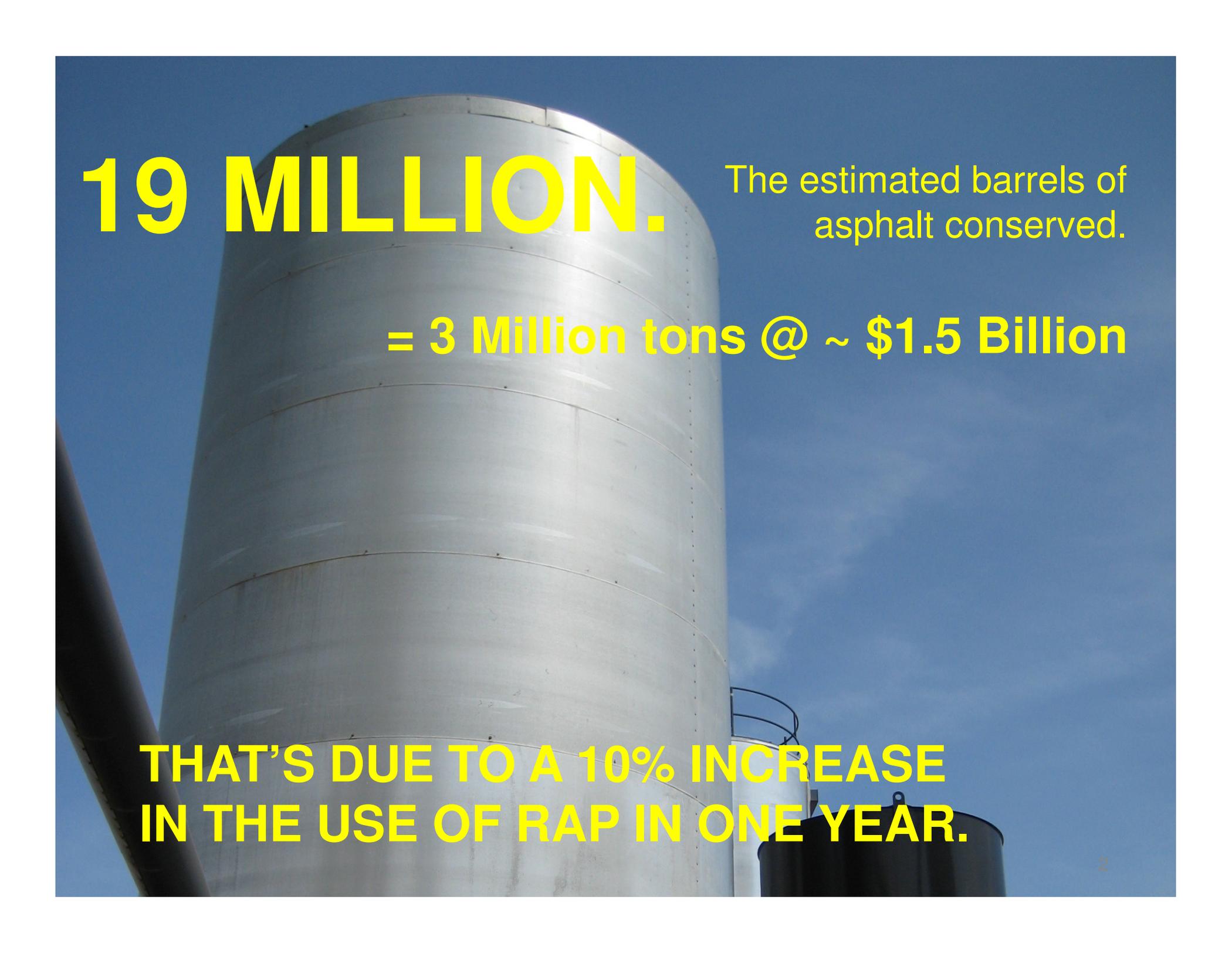




RAP: Cost Savings, Performance & Sustainability

2014 Michigan Asphalt Paving Conference



19 MILLION.

The estimated barrels of
asphalt conserved.

