Best Practices for RAP and RAS Management
Best Practices for RAP Management

Sponsored by the FHWA RAP ETG
RAP
Reclaimed Asphalt Pavement
RAP’s use and the successful performance of pavements including RAP are documented in several reports prepared by agencies and asphalt researchers.

Most notable of these reports is the *Pavement Recycling Executive Summary and Report* (FHWA-SA-95-060), which details the asphalt recycling practices in 17 states. The conclusions to this report include:

- “Pavement performance and detailed evaluations indicate that recycled HMA that is designed and controlled during production will perform comparably to conventional HMA and can improve material properties of the existing pavement layer.”
- “Recycled HMA that is designed and produced in a QA program that verifies mixture design assumptions to reasonable limits can be expected to perform comparably to conventional HMA.”
In 2002 the FHWA issued a formal policy on the use of recycled materials in highway applications.

- The policy outlines the importance of re-using materials previously used in constructing our nation’s highway system, and calls on the FHWA and state transportation departments to explicitly consider recycling as early as possible in the development of every project.

Specifically the FHWA policy states:

- Recycling and reuse can offer engineering, economic and environmental benefits.
- Recycled materials should get first consideration in materials selection.
- Determination of the use of recycled materials should include an initial review of engineering and environmental suitability.
- An assessment of economic benefits should follow in the selection process.
- Restrictions that prohibit the use of recycled materials without technical basis should be removed from specifications.
This report informs practitioners about the state of the practice for RAP use in the US

- As well as best practices for increasing the use of RAP in pavement mixtures while maintaining high quality pavement infrastructures

- Based on an evaluation of pavements containing 30% RAP through the LTPP program it has been determined that the performance of pavements containing up to 30% RAP is similar to that of pavements constructed from virgin materials
Document provided guidance for management RAP materials from the time of collection through processing, mix design and quality control practices

- Represents the current best practices for RAP management
- Goal is to facilitate the most effective utilization of RAP to ensure the greatest economic benefit for RAP and the highest quality recycled asphalt mixtures
Advocate Recycling
- Maximize the existing funding sources
  - RAP use will help mitigate increases in mix cost allowing more of the infrastructure to be addressed
- Poor road conditions cost motorist $65 billion in repairs every year
  - $413 per urban motorist
- Declare increasing the percentage of RAP used a priority within your state
  - Help drive the initiative at to the local level
Recycling of asphalt mixtures dates back to the early 1900s. It did not become a common practice until the early 1980s.
In 2007, a NAPA survey indicated that the national average RAP content for all HMA in the USA was 12%.

A goal was set to double the average RAP content to 25% by 2013.

A survey in 2011 indicates that the average RAP content had increased to 19.1%.
The Value of RAP

- Economic savings
- Environmental savings
- Energy savings
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
Why increase RAP in Asphalt?

- Economic motivation
  - Price increases in liquid asphalt in 2008 were significant
  - While the trend in pricing has flattened, it is not likely pricing will ever return to pre-2008 levels
  - Reduced first and life cycle costs
  - Increase contractor competition
Asphalt Pricing Per Ton 2002 - Current

Producer price index for cement and asphalt
Index: 1 = Jan 2002

- Cement manufacturing
- Asphalt paving and roofing materials mfg

Structural shift where liquid pricing directly linked to crude oil pricing

+26% (2002-2004)
+116% (2004-2007)
Economics Savings Example

- Aggregate: $15.00/ton
- Asphalt: $550.00/ton
- RAP: $9.00
- Mix Design AC Content: 5.0%

<table>
<thead>
<tr>
<th>Material</th>
<th>0% RAP</th>
<th>12% RAP</th>
<th>25% RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate</td>
<td>$14.25</td>
<td>$12.45</td>
<td>$10.50</td>
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<tr>
<td>Asphalt</td>
<td>$27.50</td>
<td>$24.20</td>
<td>$20.63</td>
</tr>
<tr>
<td>RAP</td>
<td>$1.08</td>
<td></td>
<td>$2.25</td>
</tr>
<tr>
<td>Total</td>
<td>$41.75</td>
<td>$37.73</td>
<td>$33.38</td>
</tr>
<tr>
<td>% Savings</td>
<td></td>
<td>9.6%</td>
<td>$20.1%</td>
</tr>
</tbody>
</table>
Why increase RAP in Asphalt?

