

Asphalt Rejuvenation 101

Mike Anderson, Asphalt Institute 64th Annual NJ Asphalt Paving Conference

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- National Cooperative Highway Research Program (NCHRP)
 - Project 09-12, "Incorporation of Reclaimed Asphalt Pavement in the Superpave System"
 - Becky McDaniel, Principal Investigator
 - NCHRP Web Document 30 and NCHRP Report 452
 - Project 09-58, "The Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios"
 - Amy Epps Martin, Principal Investigator
 - NCHRP Report 927
- Federal Highway Administration
 - $^{\circ}$ DTFH61-08-H-00030 and DTFH61-11-H-00033

- Airfield Asphalt Pavement Technology Program (AAPTP) Project 06-01
 - "Techniques for Prevention and Remediation of Non-Load-Related Distresses on HMA Airport Pavements"
- TPF-5(153)
 - "Optimal Timing of Preventive Maintenance for Addressing Environmental Aging in Hot-mix Asphalt Pavements"
- Member Companies of the Asphalt Institute

<u>Reclaimed</u> <u>Asphalt</u> Pavement

Old asphalt pavement that has been removed from the roadway by either milling or full-depth removal. It is <u>reclaimed</u> for further use.



<u>R</u>eclaimed <u>A</u>sphalt <u>S</u>hingles

Asphalt Shingles are collected during the shingle manufacturing (manufacture waste) or re-roofing (post-consumer). Facilities then process (usually grind). Once processed, RAS is then ready for Hot Mix Asphalt.



RAS Basics

- RAS is considerably stiffer than RAP
- A rough assumption is a 5 to 1 trade off • Reduce RAP 5% for every 1% RAS used
- A little RAS goes a long way to stiffen the binder
- Asphalt binder blending charts are more exact and required by some DOTs
- Standards like AASHTO PP 78 are changing to adjust for the latest findings and guidance
 - $^{\rm o}$ Most recent recommendation is addition of $\Delta {\rm T_c}$ calculation on low temperature PG



What Is Binder Ratio? (Formerly "Binder Replacement")

- NCHRP Report 752, <u>Improved Mix Design, Evaluation, and Materials</u> <u>Management Practices for Hot Mix Asphalt with High Reclaimed</u> <u>Asphalt Pavement Content</u>
- Introduces the term, RAP Binder Ratio (RAP_{BR})
 - "RAP binder ratio" is preferred because "the word "replacement" infers that virgin binder is replaced with RAP binder. Replacing virgin asphalt with recycled binder is not what is really done in mix designs with RAP materials. Rather, what the research team wants to identify with this term is the portion of the total binder content that comes from the RAP." (NCHRP 752, p96)

Recovery of Asphalt Binder

AASHTO re:Source (AMRL) PSP Analysis



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Summary

- Removal of solvent is critical during recovery procedures
 - Abson standard procedure may not perform as well, particularly for hardened asphalt binders
- Variability in recovered asphalt binder properties is approximately 3x the variability of a non-recovered asphalt binder
- Variability appears to be a function of recovery, not the specific recovery procedure
- Technique/skill matters

Blending of Virgin and Reclaimed Asphalt Binder

Developing Blending Charts - Method A



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		Continuous Grade		M320 Grade	
RAP Source	RAP %	PG 52-34	PG 64-22	PG 52-34	PG 64-22
None	0	53-33	66-26	52-28	64-22
FL	10	57-33	69-26	52-28	64-22
	20	60-31	71-24	58-28	70-22
	40	66-29	73-22	64-28	70-22
	10	57-33	69-25	52-28	64-22
СТ	20	60-31	70-24	58-28	70-22
	40	67-29	77-22	64-28	76-22
AZ	10	57-32	68-24	52-28	64-22
	20	63-29	72-21	58-28	70-16
	40	70-24	78-19	70-22	76-16

	Arizona RAP - PG 52-34				
Tcritical	0%	100%	10%	20%	40%
Estimated	-23.7	-5.6	-21.9	-20.1	-16.5
Actual	-23.7	-5.6	-22.4	-20.9	-17.6
Diff. (A-E)	0.0	0.0	-0.5	-0.8	-1.1

BBR Stiffness

BBR m-value

	Arizona RAP - PG 52-34				
Tcritical	0%	100%	10%	20%	40%
Estimated	-25.9	-7.1	-24.0	-22.1	-18.4
Actual	-25.9	-7.1	-22.8	-19.9	-14.8
Diff. (A-E)	0.0	0.0	1.2	2.2	3.6

Aging of Asphalt Binder

Zube and Skog: "Final Report on the Zaca-Wigmore Asphalt Test Road"

- 1969 AAPT Paper
- Relevance to PG Specification
 - From SHRP Report A-367 (Pages 36-37):
 - "At the suggestion of the A-003A researchers, and in light of an evaluation of the fatigue performance in field trials such as Zaca-Wigmore (figure 2.22), the fatigue criterion was changed to reflect the energy dissipated per load cycle. Dissipated energy in a dynamic shear test is appropriately calculated as G* sin δ (Ferry 1980)."

