NATIONAL ASPHALT PAVEMENT ASSOCIATION

Asphalt Recycling

2013 Annual WAPA Conference
Madison, WI
December 3, 2013


19 MILLION.
The estimated barrels of asphalt conserved.
THAT'S DUE TO A 10% INCREASE IN THE USE OF RAP IN ONE YEAR.

What's the National Trend?

- Probably the **greatest single upfront <u>cost stabilizing & saving</u>** measure available to US highway agencies today is increasing the use of RAP in construction and rehabilitation of asphalt pavements.

- The majority of State DOTs use between 10 and 20% RAP, but have potential to use up to 30%.

- Contractors can effectively use RAP often and in high amounts with *<u>processing and production best practices and now…WMA technologies.</u>*
  - –Consistency & best practices are key when combining RAP, RAS, & WMA!

- The use of RAS and interest in rubber is increasing.
  - –Start with low amounts of RAS and maintain quality.

What we're going to talk about…

- Performance of recycled pavements
- Latest industry survey on recycling & WMA
- National efforts towards binder replacement
- Resources

PERFORMANCE OF HIGH RAP MIXTURES

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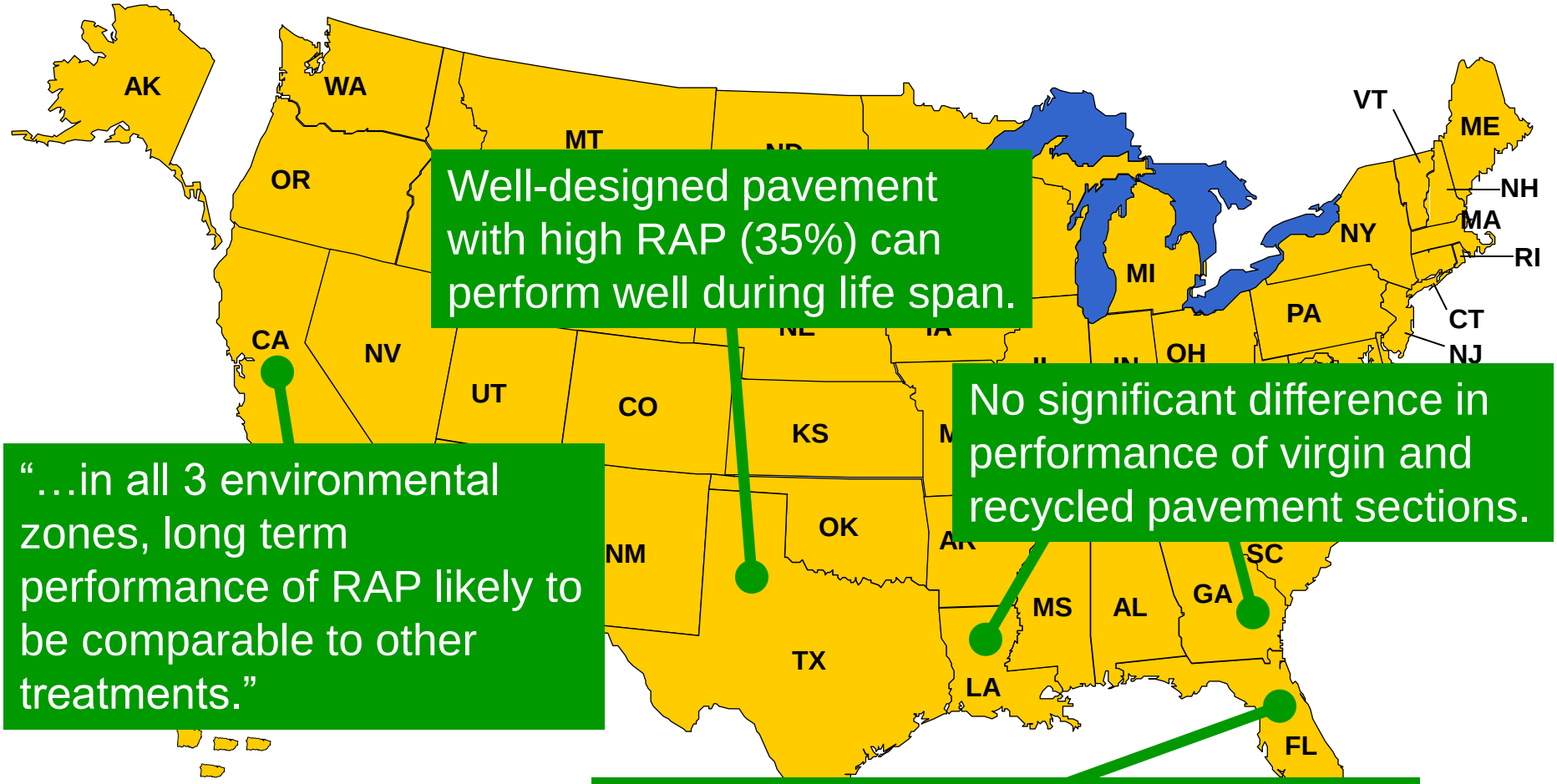
Primary Performance Concerns

- Fatigue Cracking
  - Aging characteristics – virgin vs. RAP binder
- Low Temperature Cracking
- Durability (Raveling)
  - Moisture content

Long-Term Performance of RAP in HMA



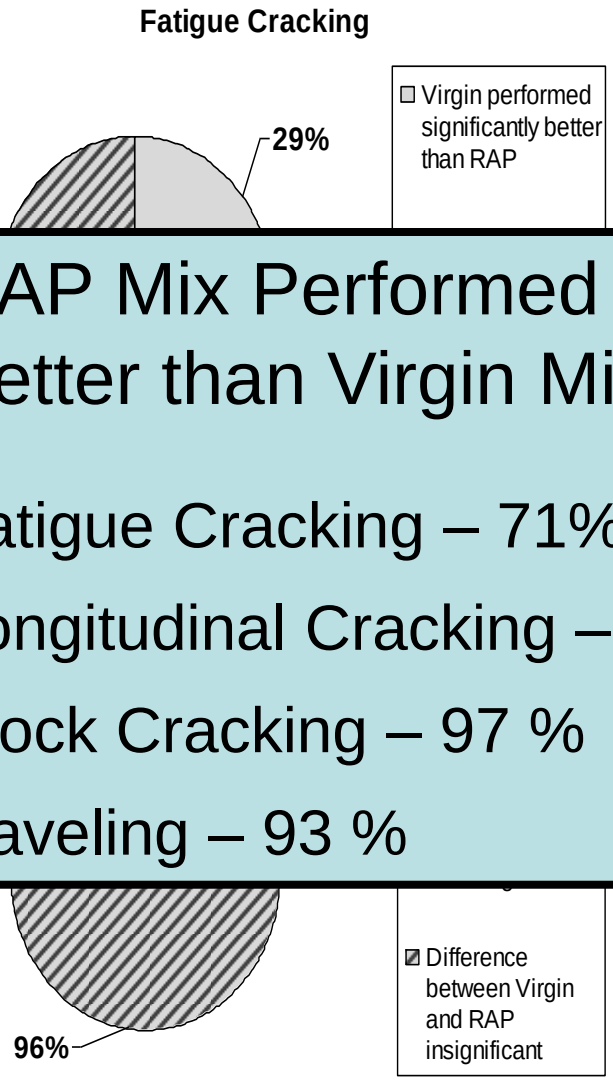
Evaluating RAP Performance

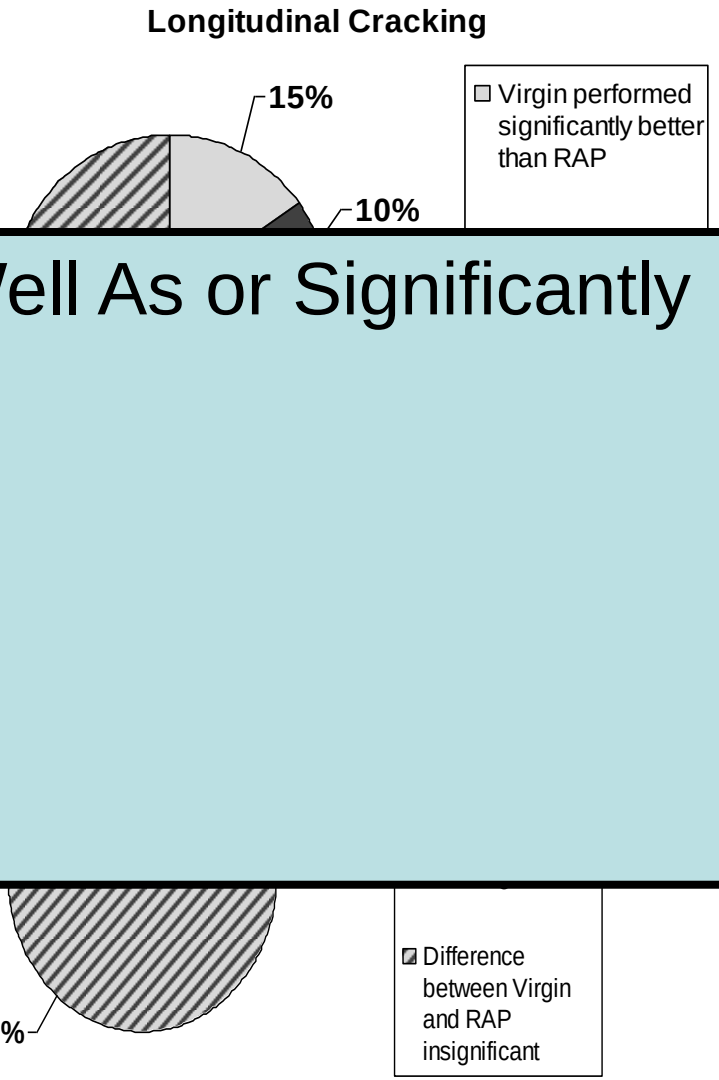
National Center for Asphalt Technology
NCAT
at Auburn University

