

# **Asphalt Pavement Recycling with Reclaimed Asphalt Pavement (RAP)**

***Stephen J. Cooper***  
***Federal Highway Administration***

***NWPMA, 18<sup>th</sup> Annual Fall Pavement Conference***

***October 20, 2011***

***Portland, OR***



U.S. Department of Transportation  
**Federal Highway Administration**

# Acknowledgements

[www.fhwa.dot.gov/pavement/recycling/rap](http://www.fhwa.dot.gov/pavement/recycling/rap)

Contact Information:

[Audrey Copeland](#)

Turner Fairbank Highway Research Center

Email: [audrey.copeland@dot.gov](mailto:audrey.copeland@dot.gov)

Phone: 202.493.3097

[John Bukowski](#)

Office of Infrastructure

Email: [john.bukowski@dot.gov](mailto:john.bukowski@dot.gov)

Phone: 202.366.1287



U.S. Department of Transportation  
Federal Highway Administration

FHWA RAP Expert Task Group

# What we're going to talk about...

- Recycled Materials and the Value of RAP
- State-of-the-Practice
  - How far have we come?
- National Effort to Increase RAP
- Long-term Pavement Performance of RAP Mixtures



# What is RAP?

- Reclaimed Asphalt Pavement
- Removed and/or reprocessed pavement materials containing:
  - ~ binder (5%)
  - ~ aggregates (95%)
- High RAP is > 25% by weight of mix.



# FHWA Recycled Materials Policy

- Recycled/Re-Use materials are viable resources
- Recycled materials should get 1<sup>st</sup> consideration
- Consider use of recycled materials early in the planning/design process
- Economic benefits should be considered in the material selection process
- Restricting the use of materials should be technically based
- Material should not adversely impact the environment and should perform as intended



# The ultimate value of RAP is in its use:

- RAP as a roadbed/base material
  - Roughly equal to granular base with some additional value
- RAP in new pavement
  - Replaces portion of expensive virgin binder and aggregate
  - Virgin aggregate + asphalt value – costs



# Use of Recycle Pavement in the United States

1925.....	0
1970.....	0
1976.....	3%
1980—85.....	15% (some 50%)
2000.....	15%
2010.....	25-30% (some 50%)

# Why Recycle Asphalt?

- Pavement Benefits
- Economic Payoff
- Energy Savings
- Natural Resource Conservation







## Pavement Benefits - Milling

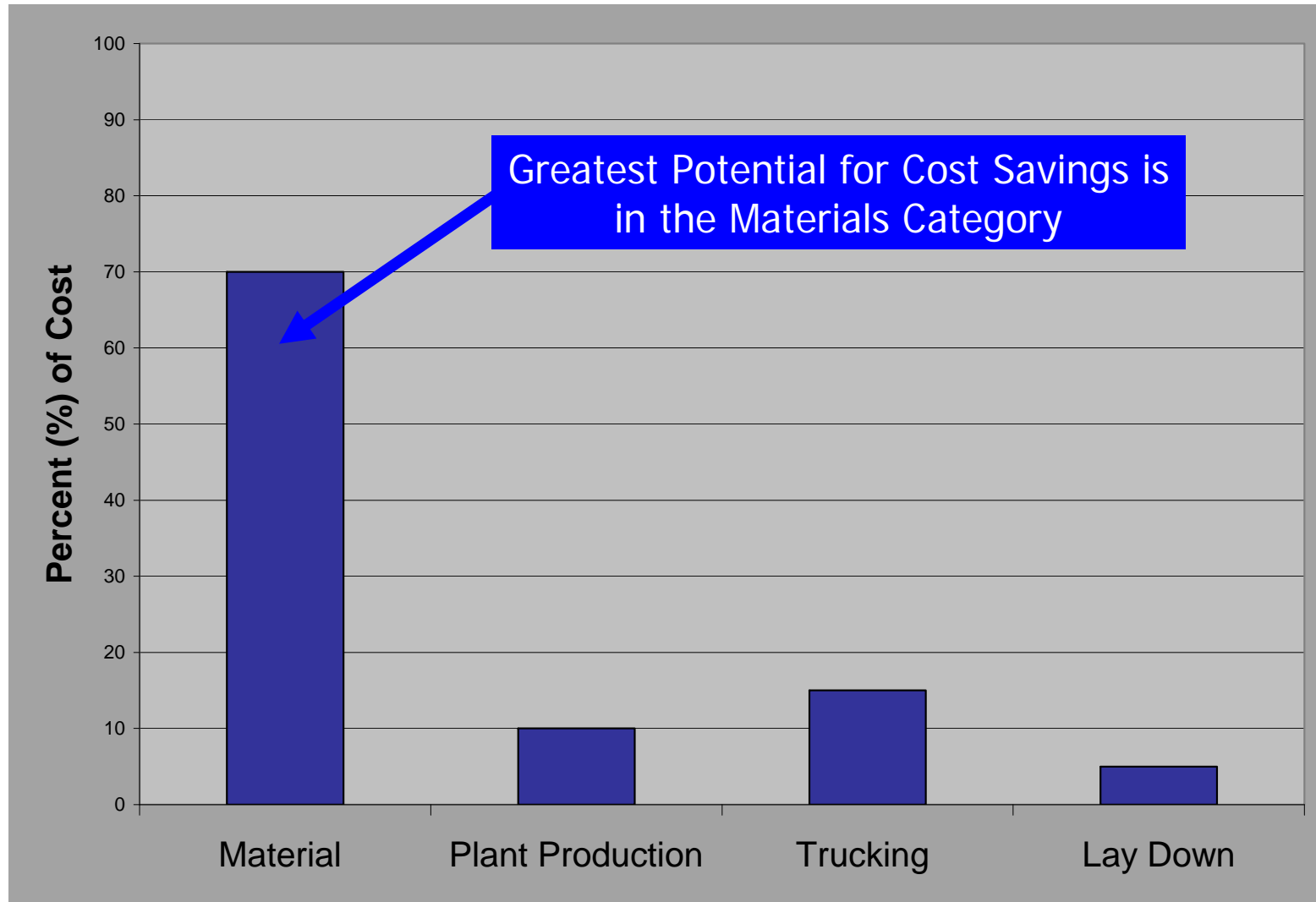
- Removes cracked and aged pavement layers
- Improves pavement smoothness and cross-slopes
- Maintains curb heights, drainage inlets, and bridge clearances
- Creates a rough texture that bonds better with the overlay

