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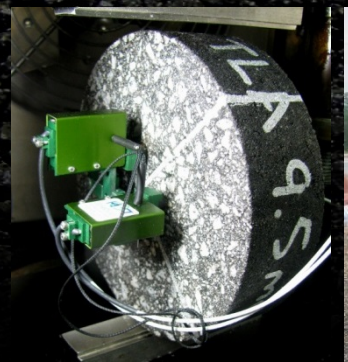
National Performance of High Recycled Mixtures



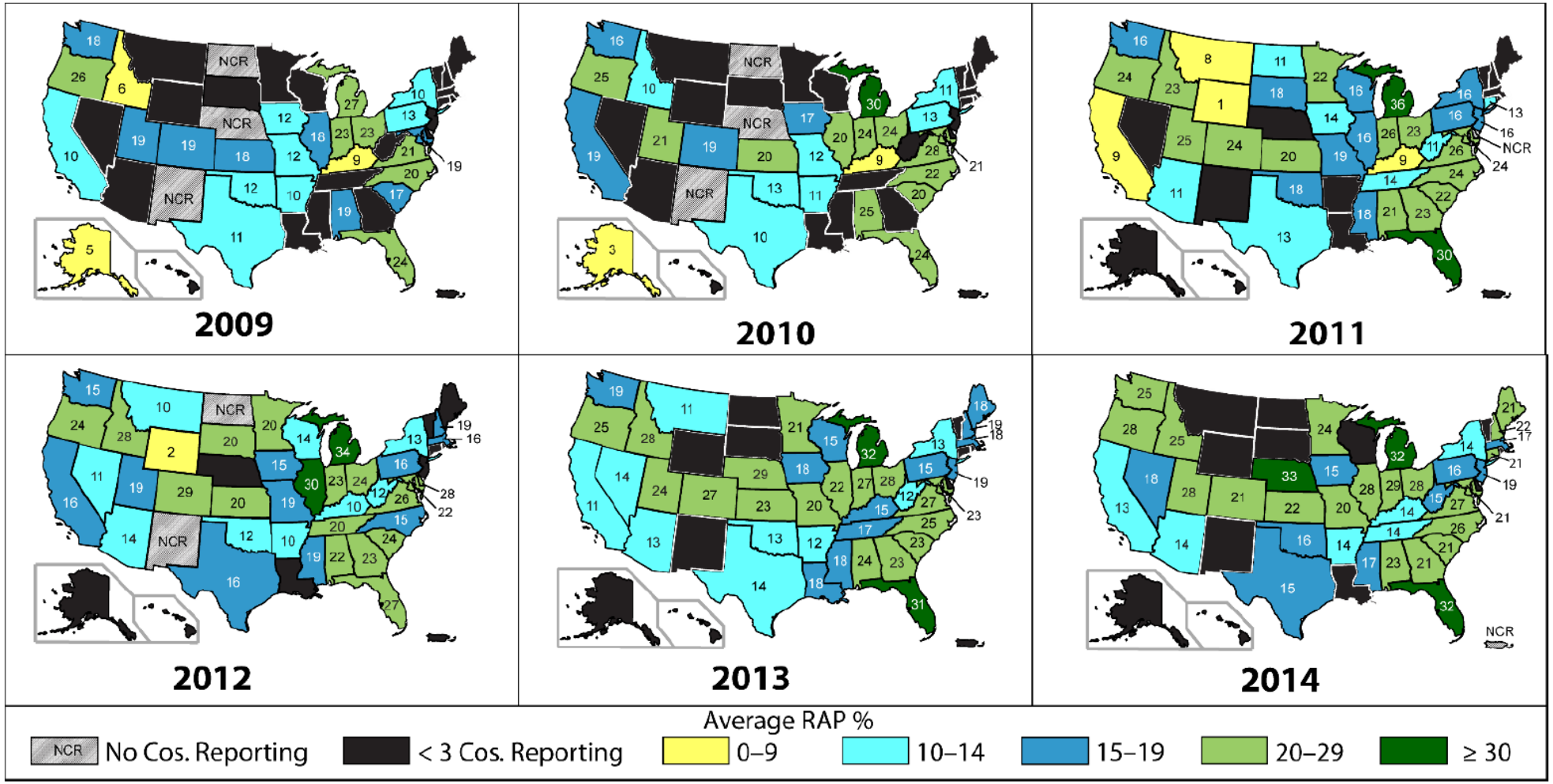
Outline

- Trends in RAP and RAS usage and practices
- Motivations for higher recycled contents
- Barriers to higher recycled contents
- Research and future directions

Estimates of RAP Usage

- NAPA surveys estimate that the national average RAP content increased from 16.2% in 2009 to 20.4% in 2014.
  - RAP contents tend to be higher in commercial projects compared to government projects.
- RAP usage varies considerably from state to state.

Average RAP contents by state



NAPA IS 138, 2015

NATIONAL ASPHALT PAVEMENT ASSOCIATION

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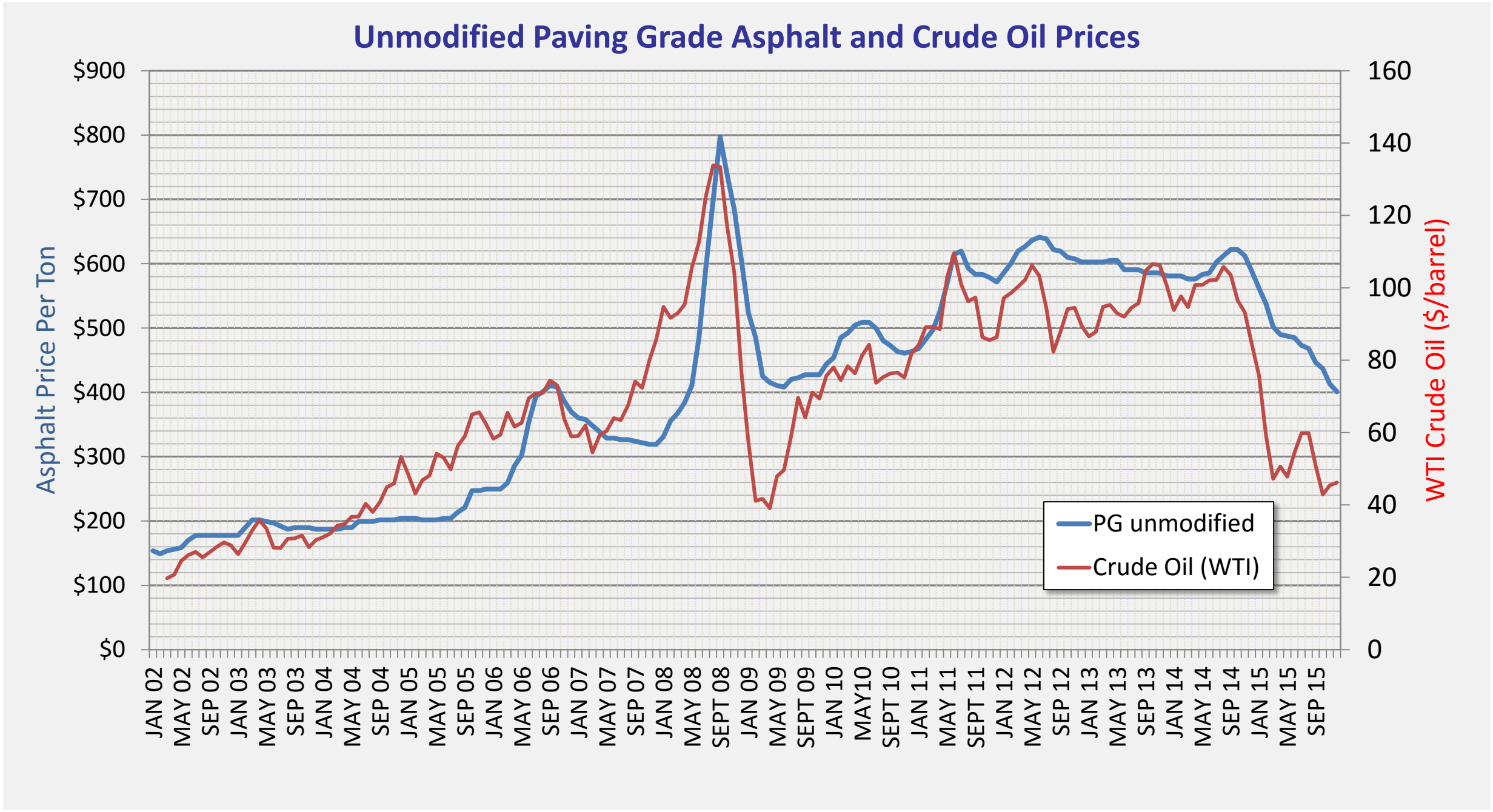
Motivations for Higher RAP Contents