- Long Term Pavement Performance SPS-5 sections
  - Virgin
  - 30% RAP
  - Milled and non-milled surface
  - 50 and 125 mm thick
  - Oldest is over 17 years
  - Variety of climates

LONG TERM Pavement PERFORMANCE

LTPP Study Results





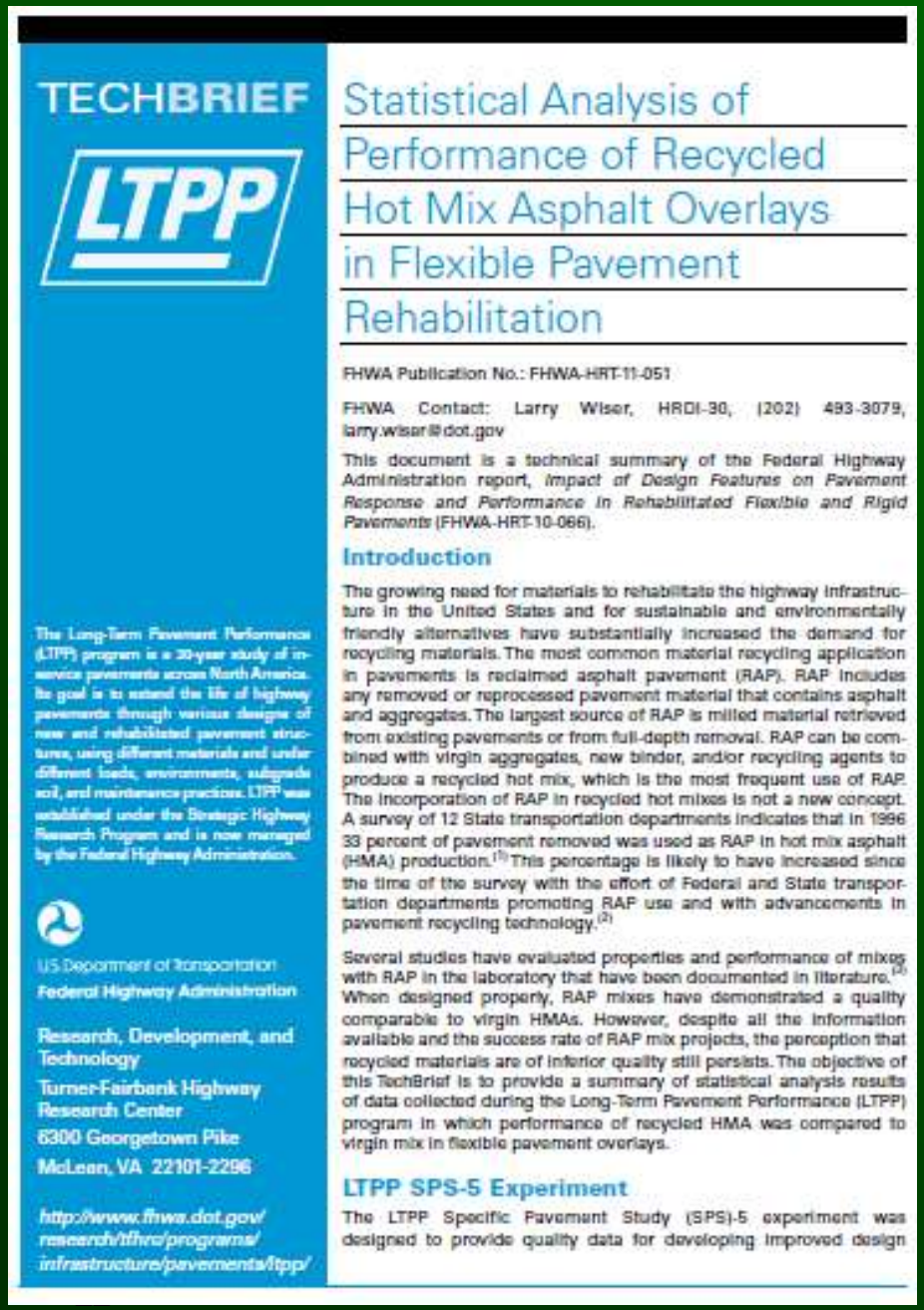
RAP Mix Performed As Well As or Significantly Better than Virgin Mix

Fatigue Cracking – 71%

Longitudinal Cracking – 85 %

Block Cracking – 97 %

Raveling – 93 %



TECHBRIEF

LTPP

Statistical Analysis of Performance of Recycled Hot Mix Asphalt Overlays in Flexible Pavement Rehabilitation

FHWA Publication No.: FHWA-HRT-11-051

FHWA Contact: Larry Wiser, HRDI-30, (202) 493-3079, larry.wiser@dot.gov

This document is a technical summary of the Federal Highway Administration report, *Impact of Design Features on Pavement Response and Performance in Rehabilitated Flexible and Rigid Pavements* (FHWA-HRT-10-066).

Introduction

The growing need for materials to rehabilitate the highway infrastructure in the United States and for sustainable and environmentally friendly alternatives have substantially increased the demand for recycling materials. The most common material recycling application in pavements is reclaimed asphalt pavement (RAP). RAP includes any removed or reprocessed pavement material that contains asphalt and aggregates. The largest source of RAP is milled material retrieved from existing pavements or from full-depth removal. RAP can be combined with virgin aggregates, new binder, and/or recycling agents to produce a recycled hot mix, which is the most frequent use of RAP. The incorporation of RAP in recycled hot mixes is not a new concept. A survey of 12 State transportation departments indicates that in 1996 33 percent of pavement removed was used as RAP in hot mix asphalt (HMA) production.[1] This percentage is likely to have increased since the time of the survey with the effort of Federal and State transportation departments promoting RAP use and with advancements in pavement recycling technology.[2]

Several studies have evaluated properties and performance of mixes with RAP in the laboratory that have been documented in literature.[3] When designed properly, RAP mixes have demonstrated a quality comparable to virgin HMAs. However, despite all the information available and the success rate of RAP mix projects, the perception that recycled materials are of inferior quality still persists. The objective of this TechBrief is to provide a summary of statistical analysis results of data collected during the Long-Term Pavement Performance (LTPP) program in which performance of recycled HMA was compared to virgin mix in flexible pavement overlays.

LTPP SPS-5 Experiment

The LTPP Specific Pavement Study (SPS)-5 experiment was designed to provide quality data for developing improved design

The Long-Term Pavement Performance (LTPP) program is a 20-year study of in-service pavements across North America. Its goal is to extend the life of highway pavements through various designs of new and rehabilitated pavement structures, using different materials and under different loads, environments, subgrade soil, and maintenance practices. LTPP was established under the Strategic Highway Research Program and is now managed by the Federal Highway Administration.

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

http://www.fhwa.dot.gov/research/tfhrc/programs/infrastructure/pavements/ltpp/

"*In summary, the performance data from LTPP SPS-5 shows that RAP and virgin HMA mixes used in overlays of flexible pavements showed approximately the same performance across a range of climates, traffic, and existing pavement conditions over a period of up to 17 years.* ***This finding should give agencies confidence in specifying RAP mixtures for overlays when economic and other conditions warrant.***"

Long-term Performance of RAP Pavements

- High percentages of RAP have successfully been used for more than 30 years.
- Long-term performance of recycled asphalt pavements not well documented.
- Recycled asphalt mixtures designed using established mix design procedures and produced with appropriate QC/QA measures perform comparably to conventional mixtures.

