Key Results from a Comprehensive Accelerated Loading, Laboratory, and Field Testing Study on Warm-Mix Asphalt in California

David Jones, Rongzong Wu, Bor-Wen Tsai
University of California Pavement Research Center
Cathrina Barros, Joseph Peterson
California Department of Transportation

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Summary

- Introduction
- Caltrans research objectives
- APT and lab testing results
- Field tests
- Conclusions & implementation
Introduction

- 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 the binder
    - Additives in the mix
  + Many projects, but limited long-term monitoring
- Better understanding required before full implementation
Introduction
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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
Long-Haul Rubberized AC
Workplan Summary

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

- **Phase 3, R-WMA-G**
  - 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
Workplan Summary

- Accelerated Pavement Testing
  - Test track construction monitoring
  - Rutting
  - Moisture sensitivity
  - Cracking

- Field studies
  - Constructability
  - Long-term performance
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Phase 1 & 2 Summary

- Testing
  + 18 months of HVS testing
  + 12 months of lab testing
  + Months of data analysis

- Reports completed:
  + 1st Level Report: Construction & Phase 1 Study
  + 1st Level Report: Phase 2 Study & forensic investigation
Phase 1 & 2 Conclusions

- No indication that the three warm-mix additives tested influence long-term rutting & fatigue performance or increase moisture sensitivity
- Construction quality/engineering remains a key concept
- Key issues
  + Beware wet aggregates
  + Beware initial "tenderness" because of less binder oxidation
Phase 2 Rutting

Rut Depth (mm)

HVS Repetitions

Rut Depth (mm)

HVS Repetitions

UCPRC
Example Initial Stiffness

WMA FMFC (Wet, Tref = 20°C)

- $E^*$ (MPa)
- Reduced Ln(freq) (freq: Hz)

Legend:
- DGAC
- Sasobit
- Advera
- Evotherm
- Gamma Fitted Lines
- Series6
- Series7
- Series8
Phase 3 Summary

- **Testing**
  - 9 months of HVS testing
  - 9 months of lab testing
  - Additional APT to assess aging effect

- **Reports completed:**
  - 1st Level Report: Phase 3 Study
  - 1st Level Report: Construction emissions
  - 1st Level Report: Lab mix, lab compact study
Ph 3 Observations & Conclusions

- WMA mixes had significantly less smoke
- WMA mixes were notably more workable
- Compaction poor
  + Difference between Control mixes and WMA on Day-1
  + No difference on Day-2
- WMA had equal or better performance on 4 of 7
  + Lower performance on 2 (subgrade moisture)
  + Comparative performance on 1 (incorrect binder content)
Phase 3a Rutting

![Graph showing Phase 3a Rutting with different load repetitions and peak rut depths for Control, Cecabase, Evotherm, and Gencor]
Phase 3b Rutting

Number of Load Repetitions (x 1,000)

Average Maximum Rut Depth (mm)

Control
Advera
Astec DBG
Rediset
Sasobit

40kN
60kN
80kN
Example Initial Stiffness

$E^*$ (MPa)

G1 Control  G2 Gencor  G3 Evotherm  G4 Cecabase

WET

$\ln(\text{freq})$ (freq: Hz)
Ph 3 Observations & Conclusions

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- Key Issues
  - Beware temperature limits
  - Final conclusions after completion of lab testing and aging effects study
  - Emissions dependent on technology
Phase 3 Emissions

Before Compaction
After Compaction

Mix

WMA 1
WMA 2
WMA 3
WMA 4
Control 1
Control 2
Control 3
WMA 5
WMA 6
WMA 7

Emissions
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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
Orland: 2009 - 2011

Control, Evotherm
Marysville: 2009-2011
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Conclusions

- Comprehensive, systematic study to guide implementation of WMA in California
  - Laboratory, APT and field performance
- Confirmed that equal performance can be obtained from WMA
  - Beware initial tenderness/initial higher rutting
  - Beware moist aggregates
  - Consider effects of H-WMA vs W-WMA, especially on RAP mixes
  - WMA does not replace good engineering practice

- Implementation
  - Pilot projects 2007-2010
  - Statewide implementation in 2011 with more than 1 million tons placed in 2011 paving season
Thank you!

David Jones
djjones@ucdavis.edu
www.ucprc.ucdavis.edu

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