

Cold Recycling of RAP in the Western USA

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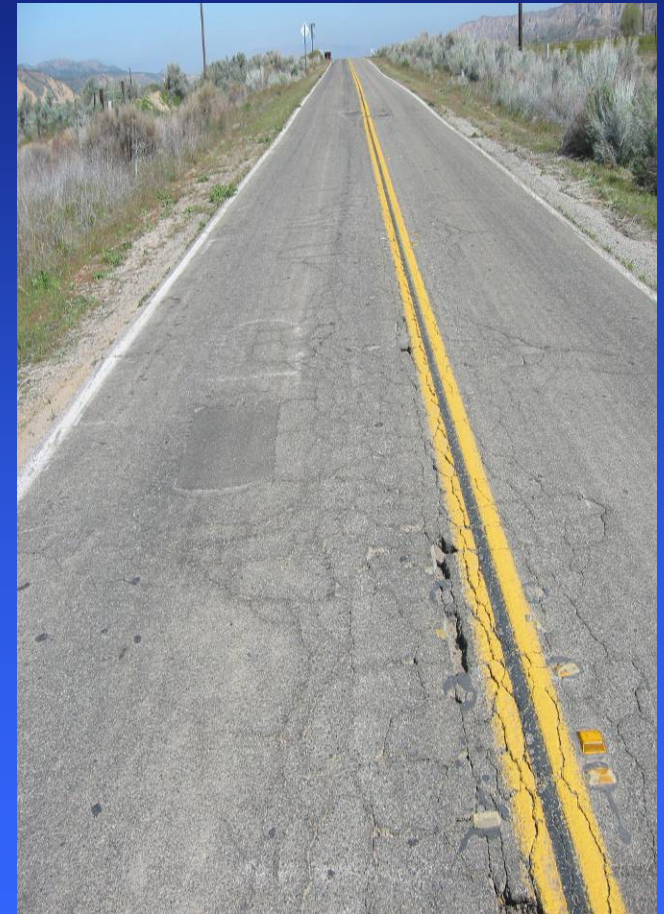
Summary

- Introduction
- Research focus areas
- Key findings
- Research implementation
- Cross-cutting issues

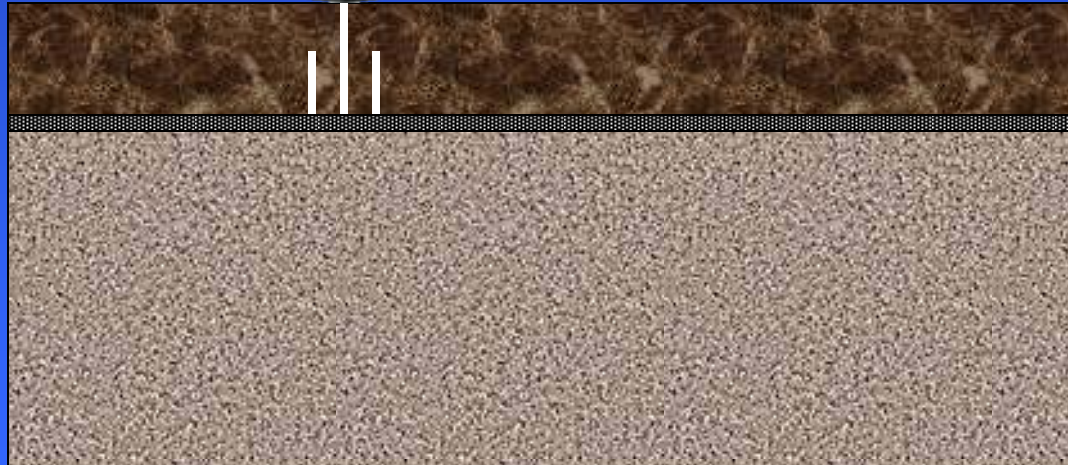


Introduction

- FDR-FA introduced to California in 2000
- Pilot study in 2001
- International research focus
- USA research focus
- California research focus
 - Thick AC "evolved roads"
 - Closure limitations
 - Mix & structural design