# Economics of HMA Recycling



U.S. Department of Transportation  
**Federal Highway Administration**

# Asphalt Production Cost Categories

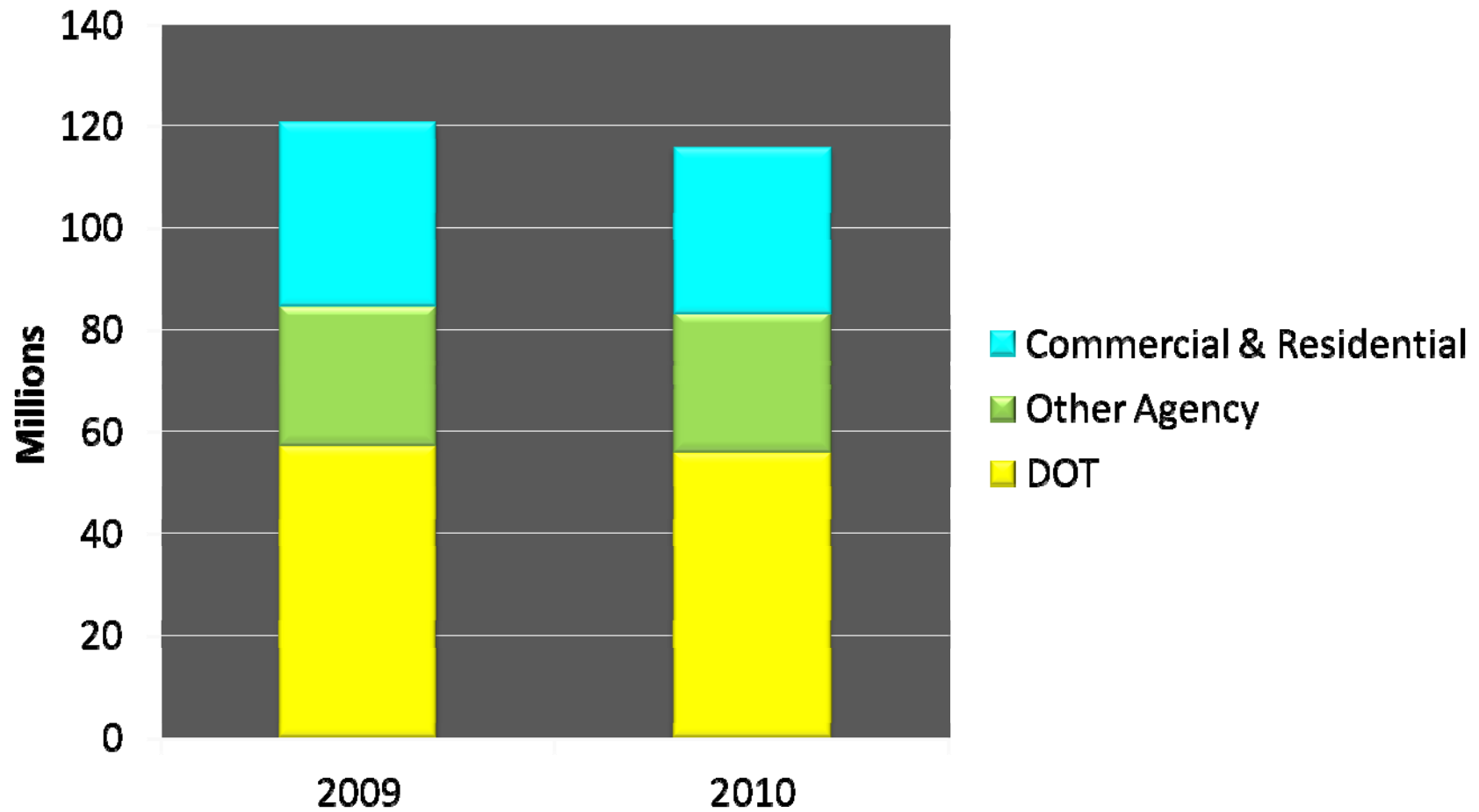


# Materials savings will depend on...

- Virgin binder cost
- Asphalt content of the mix design
- Aggregate cost
- RAP cost
- Asphalt content of the RAP
- Percentage of RAP

