Rebecca S. McDaniel, PE, PhD

Technical Director
North Central Superpave Center
Purdue University
West Lafayette, IN
765/463-2317 ext 226
rsmcdani@purdue.edu

https://engineering.purdue.edu/NCSC
Reclaimed Asphalt Pavement (RAP)

- In the USA recycling began over 40 years ago because of:
  - Oil embargo – shortages and high prices
  - Environmental concerns
  - Development of milling machines
Milling

- Removes old/distressed pavement
- Improves smoothness
- Eliminates costly shoulder work
- Maintains drainage features, curbs, overhead clearance
- Valuable rehabilitation option
Typical Asphalt Mix

- 95% aggregate
- 5% asphalt binder

Reusing:
- Reduces asphalt demand
- Reduces need to quarry more aggregate
  - Difficult to open a new pit or quarry
- Reduces energy/costs to produce, process, transport aggregate
Today in the USA

- Asphalt pavement is *the* most widely recycled material
- 100 million tons reclaimed annually
- 95% is reused or recycled
- $1.8 billion in savings
- Reduces demand for new aggregates and binder and the energy to produce them
- Strong incentives to use more RAP in more mixes – economic and environmental
Current US Guidelines

- Adjust grade of binder added to account for the hard, oxidized binder in the RAP
  - 0 to 15% RAP, no binder grade change
  - 16-25% RAP, decrease virgin binder grade
  - Over 25% RAP, test RAP binder to determine appropriate virgin grade (or allowable RAP content)
- Percentage by weight of RAP in the mixture.
- Based on non-fractionated mixes with about 5% binder in RAP and new mix.
Surface Mixes

- Typically specifications allow lower RAP contents because of:
  - Friction of unknown aggregate types
  - Potential for cracking of stiffened mixes
- Thinner lifts have less overall aggregate demand than intermediate and base mixes
- But, they are more frequently replaced
- Potential big impact by using more RAP in surfaces
50 US States

- Every state is different!
- National specifications are guidelines, not requirements
- States have adapted the guidelines to suit their methods, perceptions and experience.
Base Mixes – Average Use 2010
Changes Occurring in US Practice

- States are moving to higher RAP contents in more mixtures.
- More contractors are splitting the RAP into different size fractions, called fractionating.
- More states are changing to expressing RAP content in terms of percent of RAP binder that is replacing new binder.
- More interest in recycling asphalt shingles.
RAS = Recycled Asphalt Shingles

- Very high binder contents, as high as 30%
  - Greatly reduces demand for new binder
  - Hard, angular fine aggregate and fibers

- But, shingle binder is very stiff (oxidized) so there is concern about cracking

- So, allowable shingle content is about 20-25% as high as allowable RAP content
Recycled Shingles
RAP and RAS Binder Replacement

\[
\frac{(A \times B) + (C \times D)}{E} \times 100\%
\]

where

- \( A \) = binder content in RAP, %
- \( B \) = RAP content in mixture, %
- \( C \) = binder content in shingles, %
- \( D \) = shingle content in mixture, %
- \( E \) = total binder content in mixture, %
What We Have Learned

- High RAP contents can work – can *perform well* – if properly designed, produced and constructed.

- Start with good mix design that accounts for the RAP.

- But, need attention to detail during construction.
Some Keys to Success

- Processing the RAP
- Stockpiling the RAP
- Control during production
Composite Stockpiles

- Chunks and slabs from full depth pavement removal
- Plant cleanout
- Rejected material or excess returned from jobs
- Other sources

Variable Material
Processing RAP

- Mixed RAP can be variable
  - Crush/Screen to break up clumps
  - Improve uniformity
  - Uniformity is essential to meet specifications
In Composite Pile

After Processing
Crushing and Screening
The reprocessed products are very consistent components.
Fractionated RAP = Crushed and screened into different sizes

