation Summary

- Integrated study: Use of Mechanistic-Empirical Performance Simulations to Adjust and Compare Results from APT
- WMA APT
- Long Life Pavements
- Reflection Cracking
- LCCA
- Material Characterization
- Pavement Software
- Implementation



Integrated Study: Use of Mechanistic-Empirical Performance Simulations to Adjust and Compare Results from APT

Evaluation of New Technologies with Field Sections

- Sections for comparison between new technologies and controls
- Problems with performing comparisons with field sections:
  - Differences in construction quality
  - Differences in underlying pavement structure
  - Insufficient time for pavements to fail
  - Different traffic or climates
  - Pilot projects placed in low risk locations (low traffic)

Evaluation of New Technologies with APT Sections

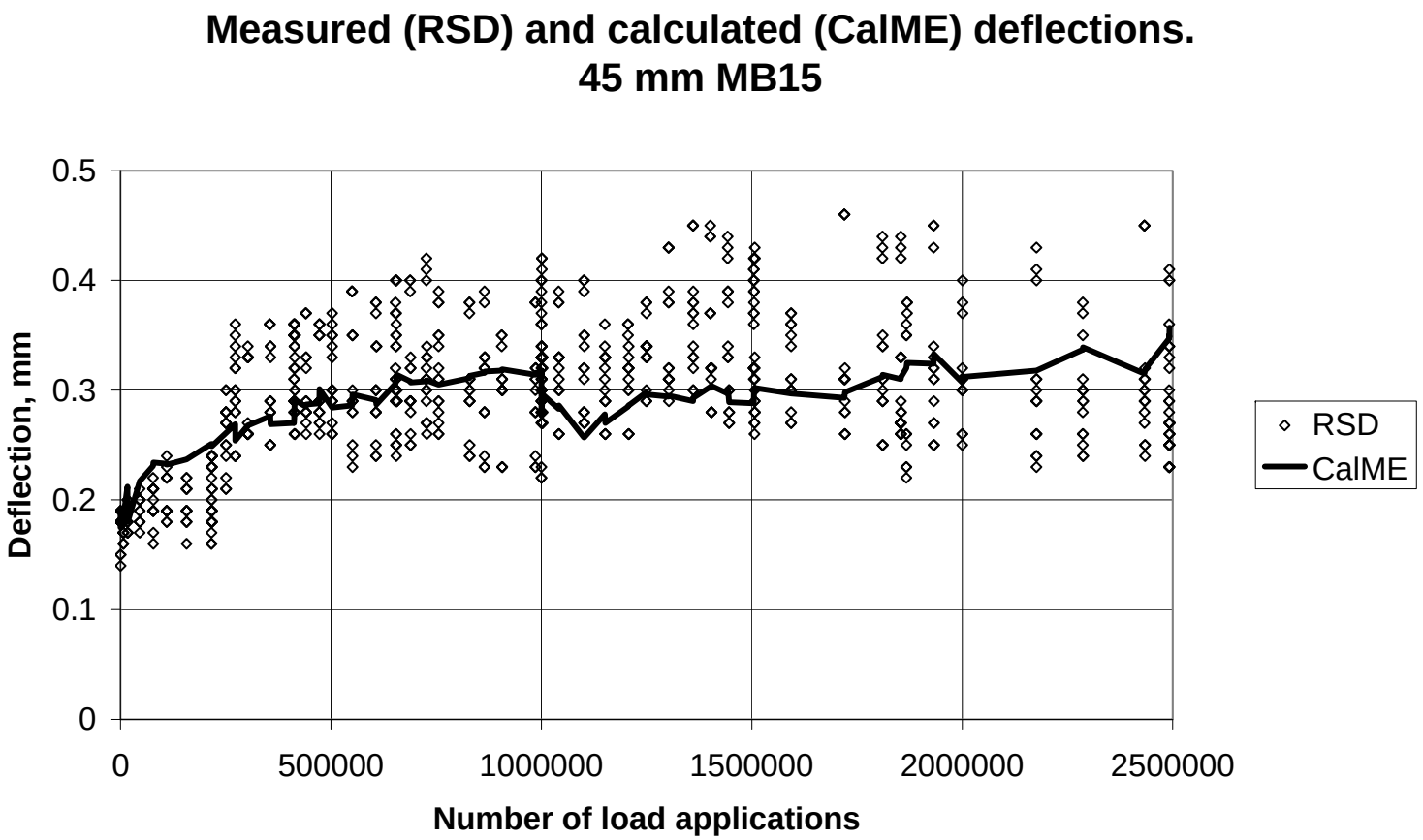
- APT also suffers from these two problems:
  - Differences in construction quality
  - Differences in underlying pavement structure
- Why?
  - Small quantities of materials
  - New technologies and practices
  - Subgrade and drainage variability
  - Climate variability (if not controlled)
  - Unintentional loading variability