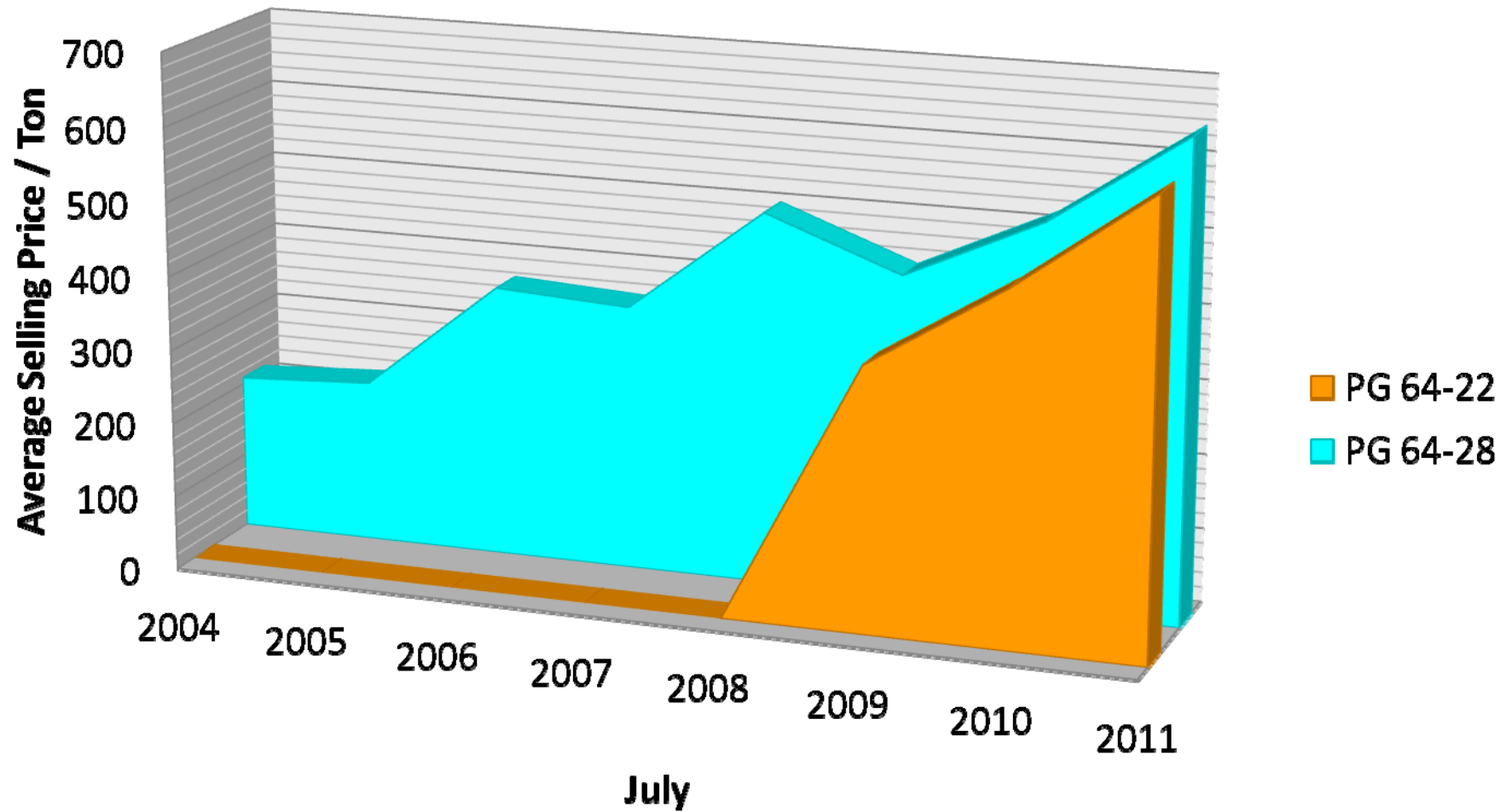


# Reported Asphalt Tons



# Asphalt Binder Prices

Source: CT DOT



# Recycling Economics Example

- Aggregate: \$10.00/ton
- Asphalt: \$500.00/ton
- Mix Design AC Content: 5.0%

$$\$10 \times .95 = \$ 9.50$$

$$\underline{\$500 \times .05 = \$25.00}$$

$$\text{Total Mix} \quad \$34.50$$

# Recycling Economics Example

- Aggregate: \$10.00/ton
- Asphalt: \$500.00/ton
- RAP: \$6.00/ton (5% AC in RAP)
- Mix Design
  - AC Content: 5.0%
  - RAP content 20% (19% rock, 1% AC)

$$\begin{array}{r} \$10.00 \times .76 = \$ 7.60 \\ \$500.00 \times .04 = \$20.00 \\ \underline{\$6.00 \times .20 = \$ 1.20} \\ \text{Total Mix} \qquad \qquad \$28.80 \end{array}$$