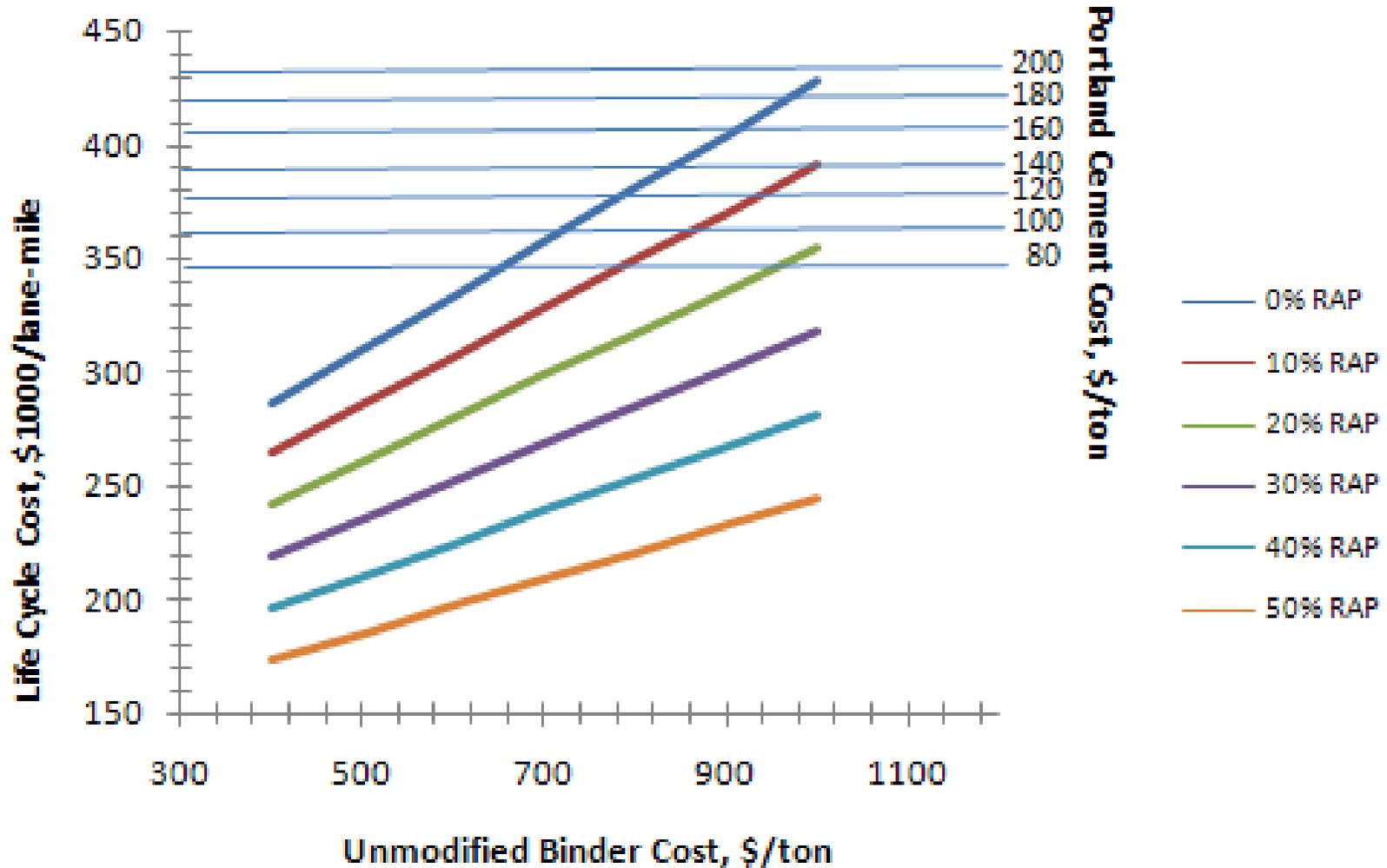
= 3 Million tons @ ~ \$1.5 Billion

**THAT'S DUE TO A 10% INCREASE
IN THE USE OF RAP IN ONE YEAR.**

Recycle vs. Cost



Life Cycle Cost Using RAP 11" AC vs. 9" PCC



What's the National Trend?



- Probably the **greatest single upfront cost stabilizing & saving** 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 processing and production best practices and now... WMA technologies.
 - 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.



INDUSTRY SURVEY OF RECYCLING & WMA



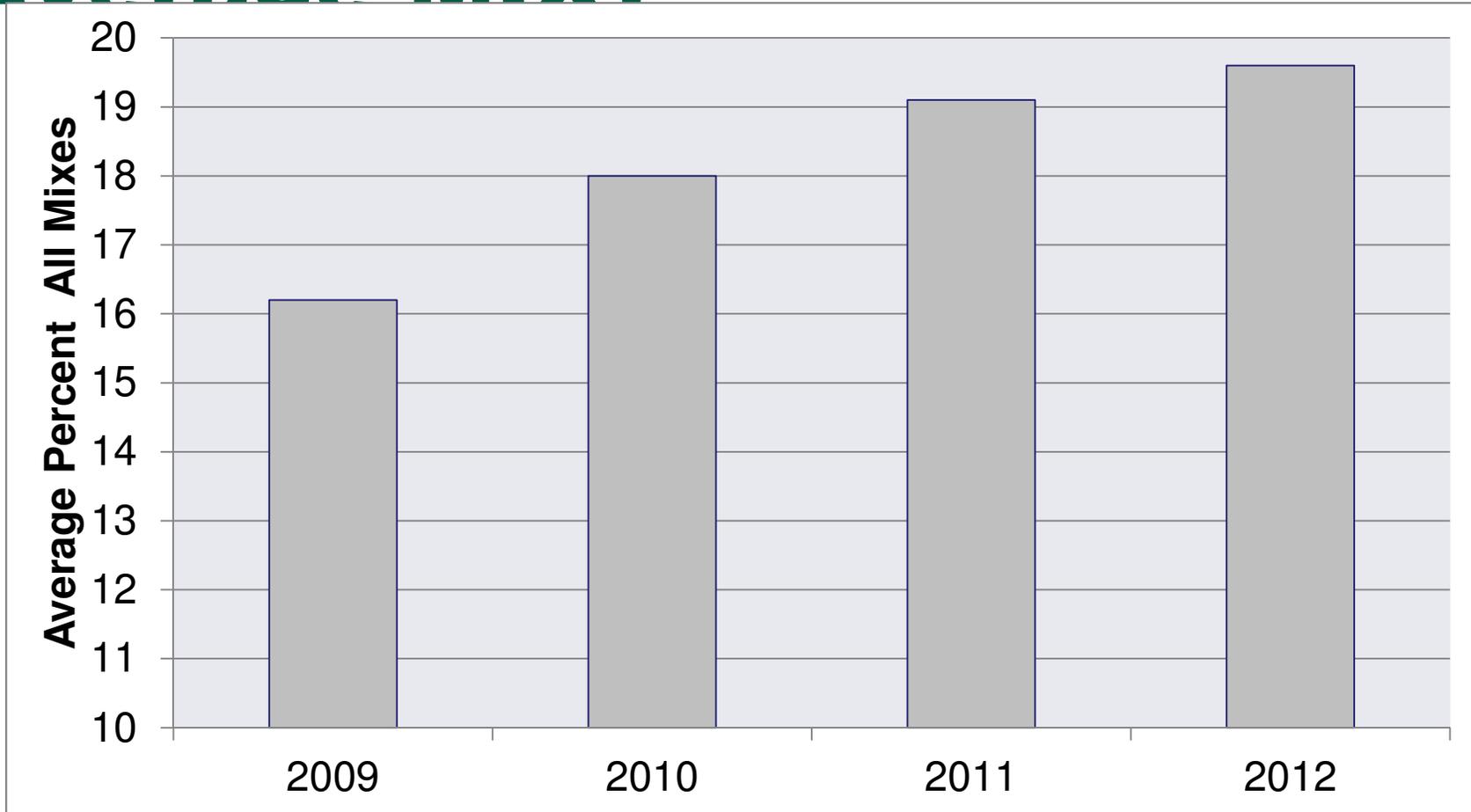
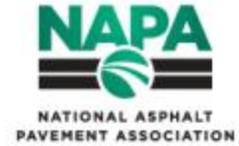
NATIONAL ASPHALT
PAVEMENT ASSOCIATION

Reclaimed Asphalt Pavement (RAP)



- **America's most recycled material: *Mining the roads***
- **Reused not just recycled**
- **FHWA / NAPA Survey (2012)**
 - **~ 93% of RAP was reused into value pavements**
 - **~ 67 million tons RAP reused (19% loading)**
 - **Utilization still growing: 19% increase since '09**
- **Future Challenges**