Need

- Use of mechanistic-empirical (ME) models to rank alternatives tested in APT comparison study by accounting for bias caused by differences in conditions of APT sections
- Use calibrated ME models to "re-run" APT test sections through simulation with completely equal underlying conditions, temperature, water content, etc

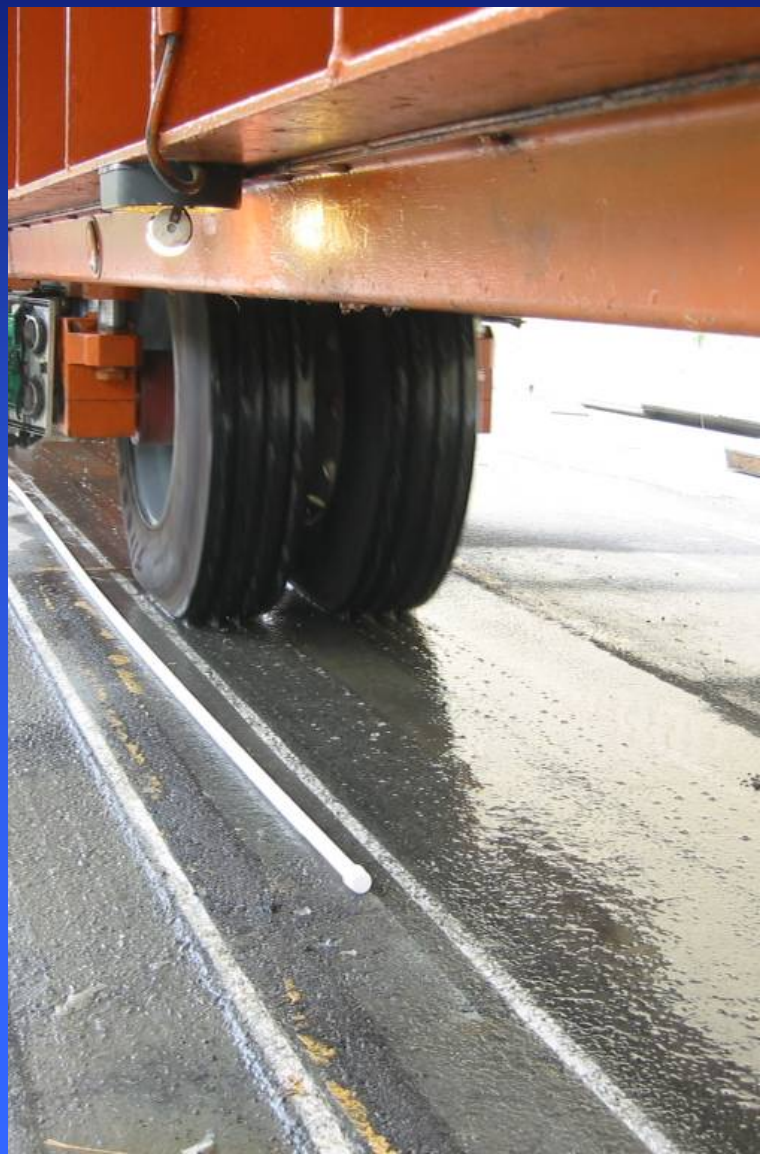
CalME: Incremental-Recursive ME

- Facilitates calibration of models with ME because simulates entire APT damage process



Steps in Process (1 of 3)

1. Calibrate and verify ME damage process models using APT data comparison test sections; simulating actual testing conditions
   - loading,
   - temperature and
   - moisture primarily



Steps in Process (2 of 3)

2. Simulate APT comparison test sections again, with uniform support conditions, construction quality, loading, temperature, moisture conditions. This provides a "fair" comparison between alternatives tested under simulated equal conditions.

