Analyses of Laboratory and Accelerated Pavement Testing Data for Warm-Mix Asphalt Using California Mechanistic-Empirical Design Method

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Outline

- Project introduction
- CalME introduction
- Data collection
- CalME analysis
- Summary and conclusions
WMA Study - Objectives

- WMS vs. HMA performance
- Guide the implementation of WMA in California
WMA Study – Summary Workplan

- Objectives met through:
  - Laboratory studies
  - Accelerated pavement testing
  - Field testing

- Phased approach followed
  - Phase 1: dry, WMA
  - Phase 2: wet, WMA
  - Phase 3: dry, R-WMA

- Field testing of most WMA pilot projects in CA continues
CalME Introduction

- California Mechanistic-Empirical Design
- Main features
  - For all pavements with flexible surface
  - Include Caltrans empirical design
  - Incremental-recursive
  - Monte-Carlo simulation for reliability
  - Long term simulation with M&R
  - 0.5 minute for 40 year simulation
CalME Calibration and Implementation

- CalME models finalized
- Calibration using HVS and WesTrack data completed
- Standard material library
  - First version established
  - More asphalt concrete mixes being added
  - Needed: recycled materials such as FDR, HIPR, CIPR etc.
Data Needed for CalME

- **Structure**
  - layer and thickness
  - Asphalt bound material parameters
  - Unbound layer stiffness

- **Loading**
  - Pavement temperature history
  - Wheel load history

- **Performance**
  - Rut accumulation history
# Pavement Structure

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness</th>
<th>Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>DGAC</td>
<td>2 x 60 mm = 120 mm (4.7 in)</td>
<td>1,000 MPa</td>
</tr>
<tr>
<td>Imported Class 2 Aggregate Base-Course</td>
<td>300 mm (12 in)</td>
<td>150 MPa</td>
</tr>
<tr>
<td>Existing Subbase</td>
<td>250 mm (10 in)</td>
<td>400 MPa</td>
</tr>
<tr>
<td>Bedrock</td>
<td>Semi-infinite</td>
<td>&gt;3,000 MPa</td>
</tr>
</tbody>
</table>
Data Collection – WMA/HMA

- Stiffness master curve
  - Beam bending frequency sweep
- Permanent deformation model
  - RSST-CH (repeated simple shear test at constant height)
- Fatigue damage model
  - Beam bending
WMA/HMA Sampling
Testing For WMA/HMA Stiffness

- Beam bending frequency sweep tests
  - 10, 20 and 30°C
  - 0.01 to 15 Hz
  - 2 replicates
  - Downward bending only
WMA/HMA stiffness master curve

Testing Temperature (°C)

Flexural Stiffness at 10Hz (MPa)

- Control
- Advera
- Evotherm
- Sasobit
Testing for WMA/HMA Fatigue Performance

- Beam bending flexural fatigue
  - Same setup as stiffness testing
  - 20C
  - Two strain levels
  - 2 replicates
Fitting WMA/HMA Lab Fatigue Data - Evotherm
Testing for WMA/HMA Rutting Performance

- RSST-CH Tests
  - 45 and 55C
  - 70, 100 and 130 kPa
  - 2 replicates
Fitting Laboratory Rutting Performance - Advera
Unbound layer stiffness

- Falling weight deflectometer (FWD)
  - Done twice: with cold and hot air temperature
  - 1-m interval
  - 20 days after construction
FWD Back-calculation – SG Stiffness

Subbase+Bedrock Equivalent Stiffness (MPa)

Testing Station (m)

Advera
Sasobit
Evotherm
Control
Pavement Performance – HVS Testing
Pavement Performance – HVS Results

![Graph showing Pavement Performance](image)

- **40kN (50°C)**
- **40kN (55°C)**
- **60kN (55°C)**

**Axes:**
- **Y-axis:** Average Downward Rut (mm)
- **X-axis:** Number of Accumulated Load Repetitions (Thousand)

**Legend:**
- 600FD (Control)
- 601FD (Advera)
- 602FD (Evotherm)
- 603FD (Sasobit)
CalME Simulation – Validation 1/2
CalME Simulation – Validation 2/2

The graph shows the relationship between measured downward rut (mm) and predicted downward rut (mm) for WMA and Control materials. The linear equations for WMA and Control are:

- **WMA**: $y = 1.4675x$, $R^2 = 0.9036$
- **Control**: $y = 1.0606x$, $R^2 = 0.7354$
CalME Simulation – Explaining Effects of Unbound Layer Stiffness

![Graph showing predicted downward rut normalized by Section 600FD results for different load repetitions and unbound layer stiffness scenarios.](image)
CalME Simulation – Normalized Rutting Performance

Corrected Average Downward Rut (mm)

Number of Accumulated Load Repetitions (Thousand)

- 40kN (50°C)
- 40kN (55°C)
- 60kN (55°C)

- 600FD (Control)
- 601FD (Advera)
- 602FD (Evotherm)
- 603FD (Sasobit)
Summary and Conclusions

- Laboratory, FWD and HVS test data provides all inputs to CalME.
- CalME prediction matches the shape of the measured with high $R^2$ value (0.90).
- Large variation of in-situ unbound layer stiffness can only affect HVS results by 20%.
- CalME provides a necessary tool for full scale studies such as HVS.
Questions and Thank You!

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