- Best use of RAP is in Asphalt
  - Reuse limited and diminishing natural resources (aggregate and asphalt) to ensure best value of the materials being recycled are being achieved, now and in future
  - Energy savings derived from RAP use
  - RAP used in 2007 would be valued in excess of $2.5 billion in today’s costs
    - This would extend work which could be completed with the existing funding, buying the US Taxpayer more for their money

- Environmental benefits of recycling
  - Sustainability movement
  - Reduction in greenhouse gas emissions
  - Each year over 100 million tons of HMA is reclaimed, over 80% is reused or recycled
  - The asphalt industry recycles nearly twice as much as the combined total of paper, glass, aluminum, and plastics
Energy Consumption Related to Road Construction and Maint.

MJ/tonne

Source: The Environmental Road of the Future, Life Cycle Cost Analysis, Chappat and Bilal, Colas Group 2003, p.34
Why increase RAP in Asphalt?

- RAP has a proven track record
    - “Hot mix recycling cannot be approached as a means of using a waste product but rather from the standpoint that a paving mixture of equal or superior quality will result”
    - “Because of the impressive pavement performance exhibited by the recycled pavements, ...benefits such as conservation of natural resources, ...and its cost advantage...hot-mix recycling has become an attractive addition to the paving program”
  - GADOT (1995 – “Performance of Recycled HMA Mixtures in Georgia”)
    - “Comparison of recycled vs. conventional mixes on 15 projects indicated the RAP mixes performed equal to or better than the virgin mixes”
  - FHWA (1996 – “Pavement Recycling Executive Summary and Report”)
    - “Recycled HMA, which is designed and produced in a quality assurance program that verifies mix design assumptions to reasonable limits, can be expected to perform comparably to conventional HMA.”
Why increase RAP in Asphalt?

- RAP mix quality is equal to virgin Asphalt
  - Processes in place currently to ensure quality of Asphalt containing RAP
  - Technical questions related to RAP can be answered
    - Improvements in mix design methods
    - Improvements in plant quality control
    - Improvements in processing RAP
    - Improvements in handling RAP
    - Modified plants
    - Improvements in placing Asphalt mixtures
    - Improvements in acceptance procedures for Asphalt
AASHTO Survey on RAP Use
Barriers Identified by States

- Stockpile Management
  - Quality of original stone, Gradation Control, Origin of Material Unknown
- Availability of RAP
  - Use in Base or Shoulders (unbound), too contaminated
- Binder Issues
  - Bumping Grade, Properties of Final Blend, Compaction Issues, Additional Tank Required
- Mix Issues
  - Durability Questions, Additional Testing Requirements, Variability of RAP Mixes
- Contractor Unwilling to Use
- Existing Specifications
- Resistance of Pavement Designers
- Resistance to Change
- Perceptions
  - Less Quality, Industry Can’t Do It, Value Not Shared, Difficult to Evaluate
RAP Sources

Pavement Milling

Asphalt Pavement Removal

Plant Waste Material

U.S. Department of Transportation
Federal Highway Administration

FHWA RAP Expert Task Group
Millings Stockpile

- Minimal Additional Processing Needed
Minimize Contamination
Contaminated RAP
Plant Waste

- Start up
- Clean out
- Project returns
### How Recycle AC content impacts Binder Reduction

<table>
<thead>
<tr>
<th></th>
<th>Average liquid Usage for the Year =</th>
<th>AC Replaced</th>
</tr>
</thead>
</table>
| 15% Binder replacement (BR) | 5.00%  
\[=5.00 \times 0.15\] or 0.75 |             |

**Impact of RAP AC on %BR**

<table>
<thead>
<tr>
<th>% BR using</th>
<th>RAP w. RAP AC of 4.5%</th>
<th>% BR using</th>
<th>RAP w. RAP AC of 5.5%</th>
<th>% BR using</th>
<th>RAP w. RAP AC of 4.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>18%</td>
<td>0.81</td>
<td>15%</td>
<td>0.825</td>
<td>15%</td>
<td>0.675</td>
</tr>
</tbody>
</table>
RAS
Recycled Asphalt Shingles
10 million tons of asphalt Shingles enter waste stream each year
- 1 million tons manufacturer waste
- 9 million tons tear-offs or used Shingles
- Third largest construction material waste

ARMA analyzed a number of recycling options and identified HMA as the best use
- Volume of waste used
- Ease of recycling since Shingles composed of materials routinely used in HMA
Why use Shingles?