# Recycling Economics Example

- Virgin Mix: \$34.50/ton
- Recycled Mix: \$28.80/ton



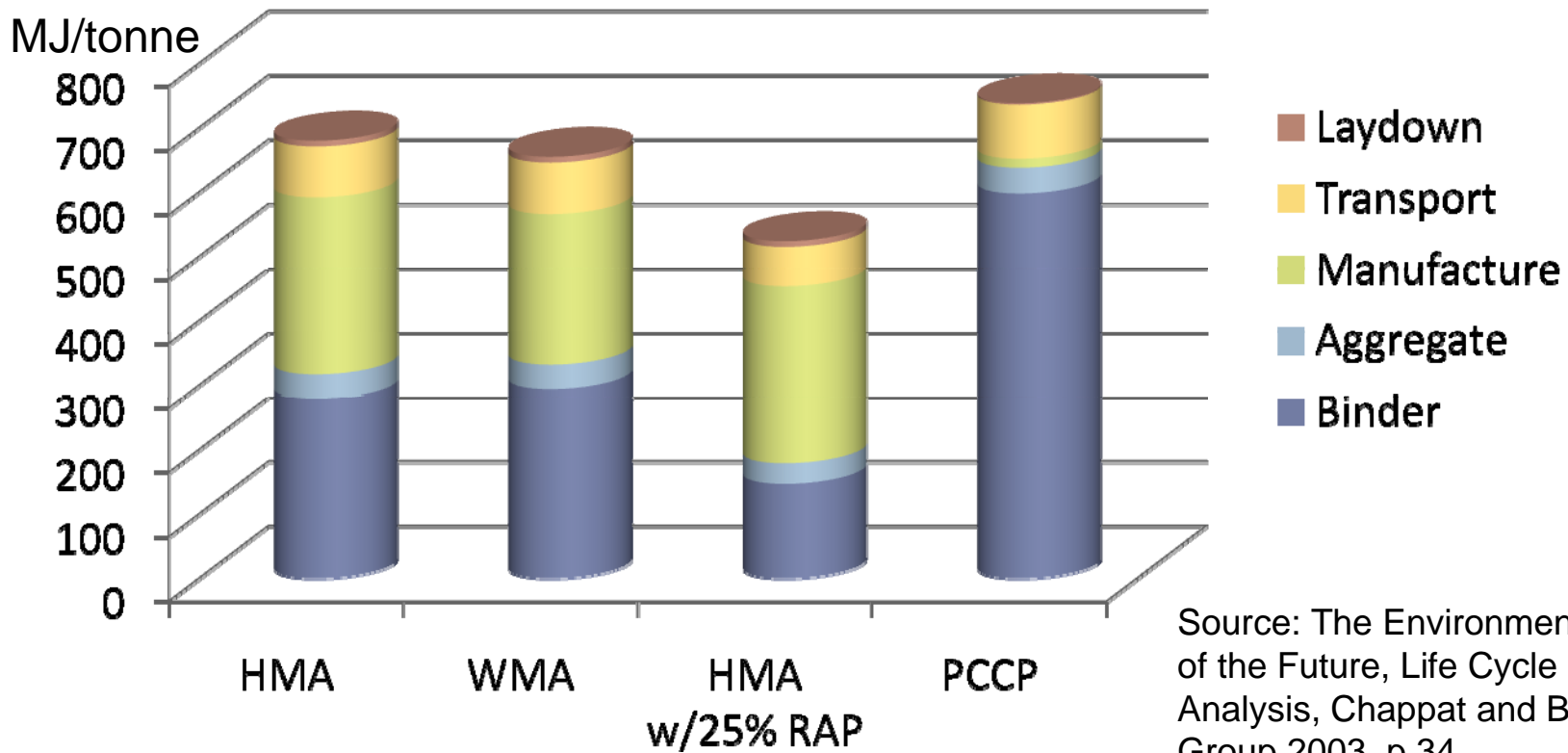
**@20% RAP: Savings = 16.5%**

# Energy Savings



U.S. Department of Transportation  
**Federal Highway Administration**

# Energy Consumption Related to Road Construction and Maint.



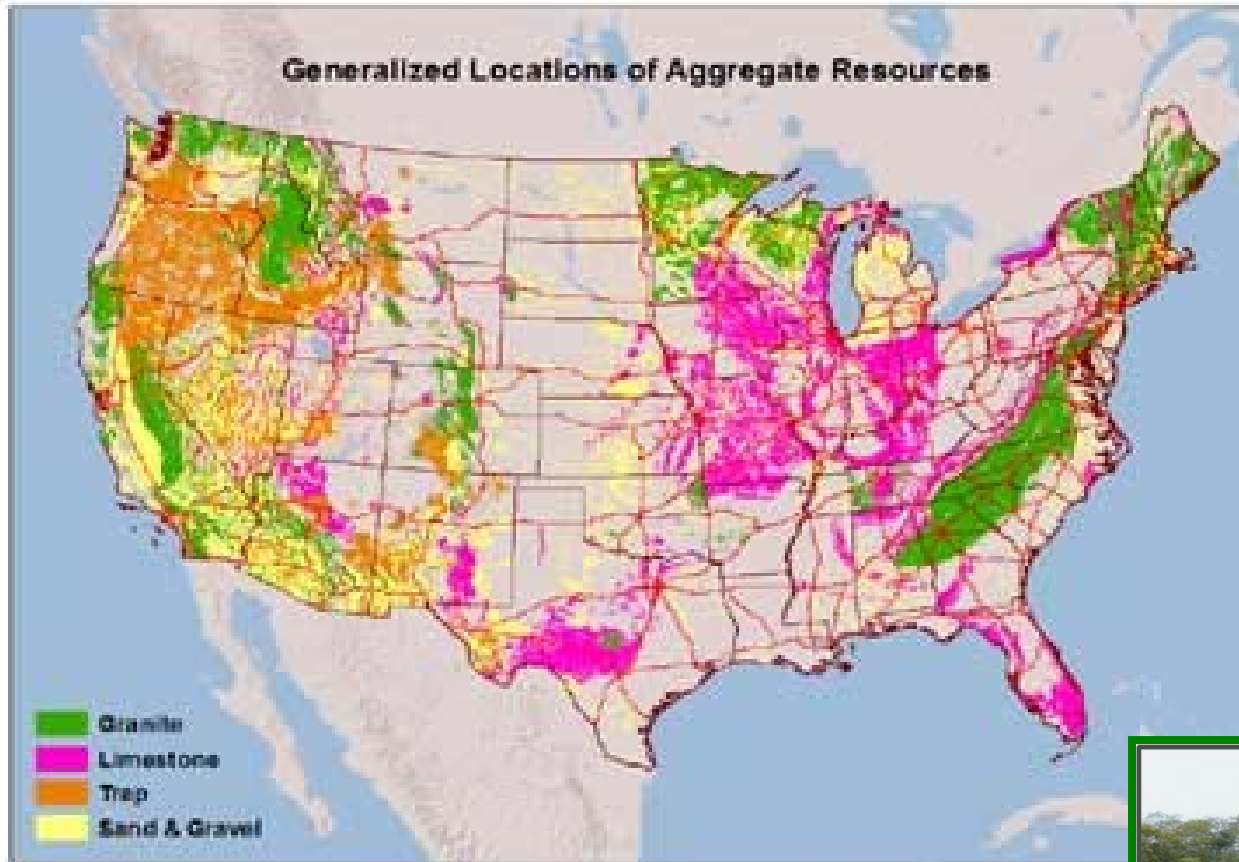
Source: The Environmental Road of the Future, Life Cycle Cost Analysis, Chappat and Bilal, Colas Group 2003, p.34

# Natural Resource Conservation

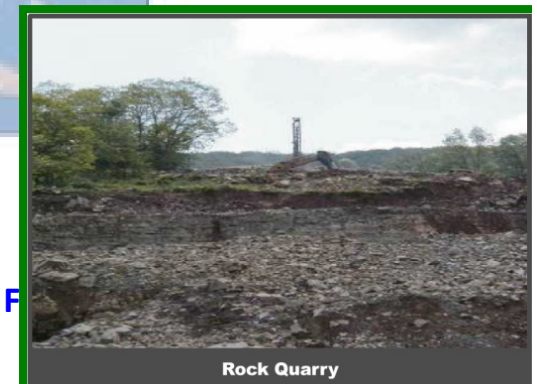


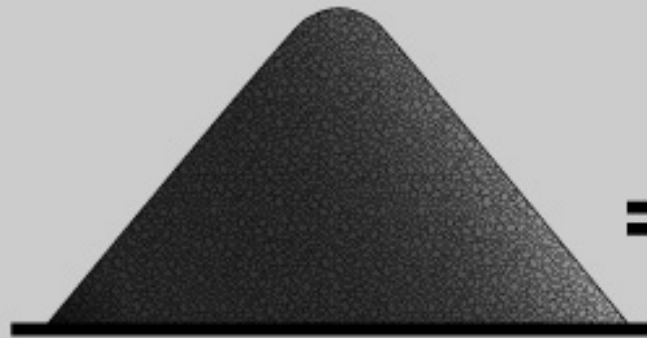
U.S. Department of Transportation  
**Federal Highway Administration**

