

Asphalt Pavement Recycling: US Experience

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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.

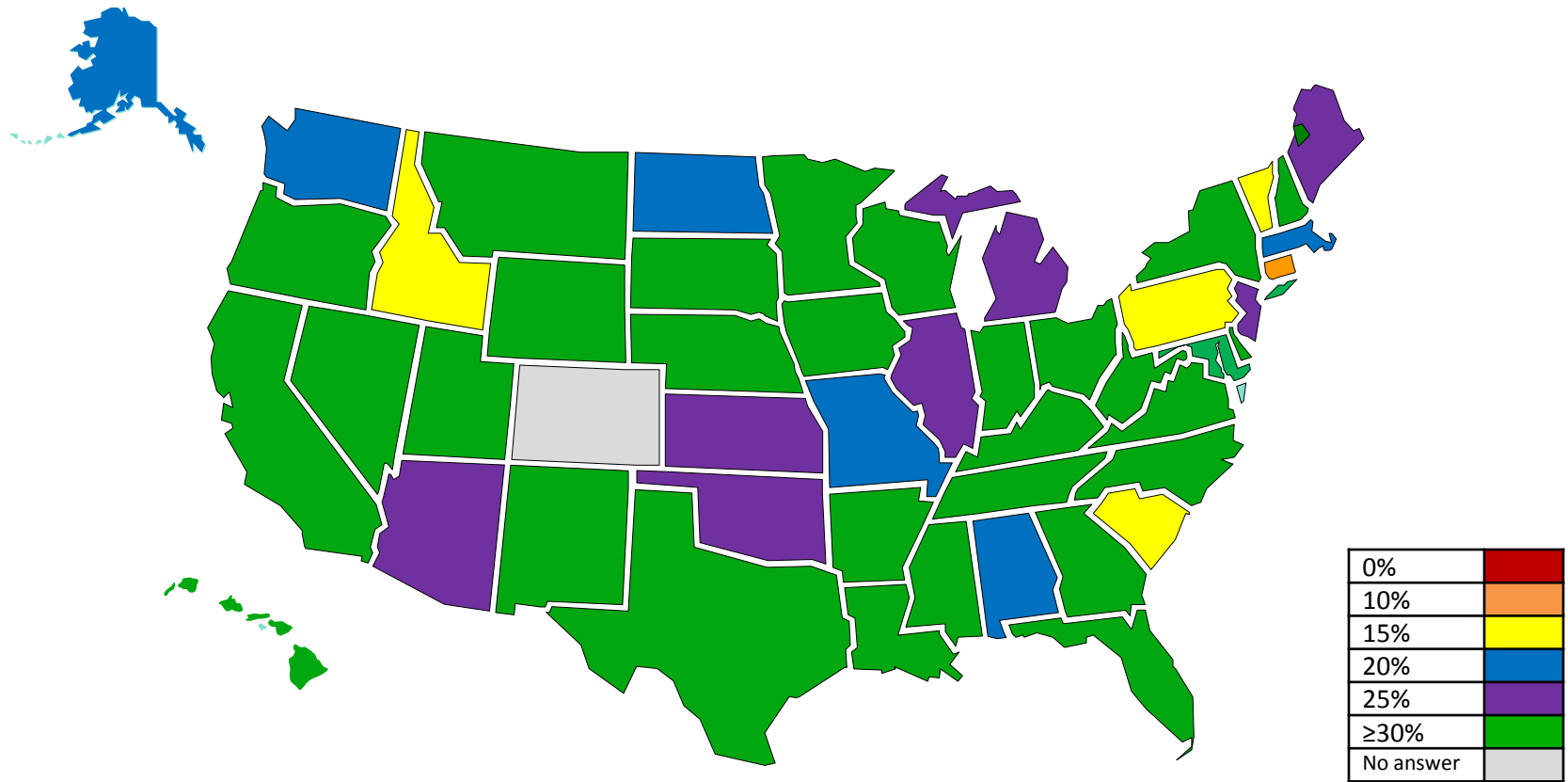
Surface Mixes

- 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

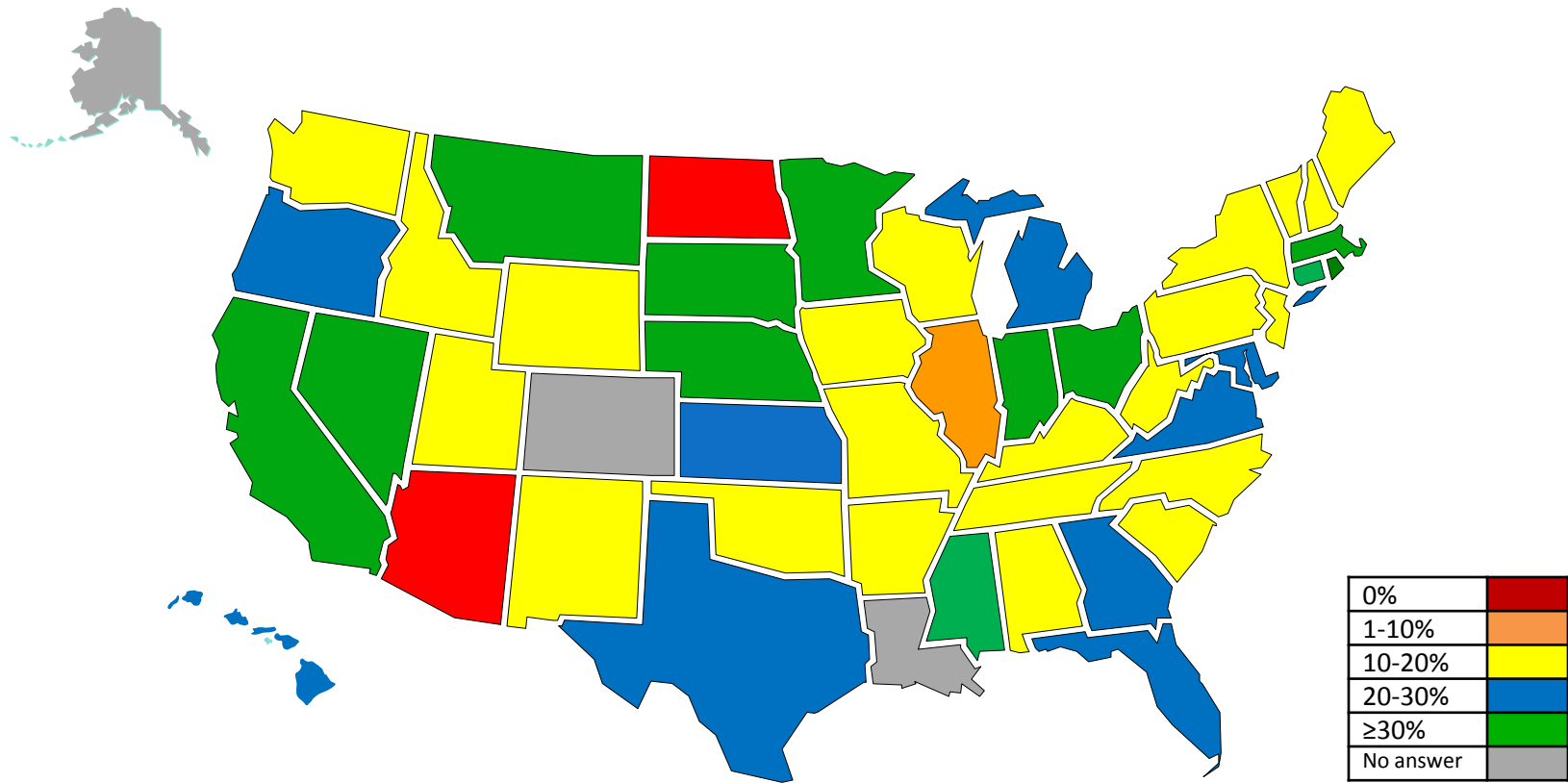
50 US States

- Every state is different!
- National specifications are guidelines, not requirements
- States have adapted the guidelines to suit their methods, perceptions and experience.

Maximum RAP in Base Mixes - Specified 2010



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



Before



The reprocessed products are very consistent components

After



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)

FRAP



Fractionated RAP

Stockpiling Practices

- Avoid segregation
- Avoid contamination
- Reduce stockpile moisture