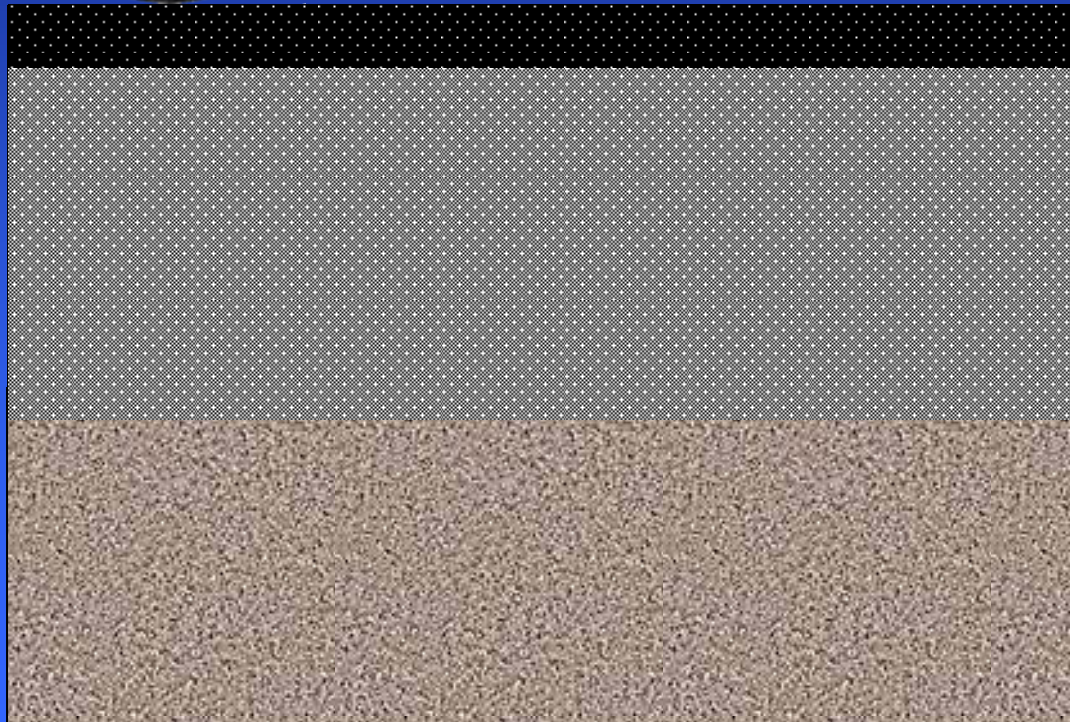


Introduction



- Asphalt concrete (50mm)
- "Oil"
- Subgrade/Base
(Old gravel road)

Introduction



Summary

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- **Research focus areas**
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UCPRC Research Focus

- Recycling/sustainability strategic initiative
- FDR and FDR-FA study
 - Literature review
 - Mechanistic sensitivity analysis
 - Pilot project assessment
 - Laboratory study
 - Guidelines
- Next phases
 - FDR with cement
 - FDR with emulsion + active filler
 - PDR (CIR) with emulsion
 - High air voids
 - Weak base / reflection crack concerns



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Literature Review (2004)