# Natural Resource Conservation



U.S. Department of Transportation  
Federal Highway Administration



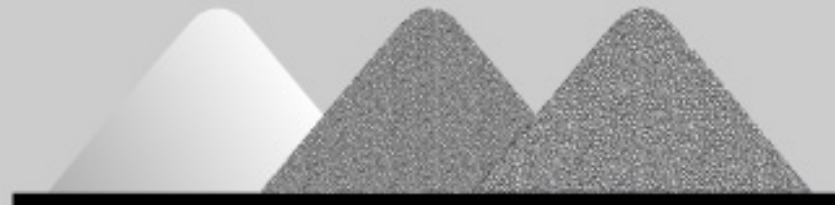


**30,000 Tons of RAP**

**=**



**70 - 6,000 Gallon Transport Trailers  
and 28,200 Tons of Clean Aggregate**



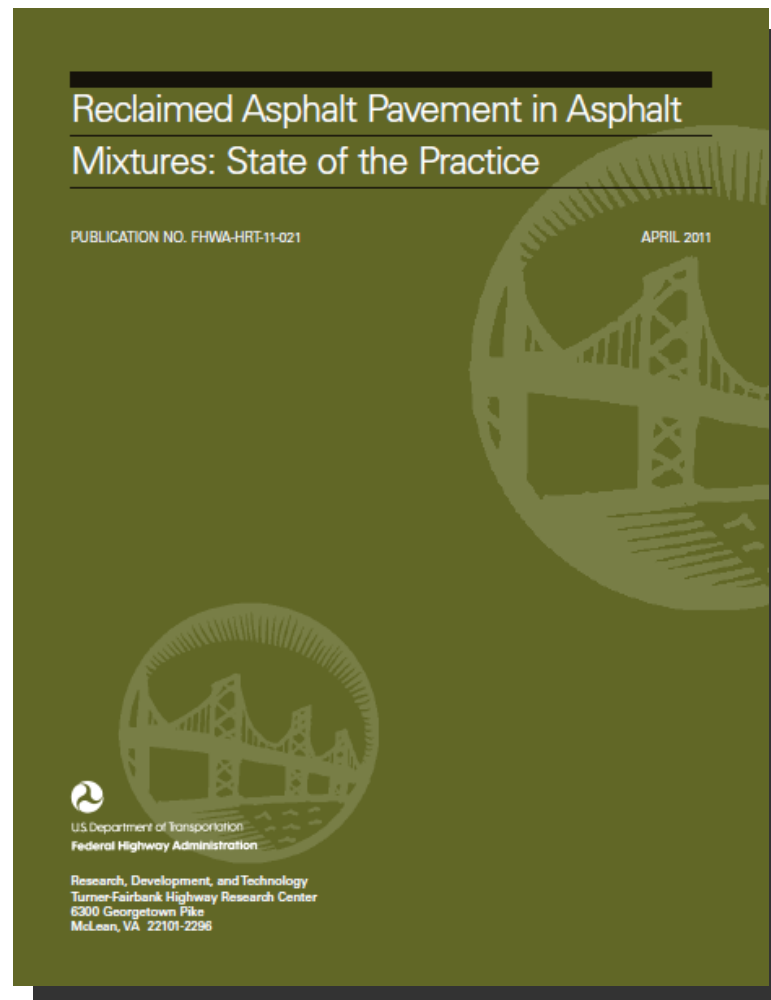
**RAP is Worth the Virgin Material It Replaces**

# State-of-the-Practice



U.S. Department of Transportation  
**Federal Highway Administration**

# FHWA RAP in Asphalt Mixtures: State of the Practice



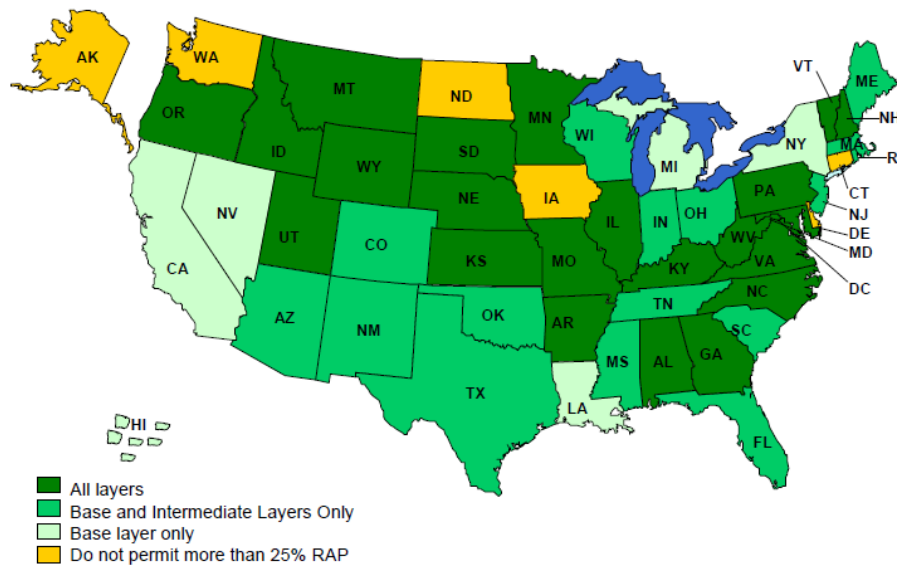
U.S. Department of Transportation  
**Federal Highway Administration**



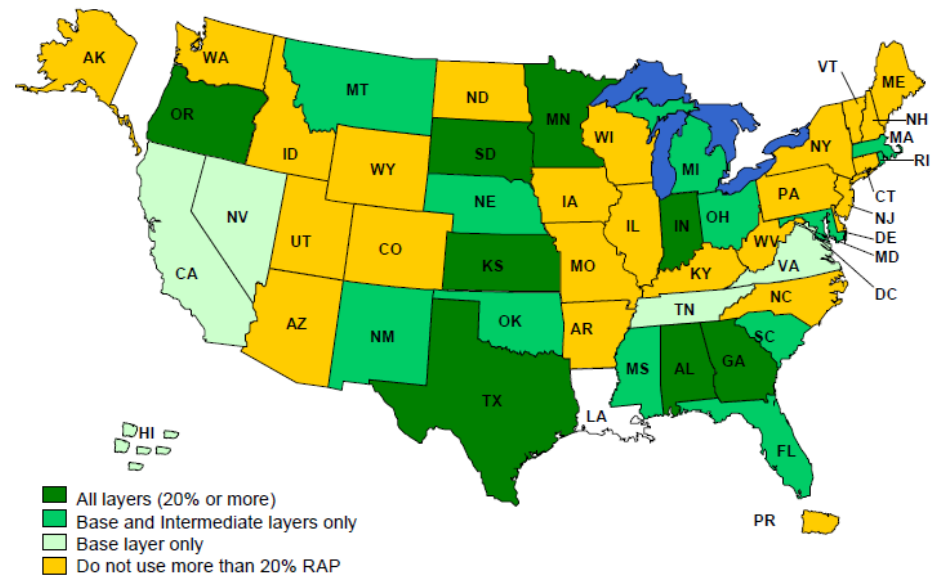
# State of Deployment 2009

## Reclaimed Asphalt Pavement

States that *Permit*  
more than 25% RAP



States that *Use*  
more than 20% RAP



Over 80% State DOTs *permitted* high RAP (> 25%) in the intermediate and surface layers.