- Environmental & Sustainability benefits
- Economic savings

Conservation of Materials

At an average RAP content of 20%, we conserve over 66 million tons of aggregate and 9 million barrels of asphalt each year.


The average RAP content in Japan is 47%


Unmodified Paving Grade Asphalt and Crude Oil Prices
Asphalt Price Per Ton
WTI Crude Oil ($/barrel)
$900
$800
$700
$600
$500
$400
$300
$200
$100
$0
160
140
120
100
80
60
40
20
0
JAN 02
MAY 02
SEP 02
JAN 03
MAY 03
SEP 03
JAN 04
MAY 04
SEP 04
JAN 05
MAY 05
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SEPT 11
JAN 12
MAY 12
SEP 12
JAN 13
MAY 13
SEP 13
JAN 14
MAY 14
SEP 14
JAN 15
MAY 15
SEP 15
PG unmodified
Crude Oil (WTI)

Current RAP Practices

In most (not all) places across the USA…

- Project millings become property of contractor
- Urban contractors have excess supplies of RAP
- Processing options for RAP
  - no additional processing for single source milling stockpiles
  - blending & crushing: multiple source stockpiles
  - fractionating: RAP contents >30%

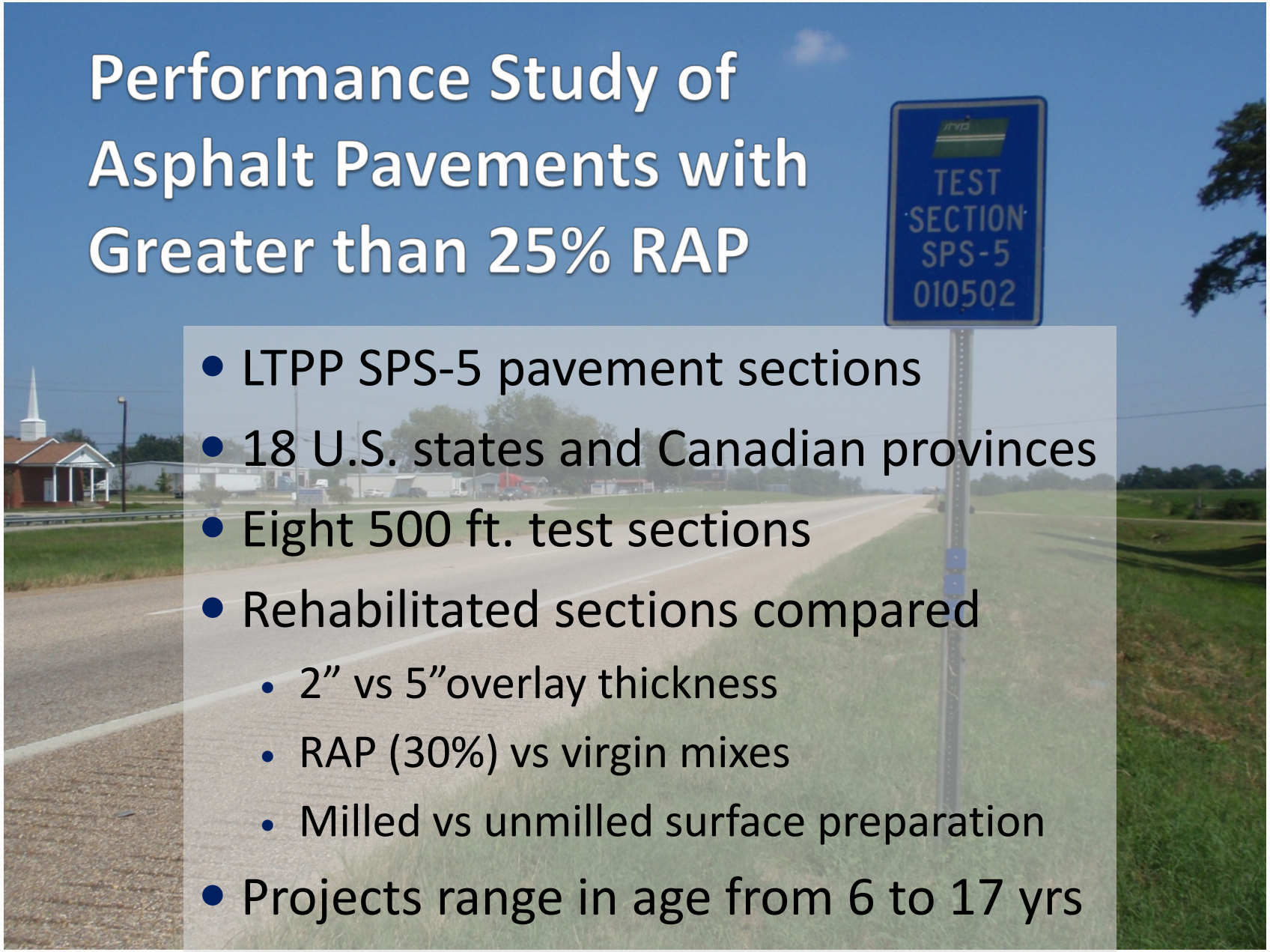
Reasons why Contractors use less RAP than allowed

