Making RAS Work through Balanced Mix Design

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Outline

- What is the current use of RAS in asphalt mixtures?
- How has RAS been used over the years?
- What are the concerns about using RAS?
- What steps do we need to take to address these concerns?
- How does RAS fit in balanced mix design?

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Use of RAS in 2023

Use of RAS	Nationwide stockpiles	Resource savings	Environmental benefits
18% increase in 2023 to 797,000 tons	1.18 million tons, a 17% decrease from 2022	$109 million from 159,000 tons of binder and 398,000 tons of aggregate	510,000 cubic yards of landfill and $47 million in gate fees

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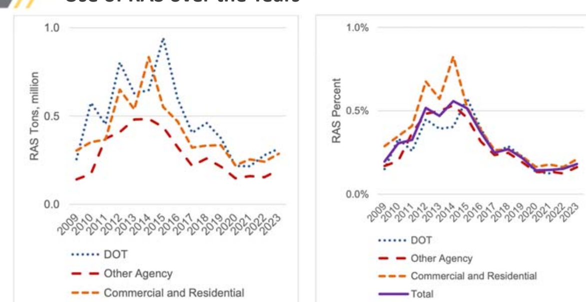
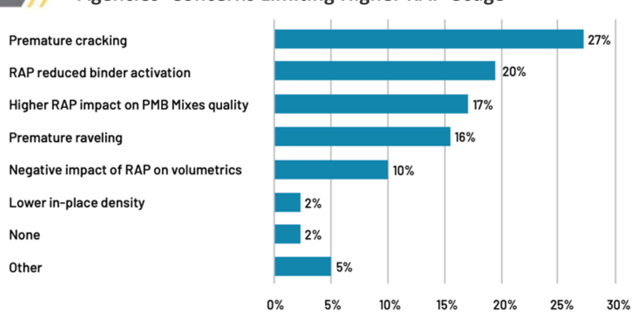
Source: NAPA Annual Asphalt Pavement Industry Survey, 2023

Use of RAS over the Years



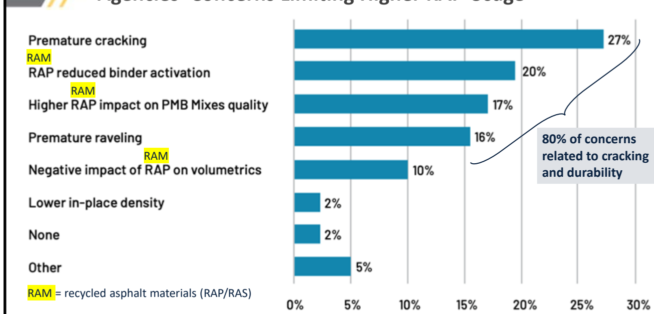
Source: NAPA Annual Asphalt Pavement Industry Survey, 2023

Agencies' Concerns Limiting Higher RAP Usage



Source: Barriers to Higher RAP Usage, NAPA SR-229

Agencies' Concerns Limiting Higher RAP (RAM) Usage

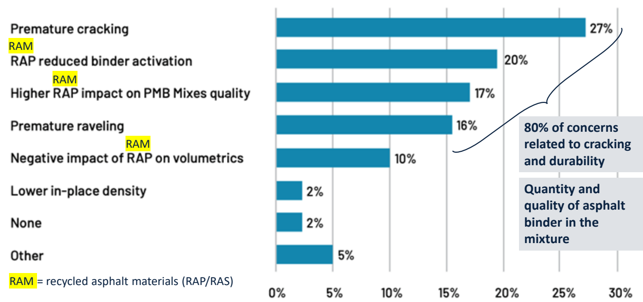


RAM = recycled asphalt materials (RAP/RAS)

Source: Barriers to Higher RAP Usage, NAPA SR-229

Agencies' Concerns Limiting Higher RAP Usage

RAM



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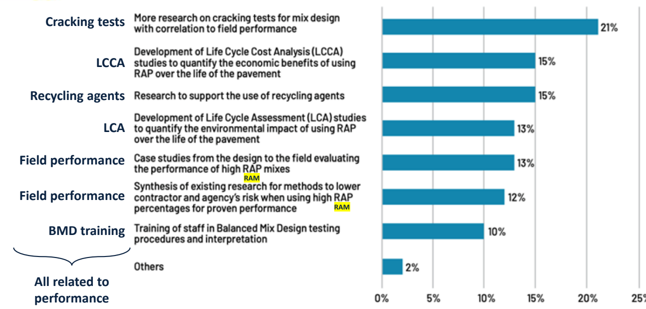
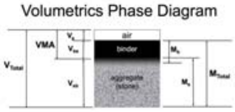
Agencies' Identified Research and Training Needs