Steps in the Process (3 of 3)

3. Extrapolate APT results by simulation of the same alternatives under different conditions of climate, traffic, materials, thicknesses, construction quality, and subgrade expected in the field.

Example project: Evaluation of Modified Binder Overlays for Reflection Cracking and Rutting

- Phase 2 overlays
  - Full thickness (90mm) AR4000-D (control)
  - Half thickness (45mm) RAC-G (control)
  - Full thickness (90mm) MB4-G (7% rubber)
  - Half thickness (45mm) MB4-G (7% rubber)
  - Half thickness (45mm) MB4-G (15% rubber [MB15])
  - Half thickness (45mm) MAC15-G (15%rubber)
- Phase 2 HVS testing on overlays
  - Reflection Cracking: temp at 20°C/15°C; Load at 60/80/100kN; Bidirectional trafficking with wander
  - Rutting: temp at 50°C; Load at 60kN; Unidirectional trafficking with no wander
  - Measured deflections: MDD, RSD, FWD

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Construction and APT Issues

- Poor bonding on some sections

Construction and APT Issues

- Recementation of recycled concrete as base

Construction and APT Issues

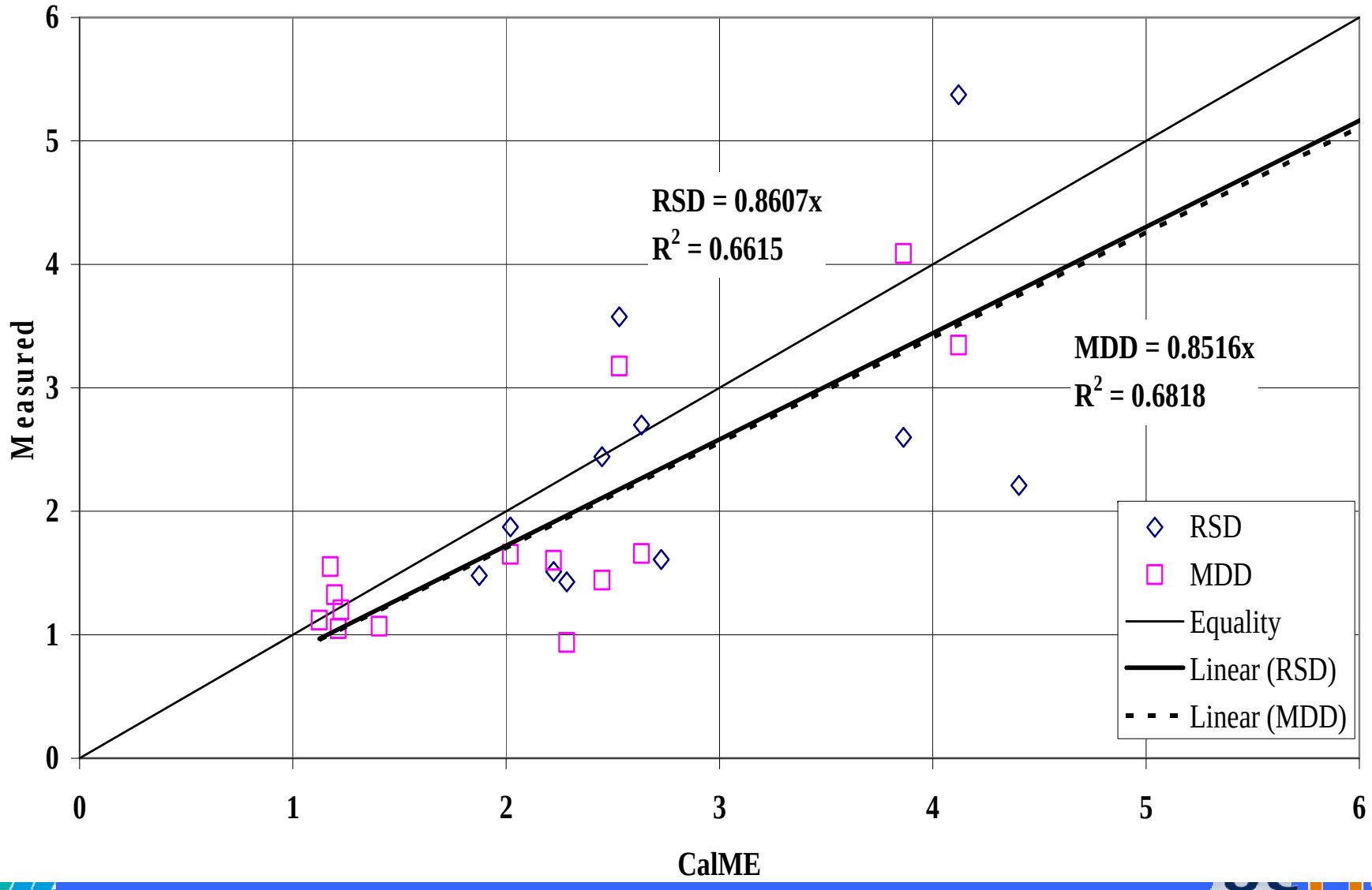
- Different underlying cracking levels
- Some sections were heavily damaged <u>but</u> not enough time for reflective cracking to reach surface