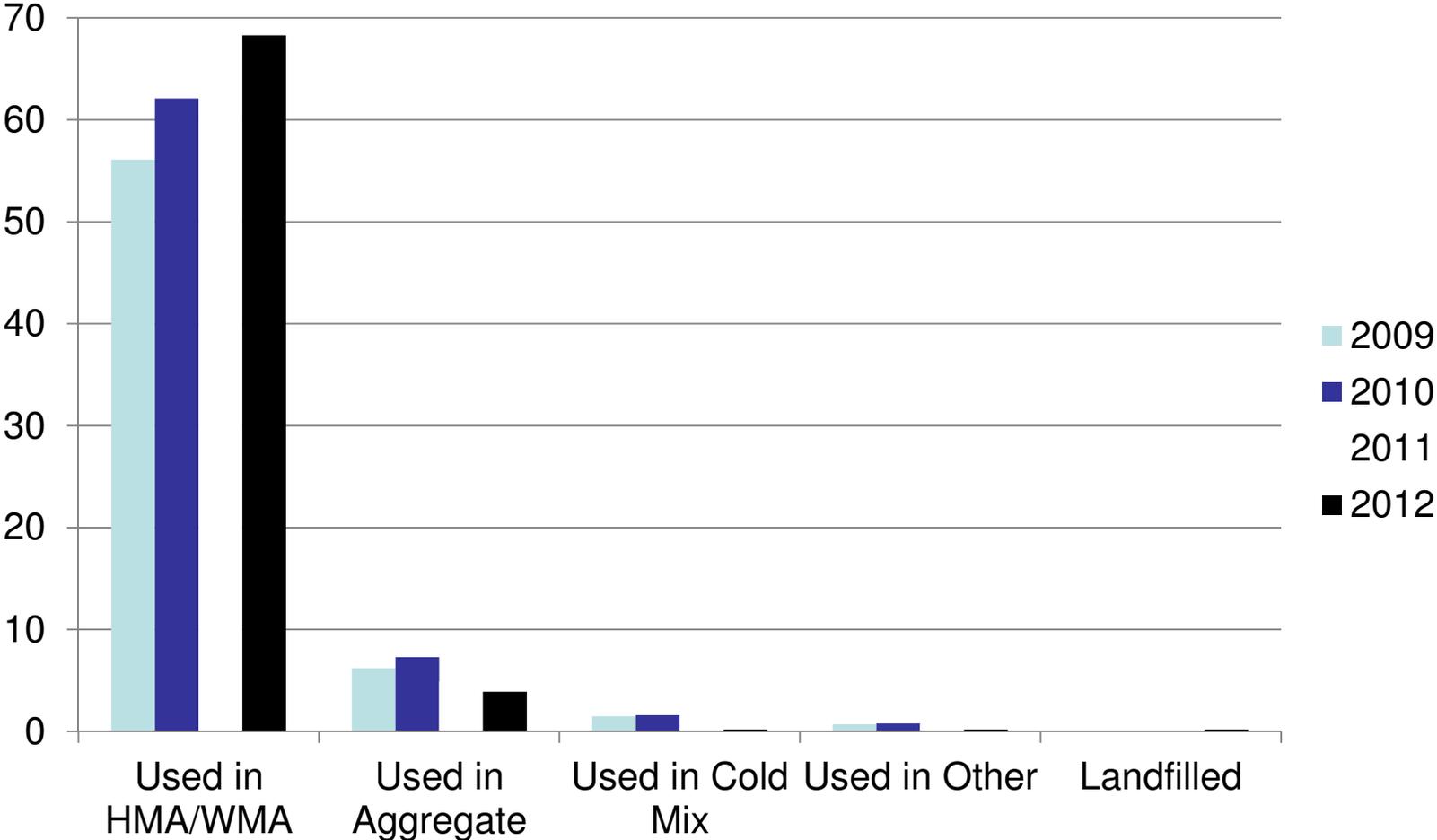
How much RAP is in an Average MIX?



Reclaimed Asphalt Pavement (RAP)

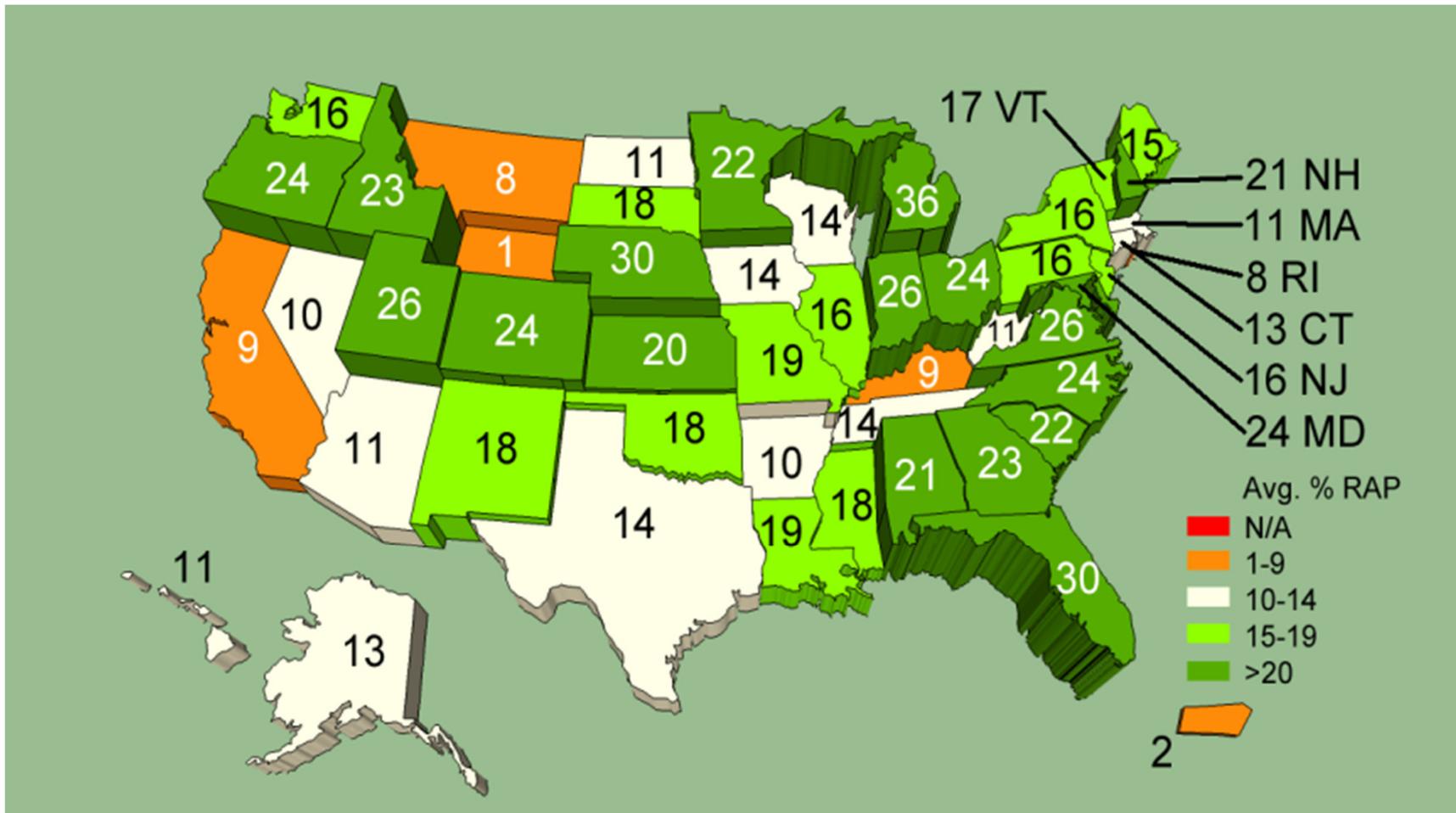
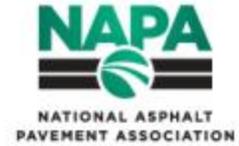


How much RAP is Being Used?