INDUSTRY SURVEY OF RECYCLING & WMA

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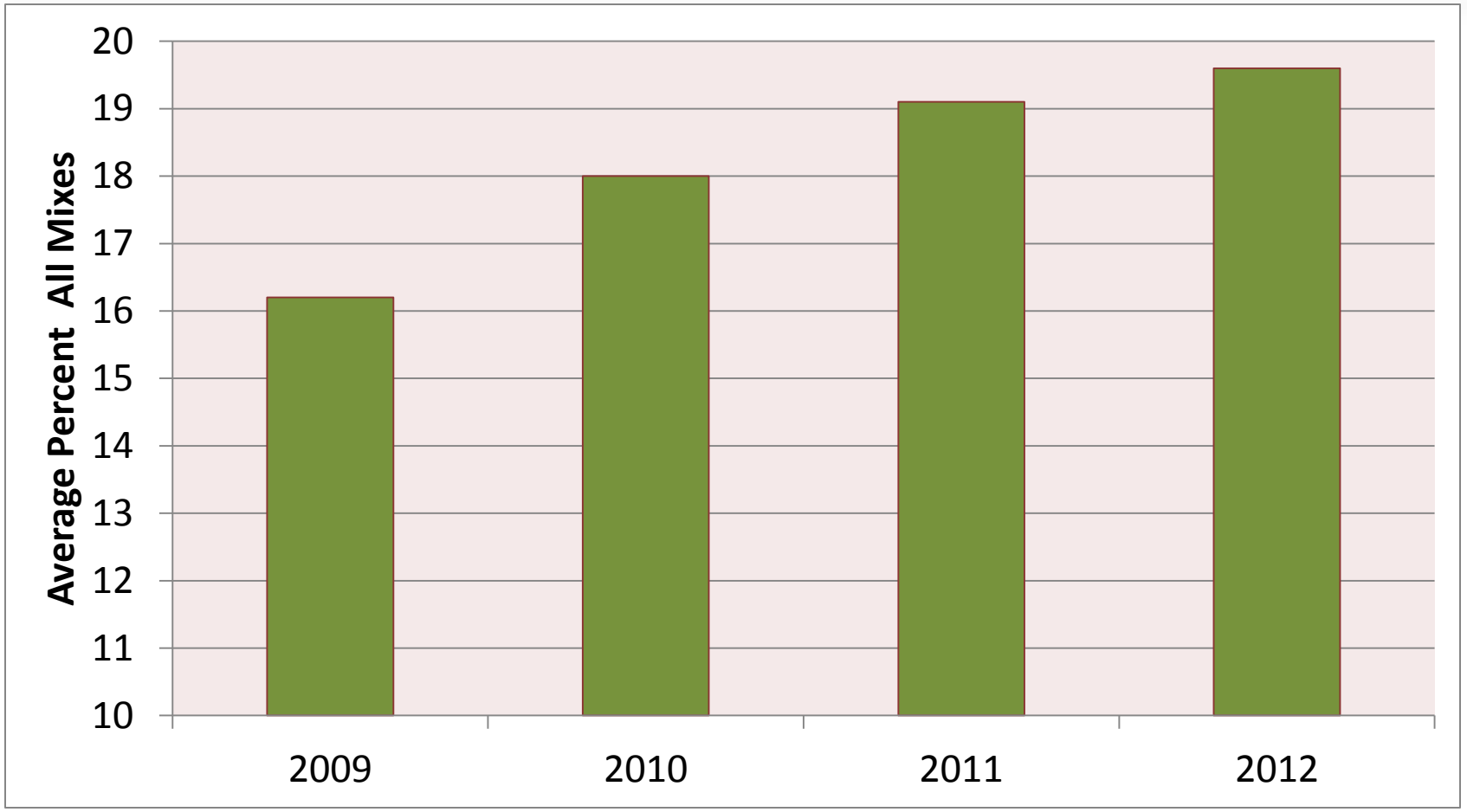
HOW MUCH RAP IS IN AN AVERAGE MIX?



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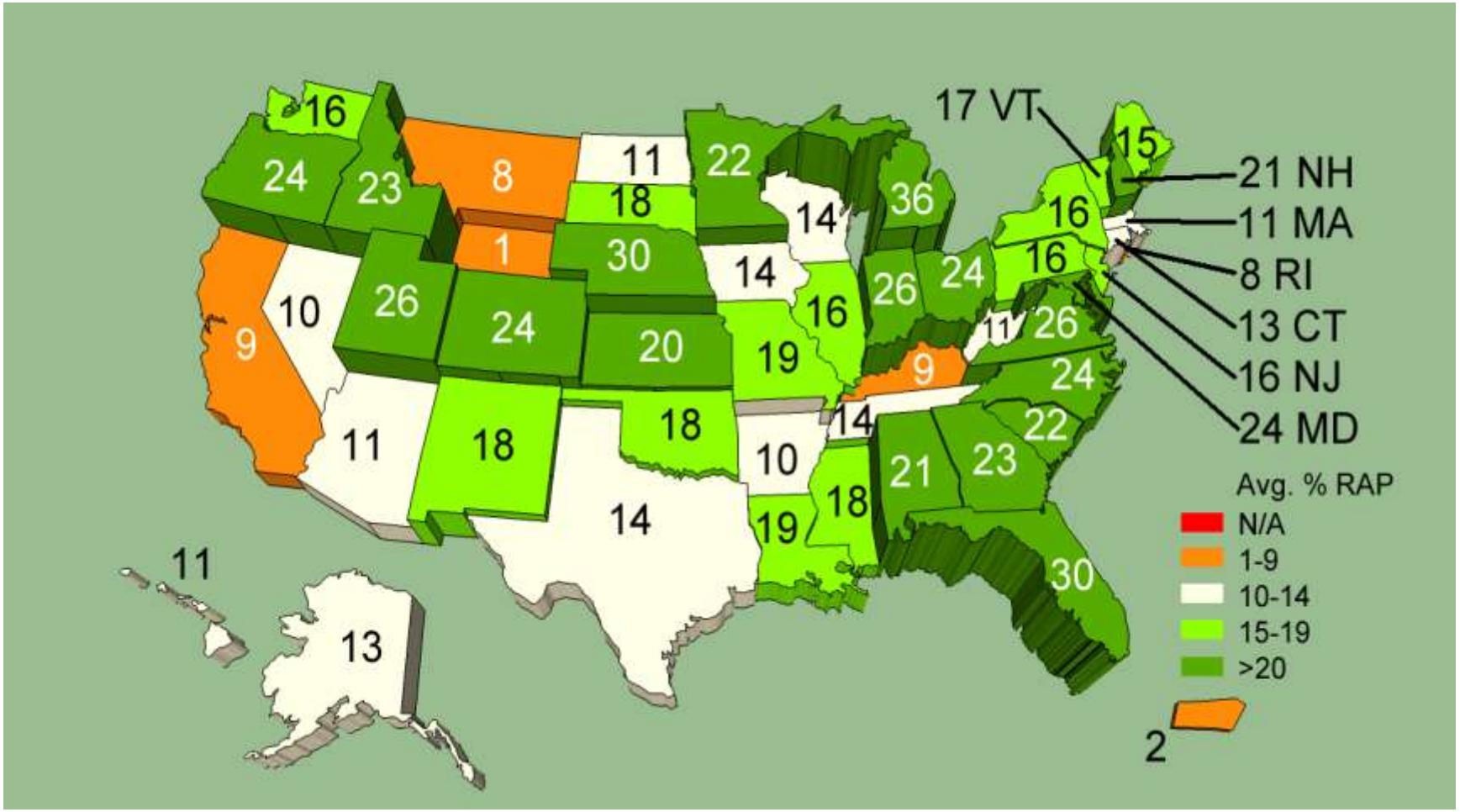
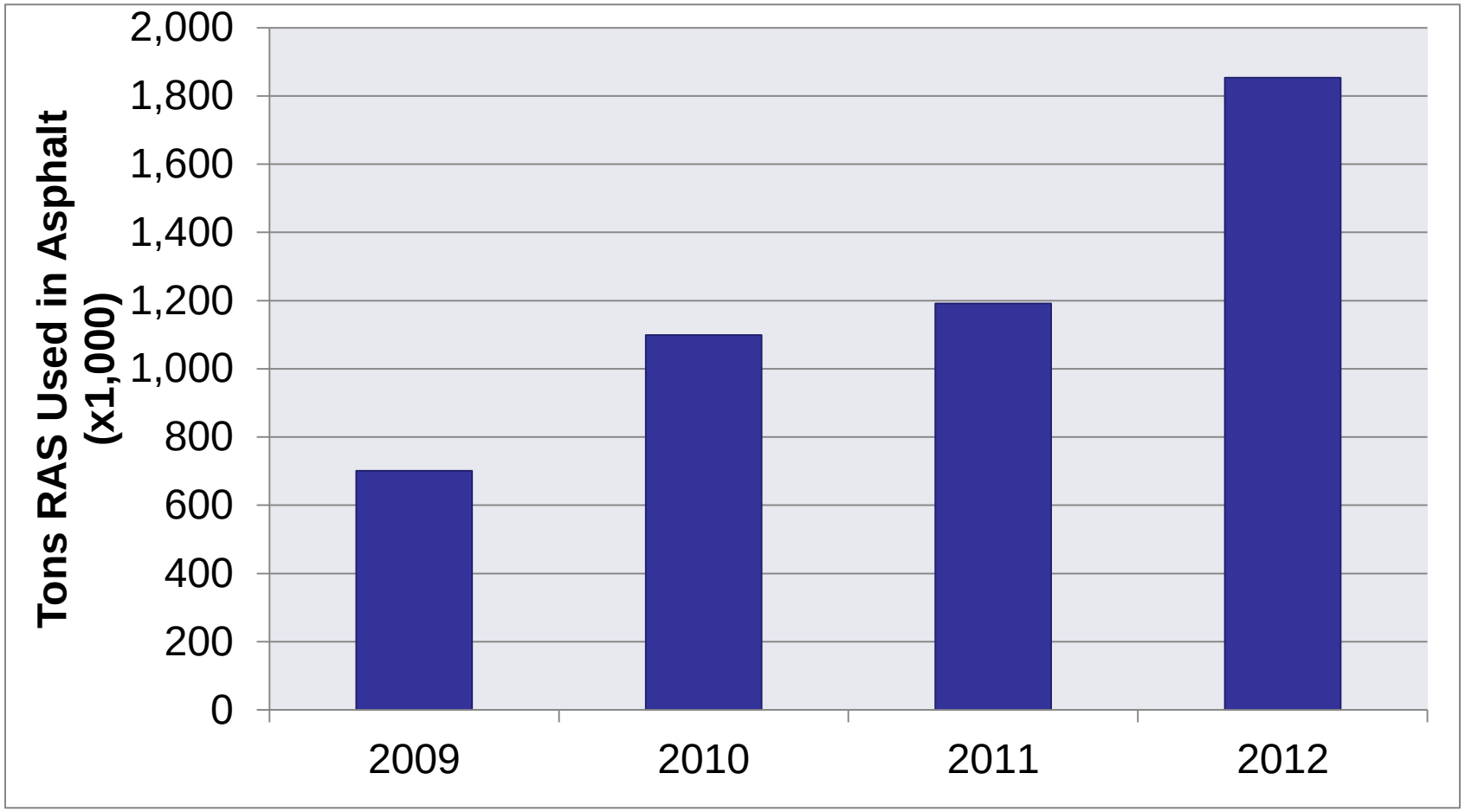
2011 Average RAP Content by State