Zube and Skog: "Final Report on the Zaca-Wigmore Asphalt Test Road"

2. Two main types of failure during service life were encountered on the project. The most prevalent was fatigue cracking as displayed by wheel track "alligator" type cracking. The other was a large block type cracking together with pitting and raveling. This was most prevalent in the passing lane. The amount of fatigue type cracking appears to be related to the consistency of the recovered asphalt as measured by penetration and viscosity. The other form of cracking appears to be related to the gain in shear susceptibility during weathering. This is also indicated by a marked drop in ductility during service life. This form of cracking, as found on this test project appears to be the same as that encountered by P. C. Doyle, reference (4), on other test roads.

- Fatigue Cracking
 - Related to recovered asphalt binder consistency (i.e., stiffness)
- Block Cracking with Raveling
 - Weathering characterized by drop in ductility (i.e., viscoelastic behavior)



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AAPTP 06-01: Durability



Can ΔTc be used to predict cracking?

- ΔTc is thought to be directly related to block cracking.
 - However, fatigue, edge, longitudinal, reflection, and transverse cracking may indirectly be related to ΔTc of the binder.
 - These distress types are typically caused by other factors, yet ΔTc can play a supporting role in their development.



Reference for Delta Tc

• In October 2019, Asphalt Institute published

- "Use of the Delta Tc Parameter and its Relevance in Characterizing the Behavior of Asphalt Materials"
- The IS can be viewed and downloaded for free from the AI website at the following link:
 - http://www.asphaltinstitute.org/en gineering/delta-tc-technicaldocument/



ΔT_c is an Indicator of Oxidative Aging



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MnROAD Cell 24

Witczak and Mirza: Global Aging Model (AAPT 1995)



ΔT_c is an Indicator of Oxidative Aging



ΔT_c is an Indicator of Oxidative Aging



NCAT Materials

- RAS study conducted by Richard Willis and Pamela Turner
 - Four RAS sources (MW, PC, Blend) supplied
 - ΔT_c values variable
 - Difficult to test BBR at elevated temperatures

RAS	Tc,High	Tc,Low	ΔΤϲ
NH (PC)	163	+12	-33
OR (Blend)	152	+14	-37
TX (MW)	122	-7	-23
WI (MW)	146	+16	-40

Durability and Recycled Materials

- A few words about durability and recycled materials (e.g., RAP and RAS)...
 - Understand effects of materials
 - Adding age-hardened asphalt binder with reduced relaxation to mix in some proportion
 - "The very high binder viscosities that can potentially exist in aged pavements could contribute significantly to surface cracking by preventing any healing from occurring at the pavement surface during hot summer weather." ~ NCHRP Report 567

Rejuvenation of Reclaimed Asphalt Binder

The French Fry Analogy



- How do you Reheat Leftover French Fries?
 - Microwave
 - Restores the warmth, but not the crispness
 - Conventional Oven
 - Heats, but can dry them out

The French Fry Analogy



- Rejuvenation of French Fries (foodnetwork.com)
 - Transfer them from the takeout container into an airtight storage container.
 - Store in refrigerator for maximum of two days.
 - Allow them to come to room temperature for about an hour.
 - Heat a few tablespoons of olive oil in a nonstick pan over medium heat just until it starts to shimmer.
 - The oil helps to "fry" the French fries a second time and get them extra crispy.
 - Put the leftover fries in the hot oil in a single layer, making sure not to crowd the pan.
 - Cook the fries undisturbed until they're warmed through, then toss in the skillet until they're crisp.
 - Remove from the oil and drain on a paper-towellined plate.
 - Add/adjust seasonings.





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Project 09-58: The Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios

NCHRP Report 927

- High RBR = 0.3 0.5
- Assess effectiveness of rejuvenators at selected dose to
 - partially restore binder rheology
 - improve mixture cracking performance without adversely affecting rutting resistance
- Evaluate the **evolution of rejuvenator effectiveness** with aging
- Recommend evaluation tools



Draft AASHTO Standard Practice for 0.3-0.5 RBR + Rejuvenator

- "Characterization of Asphalt Mixtures with High Recycled Materials Contents and Recycling Agents"
 - Component Materials Selection and Proportioning Guidelines
 - Rejuvenator Dose Selection and Incorporation Methods
 - Binder Blend Rheological Evaluation Tools
 - Mixture Performance Evaluation Tools
 - RAP Binder Availability Factor