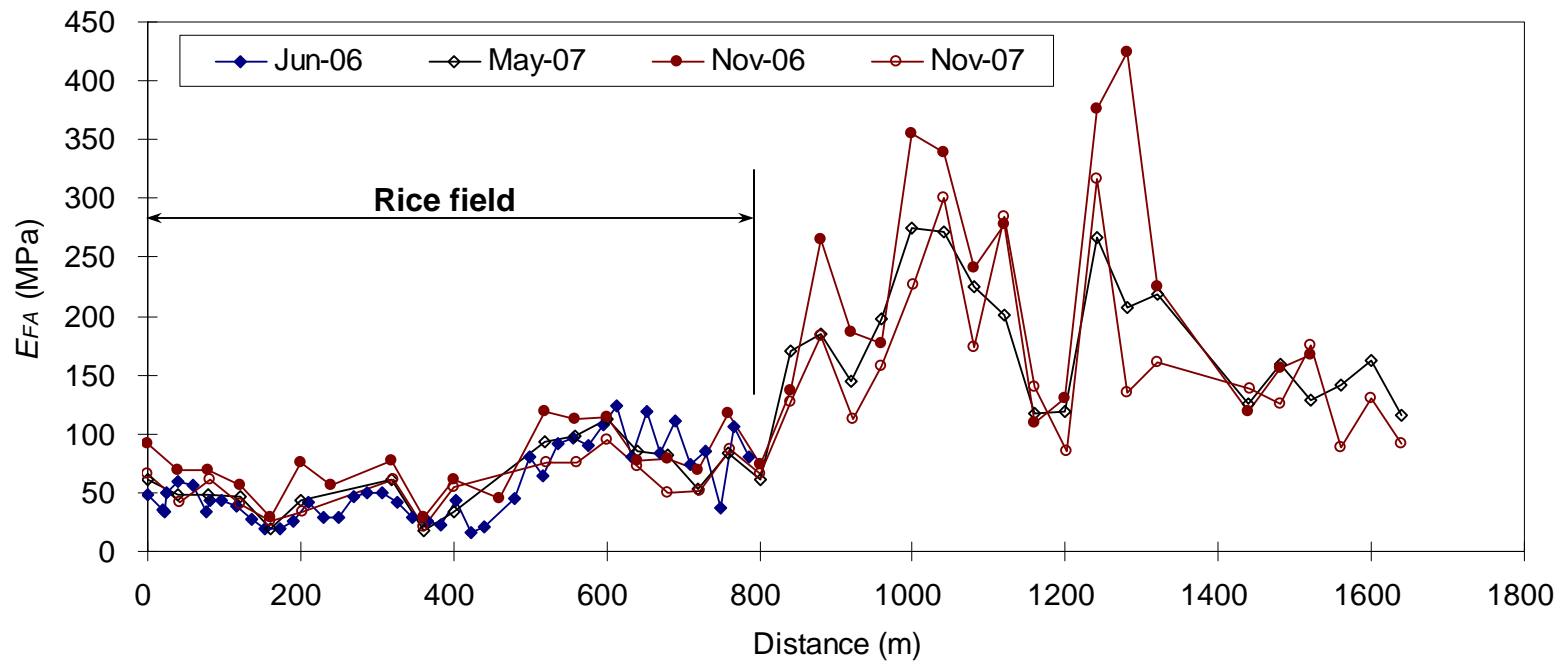
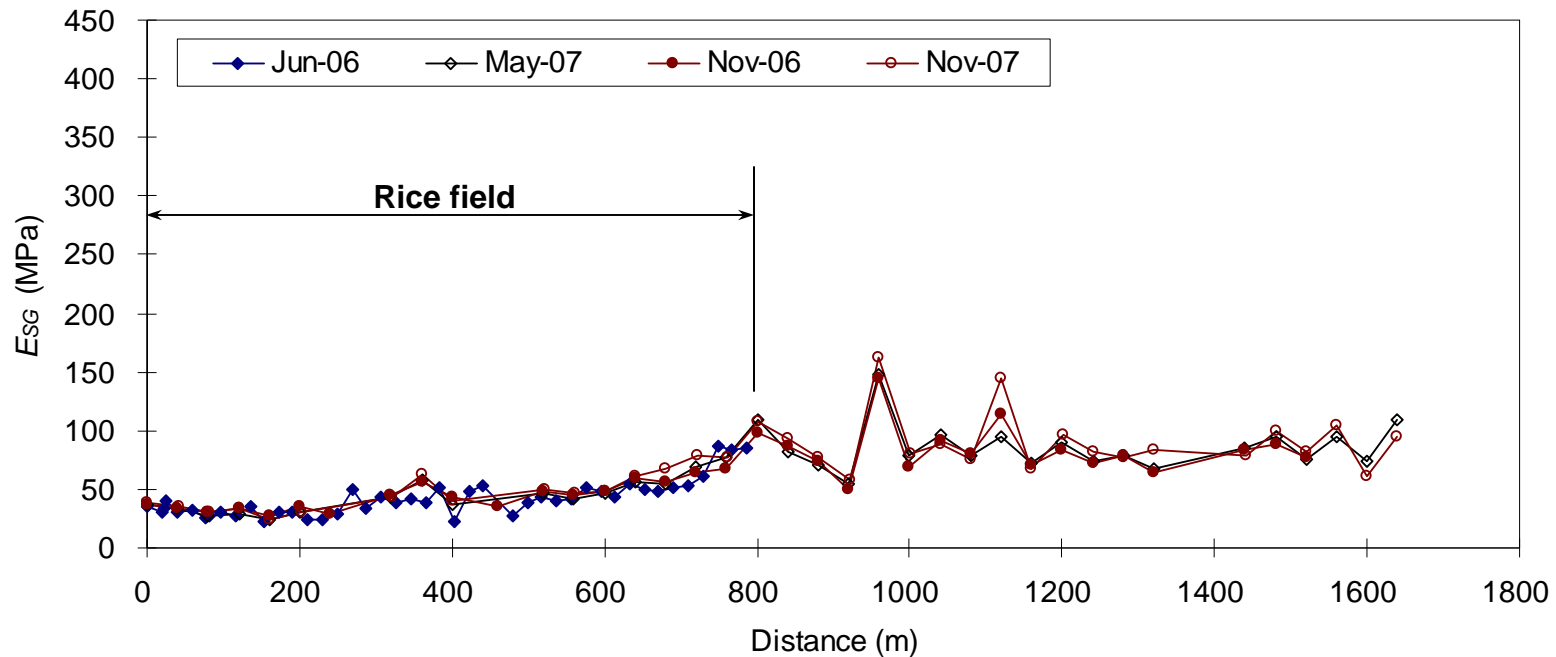
- Key findings
 - Very little work on FDR-FA of thick AC pavements
 - No guidelines suited to CA conditions & practice