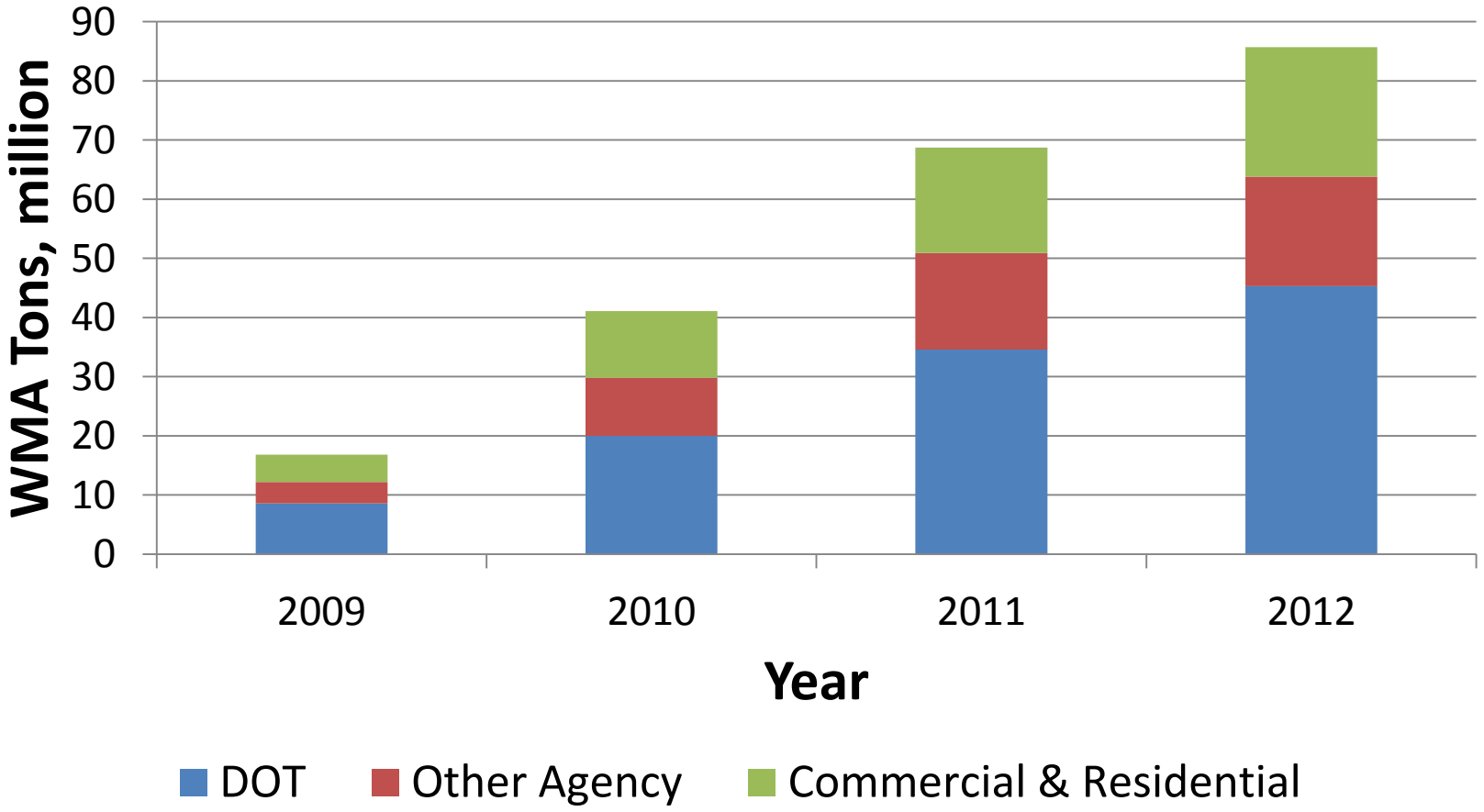
Tons RAS Used in Asphalt Mixes



In 2011, asphalt mix producers in **32 States** use RAS


85 MILLION.
The total tons of WMA placed in 2012.
THAT'S 25% MORE
THAN THE LAST YEAR. OH,
AND OVER 410% MORE THAN 2009

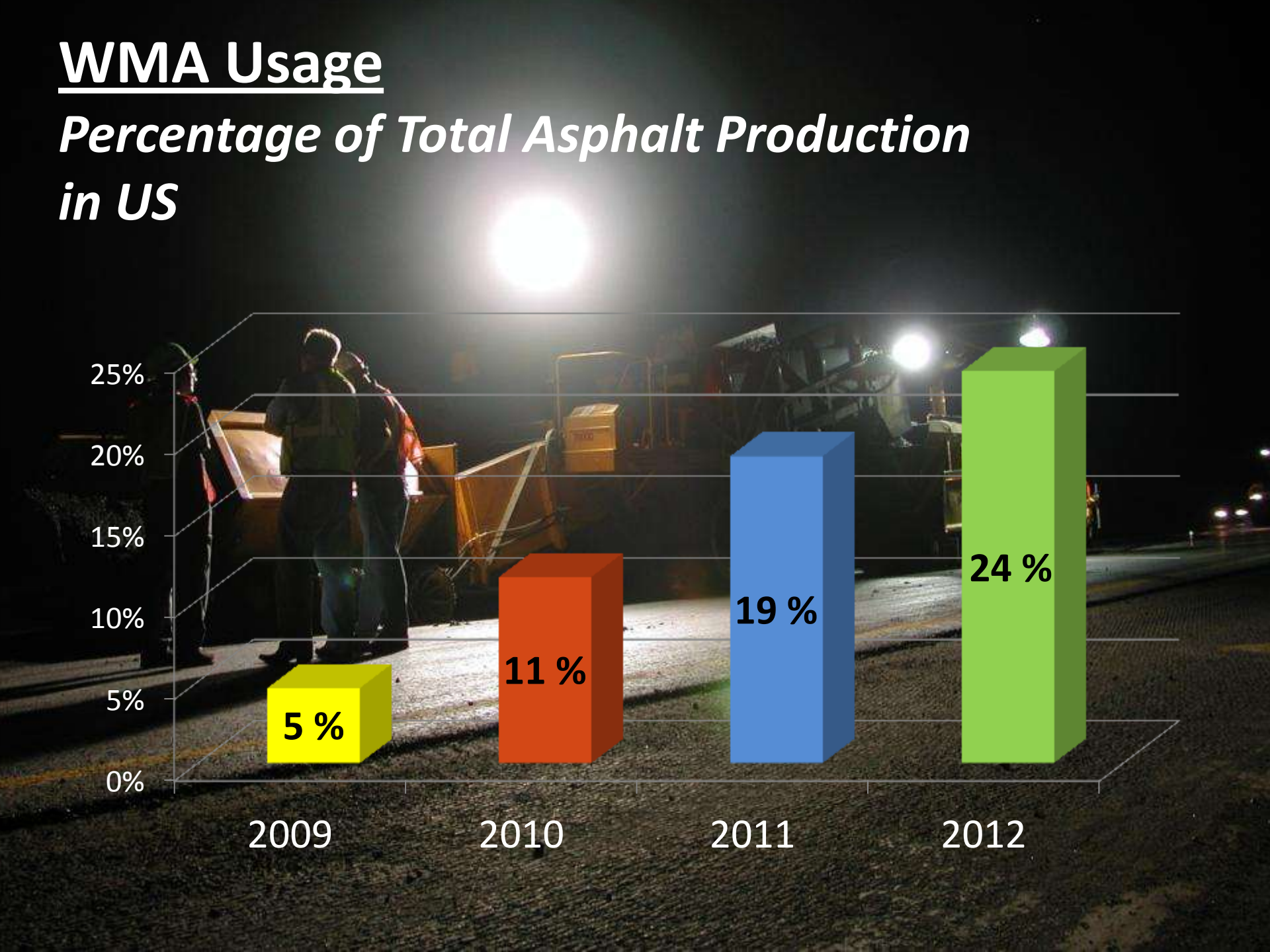
Estimated WMA Tons



*2012 data is still under review, not for distribution until finalized.

WMA Usage

Percentage of Total Asphalt Production in US



GROUND TIRE RUBBER

Preliminary 2012 data, not for distribution.

- 9 out of 23 states
  - Reported total amount of mix using GTR ≈ 692,000 tons

- 8 out of 23 states
  - Reported amount of GTR used ≈26,000 tons

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WHY ASPHALT BINDER REPLACEMENT?

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DEFINING ASPHALT BINDER REPLACEMENT (ABR)

Binder replacement is reclaimed binder that replaces virgin binder in asphalt mixtures.

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WHY ARE WE MOVING TOWARDS ABR?

- Multiple sources of reclaimed materials and sizes for different feeds
- Separate specifications for each reclaimed material (RAP, RAS, etc.) is confusing
- With high RAP contents, the primary issue is amount of binder replacement.
  - Impacts binder properties & may impact binder choice

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RECLAIMED ASPHALT BINDER SOURCES & CONTENTS

- RAP 4 – 6%
- Fine RAP 5 – 8%
- Coarse RAP 2 – 4%
- Manufacturer Scrap RAS 15 – 25%
- Post Consumer RAS 20 – 30, 40%

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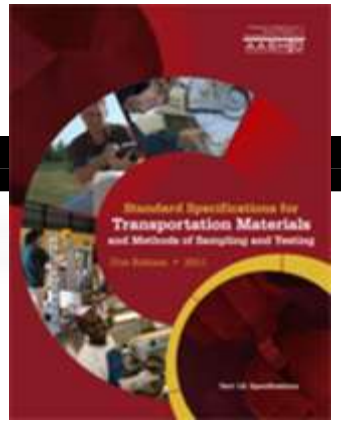
CURRENT NATIONAL SPECIFICATIONS



- RAP Use
  - AASHTO M 323 – Superpave Volumetric Design Requirements
- RAS Use
  - AASHTO MP15 – Standard Spec for Use of Reclaimed Asphalt Shingle as an Additive in HMA
  - AASHTO PP53 – Standard Practice for Design Considerations when Using Reclaimed Asphalt Shingles in HMA

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NATIONAL EFFORTS

- FHWA Asphalt Mixture Expert Task Group
- NCHRP 9-46 Improved Mix Design, Evaluation, and Materials Management of HMA with High RAP Contents
- Pooled Fund Studies
  - TPF5-213 – Performance of Reclaimed Asphalt Shingles in HMA
  - TPF5-294 - Design and Analysis Procedures for Asphalt Mixtures Containing High-RAP Contents and/or RAS

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AASHTO M323 Binder Replacement Revisions Task Force Members

- Lee Gallivan, chair
- Jeff Miles
- Jim Musselman
- Jim Pappas
- John D’Angelo
- Andy Mergenmeier
- Ron Sines
- Matthew Corrigan
- Randy West
- Jeff Withee
- Larry Michael
- Gerry Huber
- Audrey Copeland
- Becky McDaniel
- John Bukowski
- Merrill Zwanka

Binder Replacement for High RAP Mixtures

- RAP Expert Task Group compiled existing literature.

- No clear direction at national level for setting reclaimed binder limits to properly select virgin binder grade.

The Old Guidelines

- AASHTO M 323 *Standard Specification for Superpave™ Volumetric Mix Design*

Recommended Virgin Asphalt Binder Grade	Percent (%) RAP
No change in binder selection	< 15
