A rational method for selection of type and amount of rejuvenators for high RAP content HMA recycling

Karen A. O’Sullivan
Professor Rajib B. Mallick; Advisor
1. Our research challenge and proposed solution
2. Comsol simulations to understand our challenge
3. Experimental investigation of our proposed solution
4. Current Standing and What’s Next
In 2009, NAPA reported over 100 million tons of asphalt pavement is reclaimed annually.

In the same year, the FHWA reported that national RAP utilization remains at an abysmal 13%. 

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Challenge

100% recycling has been achieved by utilization of Hot in-place recycling.

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The Essence of Recycling

REJUVENATION

- Removes the need for binder bumping
- Single product storage for producers
- No limitations on upper limit of RAP
- Economically and Environmentally desirable
Diffusion of Rejuvenator into Age-Hardened Asphalt Binder

- RAP Surface Asphalt
- Absorbed RAP Bitumen

Black is un-available RAP bitumen
Grey is available RAP surface binder
Light grey hatch is rejuvenator added to RAP

Rejuvenator
Asphalt Binder
Stoke-Einstein Equation

\[ D = \frac{K_B T}{6\pi \mu(R)} \]

Fick’s Law

\[ J = -D \frac{\partial C}{\partial x} \]

- \( K_B T \) is the internal heat energy;
- \( K_B \) is Boltzmann’s constant (1.3807*10^-23 J/K);
- \( T \) is absolute temperature (K);
- \( D \) is rate of diffusion (m^2/s);
- \( R \) is the mean molecular radius;
- \( \mu \) is dynamic viscosity (Pa*s)

- \( J \) is diffusion flux (mol/m^2·s);
- \( D \) is diffusion coefficient;
- \( C \) is concentration (mol/m^3);
- \( x \) is distance (m)
Diffusion of Rejuvenator into Age-Hardened Asphalt Binder
Evaluation Plan

Select RAP, gradation, & asphalt content

Select rejuvenating agent

Determine the amount of rejuvenator to add

Add uncoated/new aggregates to compensate for the added liquid

Compact samples to obtain desired volumetrics

Volumetric Criteria Met?

Test Mechanical Properties over sequence of Aging Protocol

Properties within tolerable range of new mix?

Compact samples to construction voids

YES

NO

A

C

C

E

P

T

YES

Samples aged @ 60ºC between test cycles

Cumulative Percent Passing (%)

Cumulative Percent Passing (%)

Sieve Size (mm)

Target - High

Burnt RAP

Target - Low

0.075 0.15 0.3 0.6 1.18 2.36 4.75 9.5 12.5
Aging protocol causes an increase in $|E^*|$ over time.

-10°C

21.1°C

54.4°C

HMA Control Mix

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Progression of $|E^*|$

- **24.4°C, 10Hz**
  - HMA Control Mix
  - 0.5% RJ
  - 1.0% RJ

- **34.1°C, 10Hz**
  - HMA Control Mix
  - 0.5% RJ
In Conclusion

If a rational method of using rejuvenators in hot mix recycling can be developed, very high RAP content mixes can be implemented resulting in significant economical and environmental benefits to the paving industry.
What’s Next

• **Diffusion Modeling**
  – Effect of different variables (viscosity of aged binder, temperature of recycling)

• **Dynamic Modulus Testing**
  – Add a 100% RAP mix to matrix for a base-line
  – Continue testing $|E^*|$ until statistically insignificant changes occur
  – Once $|E^*|$ “levels” off, Creep Compliance and IDT will be determined

• **Proof Testing**
  – Hamburg Wheel Test
  – Overlay Tester

• **Recovered Binder testing will not** be included, we do not believe the extracted binder is representative of the RAP properties.
• Thank you to our contributors, Bob Frank of RAP Technologies, Tom Bennert of Rutgers University, and Maine DOT.

• Any suggestions/feedback to improve and/or expand our research efforts are welcomed.
THANK YOU!