Source: Barriers to Higher RAP Usage, NAPA SR-229

Volumetric vs. Balanced Mix Design

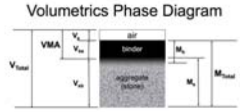
Volumetrics Phase Diagram

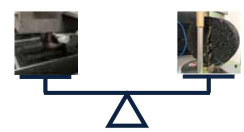


- Binder content is limited by VMA and air voids.
- Use of RAP/RAS is restricted due to concerns about cracking.
- Less flexibility to evaluate mitigation strategies to address cracking concerns

Volumetric vs. Balanced Mix Design

Volumetrics Phase Diagram

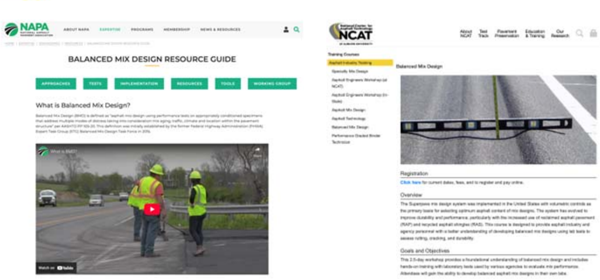




- Binder content is limited by VMA and air voids.
- Use of RAP/RAS is restricted due to concerns about cracking.
- Less flexibility to evaluate mitigation strategies to address cracking concerns

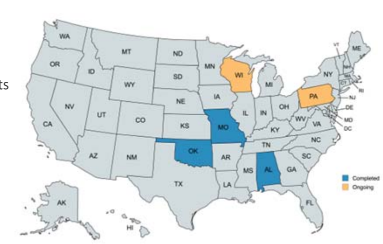
- Binder content is adjusted using cracking and rutting tests.
- High RAP/RAS can be allowed as long as performance passes.
- Recycling agents, softer binders, or other strategies are evaluated directly.

Balanced Mix Design Resource and Training



Case Studies: BMD for RAP/RAS Mixtures

- Objectives
  - Design RAP/RAS mixtures with balanced performance using BMD
  - Compare the environmental impacts of BMD-optimized RAP/RAS mixtures and control mixtures without RAS



Alabama Case Study

- Volumetrics
  - RAP/RAS maximum 20%, RAS not exceeding 3%
  - 3.5% air voids for mixtures with RAS, and 4.0% air voids for other mixtures
- BMD
  - Rutting: HT-IDT ≥ 20 psi at 50°C
  - Cracking: CT_{Index} ≥ 55, 83, and 100
  - Aging: 2 hours at 135°C before compaction

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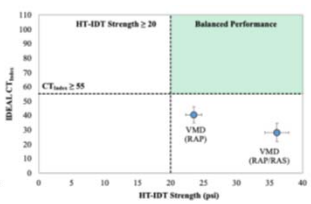
  - Rutting: HT-IDT ≥ 20 psi at 50°C
  - Cracking: CT_{Index} ≥ 55, 83, and 100
  - Aging: 2 hours at 135°C before compaction
- Control: 20% RAP, no RAS
- Experimental: 15% RAP and 5% RAS
  - Increase RAS content from 3% to 5%
- Start with volumetric mix designs
- Optimize mixtures to meet BMD requirements and verify long-term cracking resistance
  - Increasing asphalt content
  - Softer binder
  - Bio-based recycling agent

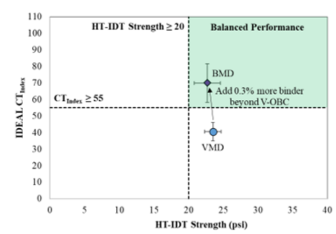
Volumetric Mix Designs

- Binder grades
  - Virgin binder: PG 64-22
  - RAP binder: hi-temp. true grade = 105.2°C
  - RAS binder: hi-temp. true grade > 176°C
- Volumetric analysis
  - 20% RAP: 5.5% AC (18.2% RBR) at 4.0% voids; 16.5 VMA, 75.8% VFA, 1.1 D/A
  - RAP/RAS: 6.0% AC (29.2% RBR) at 3.5% air voids; 16.0% VMA, 78.2% VFA, 1.1 D/A
  - In compliance with the ALDOT Superpave specification