- Availability of RAP
- Requirement to use a softer virgin binder
  - Limited availability and/or tankage issue
  - Requirement to recover and Test RAP binder
- Ability to control the quality of the mix
  - Moisture
  - Amount of material passing no. 200 sieve
  - Workability
  - RAP variability

Barriers to Higher RAP Contents

- History and Perceptions
  - Performance of high RAP content pavements
  - Concerns about quality and consistency of RAP
- Technology Limitations
  - Current mix design system
    - Relies on VMA & therefore aggregate bulk specific gravities
    - Does not adequately consider composite binder properties
  - Need reliable performance tests

Performance Study of Asphalt Pavements with Greater than 25% RAP



- LTPP SPS-5 pavement sections
- 18 U.S. states and Canadian provinces
- Eight 500 ft. test sections
- Rehabilitated sections compared
  - 2” vs 5”overlay thickness
  - RAP (30%) vs virgin mixes
  - Milled vs unmilled surface preparation
- Projects range in age from 6 to 17 yrs

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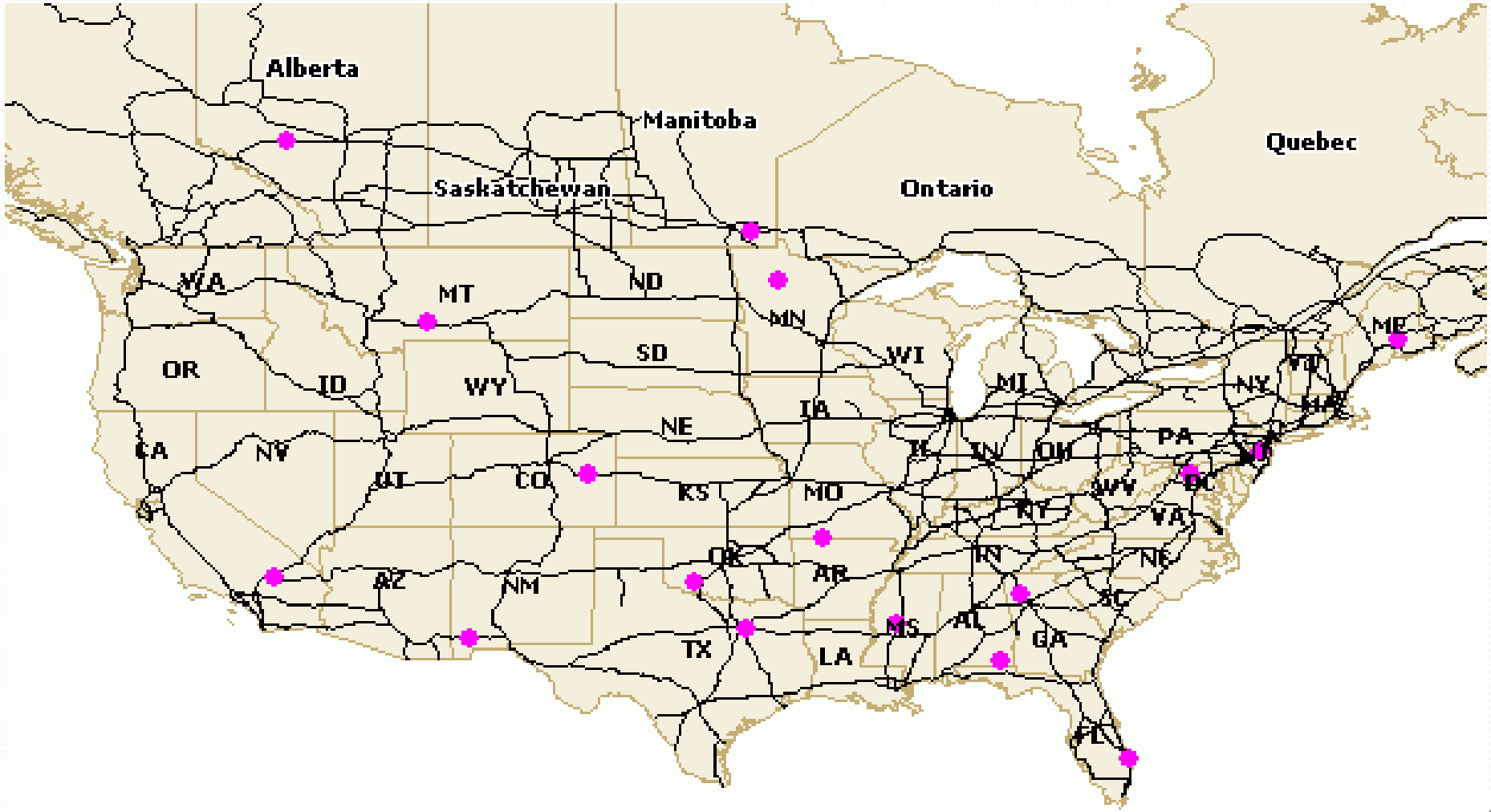
SPS-5 Project Locations