Pilot Project Assessment

- Key findings
• Selected
- Drain





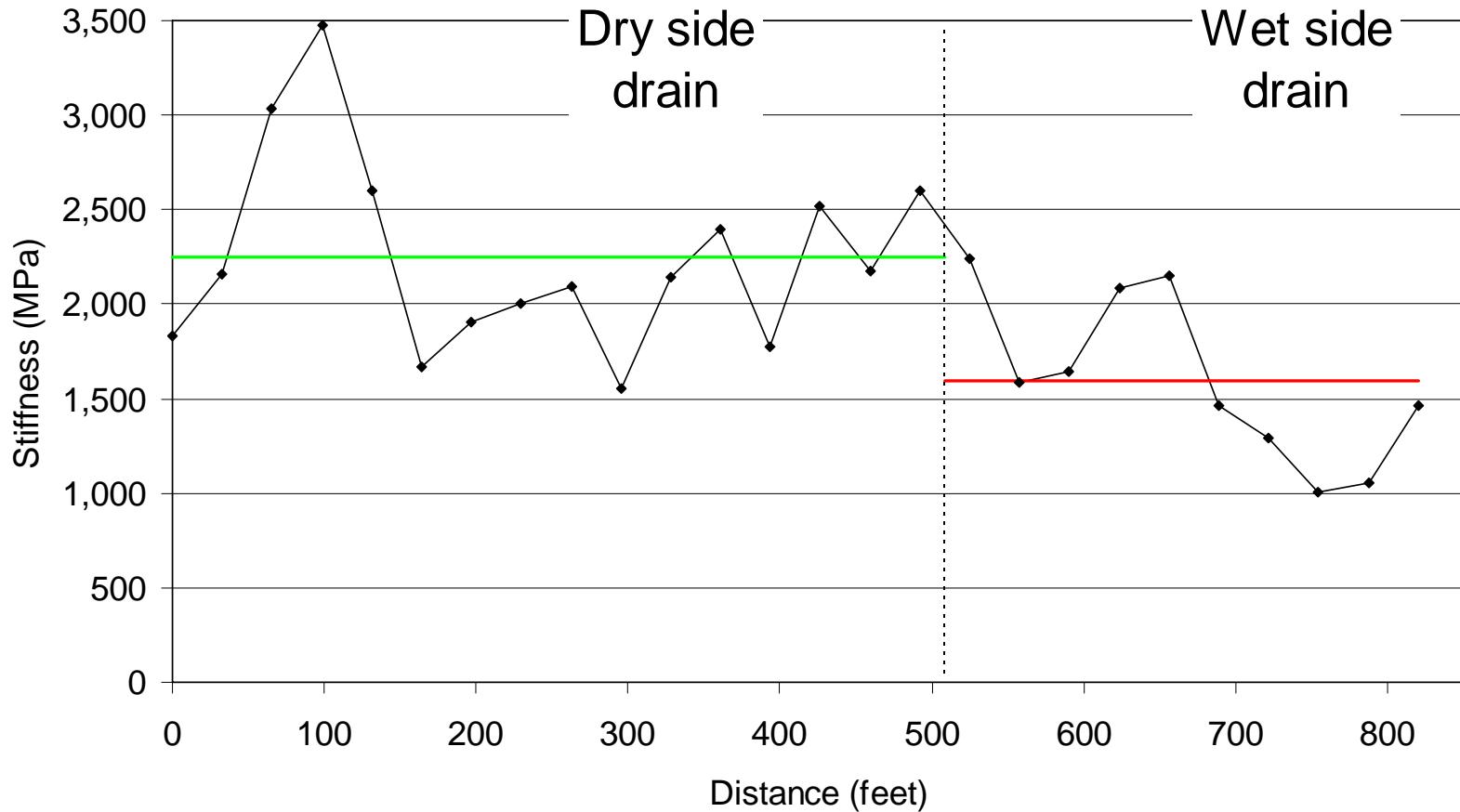
Pilot Project Assessment

Dry

Wet



Pilot Project Assessment



Pilot Project Assessment

- Key findings
 - Pre-pulverization
 - Equipment
 - Training



Pilot Project Assessment

- Key factors
 - Pre-
 - Equ
 - Tra
 - Tem



Pilot Project Assessment

- Key findings
 - Pre-pulverization
 - Equipment
 - Training
 - Temperature
 - Compaction



Pilot Project Assessment

- Key factors for success
 - Preparation
 - Equipment
 - Traffic
 - Terrain
 - Construction
 - Construction



Pilot Project Assessment

- Key findings
 - Pre-purchase
 - Equipment
 - Training
 - Temperature
 - Compaction
 - Compaction
 - Quality



Laboratory Study

- Experimental design
 - Full factorial to prepare partial factorial
 - Four phases
 - 1: Specimen preparation, test methods
 - 2: Binder and RAP properties, test components
 - 3: Binder and RAP properties
 - 4: Fillers, curing, aggregate temperature
- Scale
 - >3,000 specimens, 8 tons of RAP, ~100 buckets of asphalt binder