ME Simulations Example (1 to 5)

1. Simulation of tests on original pavement structure using actual conditions;
2. Simulation of moderate-temperature cracking tests on overlaid pavement structure using actual conditions;

Results: crack initiation and propagation equations calibrated

Calibration of Response (deflection)



ME Simulations – High Temp

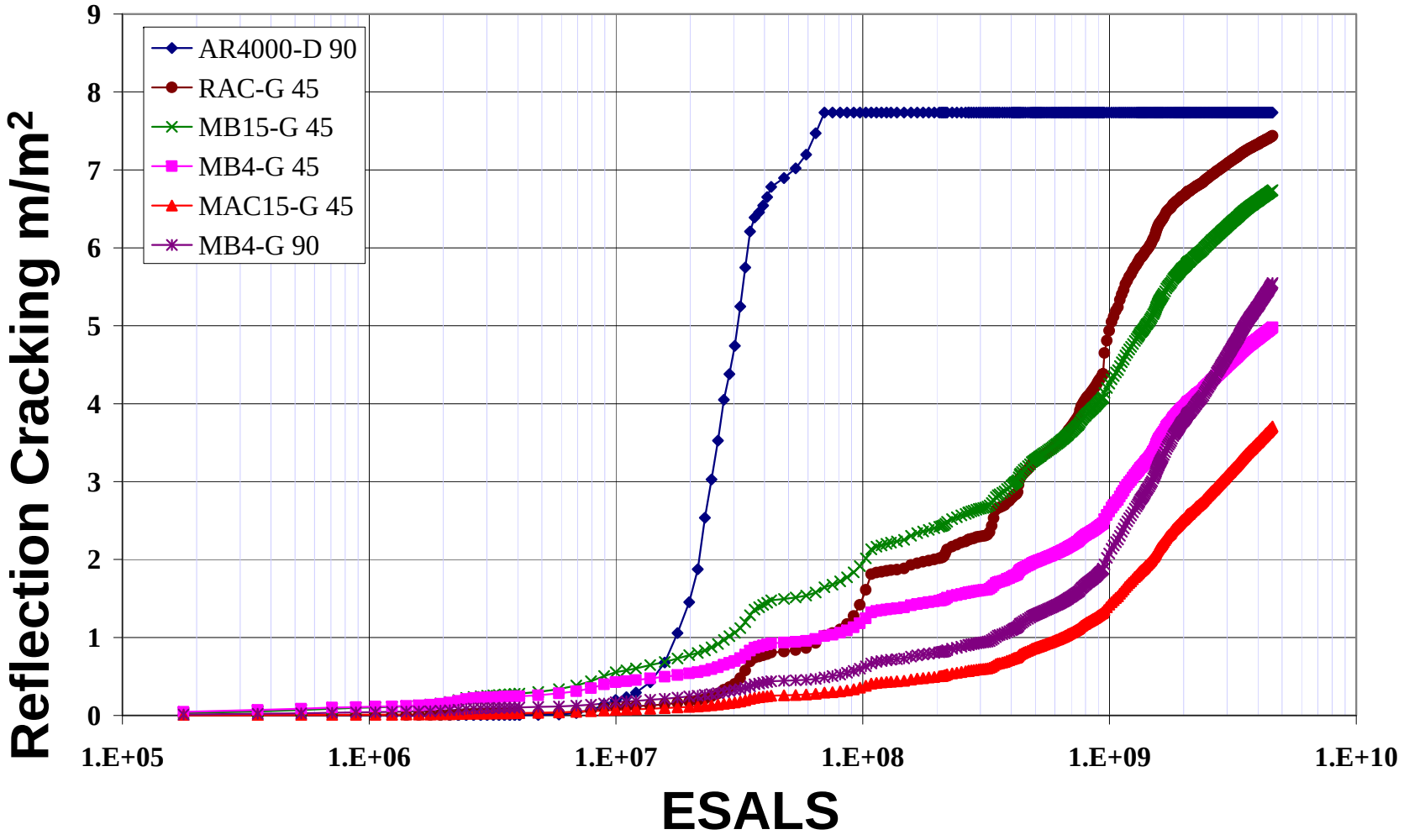
3. Simulation of the high-temperature rutting tests on overlaid pavement structure using actual conditions; Result: no changes to rutting models