Select virgin binder grade one grade softer than normal	15 – 25
Follow recommendations from blending charts	> 25

- Calls for virgin binders that may be more expensive, hard to get
- Blending chart analysis is time-consuming!

INCORPORATING ABR IN AASHTO M323

- Percent binder replacement—If the agency elects to use the percent binder replacement method, percent binder replacement is determined by the ratio of reclaimed binder to the total binder in the mixture. **Local or regional evaluations need to be completed to determine the maximum RAP amounts allowed or the minimum percentage of virgin binder.**

- Note 6—If recycled binder properties are not available, effort should be undertaken to characterize typical stockpiled materials. RAP samples should be taken from typical stockpiles in various geographical locations within the state and evaluated to determine the effect of various percentages of RAP binder on typical virgin PG binders. Details on the RAP evaluation process are contained in Appendix X2.

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WHAT'S IMPORTANT?

- How much reclaimed binder can we use before cracking occurs?
  - Cracking, low temp and fatigue, is major concern for adding shingles to mix.
- Are we using the proper virgin and, thus, end binder grade?
- Evaluating the end mixture for long term performance

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National Center for Asphalt Technology

NCAT

at AUBURN UNIVERSITY

NCHRP 9-46

Improved Mix Design, Evaluation, and Materials Management Practices of HMA with High RAP Content



SUGGESTED CHANGES TO AASHTO M323

Based on research from NCHRP Project 9-46

Recommended Virgin Asphalt Binder Grade	RAP Binder Ratio
No change in binder selection	< 0.25
Follow recommendations from X.1	≥ 0.25

X.1 is Appendix for Procedures for Estimating the Properties of Blended RAP and Virgin Binders

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SUGGESTED CHANGES TO AASHTO R 35

Based on research from NCHRP Project 9-46

- Standard Practice for Superpave Volumetric Design for HMA
  - Evaluation of High RAP Content Mixes using performance-related tests and criteria
  - Handling/drying RAP for mix design trials

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SUGGESTED CHANGES TO AASHTO R 35

Based on research from NCHRP Project 9-46

- Rutting tests & criteria
  - Asphalt Pavement Analyzer
  - Hamburg
  - Flow Number
- Low Temperature Cracking tests & criteria
  - Disc-shaped Compact Tension Test
  - Semi-circular Bend Test
- Potential tests for load-related cracking
  - Top down – Energy Ratio
  - Reflection – Overlay Tester, DCT
  - Fatigue – Bending Beam Fatigue, Simplified VCD, IDT Fracture Energy, Semi-circular Bend

ENGINEERING ABR – OTHER EXPERIENCES

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WISCONSIN DOT STANDARDS & SPECS

460.2.5 Recycled Asphaltic Materials

(1) The contractor may use recycled asphaltic materials from FRAP, RAP, and RAS in HMA mixtures. Stockpile recycled materials separately from virgin materials and list each as individual JMF components.