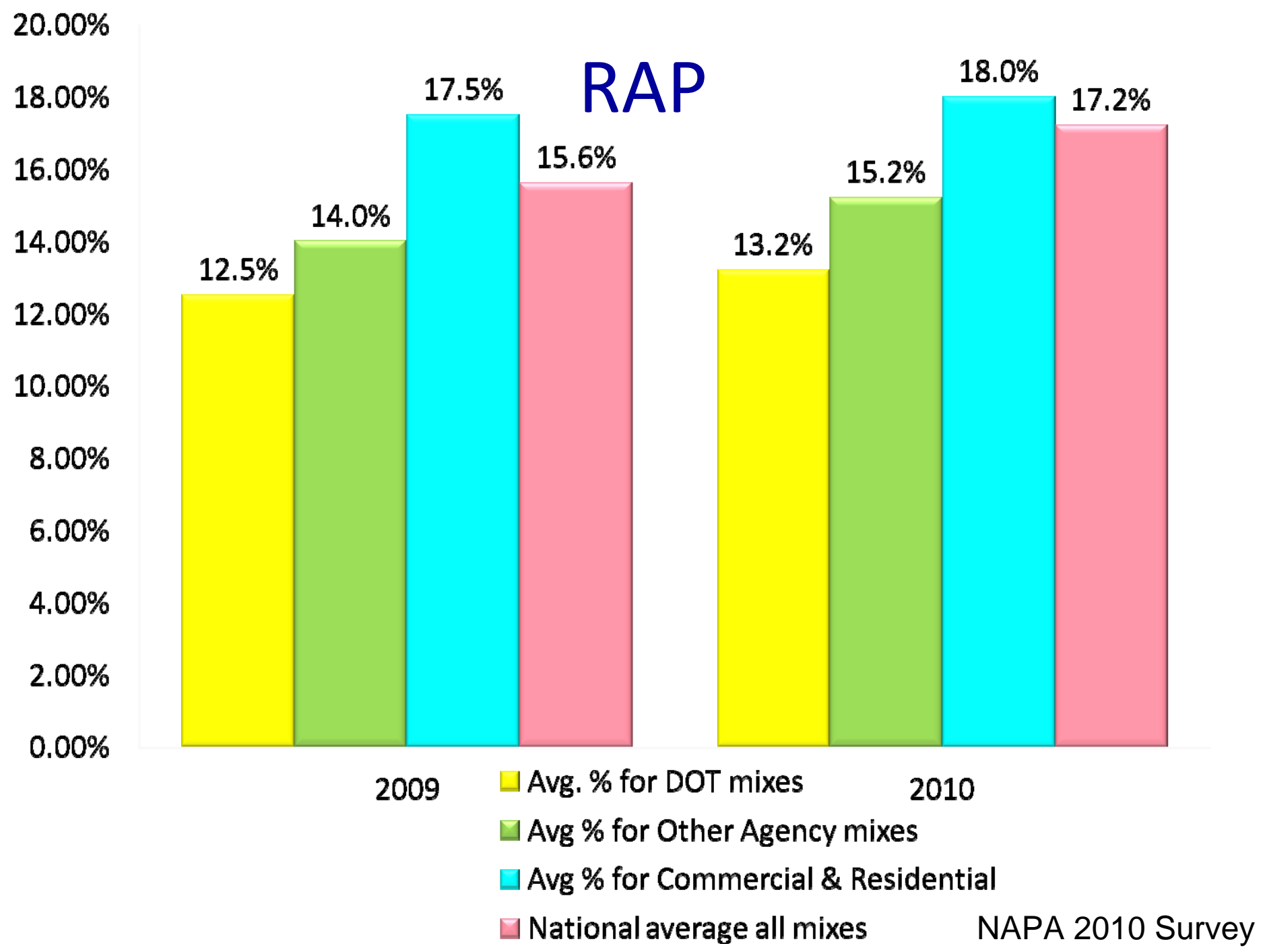
About 42% actually *used* more than 20% RAP in the intermediate and surface layers.

# How far have we come...

- In 2007...
  - Over 60% State DOTs *permitted* high RAP (> 25%) in the intermediate and surface layers.
  - About 25% actually *used* high RAP in the intermediate and surface layers.
  - The average asphalt mixture uses 12% RAP.
- Since 2007...
  - 21 States have increased amount of RAP permitted
  - 23 States now have experience with high RAP mixes
  - 11 States have experience with high RAP and Warm Mix Asphalt mixes



# RAP



# So, why does < half of the nation use < 20% RAP?

- Blended virgin and RAP binder qualities especially for high RAP mixes and polymer modified binders
- Stiffening of the mix from high RAP quantities and resulting cracking performance.



# Other “Roadblocks”

- Presence of dust
- Consistency/variability of RAP
- Lack of Quality Control (QC) by contractor
- Durability, especially in the surface layers
  - Raveling



# Current Guidelines



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

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

- Based on significant blending between virgin and RAP binder
- Effects of plant production unknown
- Calls for virgin binders that may be more expensive, hard to get
- Blending chart analysis is time-consuming!

# National Effort to Increase RAP Use



U.S. Department of Transportation  
**Federal Highway Administration**

# National Effort

- Public & Industry Working Groups
- Funded Coordinated Research and Demonstration Projects
  - NCHRP Projects
  - Cooperative Agreements
  - Mobile Testing Laboratories
  - Turner Fairbank Highway Research Center Labs
- Research Deployment & Technology Transfer for Dissemination and Education
  - Workshops and Symposiums





# HMA Asphalt Pavement Recycling Expert Task Group



Advance the use of RAP & RAS in asphalt paving applications by providing highway agencies with critical information regarding the use of RAP & RAS, technical guidance on high-RAP projects, and direction on research activities.