4. Simulation of high-temperature rutting tests on overlaid pavement structure using design thicknesses and identical conditions of underlying structure, temperature and loading

ME Simulations - Moderate Temp

5. Simulation of moderate-temperature cracking tests on overlaid pavement structure using design thicknesses and identical underlying pavement structure, temperature and loading

Repeat of simulations with uniform underlying pavements



ME Simulations

6. Simulation of rutting and cracking for hypothetical set of typical Caltrans structures and traffic conditions in different climate regions in the state.

Summary

- Benefits of using ME with APT
  - Use of calibrated ME performance models permits simulation of APT tests to provide unbiased comparisons of alternatives
  - Also permits extrapolation of results to wide range of field conditions
- Benefits to ME of APT
  - Provides process for calibrating ME with APT
  - **Key is use of incremental-recursive damage models that allow calibration using the entire damage process in APT, not just final state**

Calibration of ME Design

- **Concrete:** Palmdale - SR 14; Ukiah - US 101
  - Evaluated fatigue law for high early strength mixes
  - Validated Dowel Bar Retrofit Designs

Dowel Bar Test Program

- **Retrofit – HVS testing**
  - Ukiah, CA
  - Palmdale, CA
- **Laboratory test programs**
  - Corrosion studies (includes section of 11-year old concrete pavement supplied by WSDOT)
  - Mechanical properties of fiber reinforced polymer (FRP), hollow stainless dowels

Calibration of ME Design

- Mechanistic-Empirical (ME) Design approach in California:
  - **Concrete:** DARWin-ME
  - **Asphalt:** CalME
- Focus on rehabilitation
- Include new materials and designs

Calibration of ME Design

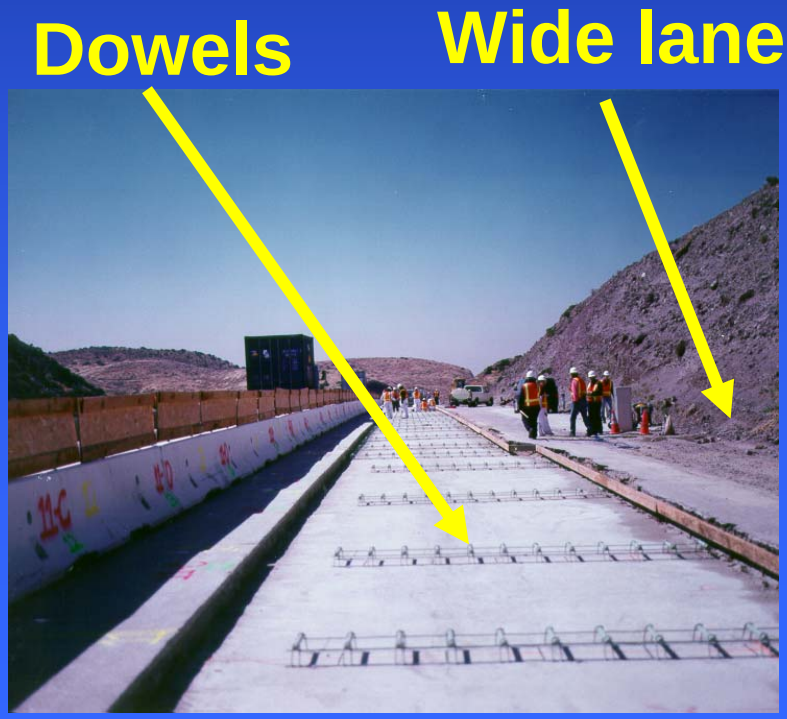
- **Asphalt:** CalME
  - California developed ME Design Code for AC