(2) Control recycled materials used in HMA by evaluating the percent binder replacement, the ratio of recovered binder to the total binder. Conform to the following:

MAXIMUM ALLOWABLE PERCENT BINDER REPLACEMENT

RECYCLED ASPHALTIC MATERIAL	LOWER LAYERS	UPPER LAYER
RAS if used alone	25	20
RAP and FRAP in any combination	40	25
RAS, RAP, and FRAP in combination[1]	35	25

[1] When used in combination the RAS component cannot exceed 5 percent of the total weight of the aggregate blend.

http://roadwaystandards.dot.wi.gov/standards/stndspec/ss-04-60.pdf#ss460

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Indiana DOT

- Virgin Binder Grade for Asphalt Binder Replacement
  - 0 to 25% - no change
  - 25 to 40% - down one grade, high and low

- Maximum Binder Replacement
  - 25% shingle binder
  - 40% RAP or Shingle plus RAP

MODOT SPECIFICATIONS

- **403.2.6.1 Reclaimed Asphalt Pavement.** Reclaimed Asphalt Pavement (RAP) may be used in any mixture, except SMA mixtures. **Mixtures may be used with more than 30 percent virgin effective binder replacement provided testing according to AASHTO M 323 is included with the job mix formula that ensures the combined binder meets the grade specified in the contract.** All RAP material, except as noted below, shall be tested in accordance with AASHTO T 327, *Method of Resistance of Coarse Aggregate Degradation by Abrasion in the Micro-Deval Apparatus.* Aggregate shall have the asphalt coating removed either by extraction or binder ignition during production. The material shall be tested in the Micro-Deval apparatus at a frequency of once per 1500 tons . The percent loss shall not exceed the Micro-Deval loss of the combined virgin material by more than five percent. Micro-Deval testing will be waived for RAP material obtained from MoDOT roadways. All RAP material shall be in accordance with Sec 1002 for deleterious and other foreign material.

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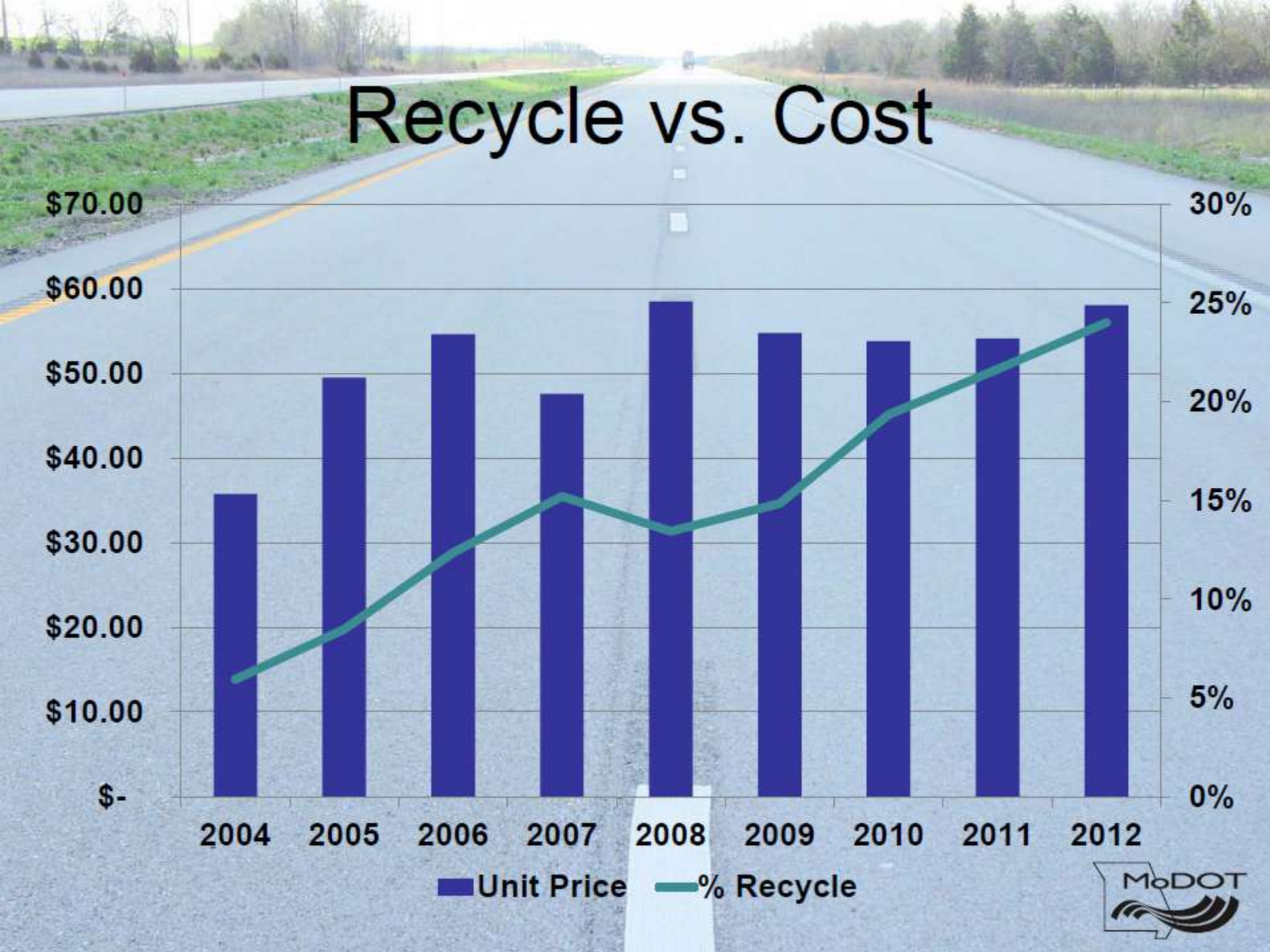
Recycle vs. Cost



ILLINOIS MAXIMUM ABR LEVELS

Level 2 – FRAP/RAS Maximum Asphalt Binder Replacement (ABR) Percentage

HMA Mixtures 1/, 2/	Level 2 – FRAP/RAS Maximum ABR %		
Ndesign	Binder/Leveling Binder	Surface	Polymer Modified 3/, 4/
30	40	40	10
50	40	30	10
70	30	20	10
90	30	20	10
105	30	15	10

1/ For HMA "All Other" (shoulder and stabilized subbase) N30, the FRAP/RAS ABR shall not exceed 50 percent of the mixture.

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IL DOT HAMBURG WHEEL CRITERIA

Asphalt Binder Grade	# Repetitions	Max. Rut Depth in. (mm)
PG76-XX	20,000	1/2 (12.5)
PG70-XX	15,000	1/2 (12.5)
PG64-XX	7,500	1/2 (12.5)
PG58-XX	5,000	1/2 (12.5)

CONTROLS

- Too Soft
  - Stripping – TSR
  - Binder Grade Selection (Polymer)
  - Hamburg
- Too Hard
  - Limits on replacement asphalt (% RAP & RAS)
  - Grade bumps down with higher replacement
  - Maximum tensile strength
  - Fracture toughness requirement (research phase)

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GRADE BUMPING IN ILLINOIS

- Low amounts of ABR can be tolerated with little to no impact
- Around 20% ABR, mix properties may be impacted.
  - Grade bumping policy
    - Above 20% - bump down from PG64-22 to PG58-28
    - Above 40% - PG46-34?

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CONSIDERATIONS – MULTIPLE LEVELS

- Asphalt Binder Replacement Limitations for when to Grade Bump
  - 20% on low end to 40% on high end
  - Processed vs. Non-Processed
  - Polymer-modified binder?
- Pavement Layer
  - Surface – need rut and cracking resistance
  - Intermediate layer – stiffness (increase RAP & RAS, no binder change)
  - Lower layer(s) – need cracking resistance
- Mix Type Based on Traffic, Use
- Performance Testing for Mix Evaluation