13

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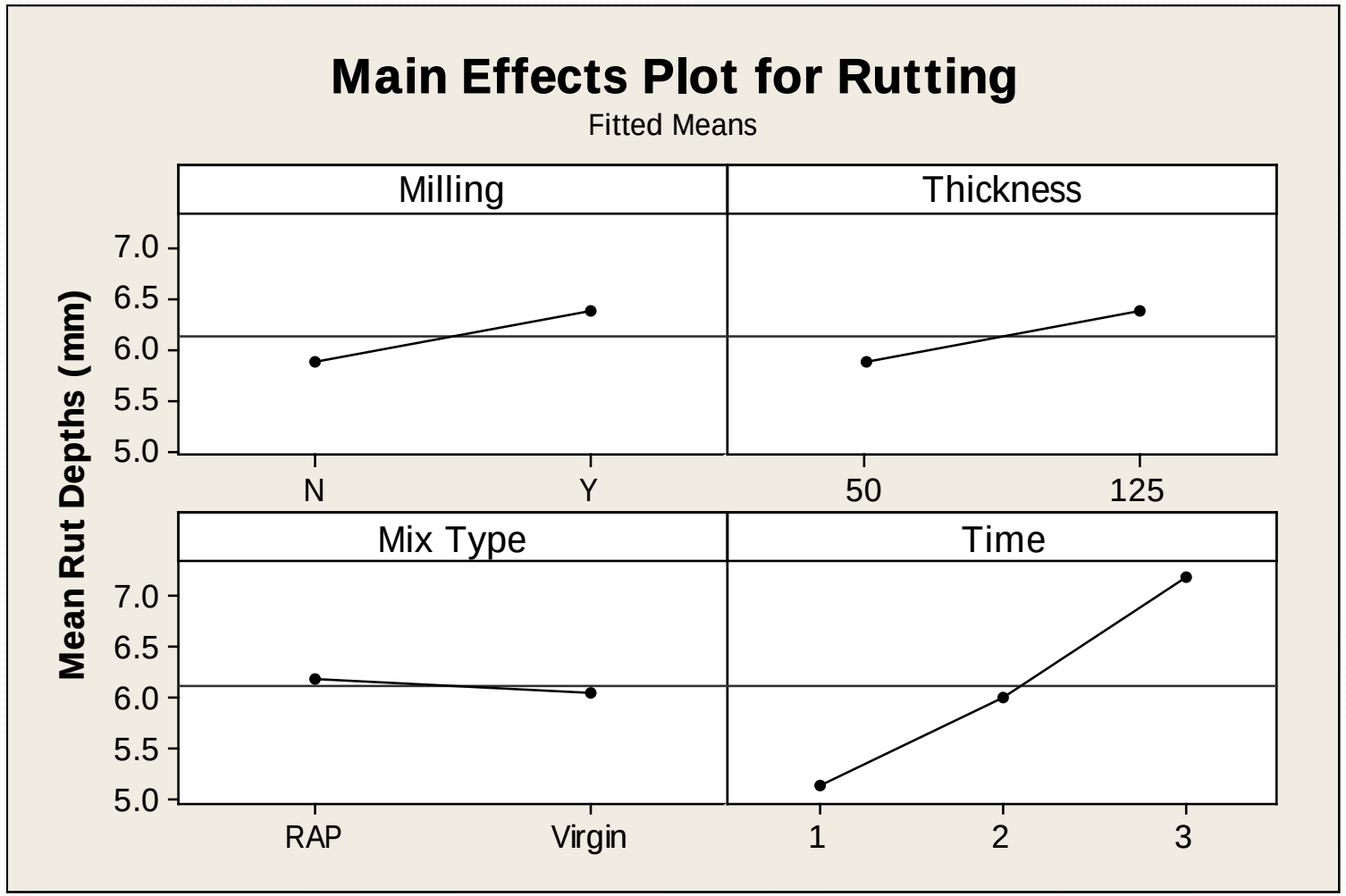
ANOVA: Rutting



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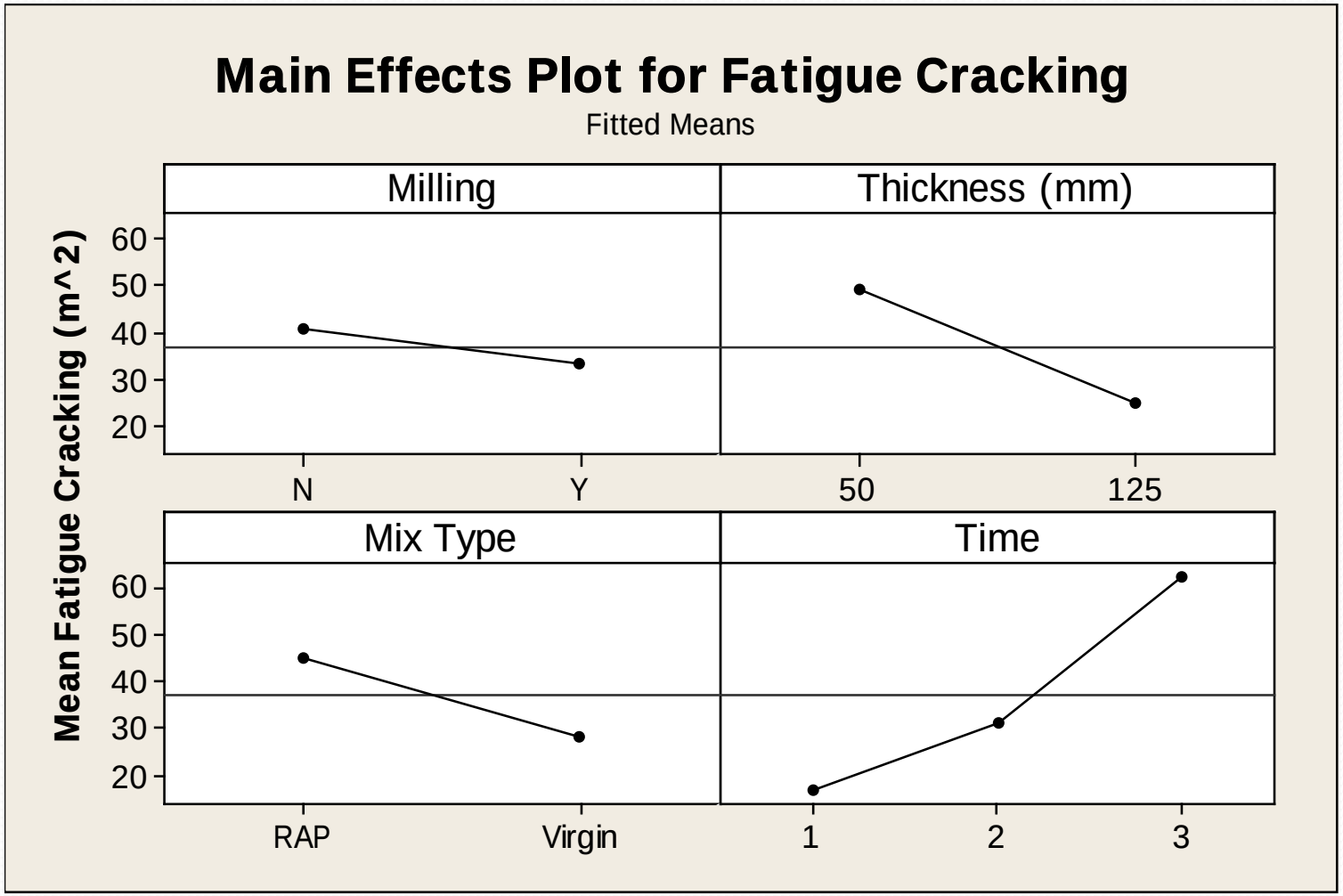
ANOVA: Fatigue Cracking