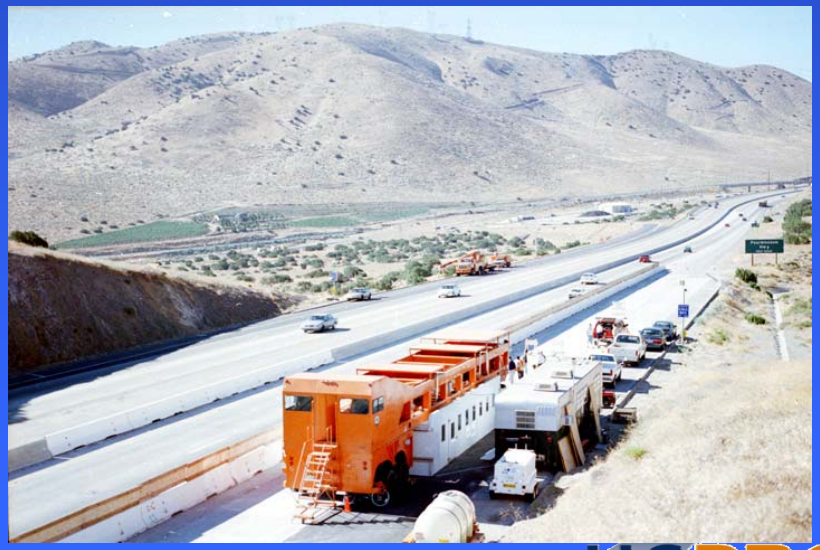
Calibration of ME Design

- **Asphalt:** CalME
  - HVS sections Used for Calibration
    - Instrumented for measurement of pavement response
  - Westrack, NCAT, MnROAD, CEDEX
    - Full-scale sections used to define performance relations (cracking, rutting)

Long-Life Pavement Projects (30-40 year designs)

- **Concrete:** Palmdale, State Route 14
  - + Validated Dowel Bar Designs in New Pavements
  - + Validated the Use of Widened Lane and Tied Shoulders





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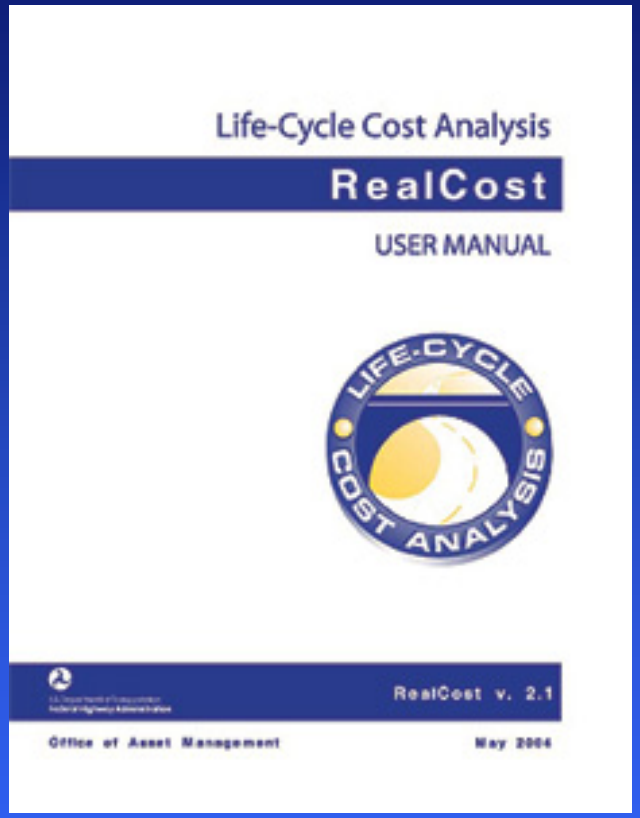
Long-Life Pavement Projects (30-40 year designs)