- Improves uniformity (remixes)
- Allows use of different sizes to meet mix design
- Better control of gradation (and binder content)
Fractionated RAP
Stockpiling Practices

- Avoid segregation
- Avoid contamination
- Reduce stockpile moisture
- Test the RAP stockpiles regularly – know what is in your stockpiles!
Contamination - Not Good
Reduce Stockpile Moisture

- Lose ~12% production capacity for every percent stockpile moisture above 2%
- Reduce fuel consumption and drying costs by keeping your materials dry
- Lower moisture leads to increased production capacity
- Lower maintenance and fuel costs for loaders
- Lower paving costs
- How can we reduce moisture?
Paved and Sloped Stockpiles

- Paving prevents mud at the bottom of pile.
- Slope grade 3 to 4°
- Moisture drains to bottom of pile and runs along the slope.
- Pick off high side of pile
- Face slope towards sun for more drying
- Can reduce moisture 2% overall
Covered Stockpiles

- Still rare but useful, especially in high moisture areas
100% Recycle Plant
Plant Control for RAP Mixes

- Control plant inputs (cold feeds)
- Control material variability
- Follow-up Quality Control test results
- Watch drum flighting – maintain protective veil inside drum
- Avoid overheating mix
- Normal production care and attention
Summary of RAP Best Practices

- Mill layers separately when you can
- Process RAP and stockpile properly
- Fractionate RAP
- Avoid contamination
- Keep the RAP and aggregates dry – paved and sloped area, covered stockpile
- Test the RAP stockpiles regularly
- Watch plant production
Performance: RAP vs. Virgin

- Using data from Long Term Pavement Performance (LTPP) 20-year study
- Five performance measurements
  - Rutting, mm
  - Roughness (IRI), m/km
  - Fatigue cracking, m²
  - Transverse cracking, # per section
  - Longitudinal cracking, m
- 18 sites with ≥ 30% RAP and control section with no RAP
Performance of RAP Mixes

- Pavements with ≥ 30% RAP perform equal to or better than virgin in most cases
- Somewhat more transverse and fatigue cracking with RAP compared all virgin materials
- Differences in cracking may have been due to lower asphalt contents and/or higher dust contents (poor mix design)

West, et al., NCAT
Cost/Benefits of RAP

- **Milling or Pavement Salvage Costs**
  - Mill, haul & stockpile: \( \approx 6.50/\text{ton} \)
  - Excavate, haul & stockpile: \( \approx 7.00/\text{ton} \)
  - Reprocessing: \( \approx 5.00/\text{ton} \)

- **Virgin Material Costs**
  - Coarse Aggregate \( \approx 12.00/\text{ton} \)
  - Fine Aggregate \( \approx 8.00/\text{ton} \)
  - PG Binder \( \approx 450.00/\text{ton} \) (when analysis was done)
  - Ton of Virgin Mix = \( 50/\text{ton} \) for Intermediate, \( 60/\text{ton} \) for surface course
### Cost Savings using RAP for a typical 19.0 mm Intermediate

<table>
<thead>
<tr>
<th>% RAP</th>
<th>Per ton Savings $ (materials only)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>$3.40</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>$5.50</td>
<td>Does not include premium PG58-28</td>
</tr>
<tr>
<td>40</td>
<td>$6.80</td>
<td>Includes premium PG58-28</td>
</tr>
</tbody>
</table>

25% RAP in an intermediate 19.0mm HMA will save approximately 11% per ton. Assuming a 3” lift; for every $1 million resurfacing project this will equate to approximately 2.2 lane miles of additional paving.
Another Way to Look at Savings

- One medium sized US paving contractor uses 900,000 tons RAP per year
- That is equivalent to 1,460,000 gallons of gas
- Which is enough to fuel 1,650 big Ford Expeditions
Conclusions

- RAP has long history of successful use.
- Asphalt recycling is sustainable.
- Asphalt recycling is economical.
- Asphalt recycling works!