- Economic benefits
  - Estimated cost savings per ton of HMA ranges from $4.00 to $6.00+
  - Not all benefits accrue to all users
    - Tipping fees and handling costs vary
    - Actual savings more likely to be $3.00 to $5.00

- RAP sources are declining

- It’s the right thing to do
  - Process can be engineered to provide HMA with equivalent performance
RAS Benefits

- Potential benefits from the use of Shingles in HMA include:
  - Improved resistance to pavement cracking
    - Due to reinforcement from fibers
  - Improved resistance to rutting
    - Due to fibers and increased stiffness of binder
  - Reduced costs for the production of HMA
    - Conservation of natural resources
  - Conservation of landfill space
    - Reduced costs for Shingle waste disposal
- Studies ongoing at this time
  - At this time consider impact as neutral
Shingles typically contain:

- Asphalt binder
  - Tear-offs contain 30 – 40% binder
  - Manufacturer waste 18 – 22% binder
- 40 to 60% hard rock granules and fillers
- 1 to 12% fiber, felt, and miscellaneous materials
Mayer, MN TH25 Overlay 1991

1995:
- Shingle sections performing as well as control
- Transverse reflective cracking evident in both control and shingle test sections

2003:
- Shingle sections performing as well as control

- Previously overlaid 1974
- Surface oxidation and severe transverse cracks every 10-feet
- Medium traffic volume: ~2,000 ADT

(From MnDOT Report No. 96-34)
Waterloo, Ontario, Canada Highway 86 1996

- 2-Lane road expanded to 4-lane highway
- Subbase
- Lower Binder: 1.5-inch
- Upper Binder: 2-inch with 3% shingles
- Wearing Course: 1.5-inch w/ 3% shingles
- See Yonke, et.al. Report for testing details

Control mix, 1999:
- Fine aggregate raveling
- Longitudinal joint raveling and opening
- Fatigue cracking in wheelpath

Shingle mix, 1999:
- No fine aggregate raveling
- No longitudinal joint raveling or opening
- No fatigue cracking in wheelpath

(Courtesy Paul Lum, LaFarge, 2001)
Worcester, MA Demonstration Project 2000

- Commercial street, Worcester, MA
- 1 ¾” of Modified Top placed over existing roadway
- 5%, ½” RAS
- Manufacturer’s off-specification shingles
- Constructed September 21, 2000
- Standard paving equipment and procedures used
- Photos taken June 2002
RAS Paving Projects – TX Bitulithic
PP 53-06 Design Considerations when Using Reclaimed Asphalt Shingles in New HMA

- Provides guidance on:
  - Design considerations
    - “the size of the RAS can be expected to affect the fraction of RAS binder that contribute to the final blended binder”
    - “Particles of undissolved asphalt binder may act like aggregate particles that require more virgin asphalt binder to accomplish coating”
    - “fibrous material present in RAS may also require additional virgin asphalt binder to accomplish coating”
AASHTO Standard Practice

- PP 53-06 Design Considerations when Using Reclaimed Asphalt Shingles in New HMA
  - Provides guidance on:
    - How to determine the shingle aggregate gradation
      - “it is suggested the shingle fiber present in the shingle be removed prior to testing”
    - How to estimate the contribution of the RAS binder to the final binder blend
      - “finer the grind, the greater the amount of the contribution of binder from the reclaimed asphalt shingle to the final blended binder”
      - “Recognized limitations in procedure due to assumptions related to: the amount of shingle binder released into the mix, the additional absorption due to the RAS present in the mix, the additional existing coating requirements due to the RAS present in the mix”
AASHTO Standard Practice