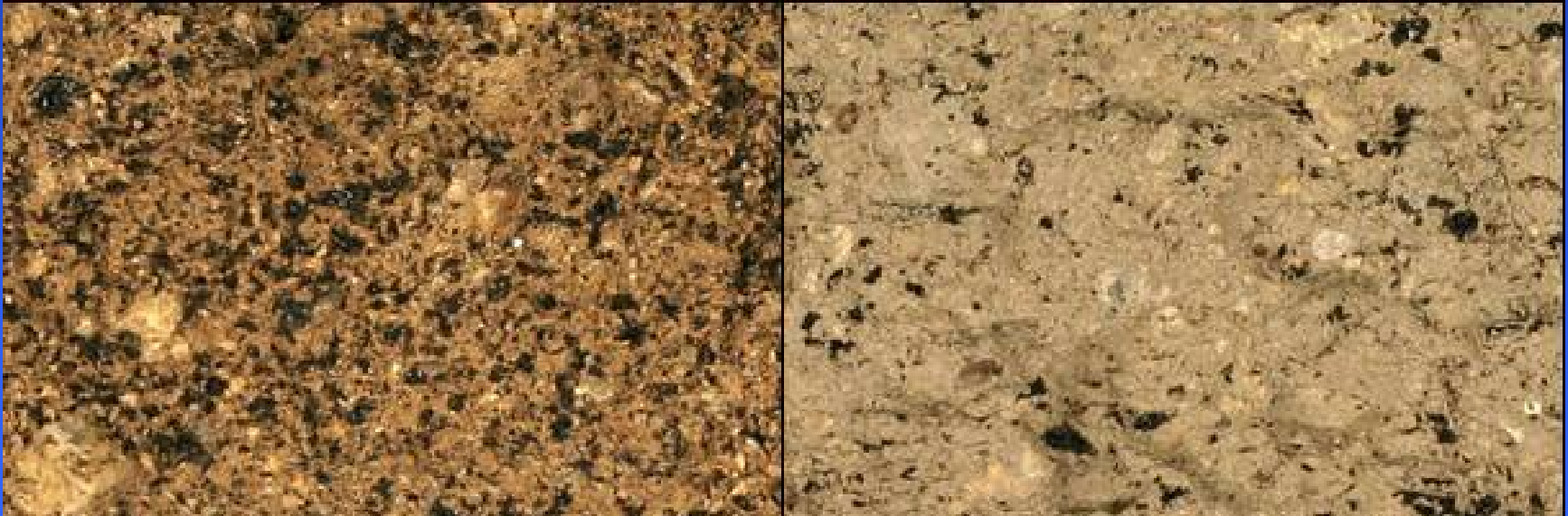
Laboratory Study

- Key findings on binders
 - Highly variable in California
 - Anti-foamants
 - Softer binders have best foam characteristics
 - Foamability requirements linked to pavement temperature



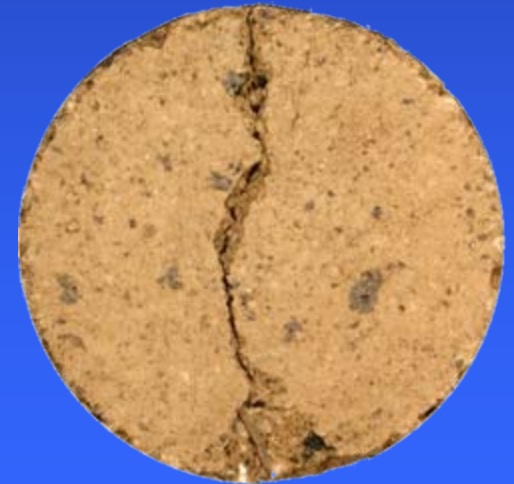
Laboratory Study

- Key findings on aggregate
 - Lab aggregate temperature $>20^{\circ}\text{C}$
 - Fines content (P0.075mm) 5-12%

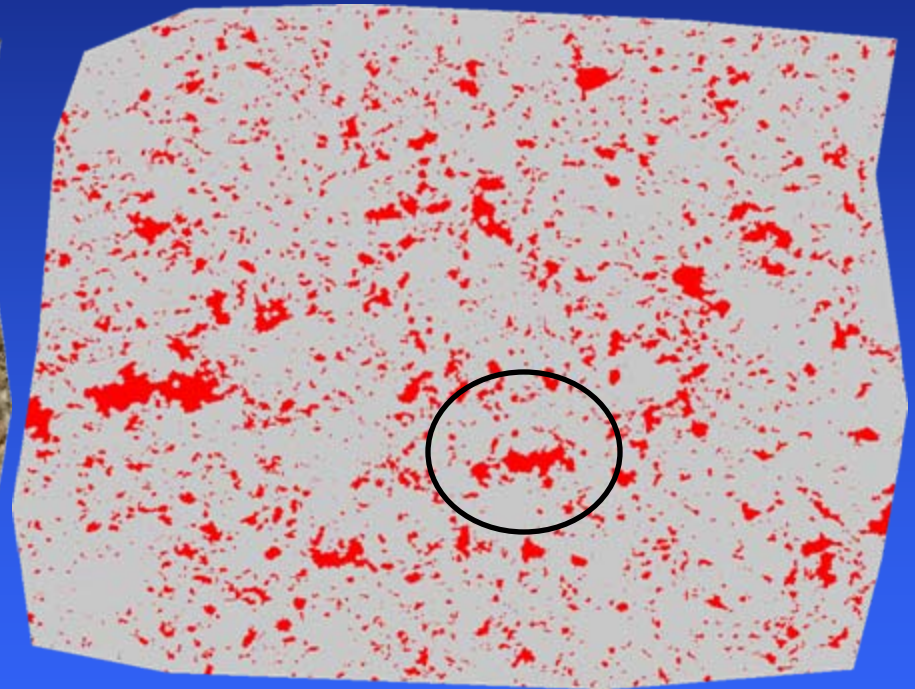
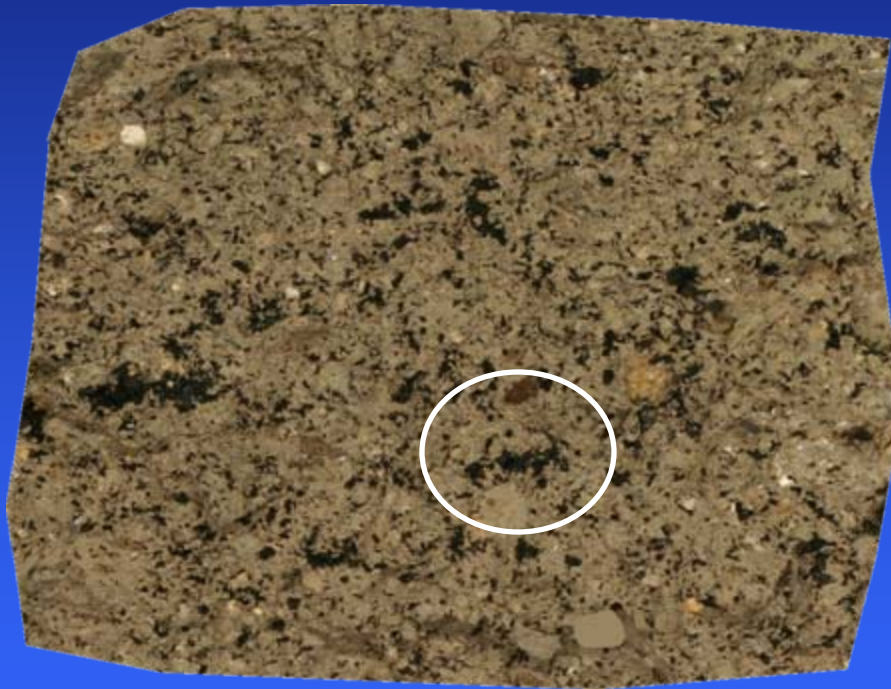