- Adequate rutting resistance
- Insufficient cracking resistance

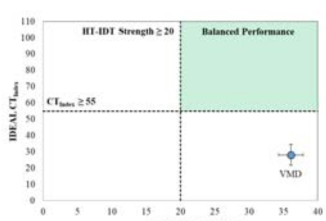
Balanced Mix Design: 20% RAP Control Mixture



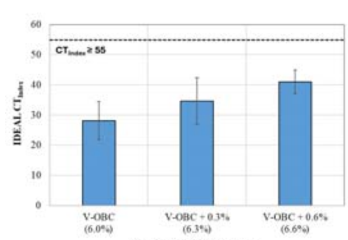
- PG 64-22 virgin binder
  - Add 0.3% more binder beyond V-OBC

Balanced Mix Design: RAP/RAS Mixture

- Similar to the RAP-only volumetric mix design
  - Adequate rutting resistance
  - Insufficient cracking resistance
- Optimize mixtures to meet BMD by
  - Increasing the asphalt content
  - Using a softer binder
  - Using a recycling agent



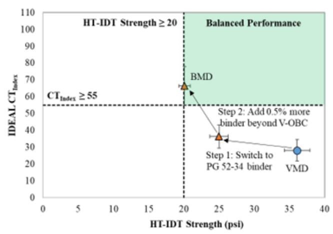
Modification #1: Increasing Asphalt Content



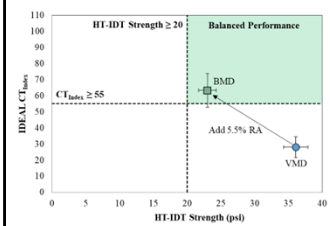
- Increase volumetric optimum asphalt content (V-OBC) by 0.3% and 0.6%
  - Insufficient cracking resistance

Modification #2: Softer Binder

- Step 1: substitute PG 64-22 binder with PG 52-34 binder
- Step 2: increase asphalt content by 0.5%

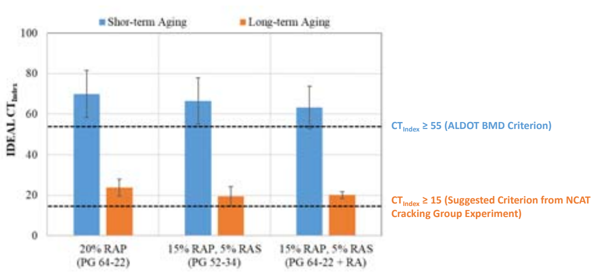


Modification #3: Recycling Agent



- Add 5.5% RA by weight of total binder
- Pre-blended into virgin binder:
  - PG 64-22 with -4.0°C ΔT_c → PG 52-34 with 0.7°C ΔT_c
  - Reduced stiffness and improved relaxation property

Long-term Cracking Resistance Evaluation of BMD-optimized Mixtures

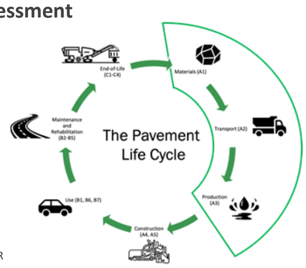


BMD-optimized Mixture Comparison

Mix Design		20% RAP	15% RAP, 5% RAS	
Cold Feed (%)	#78 Limestone	14	15	15
	Limestone Screenings	13	10	10
	3/8" Coarse Gravel	30	25	25
	Shot gravel	7	20	20
	Sand	15	10	10
	Baghouse Fines	1	-	-
	RAP	20	15	15
	RAS	-	5	5
Virgin Binder		PG 64-22	PG 52-34	PG 64-22
Virgin AC (%)		4.8	4.75	4.25
Additive (% total binder)		0.5 ASA	0.5 ASA	0.5 ASA, 5.5 RA