<1% RAP is landfilled

2011 Average RAP Content by State



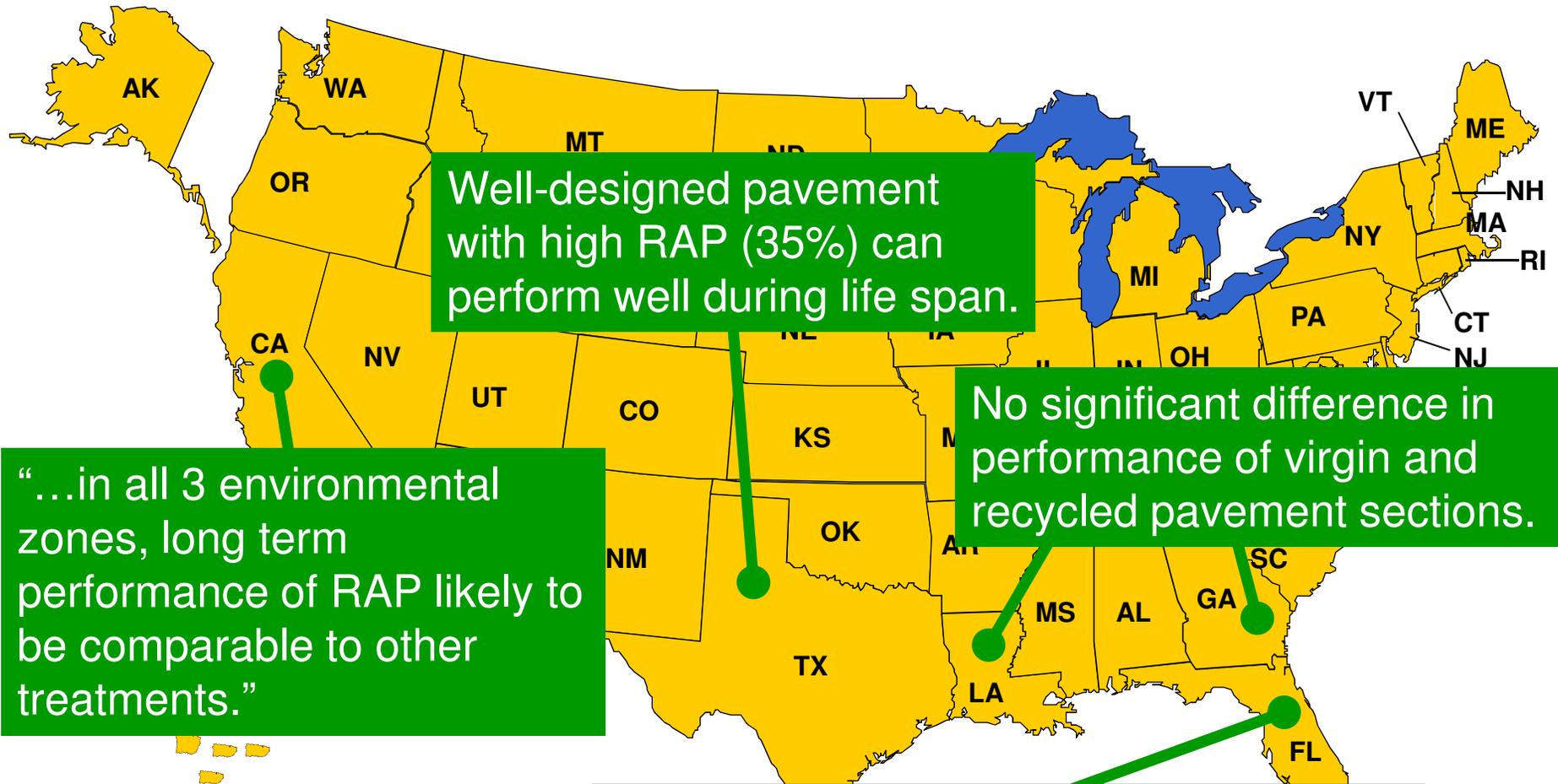


PERFORMANCE OF HIGH RAP MIXTURES

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



Well-designed pavement with high RAP (35%) can perform well during life span.

No significant difference in performance of virgin and recycled pavement sections.

“...in all 3 environmental zones, long term performance of RAP likely to be comparable to other treatments.”

Average age of virgin mixes is 11 years. For 30–50% RAP content, the average age ranges from 10–13 years.

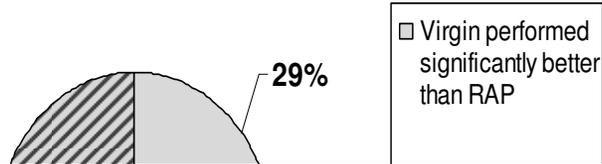
Evaluating RAP Performance



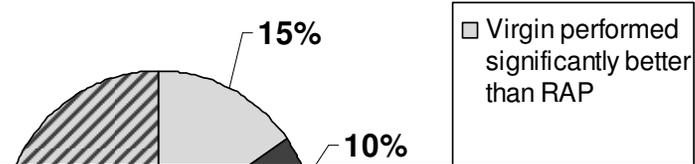
- Long Term Pavement Performance SPS-5 sections
 - Virgin
 - 30% RAP
 - Milled and non-milled surface
 - 50 and 125 mm thick
 - Oldest is over 17 years
 - Variety of climates

LTPP Study Results

Fatigue Cracking



Longitudinal Cracking



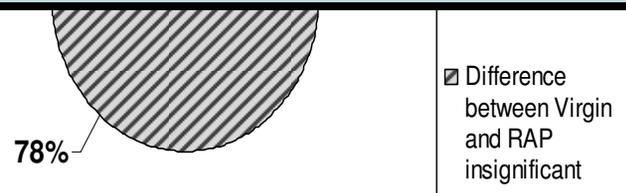
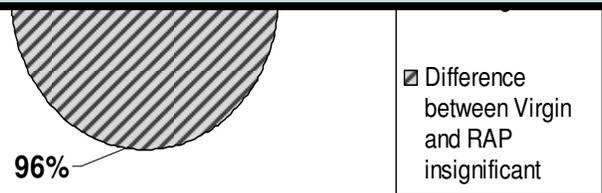
RAP Mix Performed As Well As or Significantly Better than Virgin Mix

Fatigue Cracking – 71% (RAP cracking equiv or < virgin)

Longitudinal Cracking – 85 %

Block Cracking – 97 %

Raveling – 93 %



TECHBRIEF



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/tfhrp/programs/infrastructure/pavements/ltppl/>

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

*“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 – but starting to document
- Recycled asphalt mixtures designed using established mix design procedures and produced with appropriate QC/QA measures perform comparably to conventional mixtures.



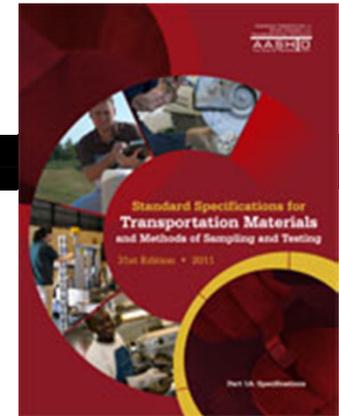
WHY ASPHALT BINDER REPLACEMENT?



~~RAP SPECIFICATIONS 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 & may impact binder choice
- 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”.

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

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



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.