- **Asphalt:** Long Beach, I-710 ME Design for Full Depth AC
  - + Validated Rich Bottom AC for Fatigue
  - + Validated AC Mix Design for Rutting

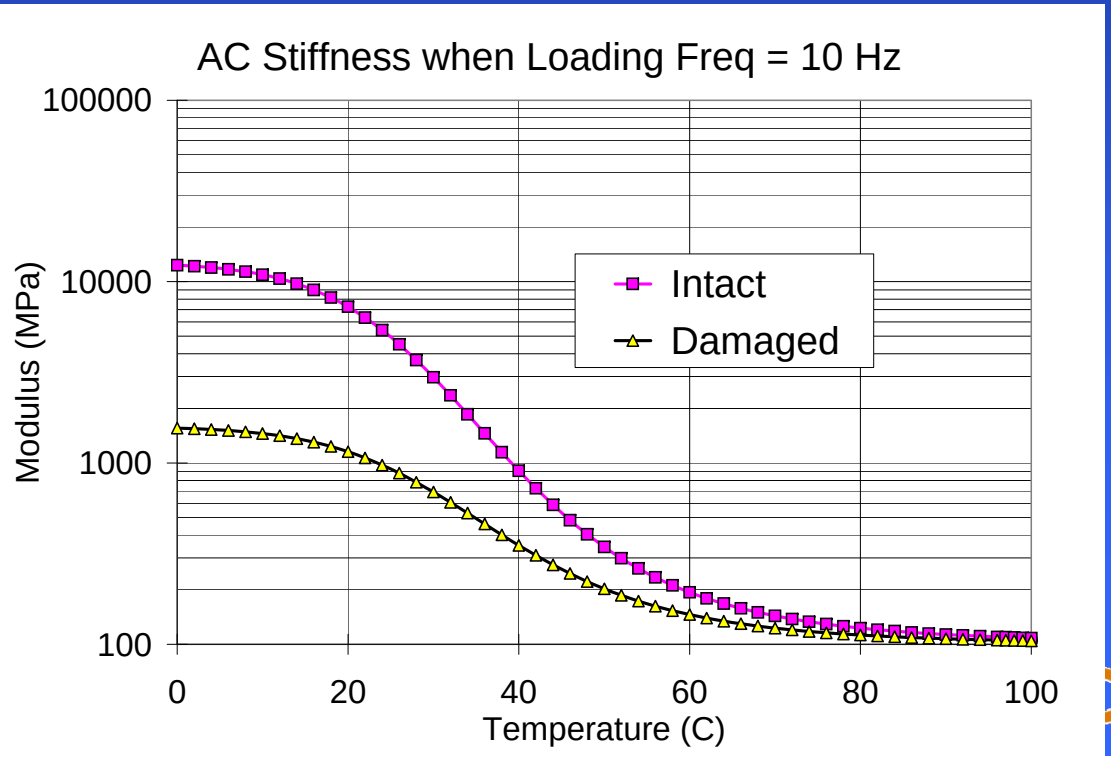
Life Cycle Cost Analysis

- UCPRC has helped Caltrans set up and implement LCCA state-wide
  - Customized RealCost software working with FHWA
  - Written LCCA manual
  - Developed custom spreadsheets to reduce time for routine analysis
    - Initial cost estimation
    - Construction productivity estimation
    - Future rehabilitation and maintenance cost
    - Annual maintenance costs
    - User costs



Materials Characterization

- Integration of Materials, APT, Field, Models leads to most benefit from APT
- Laboratory testing
  - Response characteristics
  - Damage characteristics
    - Loading
    - Environment