- Test the RAP stockpiles regularly – *know what is in your stockpiles!*



Segregation

Coarse Area

Fine Area



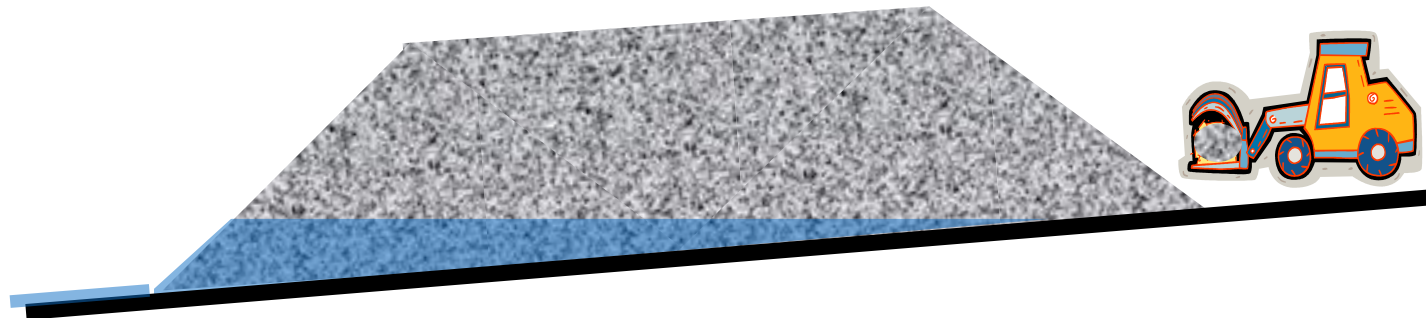
Contamination-
Not Good

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



Mix Plant Operations

RAP Collar





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 $\geq 30\%$ RAP and control section with no RAP

Performance of RAP Mixes

- Pavements with $\geq 30\%$ 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

| % RAP | Per ton Savings \$ (materials only) | Notes |
|-------|--|----------------------------------|
| 0 | 0 | |
| 15 | \$3.40 | |
| 25 | \$5.50 | Does not include premium PG58-28 |
| 40 | \$6.80 | Includes premium PG58-28 |

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!



Totally Recyclable

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