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



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



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

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

Reclaimed Asphalt Pavement (RAP)



Societal

- Natural Resource Conservation



Economic

- Reuse Aggregate and Asphalt Binder

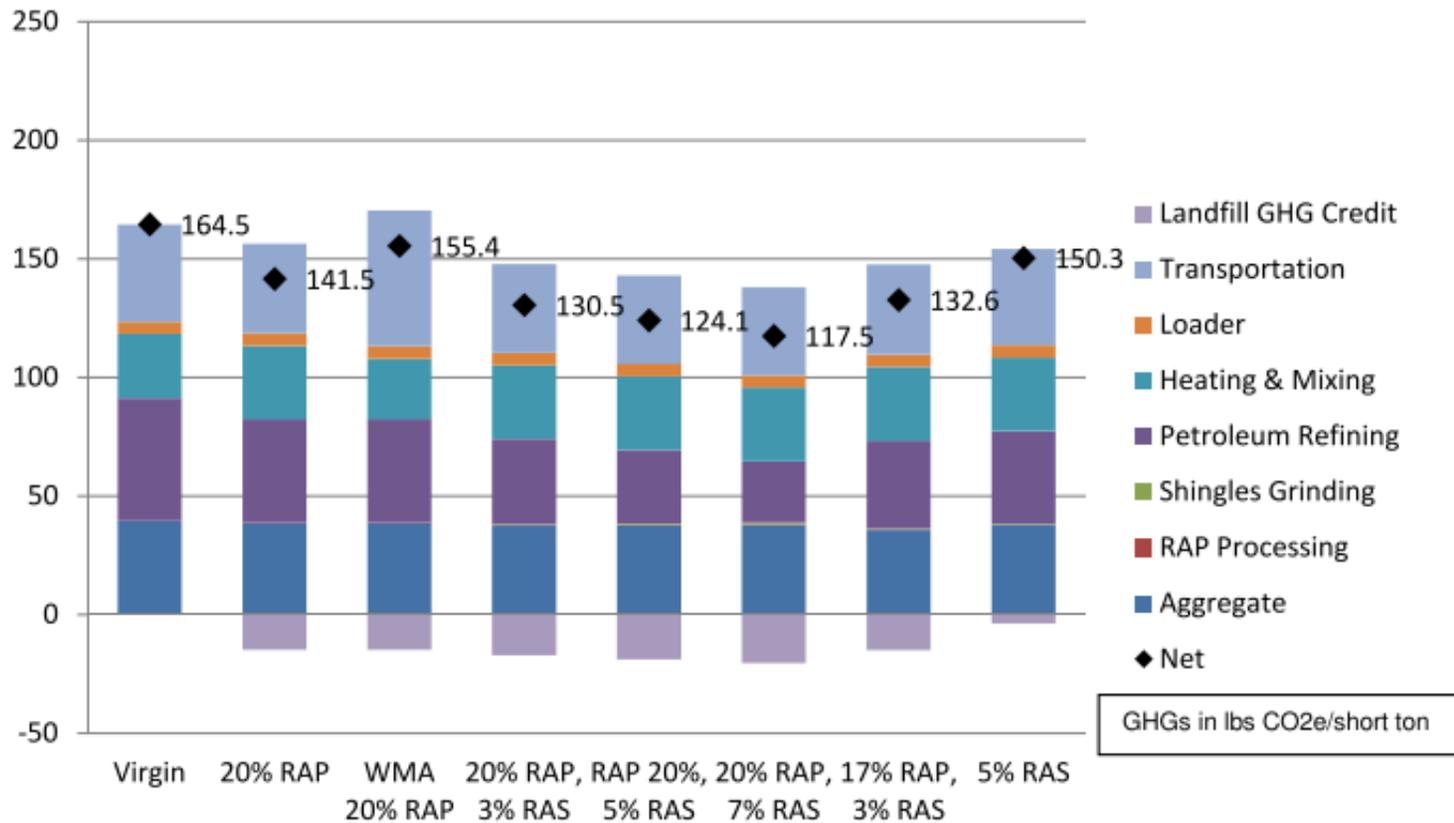


Environmental

- Reduced Emissions
- Reduced landfill space
- Closes Life Cycle Circle

GHG of RAP

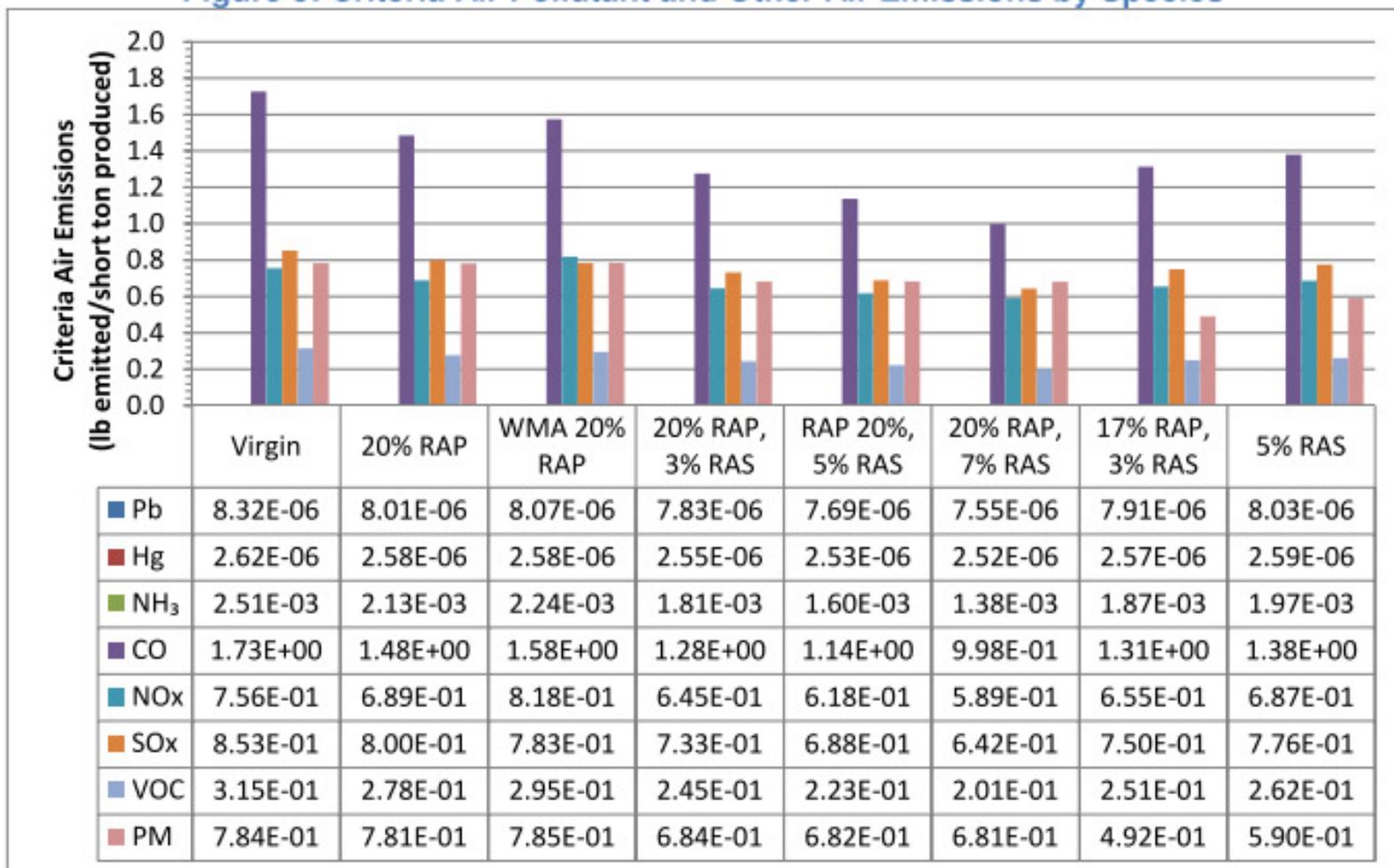
Figure ES-1: Greenhouse Gas Emissions, No Allocation