Laboratory Study

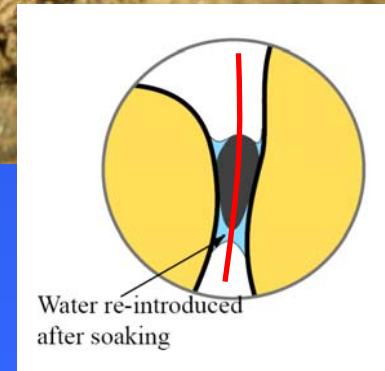
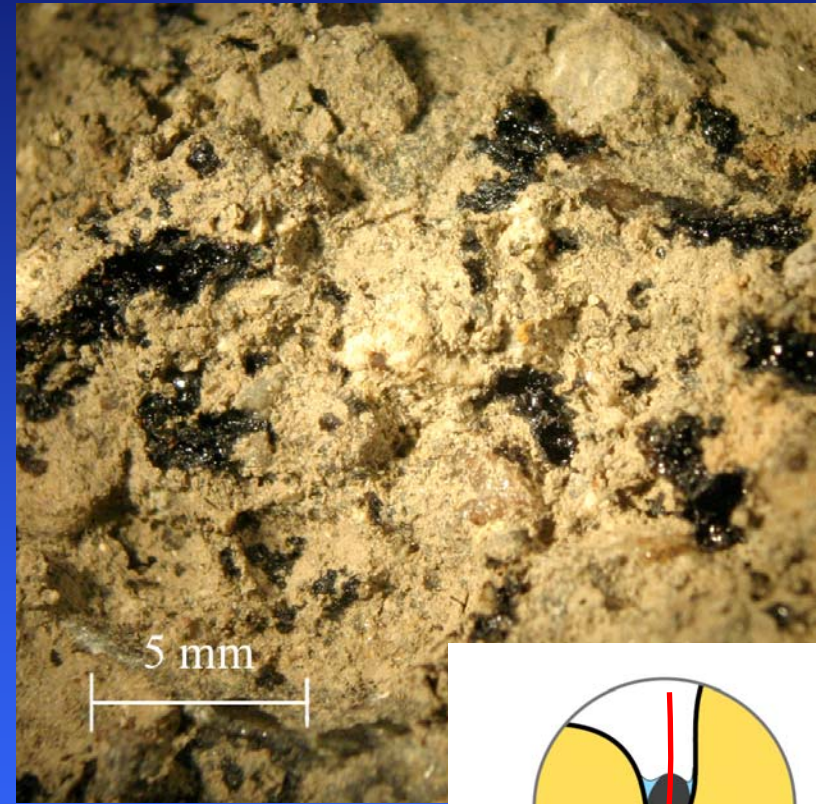
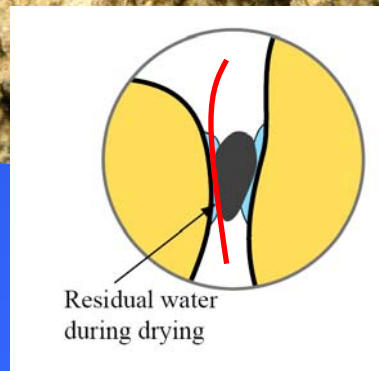
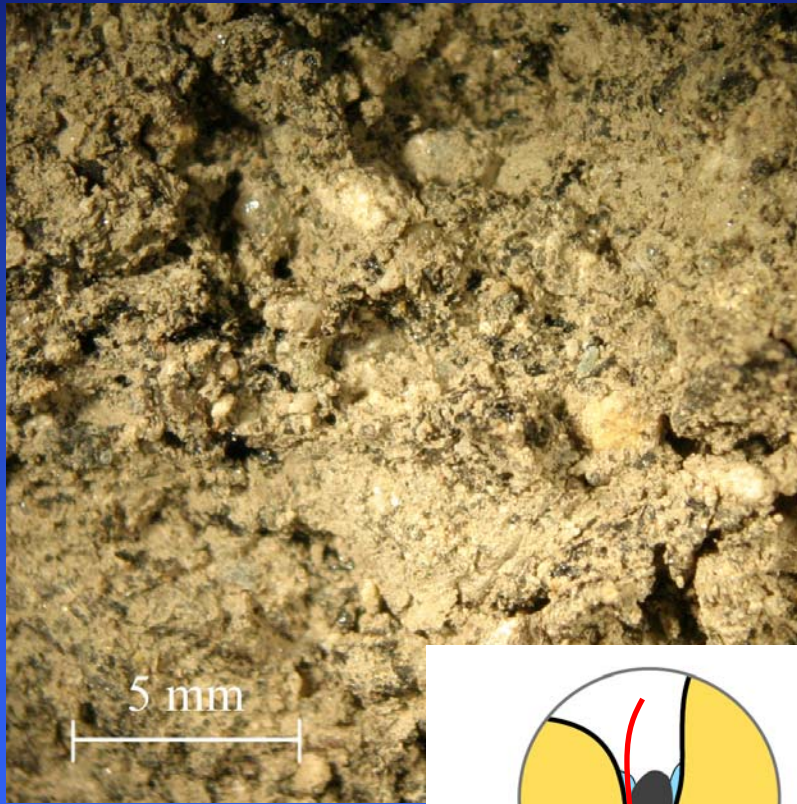
- Key findings on lab test methods
 - Focused on addressing field observations
 - Focused on same-day opening to traffic
 - Restricted by testing ability in districts
 - Monitor & record temperatures throughout
 - Beware of thermometers on WLB10
 - FA and then FA plus active filler
 - Compare fracture energy / shrinkage
 - Soaked and unsoaked tests
 - Unsoaked test for mix design
 - Mixing moisture content
 - ITS test
 - Fracture face analysis