Component Materials Selection and Proportioning

Base Binder

 $\Box PGH \leq 64^{\circ}C$ $\Box \Delta T_{c} @ PAV20 \geq -3.5^{\circ}C$

 $\Box PGH \leq 100^{\circ}C$ $\Box \Delta T_{c} @ PAV20 \geq -7.5^{\circ}C$

□ PGH < 150°C



$\Box RBR \leq 0.5$ $(RAP_{BR}+RAS_{BR})$

 $\Box RAS_{BR} \leq 0.15$

Recycling Agent Dose Selection Method

1. Determine PGH of the base binder and RAP/RAS binders per AASHTO M 320

Recycling Agent Dose Selection Method

 Select the base binder, RBR, and RAP/RAS combination and calculate PGH of the recycled binder blend using the following Equation

$PGH_{Blend} = (RAP_{BR} \times PGH_{RAP}) + (RAS_{BR} \times PGH_{RAS}) + (B_{BR} \times PGH_{Base})$

where:

PGH_{Blend} = Continuous PGH of the recycled binder blend (°C)

 $RAP_{BR} = RAP$ binder ratio

PGH_{RAP} = Continuous PGH of the RAP binder (°C)

 $RAS_{BR} = RAS$ binder ratio

PGH_{RAS} = Continuous PGH of the RAS binder (°C)

 B_{BR} = Base binder ratio = 1 - RBR

PGH_{Base} = Continuous PGH of the base binder (°C)

Recycling Agent Dose Selection Method

3. Estimate recycling agent dose using the following Equation

Recycling Agent (%) = (PGH_{Blend} -PGH_{Target}) /
$$(1.82)$$

where:

PGH_{Blend} = Continuous PGH of the recycled binder blend (°C) calculated from Step 2

PGH_{Target} = Continuous PGH of Target Climate

1.38

for petroleum-based aromatic extracts

Example: Determine PGH_{Blend}

- Conditions
 - $\circ RAP_{BR} = 0.45$
 - \circ PGH_{RAP} = 88
 - No RAS
 - \circ PGH_{Base} = 67
 - Not using petroleum-based aromatic extract as a Recycling Agent
 - \circ PGH_{Target} = 70

 $PGH_{Blend} = (RAP_{BR} \times PGH_{RAP}) + (RAS_{BR} \times PGH_{RAS}) + (B_{BR} \times PGH_{Base})$

$PGH_{Blend} = (0.45 \times 88) + (0.55 \times 67) = 76$

Recycling Agent (%) = (76 - 70) / 1.82 = 3.3%

the recycling agent percent by mass of total binder in the asphalt mixture, including base binder and RAP binder

Binder Blend Rheological Evaluation

T & Aging Conditions	Test	Parameter	Suggested Performance Threshold		
T _{high} Unaged, Short- Term	DSR	PGH	Target Climate		
T _{int} Track w/Aging	DSR	G-R	<u><</u> 180 kPa after 20-hr PAV <u><</u> 600 kPa after 40-hr PAV		
	DSR	T _{δ=45} •	< 32°C after 20-hr PAV < 45°C after 40-hr PAV		
T _{low} Long-Term	BBR	ΔT_c	<u>></u> -5.0 after 20-hr PAV		
Short-Term Aging = RTFOT Long-Term Aging = PAV @ 100°C		Crossover a the storage n and the phas	Crossover temperature : the temperature at which the storage modulus (G') is equal to the loss modulus (G'') and the phase angle is 45°.		

RAP Binder Availability

- The quantity of effective or available RAP binder in the mixture is usually unknown and less than 100%, which may yield a dry mixture with a high air void content due to less total effective binder content, potentially leading to premature distress.
- RAP Binder Availability Factor (BAF), expressed as a decimal, can be used to adjust the base binder content in hot mix asphalt mixtures with RAP to ensure that the mix design optimum, and effective, binder content is achieved

RAP Binder Availability

• The RAP BAF can be estimated using equation based on the PGH_{RAP}

$RAPBAF = -0.010 x PGH_{RAP} + 1.771$ for 150°C mixing

RAP Binder Availability Factor



Virgin binder RAP binde

 $RAPBAF = -0.010 \times PGH_{RAP} + 1.771$ for 150°C mixing

$RAPBAF = -0.010 x PGH_{RAP} + 1.771$ for 150°C mixing

RAP BAF = $(-0.010 \times 88) + 1.771 = 0.89$

Summary

- Remember the inherent variability in recovery of asphalt binder and testing of recovered asphalt binder properties
- Consider the effects of reclaimed materials
 - Adding reclaimed asphalt materials to a mix means that you are adding agehardened asphalt binder with reduced relaxation in some proportion
 - Not all reclaimed binder may be available
- Softening the blend is helpful, but softening and restoring the viscoelastic properties is better

"The French Fry Analogy"

Thanks!





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