Source: EPA 2013

Criteria Air Pollutants of RAP

Figure 5: Criteria Air Pollutant and Other Air Emissions by Species



NAPA's GHG Calculator



- Developed to estimate plant CO₂ emissions
- Based on The Climate Registry (TCR) data
- Can be used to assess state reporting requirements
- Measures impact of various technologies
 - Mix temperature, fuel type, RAP/RAS content
- Calculates actual CO₂e and identifies carbon credits
- www.asphaltpavement.org/ghgc
- Free NAPA webinar reviews how to use GHG Calculator

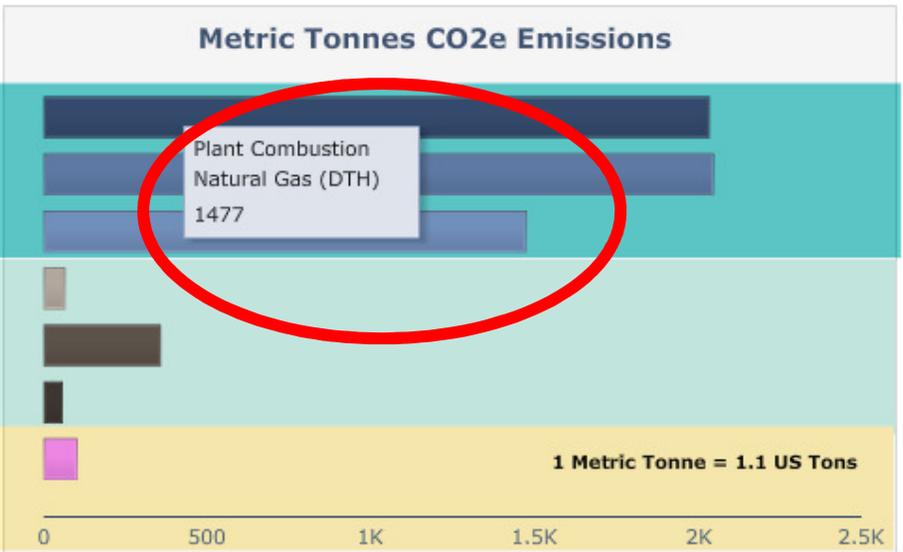


Year Mix Produced (Tons) 300,000

Plant Combustion
 Fuel Oil (Gal) 200,000
 Recycled Oil (Gal) 200,000
 Natural Gas (DTH) 27,800

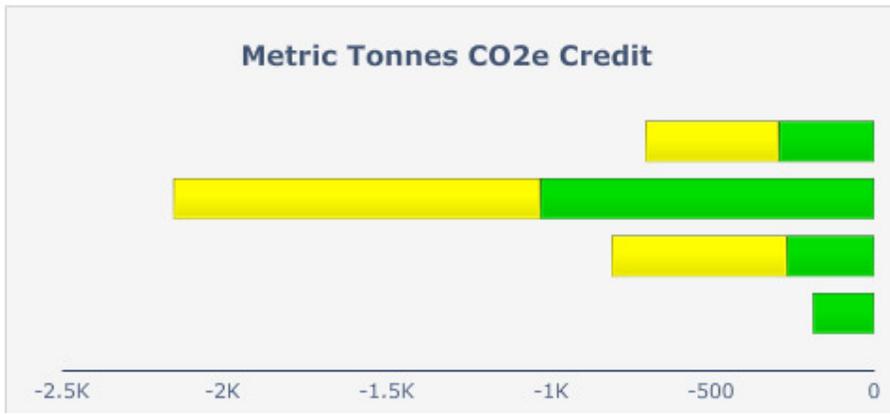
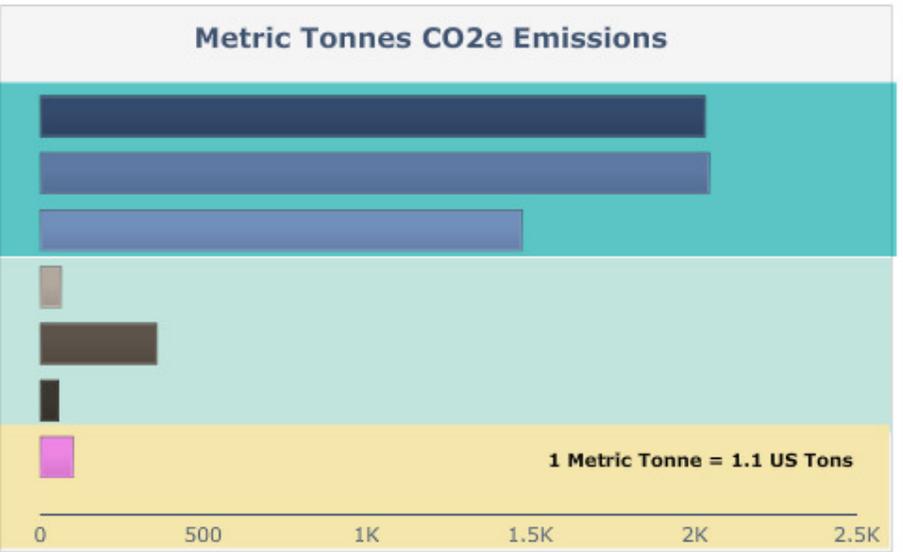
Plant Equipment & Vehicles
 Gasoline (Gal) 7,500
 Diesel Fuel (Gal) 35,000
 Propane (Gal) 10,000

Line Power (kWh)
 Pennsylvania 200,000



Year Mix Produced (Tons) 300,000

Plant Combustion	Fuel Oil (Gal)	200,000
	Recycled Oil (Gal)	200,000
	Natural Gas (DTH)	27,800
Plant Equipment & Vehicles	Gasoline (Gal)	7,500
	Diesel Fuel (Gal)	35,000
	Propane (Gal)	10,000
Line Power (kWh)	Pennsylvania	200,000

