RAP Binders and Materials: Trends in RAP Use

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Building on Past Success

- Asphalt pavement is *the* most widely recycled material in the USA
- 100 million tons reclaimed annually
- 95% is reused or recycled
- $1.8 billion in savings each year
- Reduces demand for new aggregates and binder and the energy to produce them
- Can perform as well as virgin mixes

Reclaimed Asphalt Pavement (RAP)

Recycling began in USA over 40 years ago because of:

- Arab oil embargo – shortages and high prices
- Environmental concerns
- Development of milling machines

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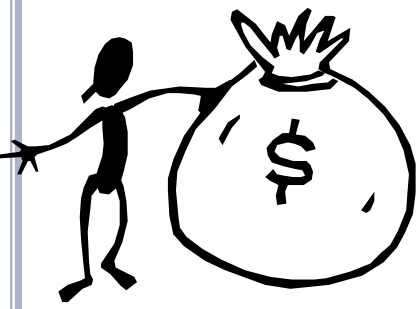
And today???


WHAT TO DO WITH THE RAP?



TODAY IN THE USA

Strong incentives to recycle more

- Economics
  - Saves money
  - Makes contractors more competitive
  - Helps asphalt retain market share
- Environmental
  - Increasing awareness, legislation, regulations

Current AASHTO 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.

NCHRP 9-12

- *Incorporation of Reclaimed Asphalt Pavement in the Superpave System*
- North Central Superpave Center (Purdue) and the Asphalt Institute
- Led to current AASHTO guidelines
- Conducted prior to fractionating RAP or before there was much experience with RAP in Superpave mixes.

Major Variables

- Three RAP Sources with Different Stiffnesses – Low, Medium and High
- Two Virgin Binders – PG64-22 and PG58-34
- RAP Contents – Up to 40%
- Same RAP, virgin binders and virgin aggregates used throughout project.

Key Findings

- As RAP content increased;
  - mix stiffness increased,
  - rutting decreased,
  - fatigue and thermal cracking resistance decreased (if binder grade was not changed at higher RAP contents).
- The stiffest RAP produced stiffest mix.
- At low RAP contents, effects of RAP were not significant.
- As RAP content increased from 20 to 40%, effects became more pronounced.

Since NCHRP 9-12

- More research has been performed
- States and contractors have gained valuable field experience with RAP mixes
- There have been technological advances
  - Fractionating RAP, in particular
  - Changes in test methods

Bottom Line

RAP mixtures should be able to perform at least as well as virgin mixes.

RAP and Virgin Binders

- When going to higher RAP contents, need more attention to RAP binder properties
  - AASHTO guidelines are a starting point for grade selection
  - Should be fine-tuned to account for local (state or regional) materials and practices

Conventional Wisdom

- RAP contains old, hardened binder that will stiffen the mix
- This will help reduce rutting
- May increase cracking tendencies
- There is research and experience to support conventional wisdom