Fracture face analysis (1)



Fracture face analysis (2)



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Research Implementation

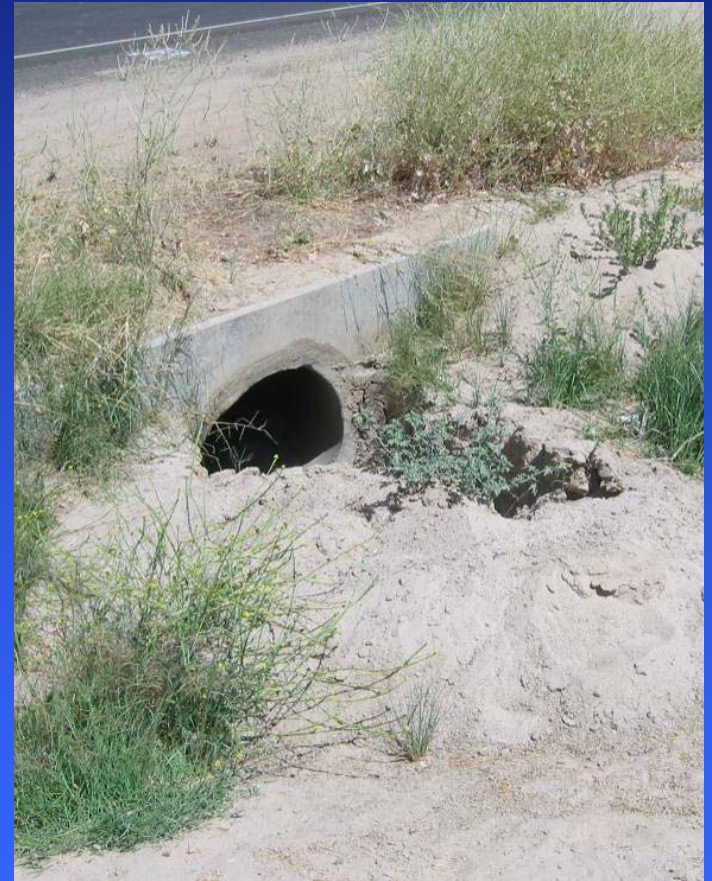
- Final report documenting entire study
- Guideline for California
 - Project investigation
 - Mix design
 - Structural design
 - Construction
- FDR and FDR-FA chapter in specification document
- Tech transfer on projects
 - Implementation decision at District Level

Guidelines - Project selection

- Each project should be designed
- FWD
 - 20m intervals
 - 600mm sensor deflection
 - < 25MPa: not suited to FDR
 - 25-45MPa: subgrade problems possible
 - >45MPa: suitable
- Cores and DCP
 - 100 to 500m intervals

Guidelines - Project selection

- Visual assessment
 - Drainage
 - Roadside activity
 - Repeat maintenance
- Test pits
 - Cold milling machine
 - E.g. Wirtgen W50 DC



Guidelines - Mix design

- Binder contents
 - Based on 3% asphalt and 1.5% active filler
- Binders
 - Optimize foam characteristics
 - ER >10x and HL 12 secs
 - Specify range of temperature and water-to-asphalt ratio
 - CBA on transport of "better" binders