- MP 15-06 Use of Reclaimed Asphalt Shingle as an Additive in HMA
  - Provides standard definitions for RAS
  - Requires RAS to be processed so that 100% passes the 12.5-mm sieve
    - Allows the blending of RAS with fine aggregate to prevent agglomeration of RAS particles
  - Requires additional testing of the composite binder if the percentage of liquid contributed by the RAS and RAP exceeds 30 percent
  - Addresses deleterious materials present in the RAS
The age old engineering question
- How do you make a square peg fit into a round hole?
Processing Shingles for Use in HMA

- Various equipment has been tried to grind the Shingles into a usable product
  - Shredding approach
Processing Shingles for Use in Asphalt

- Environmental concerns
  - Typical concerns for aggregate crushing and HMA production
  - HMA with Shingles is recyclable
  - Asbestos screening
    - Must comply with local agency requirements, which vary from state to state
### Complete performance grading of PG 64-28 blended with RAP and Shingles
- Two mixes: Binder 5.1% AC, Top 5.5% AC
- Tested various combinations of mix components

<table>
<thead>
<tr>
<th>Test</th>
<th>Criteria</th>
<th>Original Binder</th>
<th>RTFO Binder Residue</th>
<th>PAV Binder Residue</th>
<th>Resulting Binder Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotational Viscosity</td>
<td>3.0 Pa-s</td>
<td>1.165 Pa-s</td>
<td>0.526 Pa-s</td>
<td>1.203 Pa-s</td>
<td>0.863 Pa-s</td>
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<tr>
<td>Dynamic Shear</td>
<td>1.0 kPa</td>
<td>1.954 kPa</td>
<td>2.021 kPa</td>
<td>1.717 kPa</td>
<td>1.141 kPa</td>
</tr>
<tr>
<td>Mass Loss</td>
<td>1.0%</td>
<td>0.89%</td>
<td>0.80%</td>
<td>0.97%</td>
<td>0.90%</td>
</tr>
<tr>
<td>Dynamic Shear</td>
<td>2.2 kPa</td>
<td>7.094 kPa</td>
<td>7.544 kPa</td>
<td>7.39 kPa</td>
<td>5.069 kPa</td>
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<tr>
<td>Dynamic Shear Slope</td>
<td>0.300</td>
<td>0.334</td>
<td>0.314</td>
<td>0.334</td>
<td>0.309</td>
</tr>
<tr>
<td>Creep Stiffness</td>
<td>300 MPa</td>
<td>48 MPa</td>
<td>168 MPa</td>
<td>50 MPa</td>
<td>85 MPa</td>
</tr>
<tr>
<td>Creep Stiffness Slope</td>
<td></td>
<td>0.300</td>
<td>0.334</td>
<td>0.314</td>
<td>0.334</td>
</tr>
</tbody>
</table>

**Resulting Binder Grade**
- PG 76-16
- PG 64-28
- PG 76-16
- PG 76-22
Oldcastle Materials RAS Use

- Began using shingles in 2002
  - 2010 OMG used 87K tons of shingles in asphalt mixtures
  - 2011 OMG used 135K tons of shingles in asphalt mixtures
  - 2012 OMG used 308K tons of shingles in asphalt mixtures
  - 6 of 7 OMG Divisions used shingles in 2012, 17 different companies
- Shingles were used in:
  - Texas
  - Missouri
  - Oregon
  - Iowa
  - New Hampshire
  - Oklahoma
  - Pennsylvania
  - North Carolina
  - Alabama
  - Ohio
  - Arkansas
  - West Virginia
  - Kentucky
  - Virginia
  - Mississippi
  - Kansas
  - South Dakota
Oldcastle Materials RAS Production