Possible Effects of RAP Binder

RAP aggregate with oxidized binder film

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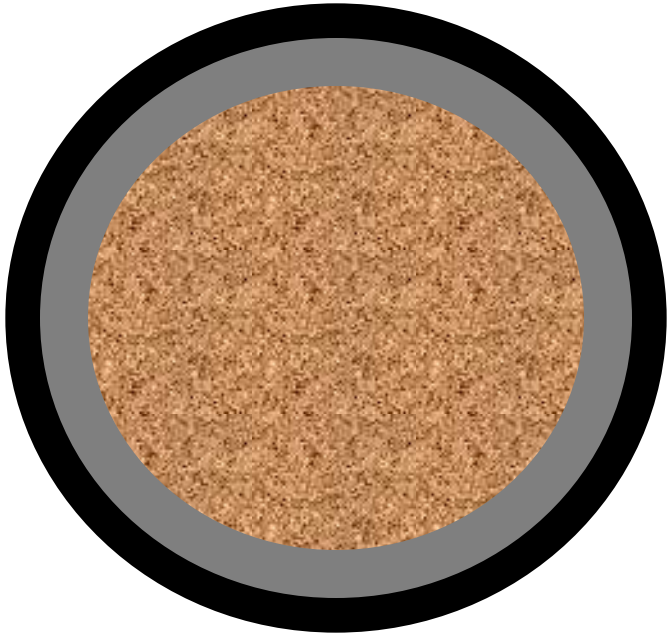
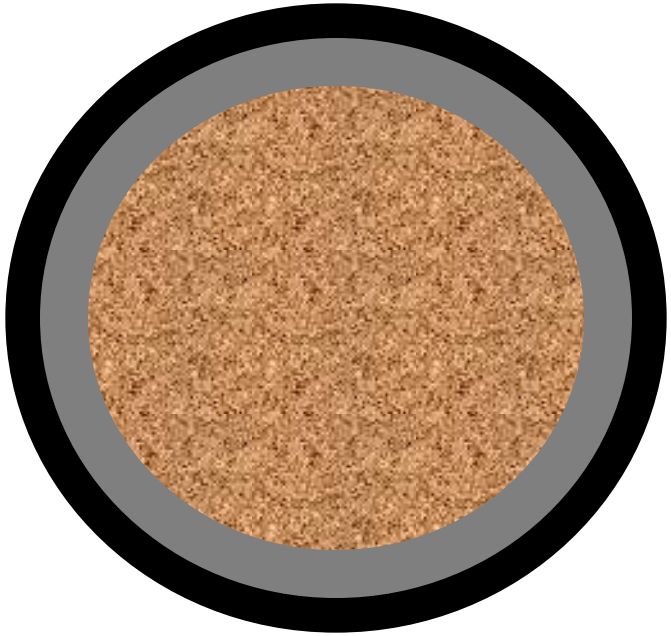


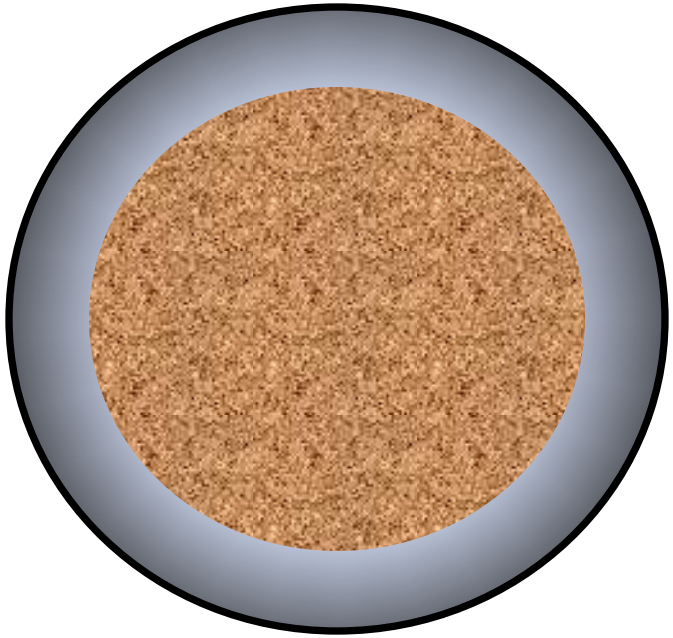
RAP aggregate with oxidized binder film plus virgin binder film

Possible Effects of RAP Binder



If RAP and virgin binders do not blend, effective binder properties will be those of the virgin binder only.

Possible Effects of RAP Binder



If RAP and virgin binders blend or merge, effective binder properties will be determined by the amount of blending that occurs.