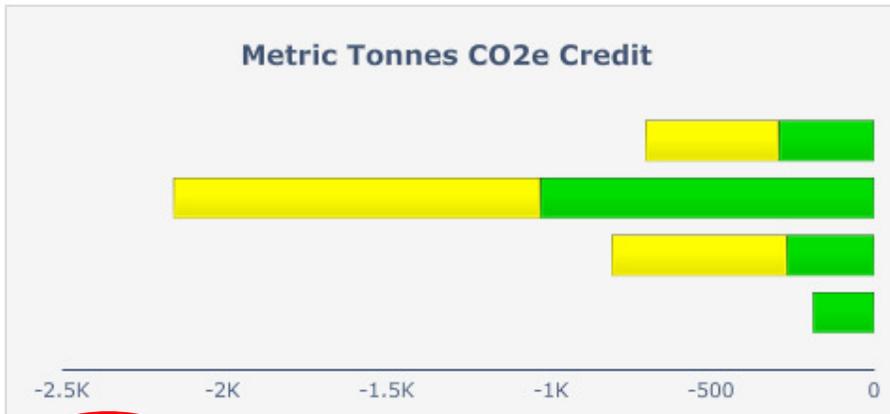
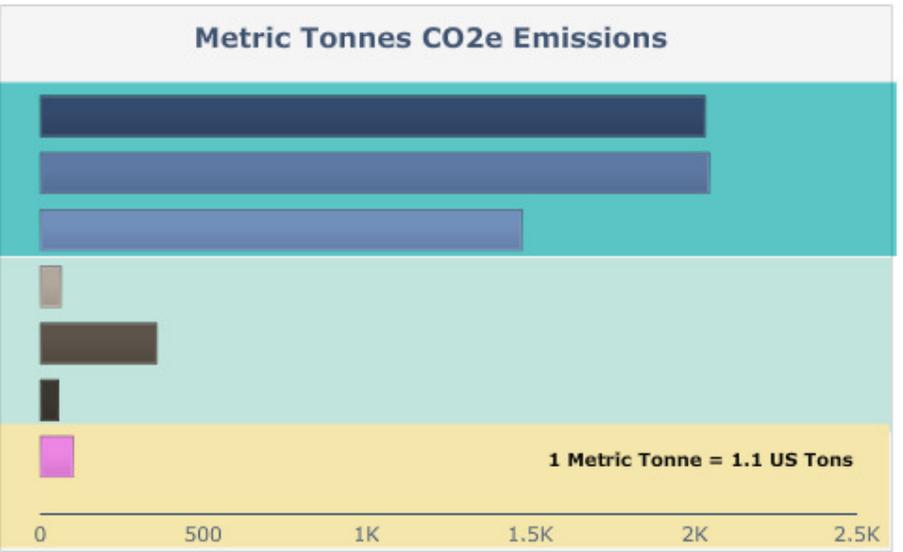


Credits

	Average		Tons	% Mix	Target %
WMA	270	Mix of	100,000	33.3	80
RAP	4.6	% AC	50,000	16.7	35
RAS	18	% AC	5,000	1.7	5
Fuels					

Year Mix Produced (Tons) 300,000

Plant Combustion	Fuel Oil (Gal)	200,000
	Recycled Oil (Gal)	200,000
	Natural Gas (DTH)	27,800
Plant Equipment & Vehicles	Gasoline (Gal)	7,500
	Diesel Fuel (Gal)	35,000
	Propane (Gal)	10,000
Line Power (kWh)	Pennsylvania	200,000

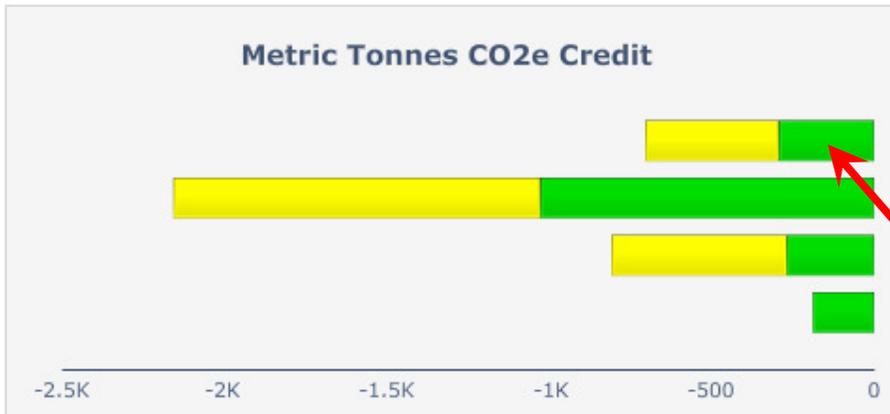
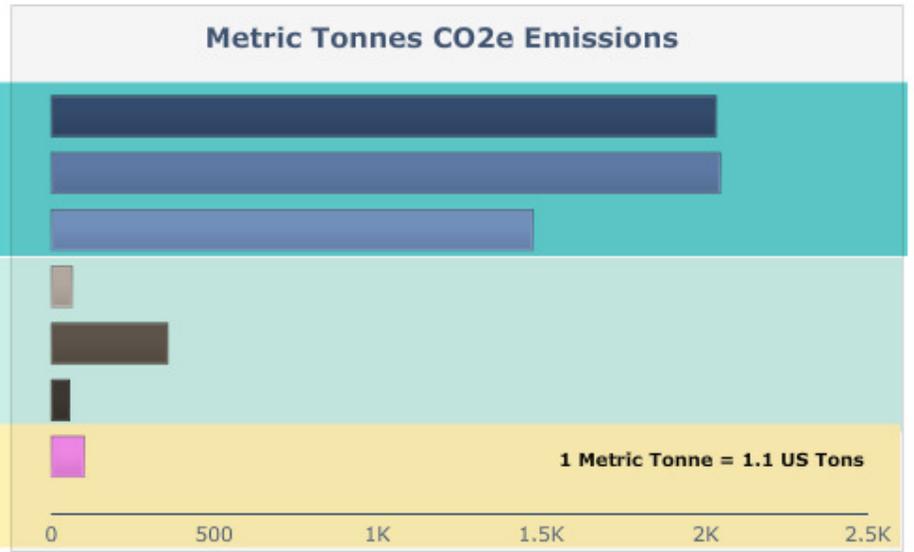


Credits					
	Average		Tons	% Mix	Target %
WMA	270	Mix of F	100,000	33.3	80
RAP	4.6	% AC	50,000	16.7	35
RAS	18	% AC	5,000	1.7	5
Fuels					

Reportable	Tonnes CO2e	Percent of Total	Lbs CO2e/Ton Mix
Plant Combustion	5,561	90.4%	40.9
Equipment & Vehicles	483	7.9%	3.6
Electric	104	1.7%	0.76
Less Credits	-1,487	-24.2%	-10.9
Net CO2e	4,662		34.3

Year Mix Produced (Tons) 300,000

Plant Combustion	Fuel Oil (Gal)	200,000
	Recycled Oil (Gal)	200,000
	Natural Gas (DTH)	27,800
Plant Equipment & Vehicles	Gasoline (Gal)	7,500
	Diesel Fuel (Gal)	35,000
	Propane (Gal)	10,000
Line Power (kWh)	Pennsylvania	200,000