- No significant production or placement problems
- Mix design considerations
  - Typical use is 3 – 5, in some cases as high as 7% of mix
  - Percentage use is based on mix type, surface vs. binder
  - Marshall and Superpave designs developed
- Shingles used in batch and drum facilities
- Concerns regarding the control of the addition of small amounts of shingle materials
  - Belt scale, belt speed, or use of carrier aggregate to address
- Have not encountered serious problems with shingles stored over the winter
Issues and concerns noted:
- Shingle sand and Shingle RAP blends tend to retain moisture
- Mix working time reduced
- Material handling
- Shingle tabs can get through grinder
- Lack of general acceptance of this recycling practice
  - Necessitates ability to use multiple recycled products at the same time
- Uniformity of Shingle grind supplied
  - Oversized particles may require screening after grinding
  - Binder content consistency
RAP and RAS
Inventory Management and Processing
# Binder Replacement Explained

![Diagram showing the contribution of different factors to binder replacement]

<table>
<thead>
<tr>
<th>Design Binder %</th>
<th>Binder % Contribution from RAP</th>
<th>Binder % Addition from RAP Management</th>
<th>Binder % Addition from Plant Operation Inefficiencies</th>
<th>Binder % Addition from Plant Calibration Errors</th>
<th>Actual New Binder % Demand</th>
</tr>
</thead>
</table>

Represents Lost Opportunity
Inventory Analysis

- **Purpose**: establish realistic goals for how much RAP or RAS can be used at a particular plant
- **Analysis should include**:
  - Inventory of RAP and RAS on hand and what is generated per year
  - Summary of mix produced per year by mix types and customers
  - Determine the max amount of RAP and RAS that can be used
  - Comparison of the quantity of RAP and RAS available to the amount needed

50
Simple spreadsheets can be developed to evaluate different use scenarios to identify the best case for individual plants

- Analysis should consider allowable recycle material % by specifications and any plant limitations
- Analysis can show the maximum opportunity to use RAP or RAS
Initial RAP management decision is whether or not to create one or multiple RAP stockpiles based on the following factors:

- Agency specifications
  - RAP from other sources
  - Captive vs. Replenished stockpiles
- Potential for Contaminants
- Space availability
- Target use levels
- RAP from single project
Types of RAP Stockpiles

- Captive Stockpiles
  - Some agencies require no additional material can be added to a RAP stockpile once it is built and tested
    - May be required when pavement friction is a concern
    - Based on premise that the properties of the stockpile must be precisely known if it to be used
    - This requirement can be problematic if plant footprint is limited

- Continuously Replenished Stockpiles
  - Many agencies allow RAP stockpiles to be replenished with new material
    - Need to ensure RAP consistency through a RAP quality control plan
Goals of processing RAP are to:

- Create uniform stockpile from a collection of different RAP materials
- Break apart large agglomerations of RAP particles to a size that can be used during production
- Reduce the max aggregate size so RAP can be used in surface mixes
- Minimize the generation of additional P200
  - Screening prior to crushing will help reduce unnecessary aggregate break-down
Millings from single project are usually very consistent in:
- Gradation
- Binder content
- Aggregate properties
- Binder properties

Processing may only be required to:
- Eliminate agglomerations
- Reduce max aggregate size

Recommended Processing Options
- Sample and test multiple locations of the millings stockpile to determine RAP quality
- If the max aggregate size is too large either:
  - Fractionate the RAP for use in different mixes
  - Process by crushing to the desired agg size
Processing Millings

- It is considered a best practice **not** to further crush millings, but to use it “as is” in mix designs or to screen the milling to remove larger particles.
RAP from multiple sources must be processed to create a uniform material
- Data suggest very consistent material can be produced
- Key is careful blending as part of the processing operation
  - Bulldozer, excavator, loader can be used to blend materials from different areas of the stockpile
- In most cases, processed RAP will be moved to the plant site for convenient use
  - This is an opportunity to remix the RAP to improve its consistency
  - Use the loader to mix the RAP from different locations in the processed RAP stockpile
Crushing RAP will create more aggregate fines
  - Ideally RAP should be screened before crushing to remove particles which do not need to be processed
A variety of crusher types are used for processing RAP

- Cone crusher
- Jaw crusher
- Vertical Shaft Impactor
- Horizontal Shaft Impactor
- Roller/Mill-type Breakers

HSI are preferred because they break up chunks of pavement or agglomerations of RAP rather than downsizing aggregate size.
Care must be used when in-line RAP crushing is undertaken