Impacts of Blending on Performance

- If we assume there is blending and there isn't, virgin binder may be softer than desired.
  - Increased chance for rutting
  - Decreased chance for cracking

- If we assume there is no blending and there is, effective binder grade may be stiffer than desired.
  - Decreased chance for rutting
  - Increased chance for cracking

Risks of False Assumptions

- Assuming there is blending may be more conservative.
  - Shouldn't rely on binder to control rutting
  - Increased cracking can have performance and economic impacts
- Current guidelines are a starting point, but not the definitive answer
  - Several states have increased RAP contents to ~20-25% before grade change based on testing and monitoring performance

Guidelines May Be Conservative

- Study for Indiana DOT showed they could use higher RAP contents before changing grade
  - Up to 25% RAP before changing grade
  - Up to 40% RAP by using one grade softer
- INDOT evaluated over 30 RAP stockpiles around the state
  - *They know what their RAP is like*

RAP Aggregate Considerations

- RAP Aggregate Properties
- Gradation
- Specific Gravity
- RAP Frictional Properties

RAP Aggregate Properties

- Mixes with and without RAP should be held to same blended aggregate properties
  - Fine aggregate angularity
  - Coarse aggregate angularity
  - Gradation
  - Flat and elongated limit
- Exception – sand equivalent value waived on RAP aggregates since they have already been coated with binder

Aggregate Gradation Considerations

- Final mixture must meet gradation requirements
- Fineness of some RAPs can limit use
- Fractionating can help – you can choose how much fine and coarse RAP to use
- Variability in RAP gradation can impact ability to meet mix requirements – consider processing RAP and stockpile best practices (next presentation)

RAP Specific Gravity

- NCHRP 9-12 recommended:
  - Use RAP agg effective specific gravity, or
  - Backcalculate bulk s.g. from Rice density and assumed/ estimated absorption.
  - Agency discretion.
- Other options
  - If aggregate properties do not change during extraction or ignition oven burn-off, recover and test RAP aggs
  - State specified specific gravity, if known not to be highly variable (typically not recommended)

RAP Aggregate Friction Concerns

- RAP may contain aggs with poor friction Concern for surface mixes
- Some states (like Illinois) require milling surfaces separately so that agg properties for new surfaces are known
  - Mixed layers not allowed for use in surfaces
- Other states (like Indiana) have evaluated 'worst case' aggregates to explore blending with higher friction aggs to establish allowable surface RAP contents

Changes Occurring in US Practice

- States are moving to higher RAP contents in more mixtures (with or without grade change)
- More contractors are splitting the RAP into different size fractions
- More states are expressing RAP content in terms of percent of RAP binder
  - Helps account for different RAP binder contents in fine vs coarse RAP
  - Also helpful with other recycled materials, like shingles (where used)

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)
- Fine RAP contains higher binder content

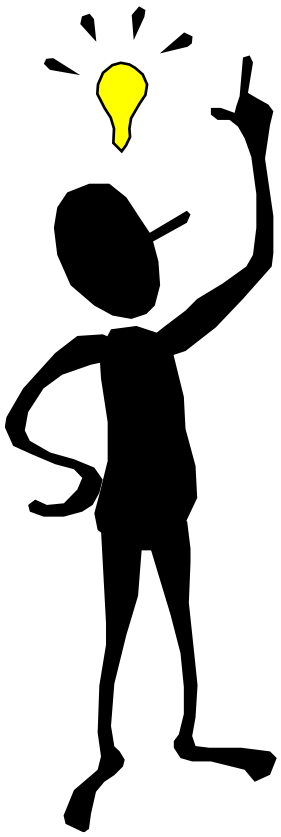
FRAP

Binder Replacement

$$\frac{(AxB) + (CxD)}{E} \times 100\%$$

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, %

Alternates: Maximum Reclaimed Binder Content or Minimum Virgin Binder Content



What We Have Learned

- High RAP contents can work – can *perform well* – if properly designed, produced and constructed.
- Start with good mix design and materials selection to account for the RAP.
- And, need attention to detail during construction.

THANK YOU!

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