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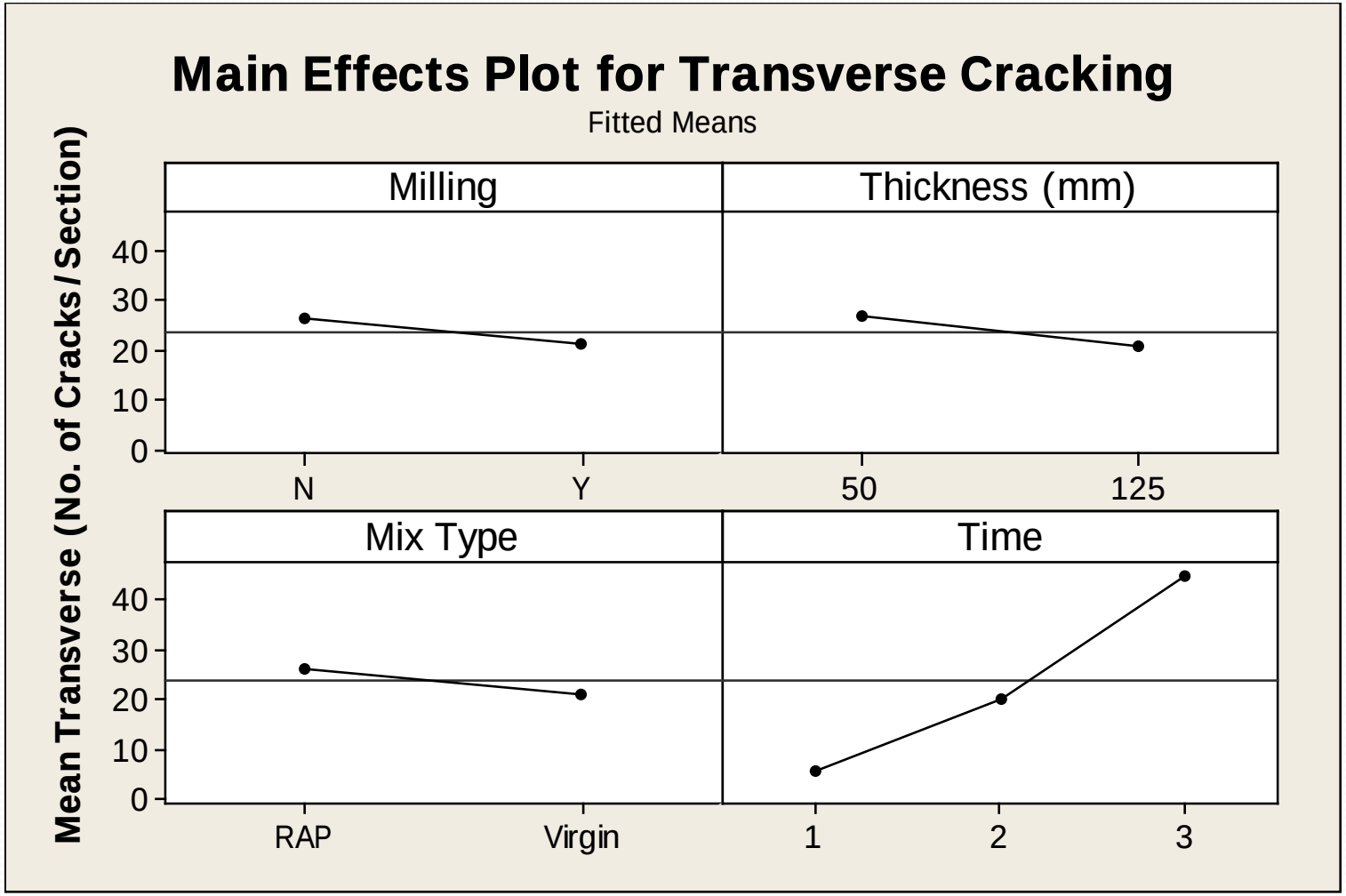
ANOVA: Transverse Cracking



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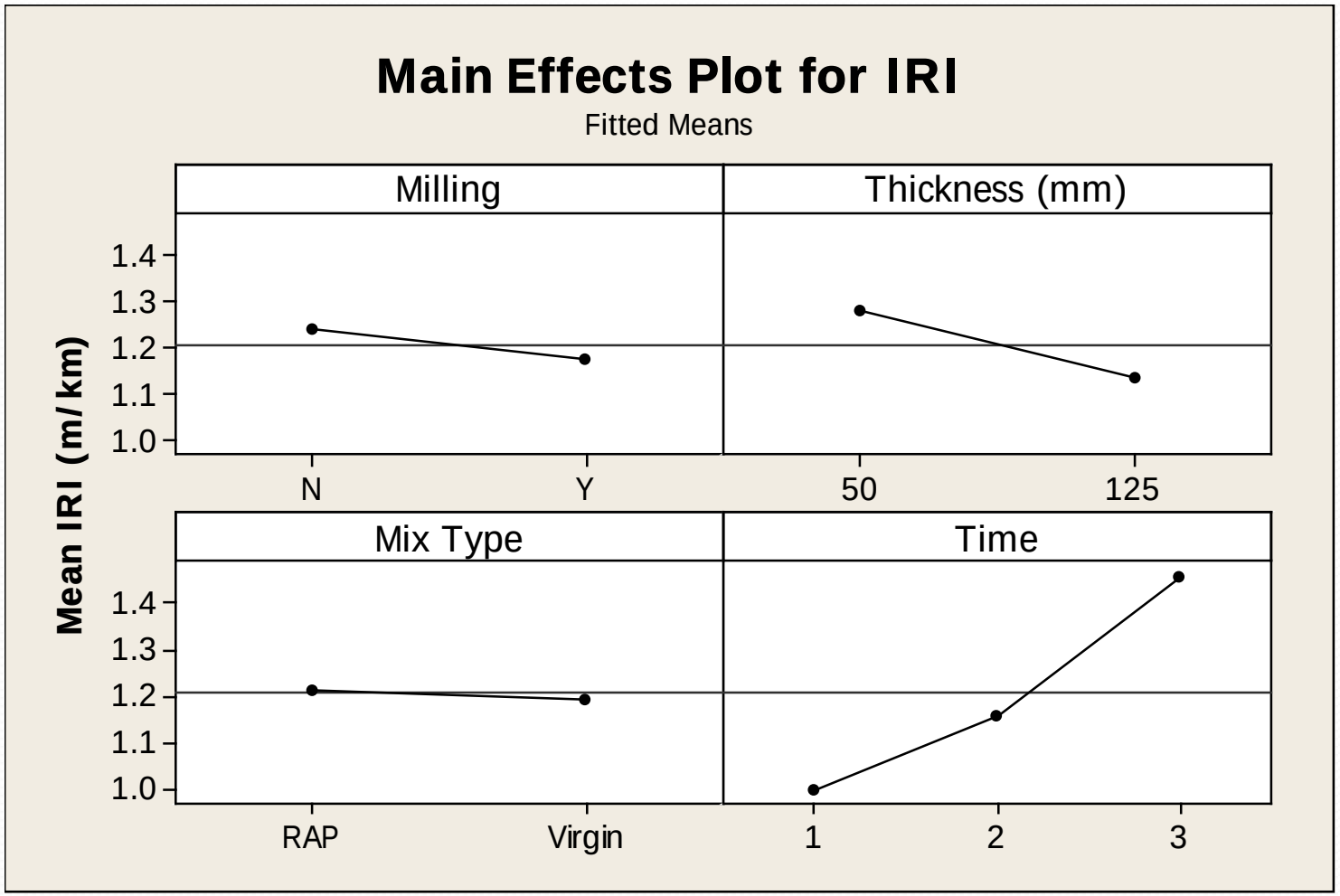
ANOVA: International Roughness Index



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Conclusions on LTPP SPS-5

Based on a long-term performance analysis of a large number of projects across North America…

- Pavements using ≥ 30% RAP performed well, and in most cases, perform equal or better than virgin pavements
- Transverse and fatigue cracking were observed at higher percentages in pavements with RAP compared to pavements with all virgin materials.
  - Higher percentages cracking did not impact overlay lives
  - Mix designs on several projects indicate high dust contents and low asphalt contents for RAP mixes.