- Important to understand the potential for and address changes in RAP gradation when these systems are used
- Ideally in-line crushing circuits will be designed to only break up agglomerations
Weather

- Moisture and temperature affect crushing, or shredding, and screening of RAP and RAS
  - During wet or hot periods RAP and RAS will be sticker and tend to:
    - Build up in feeders and crushers
    - Blind screens
    - RAP fines will stick to belts
  - This can impact the RAP and RAS gradation and binder content
Fractionating RAP

- Primary advantage of fractionating RAP is having stockpiles of different RAP sizes provide flexibility in meeting mix design requirements
- Typical Sizes
  - 3/4” – 3/8”
  - 3/8” – 3/16”
  - Minus 3/16”

- When should fractionating be considered:
  - Plants can produce mixes with more than 20% RAP
  - Typical specifications allow more than 20% RAP
  - RAP is readily available
  - Plant site has space for multiple RAP stockpiles
  - Problems meeting mix design requirements
  - Problems meeting project QC requirements
Fractionating RAP

3/4 x 3/16” RAP
In back

-3/16” RAP
+3/4” RAP
Fractionating should not be mandated

- It should be the contractor’s business decision if and when to fractionate RAP
Stockpiling RAP

- Segregation Control
  - There is a potential for RAP to become segregated in stockpile
    - More common when:
      - Piles are built using fixed conveyors that allow RAP to drop long distances
      - Steep sided conical piles are built
  - Use of an indexing conveyor can be used to help eliminate pile segregation
Stockpiling RAP and RAS

- Moisture Control
  - Consider the following to reduce the moisture in RAP and RAS
    - Process RAP and RAS on an as needed basis when possible
    - Cover the processed material with a shelter or building
    - Place RAP in well built conical stockpile
    - Place on a paved sloped surface
    - Avoid depressions in piles which will accumulate water
Advantages and Disadvantages of Different RAP and RAS Processing Options

- When making your business decision on how to handle and process RAP and RAS ensure you consider the advantages and disadvantages of each process

<table>
<thead>
<tr>
<th>Process</th>
<th>Possible Advantages</th>
<th>Possible Disadvantages</th>
</tr>
</thead>
</table>
| Use of Millings without Further Processing | • Avoids further crushing of aggregate particles in RAP, which may allow higher RAP contents in mixes  
  • Lowest cost of RAP processing options  
  • Millings from large projects are likely to have a consistent gradation and asphalt content | • Requires multiple RAP stockpiles at the plant  
  • Millings from individual projects are different; therefore, when a particular millings stockpile is depleted, new mix designs must be developed with other RAP |
| Screening RAP Before Crushing              | • Limits crushing of aggregate particles in RAP, which reduces dust generation       | • Few RAP crushing and screening units are set up to pre-screen RAP                     |
| Crushing all RAP to a Single Size          | • Allows the processed RAP to be used in many different mix types  
  • Generally provides good uniformity from RAP materials obtained from multiple sources  
  • Large RAP stockpiles can be generated for annual production | • Tends to increase the dust content of RAP stockpiles, which may limit how much RAP can be used in mix designs |
| Fractionating RAP                          | • Using different sized RAP stockpiles provides greater flexibility in developing mix designs | • Requires the most space for multiple smaller stockpiles  
  • Most expensive processing option (cost of fractionation unit plus additional RAP cold feed bin)  
  • May generate an excess of a RAP size if the mix designs are not balanced to the RAP feed |
Sampling and Testing RAP
Principles of RAP Management

• Good materials management practices should always be part of the quality control program for any asphalt mix production operation

• As RAP contents increase, it becomes more important to accurately determine properties of RAP and control its consistency
Variability: RAP vs. Aggregate

Based on 74 RAP stockpiles in 14 states, and 60 Aggregate stockpiles in 6 states
Fractionated vs. Unfractionated

Standard Deviations

- Non
- Fine
- Coarse

<table>
<thead>
<tr>
<th></th>
<th>Pb</th>
<th>P0.075</th>
<th>Median Sieve</th>
</tr>
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<tbody>
<tr>
<td>Non</td>
<td>0.43</td>
<td>1.27</td>
<td>5.89</td>
</tr>
<tr>
<td>Fine</td>
<td>0.55</td>
<td>1.1</td>
<td>4.61</td>
</tr>
<tr>
<td>Coarse</td>
<td>0.47</td>
<td>0.98</td>
<td>4.39</td>
</tr>
</tbody>
</table>
Sampling RAP

• The goal of sampling RAP is to obtain representative samples for evaluating materials properties.