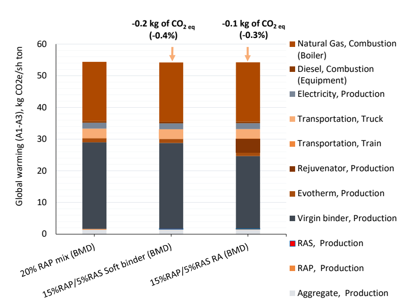
Comparative Life Cycle Assessment

- LCA Methodology
  - System boundary: Cradle-to-gate
  - Declared unit: 1 short ton
  - Background data: LCA commons
  - LCIA method: TRACI 2.1
- RAS processing
  - NAPA PCR assumes 0.1-gallon diesel consumption for one ton processing of RAS
  - This is assumed to be same as RAP processing in the PCR
  - Contractor provided diesel consumption information for front end loaders and Roto chopper for RAS processing



Cradle-to-Gate LCA

- No change in global warming was observed between control and RAP/RAS mixes in the Alabama case study



Oklahoma Case Study

- Volumetrics
  - No RAP or RAS in surface mixtures
- BMD
  - Up to15% RAP (no grade change)
  - Up to 25% RAP (one grade softer)
  - No RAS in surface-course mixtures
  - Air voids relaxed to 3 to 4%
  - Rutting: HWTT N12.5 ≥ 10,000 passes at 50°C (PG 64-xx)
  - Cracking: CT_{Index} ≥ 100
  - Aging: 4 hours at 135°C before compaction

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- Volumetrics
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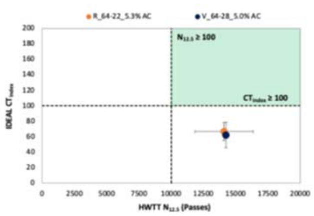
  - Air voids relaxed to 3 to 4%
  - Rutting: HWTT N12.5 ≥ 10,000 passes at 50°C (PG 64-xx)
  - Cracking: CT_{Index} ≥ 100
  - Aging: 4 hours at 135°C before compaction
- Control: virgin mix
- Experimental: 7% RAP and 2% RAS
  - RBR = 14%
- Start with volumetric mix designs
- Optimize mixtures to meet BMD requirements
  - Using a softer binder
  - Increasing the asphalt content

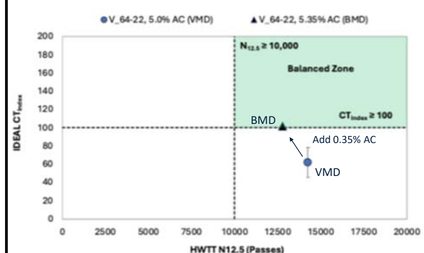
Volumetric Mix Designs

- Binder grades
  - Virgin binder: PG 64-22
  - RAP binder: hi-temp. true grade = 94.1°C
  - RAS binder: hi-temp. true grade = 151.8°C
- Volumetric analysis
  - Virgin: 5.0% AC at 4.0% voids; 14.8 VMA, 73.3% VFA, 0.7 D/A
  - RAP/RAS: 5.3% AC (14.0% RBR) at 4.0% air voids; 15.2% VMA, 74.1% VFA, 0.8 D/A
  - In compliance with the ODOT Superpave specification



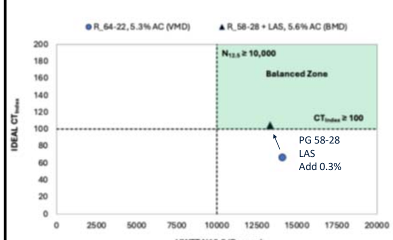
- Adequate rutting resistance
- Insufficient cracking resistance

Balanced Mix Design: Virgin Control Mixture



- PG 64-22 virgin binder
  - Add 0.35% more binder beyond V-OBC

Balanced Mix Design: 7% RAP, 2% RAS Mix



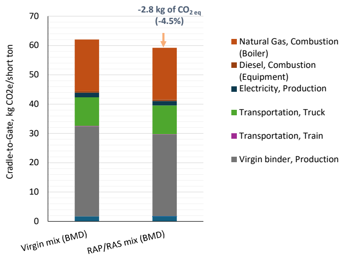
- Change from PG 64-22 to PG 58-28
- Use LAS
- Increase virgin binder content from 5.3% to 5.6%