Barriers to Higher RAP Contents

- History and Perceptions
  - Performance of high RAP content pavements
  - Concerns about quality and consistency of RAP
- Technology Limitations
  - Current mix design system
    - Relies on VMA & therefore aggregate bulk specific gravities
    - Does not adequately consider composite binder properties
  - Need for reliable performance tests

NCAT Research on Using Recycled Materials

- NCHRP 9-46: high RAP content mix design
- Lab studies on how to improve cracking resistance for mixes containing RAP and RAS
- NCHRP 9-53: Combining RAS & WMA
- Test Track experiments in 3rd, 4th, 5th, and 6th cycles
  - High RAP contents
  - RAS
  - GTR

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RAP Aggregate Bulk Specific Gravity

Method 1: Recover aggregate using a solvent extraction, then conduct AASHTO T84 and T85 on the fine and course fractions like any other aggregate.

Method 2: Recover aggregate by the ignition method, then conduct AASHTO T84 and T85 on the fine and course fractions like any other aggregate.

RAP Aggregate Bulk Specific Gravity

Method 3: Estimated G_{sb} from G_{mm} & P_{ba}

1. Determine G_{mm} (w/ dryback) of RAP sample
2. Calculate G_{se} using Eq. 1:
3. Estimate the absorbed asphalt, P_{ba} , based on historical values for the plant location.
4. Calculate G_{sb} using Eq. 2:

Equation 1

$$G_{se(RAP)} = \frac{100 - P_{b(RAP)}}{\frac{100}{G_{mm(RAP)}} - \frac{P_{b(RAP)}}{G_b}}$$

Equation 2

$$G_{sb(RAP)} = \frac{G_{se(RAP)}}{\frac{P_{ba} \times G_{se(RAP)}}{100 \times G_b} + 1}$$

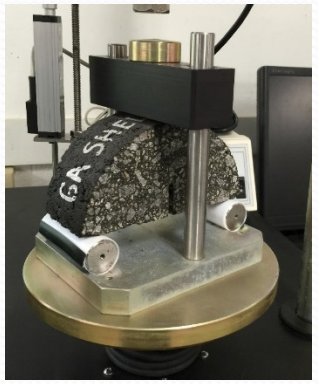
Recommendations

RAP Aggregate Gsb

One method of determining RAP aggregate Gsb will not work for all material types. Agencies should evaluate options to find the best method for their materials. The method that gives the lowest Gsb will result in the lowest mix VMA. This is desirable since it will lead to higher asphalt contents and better durability.

Some Tests for Assessing Cracking Resistance

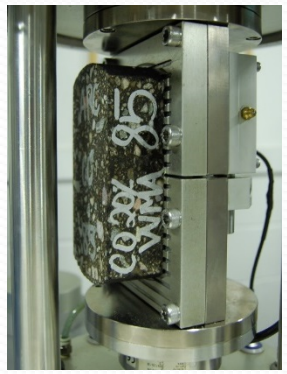
BBF



SCB-LA

I-FIT

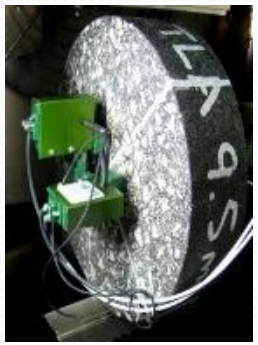
OT-TX



OT-NCAT

SVECD

DCT



Energy Ratio

Nflex Factor

Cantabro

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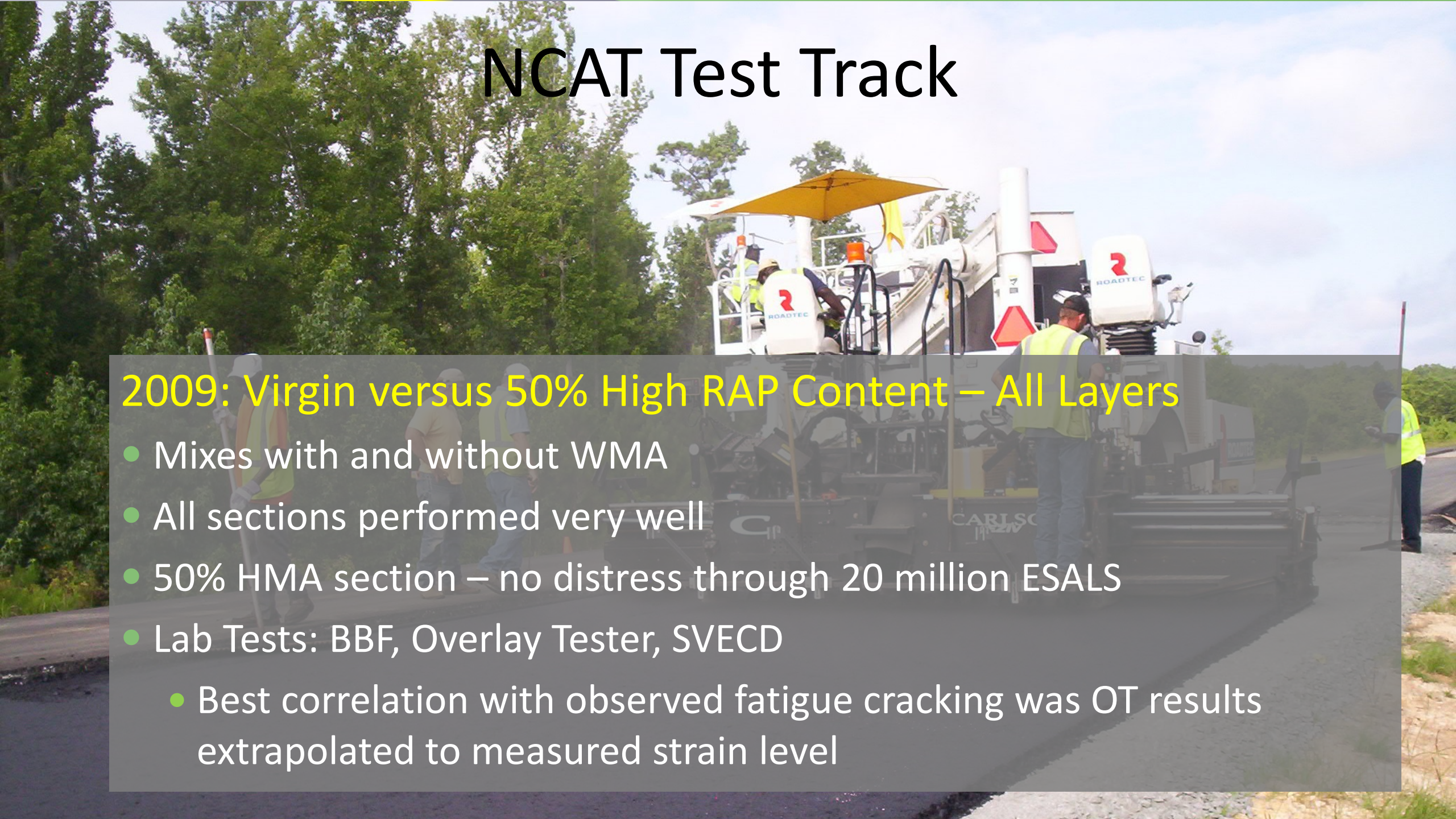
NCAT Test Track