Materials Characterization Example: Warm Mix Asphalt

- Rapid growth in the use of WMA
- In 2006, limited research to back up claims
  - Fundamental properties of HMA change
    - Lower production and compaction temperatures
    - Less oxidation of binder
    - Additives in the mix
  - Many projects, but limited long-term monitoring
- Better understanding required before full implementation

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WMA California Research Objectives

- Determine whether the addition of additives [to reduce the production and construction temperatures of asphalt concrete] influences performance
- Investigate additional benefits
  - Use in rubberized AC
  - Increased RAP content
  - Night paving
  - Late season paving
  - Long hauls
  - Overcome environmental constraints, etc
- Guide the implementation of WMA in California

WMA Workplan Summary (1)

- Objectives met through:
  - Laboratory studies
  - Accelerated pavement testing
  - Field testing
- Phased approach followed
- Phase 1 & 2 DGAC
  - 3 most prominent technologies in 2007
    - Advera WMA®
    - Evotherm™
    - Sasobit®
  - Rutting and moisture sensitivity

WMA Workplan Summary (2)

- Phase 3, R-WMA-G APT HVS
  - 7 technologies/each group
    - Advera® WMA.
    - Astec Double Barrel® Green.
    - Cecabase RT®.
    - Evotherm DAT™.
    - Gencor Ultrafoam GX™.
    - Rediset™ WMX.
    - Sasobit®
- Lab studies
  - Rutting & cracking performance
  - Moisture sensitivity
  - Other
    - Durability (OGFCs)
    - Aging
    - Emissions

New method of measuring emissions differences

WMA Field Tests

- Morro Bay (SLO-1)
  - PM, cold coastal
- Pt Arena (Men-1)
  - R-OGFC, long haul, cold coastal
- Mendocino (Men-1)
  - R-OGFC, long haul, cold coastal
- Orland (Gle-I5)
  - Night pave, high traffic
- Marysville (Yub-70)
  - Agricultural traffic
- McKinleyville (Hum-20)
  - PM-OGFC, long haul, cold coastal

McKinleyville: 2008 - 2012

Materials Characterization Example: Evaluation of In-Place Recycling Methods

- Full-depth
  - FDR with no stabilizer (NS)
  - FDR with foamed asphalt (FA)
  - FDR with foamed asphalt + cement (FA)
  - FDR with asphalt emulsion (+ cement or lime, EE)
  - FDR with cement or lime (PC)
  - FDR with synthetic polymer emulsions (EE)
- Partial depth
  - Hot in place
  - Cold in place

FDR Field Testing: APT

Phase 2 APT Test Track

<table>
<tr><td colspan="3">FDR-NS</td></tr>
<tr><td>FDR-NS</td><td colspan="2">FDR-EE
(5%)</td></tr>
<tr><td>FDR-PC
(6%, Micro Crack)</td><td colspan="2">FDR-FA-C
(3% AC, 1.5% PC)</td></tr>
<tr><td>FDR-PC
(6%)</td><td>FDR-PC
(5%)</td><td>FDR-PC
(4%)</td></tr>
</table>

Phase 2 FDR Study Test Track

Full-Depth Recycling

- Laboratory testing
  - Stiffness
  - Permanent deformation
  - Fatigue
  - Strength
- Validation of stiffness and damage from APT, FWD
- Calibrated models included in CalME software
- Guidelines produced for NS and FA, underway for PC and EE stabilization

Pavement Design / Software

- Results need to be implemented in tools for users
- Examples:
  - CalME design and analysis software
  - RealCost customized LCCA software
  - CA4PRS pavement rehabilitation construction productivity software
  - Environmental Life Cycle Assessment software under development

Implementation

- Final results must be made useful through a variety of means for different purposes and audiences:
  - Technical research report
  - Summary report
  - 4-pager
  - Guidelines
  - Manuals
  - Software
  - In-person training materials
  - On-line training materials

Summary

- ME APT & Modeling
- WMA APT
- Long Life Pavements
- Reflective Cracking
- LCCA
- Material Characterization
- Pavement Software
- Implementation

Thank you!

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