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RESOURCES

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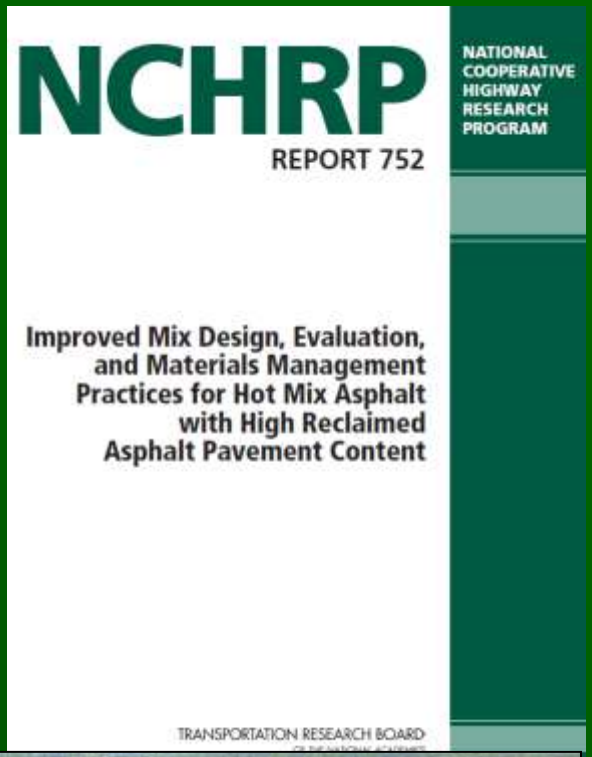
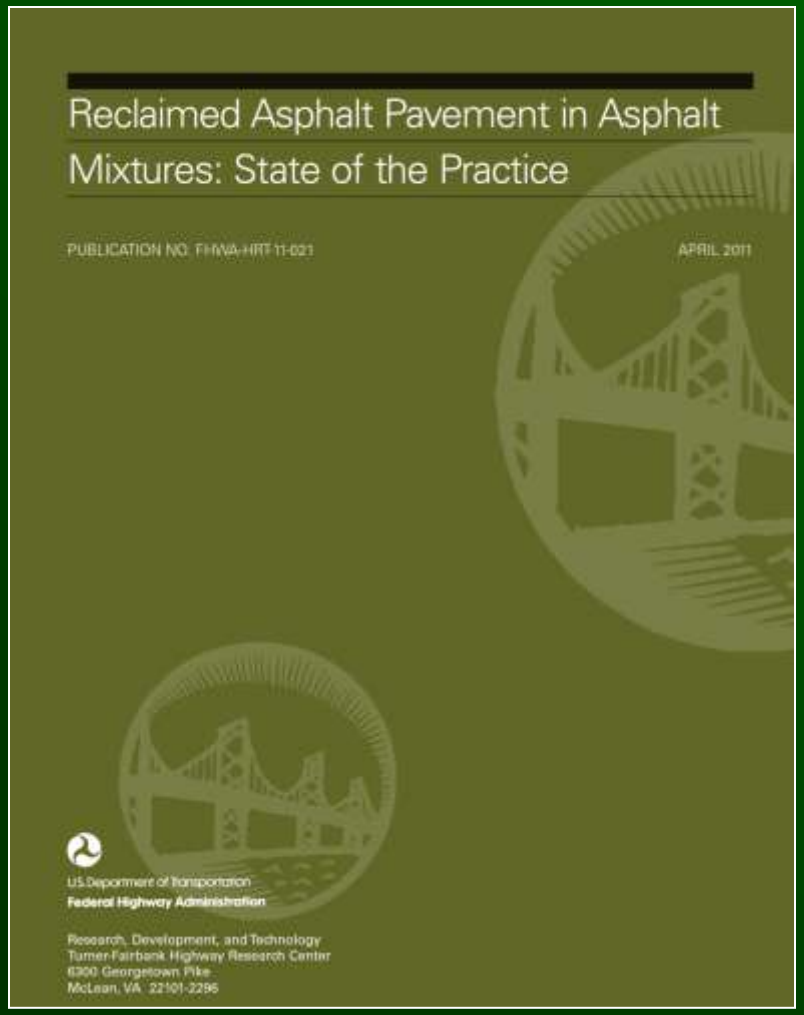
NCHRP 9-46 Mix Design and Evaluation Procedure for High Reclaimed Asphalt Pavement Content in Hot Mix Asphalt



- Report 752
- Best Practices for RAP Management

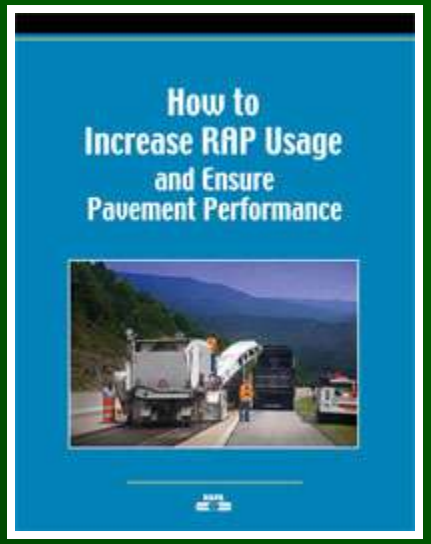
Resources from FHWA



http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/11021/11021.pdf
http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/11057/11057.pdf

Resources

- Designing HMA Mixtures with High RAP Content: A Practical Guide, Publication QIP-124
- How to Increase RAP Usage and Ensure Pavement Performance, NAPA Publication PS 34
- Uses of Waste Shingles in HMA: State-of-the-Practice, Special Report 179
- Guidelines for the Use of Reclaimed Asphalt Shingles in Asphalt Pavements, Information Series 136
- Webinars at asphaltpavement.org



FHWA/NAPA COOPERATIVE AGREEMENT

- NAPA has been awarded a $2.5 million agreement for "*Advancement of Innovative Asphalt Technology*"
- Partnership provides a mechanism to advance innovative technologies
- Agreement is for 5 years, FY 2014-2018

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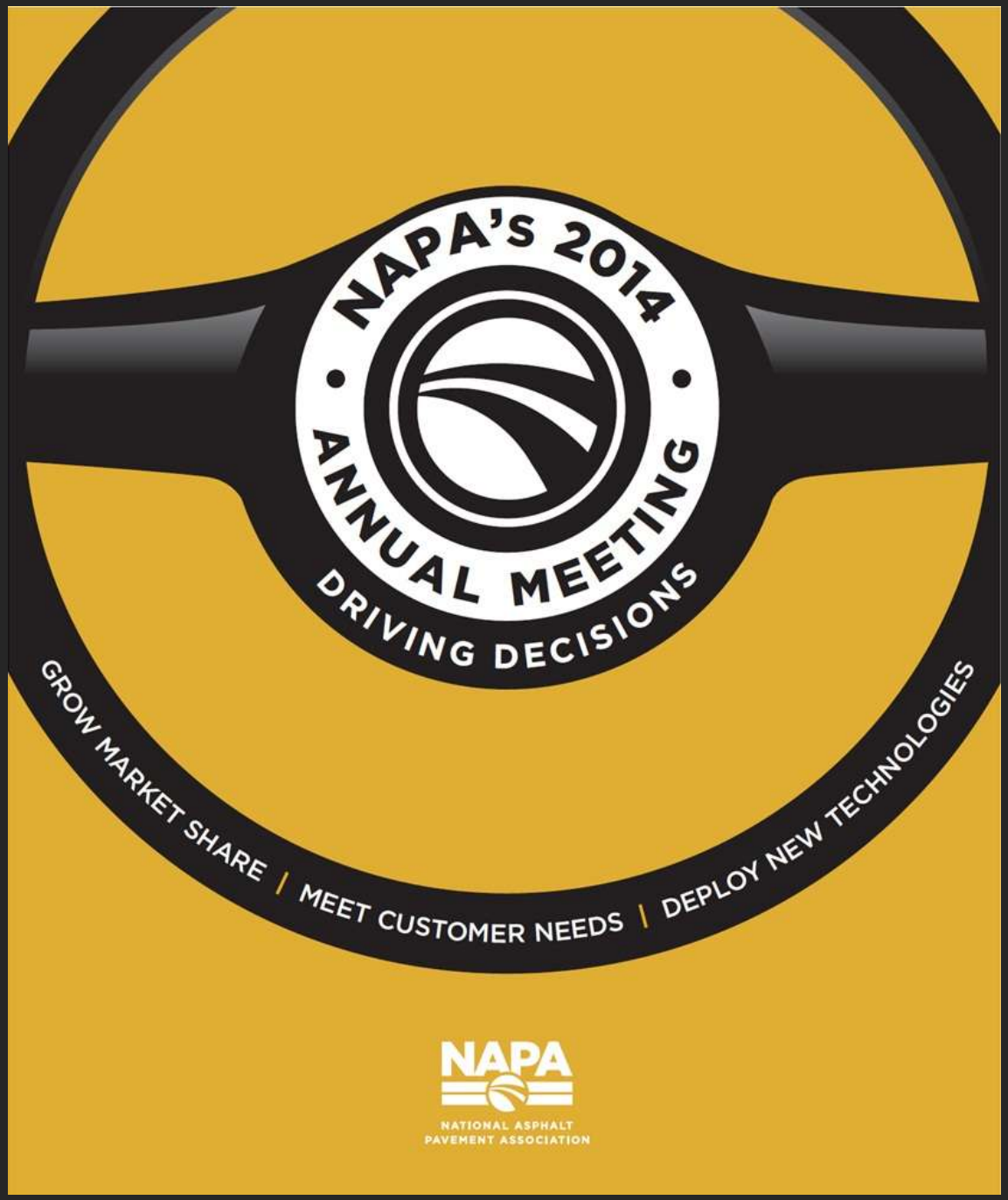
U.S. Department of Transportation
Federal Highway Administration



NAPA 59th Annual Meeting

Driving Decisions: Taking Charge for Tomorrow

February 2–5, 2014
Boca Raton Resort & Club
Boca Raton, Florida
www.asphaltpavement.org

For more information:
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www.asphaltpavement.org
www.asphaltroads.org

FHWA/NAPA COOPERATIVE AGREEMENT

- Year 1 Topics (i.e. FHWA/NAPA mutual interests)
  - RAP, RAS, WMA Survey for 2013
  - RAP Management Best Practices
  - Recycled Tire Rubber Best Practices
  - Mix Type Selection Guide update
  - Thin Asphalt Overlays update
  - LCCA Webinar?