Credits					
	Average		Tons	% Mix	Target %
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Equipment & Vehicles	483	7.9%	3.6
Electric	104	1.7%	0.76
Less Credits	-1,487	-24.2%	-10.9
Net CO2e	4,662		34.3

Already included in emissions

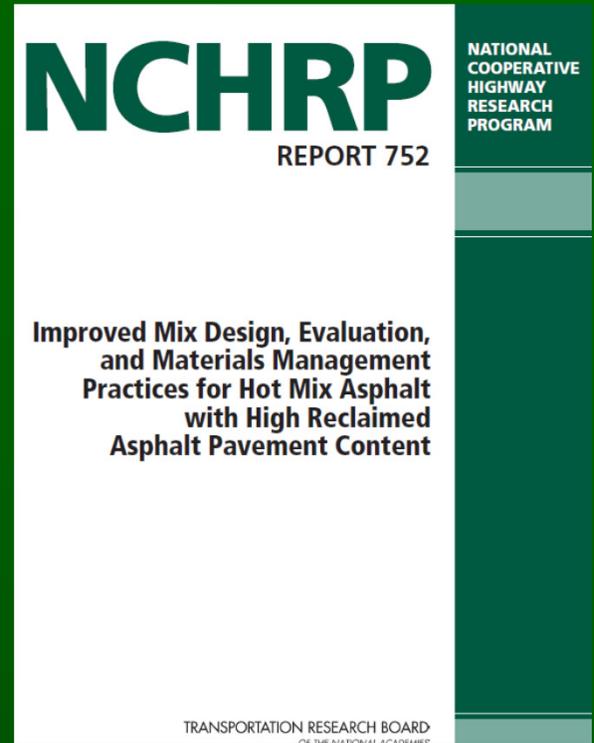


RESOURCES



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

Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice

PUBLICATION NO. FHWA-HRT-11-021

APRIL 2011



U.S. Department of Transportation
Federal Highway Administration

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

INFOBRIEF



With changes in construction materials economics, stricter environmental regulations, and an emphasis on "green" technologies (e.g., warm mix asphalt) and sustainable pavements, the highway community is reassessing the economic and environmental benefits of allowing higher percentages of reclaimed asphalt pavement (RAP) in premium pavements and asphalt surfaces while maintaining high-quality pavement infrastructure. In 2007, the Federal Highway Administration created the RAP Expert Task Group (ETG) to advance the use of recycled materials such as RAP and recycled asphalt shingles in asphalt paving applications. The purpose of the ETG is to provide State transportation departments and the industry with information that emphasizes the production of high-quality, high-content RAP mixtures, the performance of asphalt mixtures containing RAP, technical guidance on high-content RAP projects, and RAP research activities. Members of the RAP ETG consist of representatives from State highway agencies, industry, and academia. This Infobrief summarizes the accomplishments of the RAP ETG and resources available for increased RAP use. More information may be found online at www.fhwa.dot.gov/pavement/ recycling or at www.moreRAP.us, as well as through the National Asphalt Pavement Association and the Asphalt Institute.

U.S. Department of Transportation
Federal Highway Administration

<http://www.fhwa.dot.gov/research/>

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

High Reclaimed Asphalt Pavement Use

FHWA Publication No.: FHWA-HRT-11-057

FHWA Contact: Audrey Copeland, HRDI-10, (202) 493-3097,
audrey.copeland@dot.gov

RAP Defined

Existing asphalt materials are commonly removed during resurfacing, rehabilitation, and reconstruction operations. Once removed and processed, the pavement materials become reclaimed asphalt pavement (RAP), which contains valuable asphalt binder and aggregate. RAP is a valuable, high-quality material that can replace more expensive virgin aggregates and binders. The most economical use of RAP is in the intermediate and surface layers of flexible pavements where the less expensive binder from RAP can replace a portion of the more expensive virgin binder. While RAP has been used for decades, there is a current interest in using higher RAP contents. High RAP content mixtures have greater than 25 percent RAP by weight of the mix.

RAP Use Today

The RAP ETG, in partnership with the American Association of State Highway and Transportation Officials (AASHTO), conducts a RAP use survey every 2 years. The survey was conducted in 2007, 2009, and 2011. In 2007, the typical hot mix asphalt (HMA) mixture contained about 12 percent RAP. From 2007 to 2009, about 27 States increased the amount of RAP permitted in asphalt mixtures, and, as of 2009, 23 States have experience with high RAP mixtures. The results of the 2007 and 2009 surveys are summarized in the *Public Roads* article "Reclaiming Roads."⁽¹⁾ As of 2011, the majority of State highway agencies (more than 40) allow more than 30 percent RAP; however, only 11 report actually using 25 percent RAP or more.⁽²⁾

Providing Technical Information

Designing High RAP Mixes

The RAP ETG developed and disseminated technical information for high RAP use. In the first major effort, the Federal Highway Administration partnered with AASHTO and the National Asphalt Pavement Association to create *Designing HMA Mixtures with High RAP Content: A Practical Guide*, which provides guidance for designing high RAP mixtures.⁽³⁾ As a follow-up and in conjunction with the Transportation Research Board, the RAP ETG conducted the webinar *Design and Production of High Reclaimed Asphalt Pavement Mixes*.⁽⁴⁾

Management and Production Best Practices

There are two best practices reports available.^(5,6) In addition, presentations by three RAP ETG members are available, which provide a historical

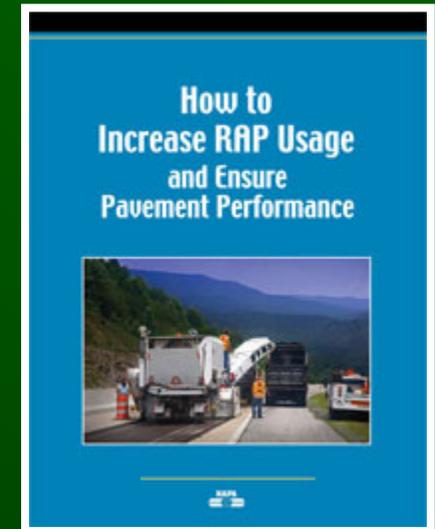
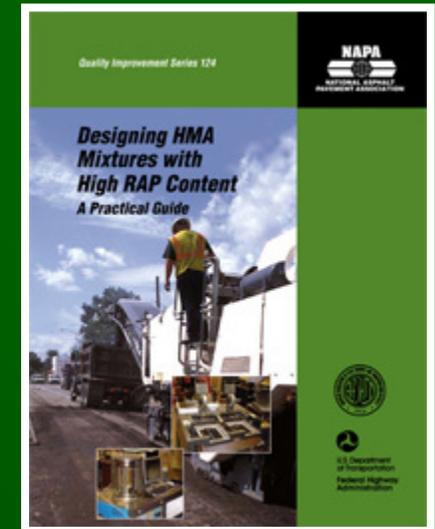
<http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/11021/11021.pdf>

<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





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www.asphaltpavement.org
www.asphaltroads.org