The members consist of representatives from highway agencies, industry, and academia.

Website: [www.moreRAP.us](http://www.moreRAP.us)



U.S. Department of Transportation  
Federal Highway Administration

FHWA RAP Expert Task Group

- NCHRP 9-46 Mix Design and Evaluation Procedure for High Reclaimed Asphalt Pavement Content in Hot Mix Asphalt
- Objective:  
Develop mix design method and specification for HMA containing up to 50% RAP.



# Summary of on-going research...

- Experience and data supports the proper use of high RAP can provide similar or better performance than virgin mixes, but available plant and field data is sporadic.
- On-going research results indicate high RAP use is possible without adversely affecting performance.
- More studies are needed with emphasis on plant mixtures and field performance.



# Increasing RAP Use

The question we're posing...

- *How much RAP can we allow in the mix and meet specification and constructability requirements?*
- Biggest impact can be made in processing and production.



# Issues to Consider when Increasing RAP

- Additional 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

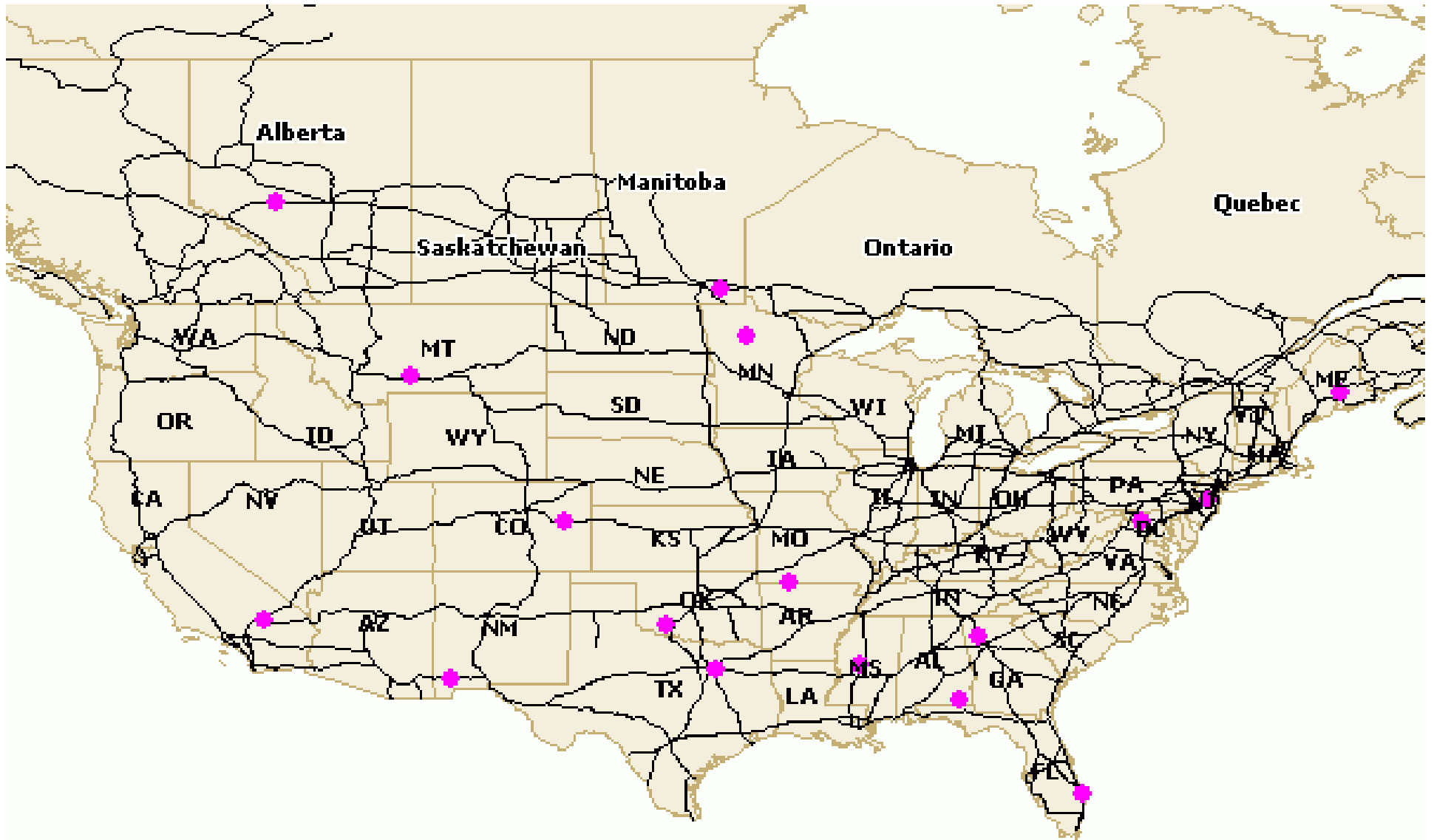


# Long Term Pavement Performance of RAP Mixtures



U.S. Department of Transportation  
**Federal Highway Administration**

# SPS-5 Project Locations



# Evaluating RAP Performance

- Long Term Pavement Performance SPS-5 sections
  - 18 U.S. states and Canadian providences
  - At least 30% RAP
  - Milled and non-milled surface
  - 50 and 125 mm thick
  - Project range in age from 6 to 17 years