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U.S. Department of Transportation
Federal Highway Administration

Obtaining uniform gradation of RAP

- RAP aggregate separation based on size increases control and may reduce variability.

- Sizing of RAP materials
  - –Screening is used to separate sizes & control dust
  - –Fractionation
  - –Allows for adjustments for variability to be made within the RAP

Fractionated RAP (FRAP)

- Fractionation is processing and separating RAP into at least two sizes, typically a coarse fraction and a fine fraction.

Asphalt Roofing Shingles

- *11 million tons* of waste asphalt roofing shingles are generated in the US per year.
  - –Manufacturing Waste ~ 1 million
  - –Roofing tear-offs ~ 10 million

- HMA is the most common process to which waste shingles can be added and the best use of shingles.

Recycled Asphalt Shingles (RAS)

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- Manufactured Shingle Scrap
  - –Air-blown, unmodified binder
  - –Harder than road asphalt
- Post Consumer (Tear-off) Shingle Scrap
  - –Aged 10 years or more
  - –Even harder than road asphalt
- Recycled Asphalt Shingles
  - –Crushed and Screened

Shingles Composition

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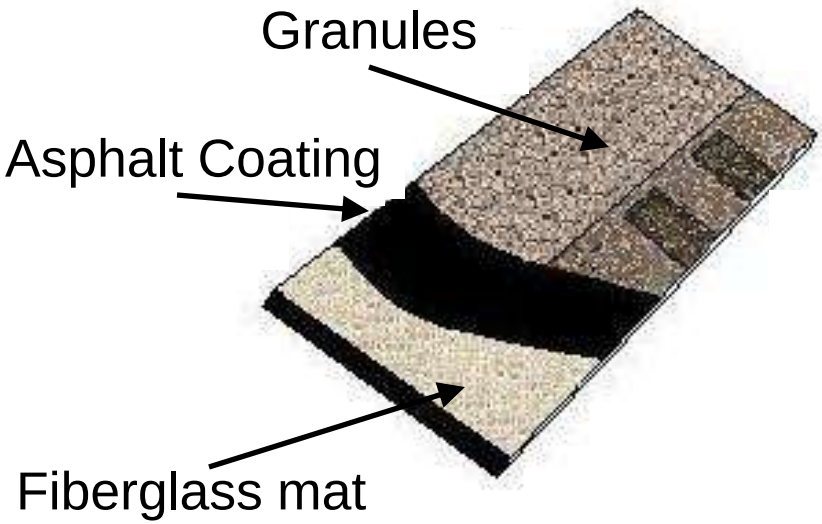
- Shingle Asphalt Binder
  - –Manufactured Waste 15-25%
  - –Tear-offs 30-40%
- Hard Rock Granules & Fillers
  - –40 to 60%
- Fiber, felt, miscellaneous materials
  - –1 to 12%



BEST PRACTICES

Increasing RAP Use

The question we're posing…

- *How much RAP can we allow in the mix and meet specification and constructability requirements for performance?*

- Biggest impact can be made in processing and production.

Issues to Consider when Increasing RAP

- Processing & Quality Control (QC)
  - Mill Intelligently
  - Processing RAP
  - Stockpile Management
- Characterizing RAP
- Changing Binder Grade
- Mix Design
- Blending/Co-mingling of Virgin and RAP Binder
- Performance

Quality Control

- RAP mixtures must meet the same mix design specifications required for virgin mixtures.

- Most State DOTs do not have additional means of determining the acceptability of high RAP mixtures.

Obtaining uniform gradation of RAP

- RAP aggregate separation based on size increases control and reduces variability.

- Sizing of RAP materials
  - Screening is used to separate size & control dust
  - Fractionation
  - Allows for adjustments for variability to be made within the RAP

Fractionated RAP (FRAP)

- Fractionation is processing and separating RAP into at least two sizes, typically a coarse fraction and a fine fraction.

Characterizing RAP Materials for High RAP Use

- Asphalt Content
  - RAP binder contribution, reduce virgin binder required
  - Ignition oven or solvent extraction
- Performance Grade of RAP binder
  - Estimate blended binder properties
  - Evaluate stiffness of RAP
  - Recovered binder is unaged
- RAP Aggregate Gradation
  - Ensure quality material
  - Determining Gsb, Gse of RAP aggregate – significant effect on VMA and asphalt content
  - Combined aggregate properties must meet consensus requirements

Binder Grade Selection

- For high RAP contents, the virgin binder Performance Grade (PG) may have to be lowered to account for the aged (stiff) RAP binder OR the RAP % is chosen based on a given virgin binder PG.

- Bumping a grade may increase cost
- Blending charts
- Standardized PG based on region

How to check for blending?

- No direct method for measuring blending
- Blending Charts
  - AASHTO M 323 Appendix
  - Assumes complete blending
  - Time consuming, hazardous solvents
- Mixture Testing with the Asphalt Mixture Performance Tester (AMPT)

RAP Percentage Based on Binder

- Historically, agency specs limit RAP based on RAP percentage by weight of total mix or weight of aggregate.
- With high RAP contents, the primary issue is amount of binder replacement.
  - Impacts binder properties
- Determine contribution of RAP binder toward total binder in the mix, by weight.
  - Typically specified as “70% of binder content must be virgin” or “no more than 30% binder content can come from RAP or RAP & RAS”.

RAP Aggregate Testing

- Gradation - AASHTO T 30 Mechanical Analysis of Extracted Aggregate
- RAP aggregates must meet the same quality requirements specified for virgin aggregates.
  - Coarse Aggregate Angularity (D 5821)
  - Fine Aggregate Angularity (T 304)
  - Flat & Elongated (D 4791)
  - Sand equivalent requirements (T 176) are waived for RAP aggregate.
  - Agency Specifications
    - Source properties

Superpave Volumetric Mixture Design Requirements

Design ESALS (millions)	Required Density (% of Theoretical Max Specific Gravity)			VMA (%), minimum					VFA (%)	Dust-to-binder ratio
				Nominal Max Agg Size, mm						
	$N_{initial}$	N_{design}	N_{max}	37.5	25.0	19.0	12.5	9.5		
< 0.3	≤ 91.5								70 - 80	0.6 – 1.2
0.3 to < 3	≤ 90.5	96.0	≤ 98.0	11.0	12.0	13.0	14.0	15.0	65 - 78	
3 to < 10	≤ 89.0								65 - 75	
10 to < 30										
≥ 30										

Determining RAP Aggregate BSG

- Bulk Specific Gravity (BSG) is used in the calculation of VMA.
  - Combined BSG of RAP and virgin aggregates
- Not practical to directly determine BSG of RAP aggregate
  - Extraction required
  - Ignition oven – BSG value is too low
  - Solvent extraction – aggregate may contain asphalt or solvent which may influence results

What value should I use for RAP aggregate BSG (G_{sb}^{RAP})?

- Bulk Specific Gravity (G_{sb}) of RAP aggregate from original construction records
- Direct Measure

NCAT/ARC

- Use effective specific gravity of RAP aggregate, G_{se}^{RAP}
  - This will overestimate the combined aggregate G_{sb} and is not recommended.
  - Based on experience with mix designs for the specific location, assume a typical value for asphalt absorption, P_{ba}, and use this value to estimate the bulk specific gravity of the RAP aggregate, G_{sb}^{RAP}, from the calculated G_{se}^{RAP}.

Asphalt Inst.

Dealing with Dust

Dust to Binder Ratio

- Big challenge in using higher RAP contents
  - Fills voids and reduces VMA
- Removing dust increases costs

Insuring Quality

- Final mixture
  - Volumetric properties
  - Extraction & recovery
  - Gradation
  - Asphalt content
  - High-RAP
    - PG grade of blended binder
    - Quality of Aggregate
- Performance Testing

Performance Testing Options

Distress	Test	Reference
Permanent Deformation*	Asphalt Pavement Analyzer (APA)	AASHTO TP 63
	Hamburg Wheel Tracking Device	AASHTO T 324
	Flow Number (AMPT)	AASHTO TP 79
Moisture Sensitivity	Tensile Strength Ratio (TSR)	AASHTO T 283
	Hamburg Wheel Tracking Device (wet)	AASHTO T 324
Fatigue	??	??
Thermal Cracking**	Creep Compliance & Strength Using Indirect Tensile Test (IDT)	AASHTO T 322

* If softer binder or rejuvenator is used.

** For surface mixes in climates prone to thermal cracking.