BMD-optimized Mixture Comparison

Mix Design	Virgin Mix	7% RAP & 2% RAS
Virgin Binder	PG 64-22	PG 58-28
Additive (% total binder)		0.5 ASA
Total AC (%)	5.4	5.6
Virgin AC (%)	5.4	4.9
RBR (%)		13.3
Air Voids (%)	3.0	3.0
VMA (%)	14.6	15.1
VFA (%)	79.7	80.3
Dust/Asphalt Ratio	0.68	0.70

Cradle-to-Gate LCA

- A reduction of 2.8 kg CO_{2e}/ton of mix was achieved with the use of RAP/RAS
- 4.5% reduction in GWP compared to the control mix



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Case Study Findings

- Feasible to design RAP/RAS mixes with balanced performance using BMD
- Alabama and Oklahoma studies
  - RAP/RAS mixtures require cracking mitigation strategies
    - Recycling agent
    - Softer binder
    - Increasing asphalt content
- Missouri study
  - RAS can help meet rutting test requirements
- BMD-optimized RAP/RAS mixtures have slightly lower (4-5%) or similar environmental impacts compared to control mixtures without RAS

Acknowledgments

- Owens Corning
  - Courtney Rice
  - Toni Newsome
- Contractors
  - Alabama
  - Oklahoma
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  - Pennsylvania
  - Wisconsin
- NCAT team
  - Fan Yin
  - Suri Gatiganti
  - Sam Dixon
  - Lam Nguyen
  - Liz Valenca

THANK YOU!

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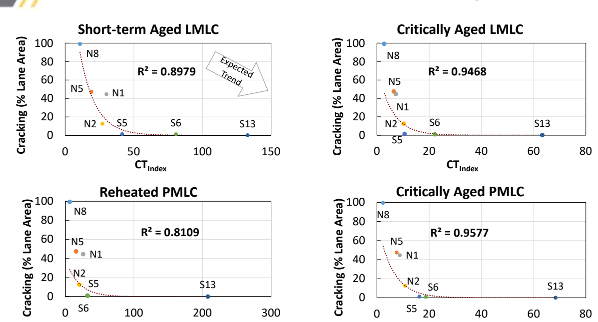
Cracking Test Correlation to Test Track Performance

Test and Parameter	Average COV (Repeatability)	Range of R^2 (Correlation)
Energy Ratio, ER	Not available	0.03 to 0.28
Texas Overlay Test, β	17%	0.76 to 0.91
NCAT Overlay Test, β	10%	0.79 to 0.97
Louisiana SCB, J_c	20%	0.13 to 0.78
Illinois Flexibility Index Test, *FI*	34%	0.76 to 0.89
IDEAL Cracking Test, CT_{Index}	18%	0.87 to 0.94
AMPT Cyclic Fatigue, S_{app}	16%	0.89 to 0.90

Correlations of IDEAL-CT Results to Cracking on Test Track



Field Cracking vs. CT_{Index}

100% lane area cracked, lowest CT_{Index}

No crack, highest CT_{Index}

ALDOT Mix Design Specifications

- Superpave Specification
  - Combined RAP/RAS content limited to 20%, RAS not exceeding 3%
  - 3.5% air voids for mixtures containing RAS, and 4.0% air voids for other mixtures
  - Minimum VMA and P_b, and dust/asphalt ratio
- BMD Special Provision
  - Approach D (BMD Design Only) per AASHTO PP 105
  - Minimal requirements on maximum aggregate size and carbonate stone content
  - No limits on RAP/RAS content or volumetric properties
  - Rutting resistance: High-temp. IDT (ALDOT 458) at 50°C, IDT strength ≥ 20 psi
  - Cracking resistance: IDEAL-CT (ALDOT 459) at 25°C, CT_{Index} ≥ 55, 83, and 100 depending on design traffic

Alabama Case Study

- Modify an existing RAP/RAS mixture to increase RAS content
- Optimize the RAP/RAS mixture to meet BMD requirements and verify long-term cracking resistance
  - Increasing asphalt content
  - Softer binder
  - Bio-based recycling agent
- Conduct comparative life-cycle assessment (LCA) for BMD-optimized RAP/RAS vs. control (20% RAP, no RAS) mixtures