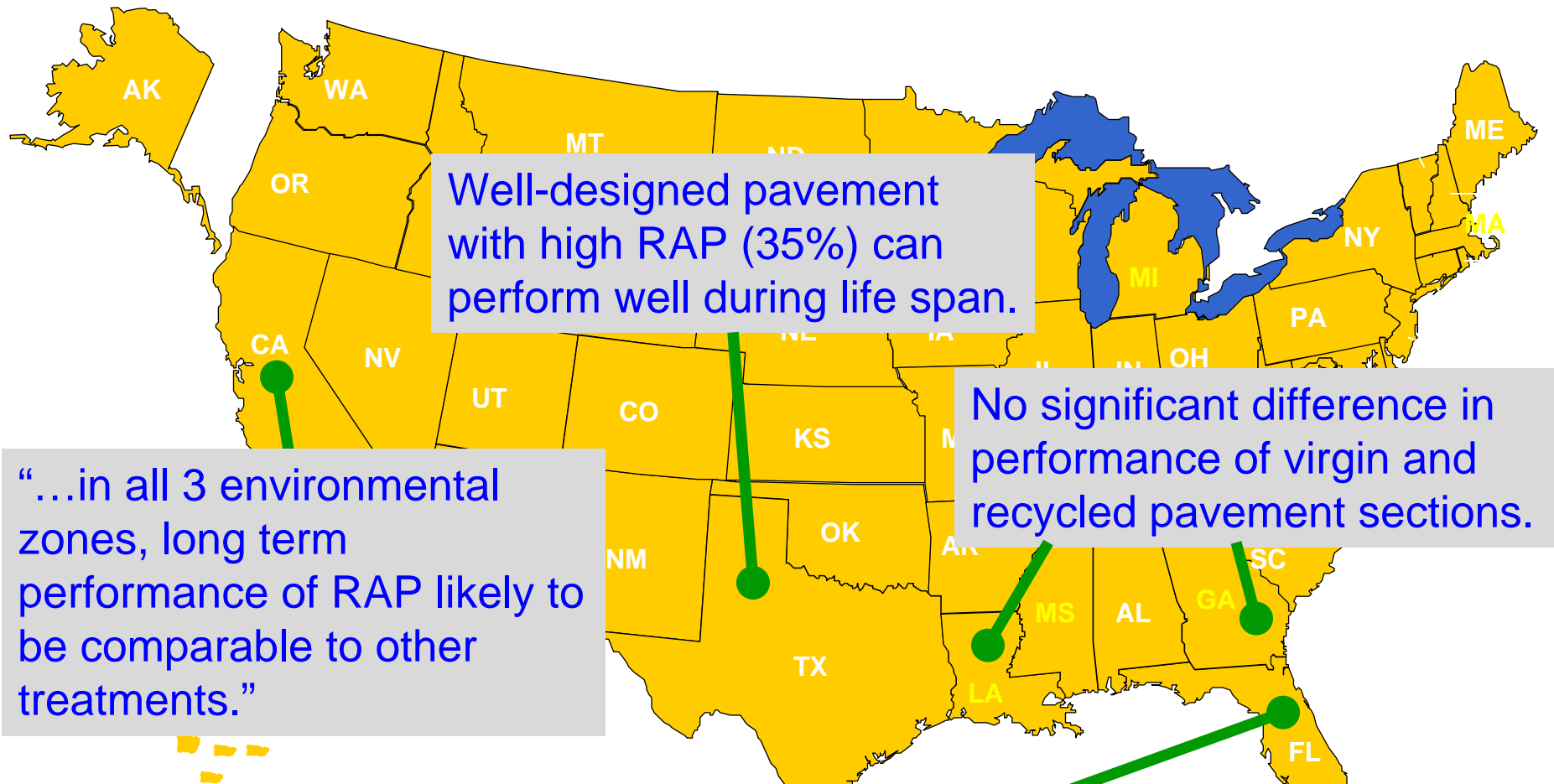


U.S. Department of Transportation  
Federal Highway Administration

LONG TERM  
pavement  
PERFORMANCE



# Long-Term Performance of RAP in HMA



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

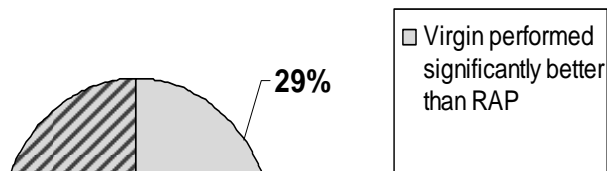
No significant difference in performance of virgin and recycled pavement sections.

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

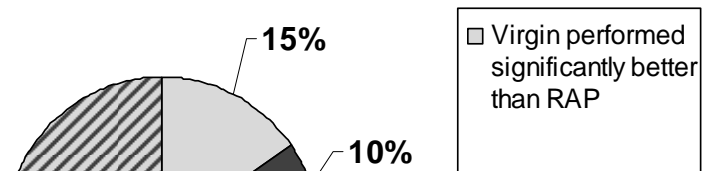
Average age of virgin mixes is 11 years. For 30–50% RAP content, the average age ranges from 10–13 years.

# LTPP Study Results

Fatigue Cracking



Longitudinal Cracking



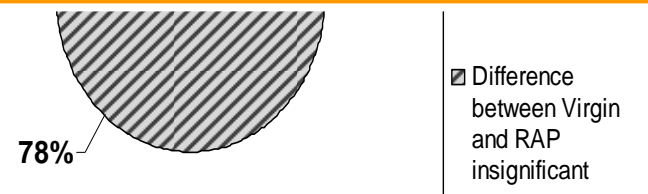
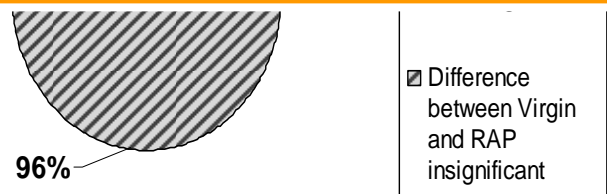
6 RAP Mix Performed As Well As or Significantly Better than Virgin Mix

Fatigue Cracking – 71%

Longitudinal Cracking – 85 %

Block Cracking – 97 %

Raveling – 93 %



# 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.

# TN DOT Video



U.S. Department of Transportation  
**Federal Highway Administration**

# Thoughts...

- Probably the **greatest single upfront cost saving** measure available to US highway agencies today is increasing the use of RAP in the 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.

# Keep Moving Forward



“Get out of my way Daddy, I don’t need your help anymore!”



U.S. Department of Transportation  
**Federal Highway Administration**

FHWA RAP Expert Task Group  
46

# *Thank You*

## Contact Information:

Stephen J. Cooper  
Office of Technical Services (OTS)  
FHWA Resource Center - Baltimore  
10 S. Howard Street, Baltimore, MD 21201  
Email: [stephen.j.cooper@dot.gov](mailto:stephen.j.cooper@dot.gov)  
Phone: 443.257.7145