2006: Moderate and High RAP Content Surface Mixes

- Mixes with 20% and 45% RAP performed very well
- 30 million ESALS over 8 years
- Minor differences in cracking support the use of softer binder for high RAP content mixes
- Lab Tests: Bending Beam Fatigue, Energy Ratio, Texas Overlay Tester
  - Best correlation with top-down cracking in sections was IDT Creep Rate

NCAT Test Track



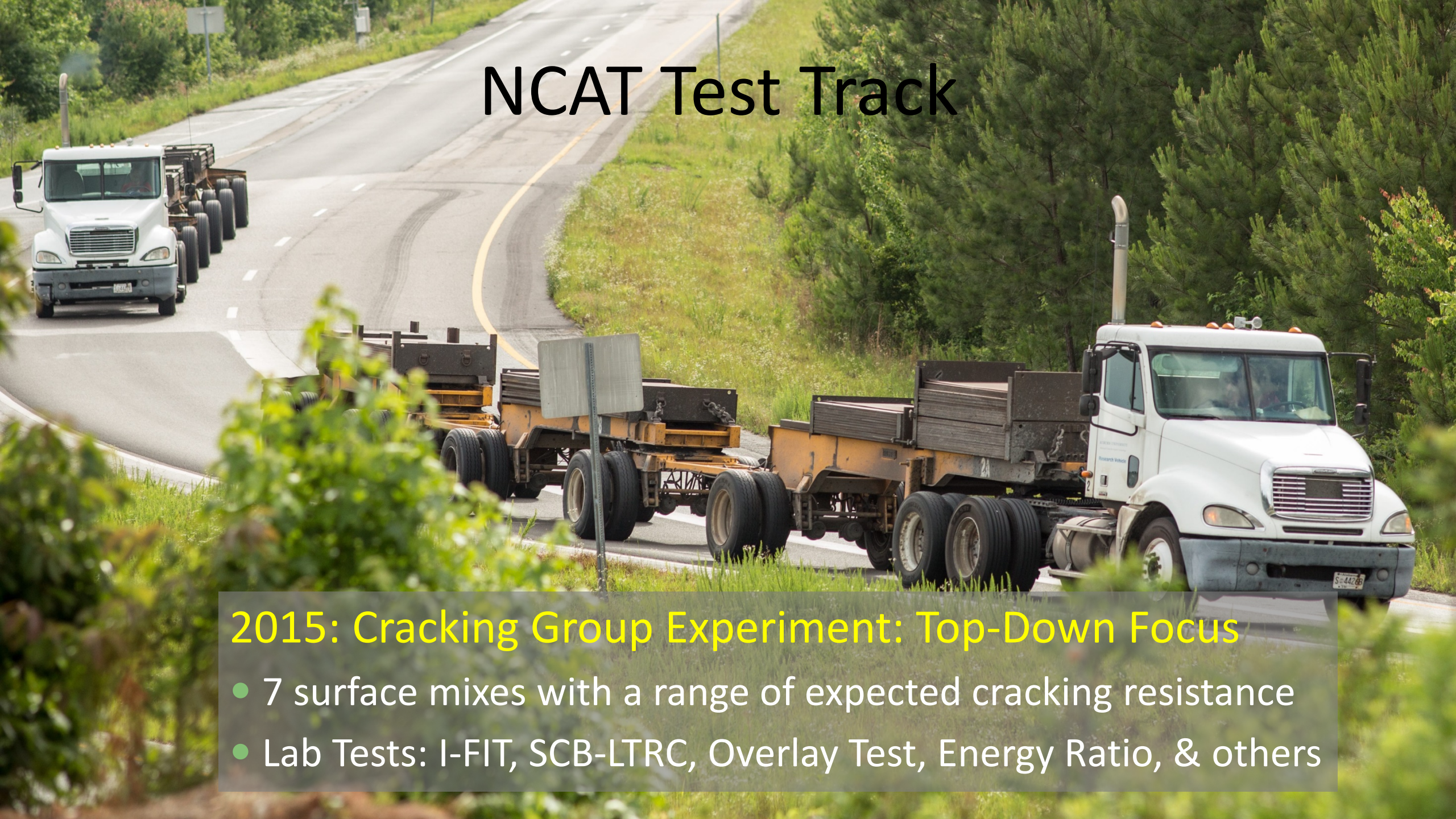
2009: Virgin versus 50% High RAP Content – All Layers

- Mixes with and without WMA
- All sections performed very well
- 50% HMA section – no distress through 20 million ESALS
- Lab Tests: BBF, Overlay Tester, SVECD
  - Best correlation with observed fatigue cracking was OT results extrapolated to measured strain level

Cold Central Plant Recycling

- Sponsored by Virginia DOT
- Processed RAP 2% foamed asphalt and 1% cement
- Serves as base layer with overlays of 4 inches and 6 inches
- Objective: quantify the structural contribution (empirical and M-E)
- Performance has been outstanding – no distress 11 MESALs and counting

NCAT Test Track



2015: Cracking Group Experiment: Top-Down Focus

- 7 surface mixes with a range of expected cracking resistance
- Lab Tests: I-FIT, SCB-LTRC, Overlay Test, Energy Ratio, & others

2016 MnROAD Thermal Cracking Experiment

Cracking Group Sections							
16-3	17-3	18-3	19-3	20-3	21-3	22-3	23-3
5" HMA1	5" HMA2	5" HMA3	5" HMA4	5" HMA5	5" HMA6	5" HMA7	5" HMA8
12" Agg Base							
12" Class 3							
7" Select Gran							
Clay							
2016	2016	2016	2016	2016	2016	2016	2016
500	500	500	500	500	500	500	500
50	70	70	50	90	80	80	