• Samples are needed from throughout the stockpile to assess variability. A minimum sampling frequency of 1 per 1000 tons with a minimum of 10 samples is strongly recommended.
Sampling RAP

- The best method to sample RAP is to use a loader to create flat-topped miniature stockpiles.
- A good time to sample is when a stockpile is being built at its final location.
- Do not combine samples from different parts of the stockpile. Tests need to be performed on individual samples to assess uniformity.
Testing RAP

• General properties:
  - asphalt content
  - aggregate gradation
  - aggregate bulk specific gravity
  - fine aggregate angularity
  - fractured face count
  - flat & elongated percentage
  - deleterious materials
Testing RAP

• Depending on agency specifications, aggregate source properties may also need to be tested
  – LA Abrasion
  – Sulfate Soundness

• For use of RAP in friction courses, additional aggregate properties such as acid insoluble, loss on ignition, or petrographic analysis may be needed.
Testing RAP

- Asphalt Content: ignition method is preferred. An aggregate correction factor must be assumed. For regions that utilize dolomite aggregates that have erratic correction factors, a solvent extraction method is recommended.
Potential Errors with the $G_{sb}$ Determination

- Creates uncertainty with VMA, a very important property related to durability
- Thus, it is important to conduct durability performance tests for high RAP content mixes
- Binder Grade Selection
  - 15%
  - 25%
- AASHTO M323
FIELD EXPERIENCE

• <15% most common

• >15% brings increased cost
  (PG 58-28 instead of PG 64-22)

• >25% almost never used
  Extraction and recovery too cumbersome
RAP Expert Task Group
Current Activities

• Asphalt Binder Replacement
  – AASHTO M323
    • Based on RAP %
    – Formulating recommendations for
      • % Binder replacement

• Recommendations to DOTs
  – Before changing to binder replacement
    • Quantify properties
Indiana Change to Binder Replacement

- January 2010
- Previously % RAP
  - 15%, reduce one grade
  - 25% maximum allowed
- Currently
  - Up to 25% no change in grade
  - 25 to 40% reduce one grade
  - 40% maximum allowed
Determining RAP Properties in Indiana

33 RAP Stockpiles

U.S. Department of Transportation
Federal Highway Administration

FHWA RAP Expert Task Group
At least 10 samples when building stockpile

Split each sample

Ignition method tests

Max. specific gravities

Gradations

Asphalt contents

Gse → Gsb

Combine samples for other aggregate tests

Table:

<table>
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<th>3/4&quot;</th>
<th>1/2&quot;</th>
<th>3/8&quot;</th>
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<th>#8</th>
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<td>45.6</td>
<td>34.4</td>
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Summary & Analysis of RAP Data

- Calculate average and standard deviation of asphalt contents, gradations, and estimated $G_{sb}$
- Compare to these recommended tolerances

<table>
<thead>
<tr>
<th>RAP property</th>
<th>Max. Standard Deviation (%)</th>
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<tr>
<td>Asphalt Content</td>
<td>0.5</td>
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<td>% Passing Median Sieve</td>
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<tr>
<td>% Passing 75 micron Sieve</td>
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Conclusions

- RAP has a proven record of performance when properly design and produced
- RAS use is growing across the US and offers the ability to achieve binder replacement when RAP may be unavailable
- Use of recycle materials will keep asphalt competitive and provide value to owners
- Use best management practices to ensure quality mixes are produced while maximizing the value opportunity of the recycle materials
Impact of RAP and Thickness on Cost

- Boost use of RAP and RAS to lower asphalt prices
- Target: Increase RAP/RAS content to average of 25%
- NCAT research suggest pavement thickness could be reduced by up to 18%
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