Guidelines - Mix design

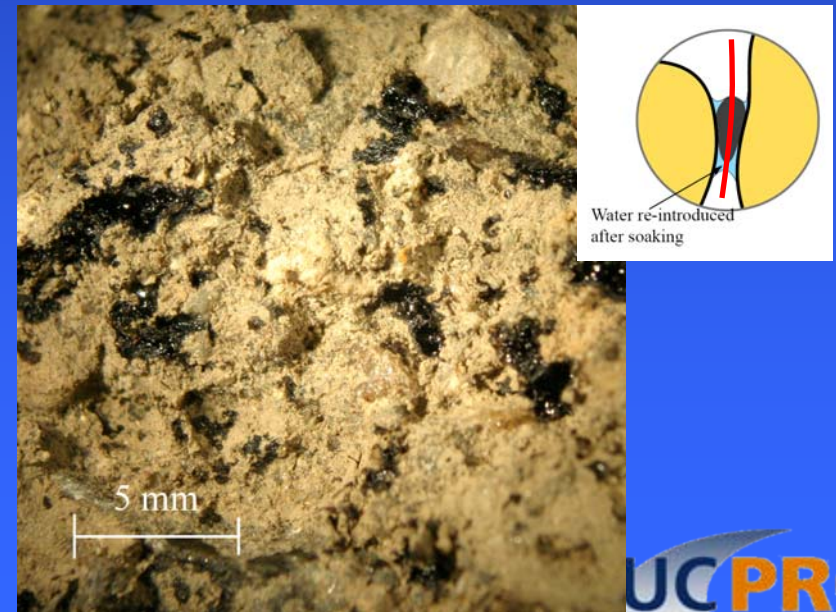
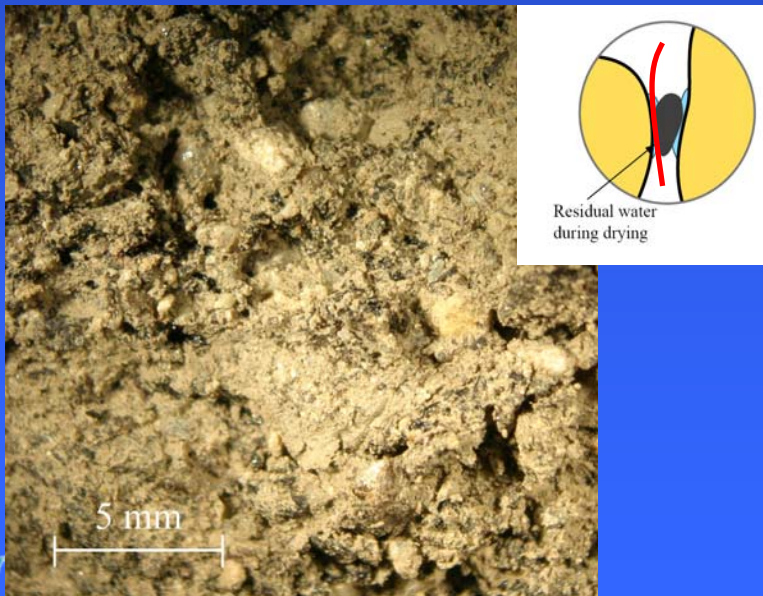
- Aggregate temperatures
 - 25°C and minimum field temperature expected
- Active fillers
 - Acid crystalline, arenaceous, high silica
 - Cement
 - Basic crystalline
 - Lime & cement until sufficient knowledge gained

Guidelines - Mix design

- Testing
 - Fines content
 - 5-12% recommended (excl active filler)
 - >15%: monitor soaked strengths closely
 - >20%: not appropriate for FDR
 - Atterberg limits
 - Specification
 - Mixing moisture content
 - 75 - 90% of OMC
 - Monitor agglomerations

Guidelines - Mix design

- Testing
 - All mix designs based on soaked results
 - ITS test okay (4 replicates)
 - Monitor fracture faces



Guidelines - Structural design

- Standard pavement design procedures
- Gravel factor: 1.4
- Mechanistic-empirical design in process
 - Dependent on testing
 - Lower volume roads likely at first because of early opening requirements

Guidelines - Construction

- "Walk behind" technician
- Temperatures
 - Air: $> 10^{\circ}\text{C}$
 - Surface, filler (and mid depth): $> 15^{\circ}\text{C}$
- Mixing moisture content
 - In recycler, not after
 - No additional water until after pad-foot
- Tanker changes
 - Temperature, ER and HR checks



Guidelines - Construction

- **Compaction equipment**
 - Weights specified in project specifications
 - Enforced
 - Follow Wirtgen manual recommendations
- **Compaction**
 - Test strip for rolling patterns
 - Pad-foot: until no indentations (use blade)
 - Refusal density vs target density?
 - One pad-foot roller per recycling train
 - Distance control behind recycling train

Guidelines - Construction

- Quality control
 - Milling depth
 - Presence of unfoamed asphalt, oversize material, loose material prior to surfacing
 - Compaction moisture content and density clearly defined in the Project Special Provisions, and strictly enforced.
 - Nuclear gauges calibrated on foamed asphalt material.
 - Densities should meet requirement throughout layer.

Guidelines - Construction

- Dust control / surface seal
 - Consider emulsion spray each day
- Surfacing
 - Moisture content (30 - 50% of OMC)
 - No ravelling/loose material permitted
 - Visual assessment before surfacing



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Cross-Cutting Issues

- CIR vs FDR
 - Mostly FDR (90% RAP and 10% Granular)
 - Concerns with CIR on weak structures
- Emulsion vs foamed bitumen
 - All FDR foamed bitumen + active filler
 - Moisture content issues
- In-place vs plant
 - All in-place
- Active filler
 - All FDR-FA projects have active filler
 - Cement or lime depending on aggregate chemistry
 - 1 to 2 percent

Thank you!