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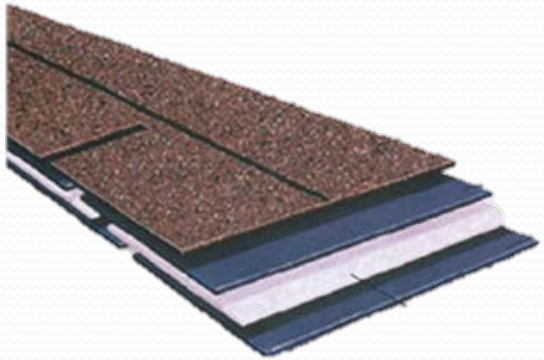
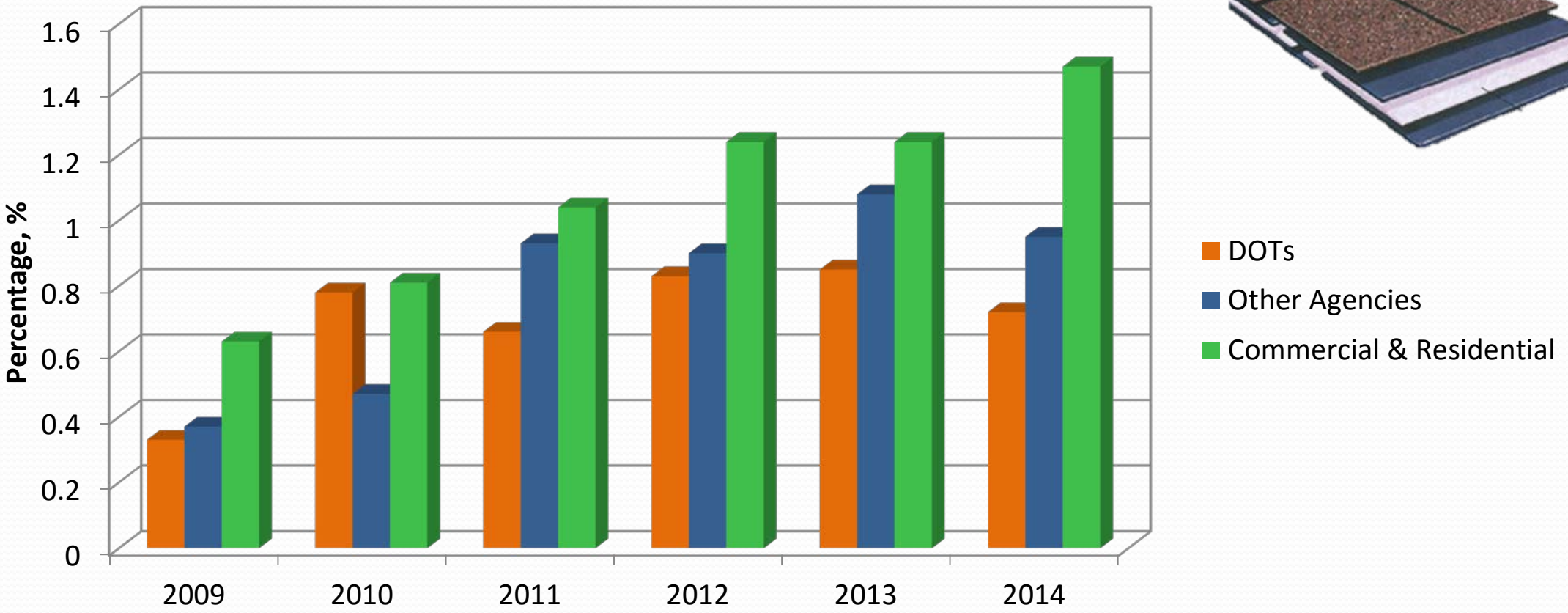
Recycled Asphalt Shingles Usage





Hansen and Copeland, *Annual Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2009-2014*

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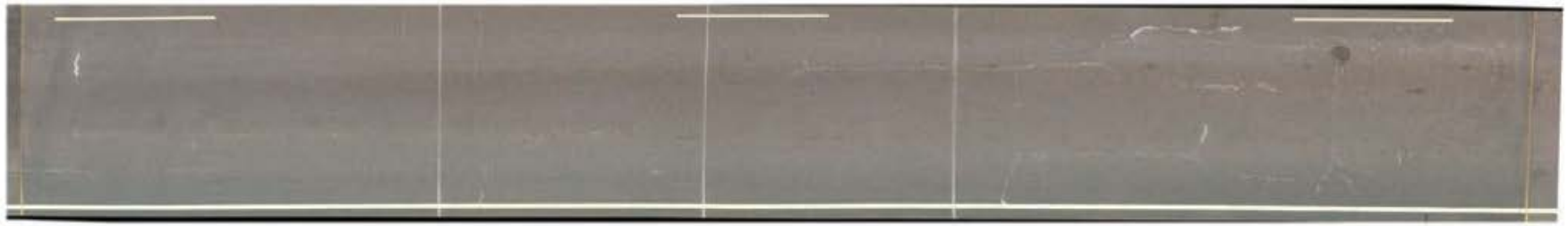
Recycling Asphalt Shingles

- Currently used in about 37 states, but routinely for state DOT projects in only about a dozen states
- Typically 3 to 5% RAS by weight of mix
- Field performance has been mixed
- Mix design approaches continue to evolve

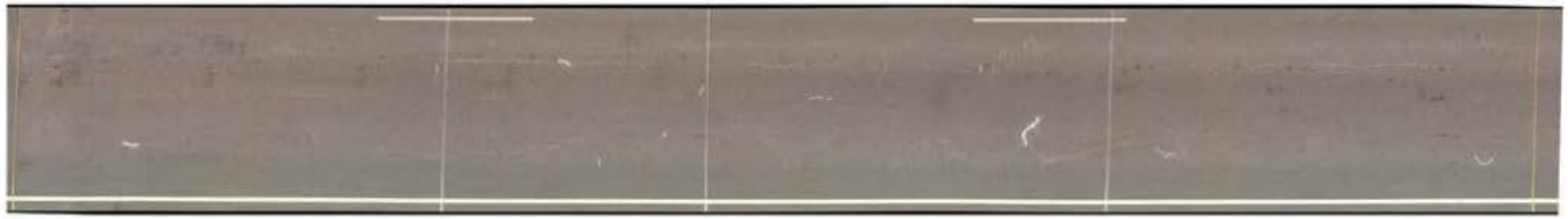
Performance of Mixes with RAS

Virgin Mix
PG 76-22 SBS

Virgin Mix
PG 76-22 GTR



20% RAP Mix
PG 76-22 SBS



20% RAP + 5% RAS
PG 76-22 SBS

Research and future directions

- Validation of mix cracking tests
- “Balanced” mix designs will replace volumetric-based mix designs
- Rejuvenator formulations will mature
- Much higher RAP content asphalt mixtures
- Cold recycled 100% RAP (with some minor additives) as base layer for heavy traffic roads and as a primary structural layer in light traffic pavements.

Thank You!