Resource Responsible Use of High RAP (up to 50%) Asphalt Mixtures

Tim Aschenbrener

Federal Highway Administration

Image: Adam Hand

FHWA is the source for all images unless otherwise noted.

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Acronyms

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- AASHTO = American Association of Highway and Transportation Officials
- BMD = balanced mix design
- COAC = corrected optimum asphalt content
- CO_2e = carbon dioxide equivalents
- DGFC = dense-graded friction course
- FDR = full-depth reclamation
- G_{sa} = apparent specific gravity of the aggregate
- G_{sb} = bulk specific gravity of the aggregate
- GTR = ground tire rubber
- GHG = green house gas
- HP = high polymer
- IS = information series
- MSCR = multiple stress creep compliance
- NAPA = National Asphalt Pavement Association
- NCHRP = National Cooperative Highway Research Program
- OGFC = open-graded friction course
- PMS = pavement management system
- PWL = percent within limits
- QA = quality assurance
- QC = quality control
- RAM = reclaimed asphalt materials
- RAP = reclaimed asphalt pavement
- RAS = recycled asphalt shingles
- RBR = reclaimed binder ratio
- VMA = voids in the mineral aggregate
- WMA = warm mix asphalt

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"Development and Deployment of Innovative Asphalt Pavement Technologies"

DDIAPT Innovation Area: *Resource Responsible use of Materials for Flexible Pavement Systems*

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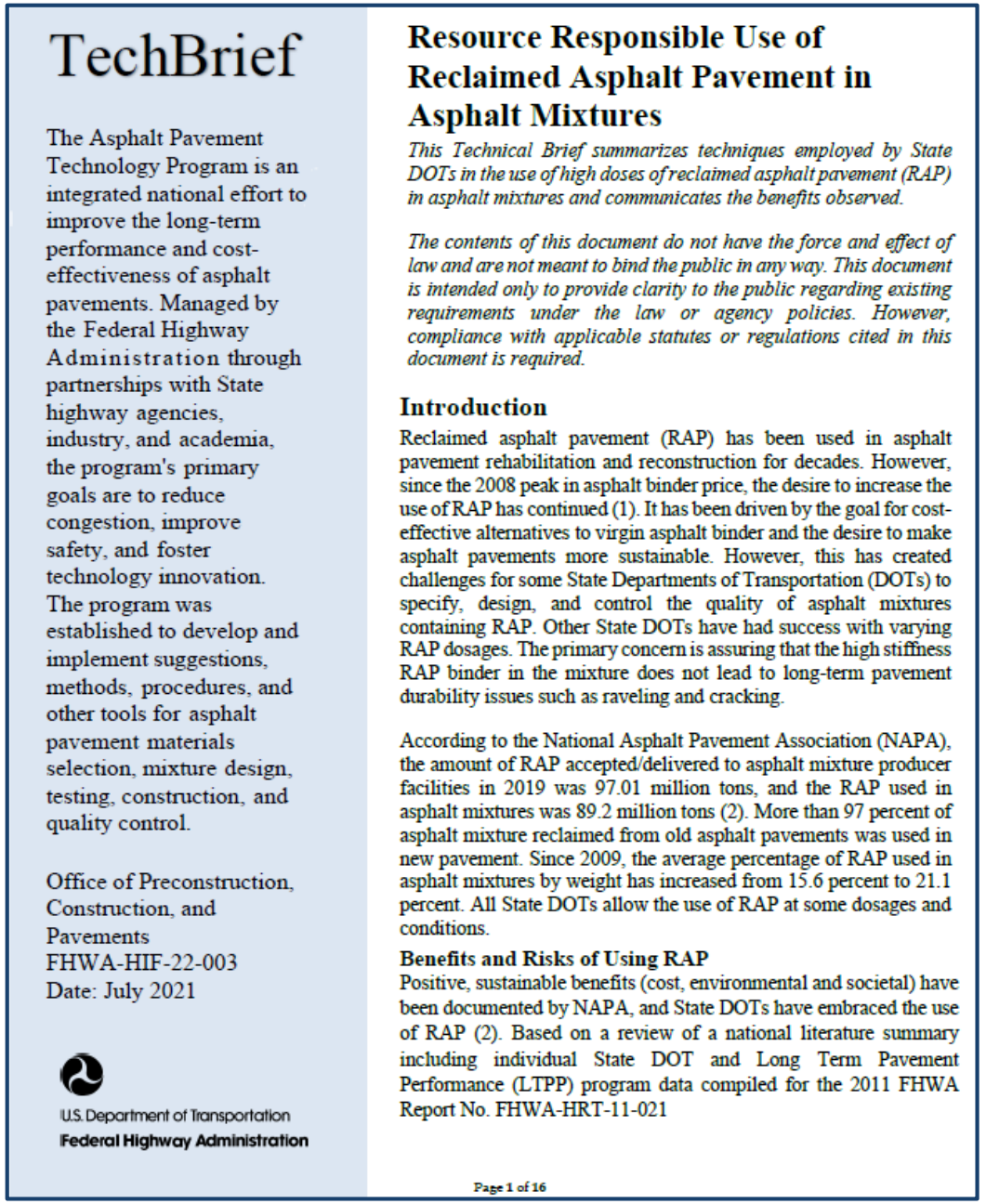
Innovation Area	Task	Topic	Tech Brief	FHWA Document
Resource Responsible use of Materials for Flexible Pavement Systems	B.1	High Reclaimed Asphalt Pavement (RAP) Mixtures	Resource Responsible us of Reclaimed Asphalt Pavement in Asphalt Mixtures	FHWA-HIF-22-003
	B.2	Reclaimed Asphalt Shingles (RAS) Modified Binders and Mixtures	Practices and Lessons Learned when Using Reclaimed Asphalt Shingles in Asphalt Mixtures	FHWA-HIF-22-001
	B.3	Asphalt Rubber-Modified Binders	Effective Use of GTR Modified Asphalt Binder in Asphalt Mixtures	FHWA-HIF-20-043
			Recycled Tire Rubber – Hybrid GTR Binders and Dry Added GTR – How to use them in Asphalt Pavement Mixtures	FHWA-HIF-22-011

https://www.fhwa.dot.gov/pavement/recycling/

Target Audience

- State DOTs
- Asphalt Producers
- Contractors
- Consulting Engineers
- Academia

Images: Pixabay



TechBrief

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Office of Preconstruction, Construction, and Pavements
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Benefits and Risks of Using RAP

Positive, sustainable benefits (cost, environmental and societal) have been documented by NAPA, and State DOTs have embraced the use of RAP (2). Based on a review of a national literature summary including individual State DOT and Long Term Pavement Performance (LTPP) program data compiled for the 2011 FHWA Report No. FHWA-HRT-11-021

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- Design Considerations
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https://www.fhwa.dot.gov/pavement/recycling/rap.cfm

Introduction

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Past:

- Long History of RAP.
  - All State DOTs Allow.
- 2008 Asphalt Binder Price Peak.
  - Desire to Increase RAP.
- Reports.
  - 2011 FHWA.
  - 2013 NCHRP.
- 2014 Some Challenges.
  - High Stiffness and Long-Term Durability.

Moving Forward:

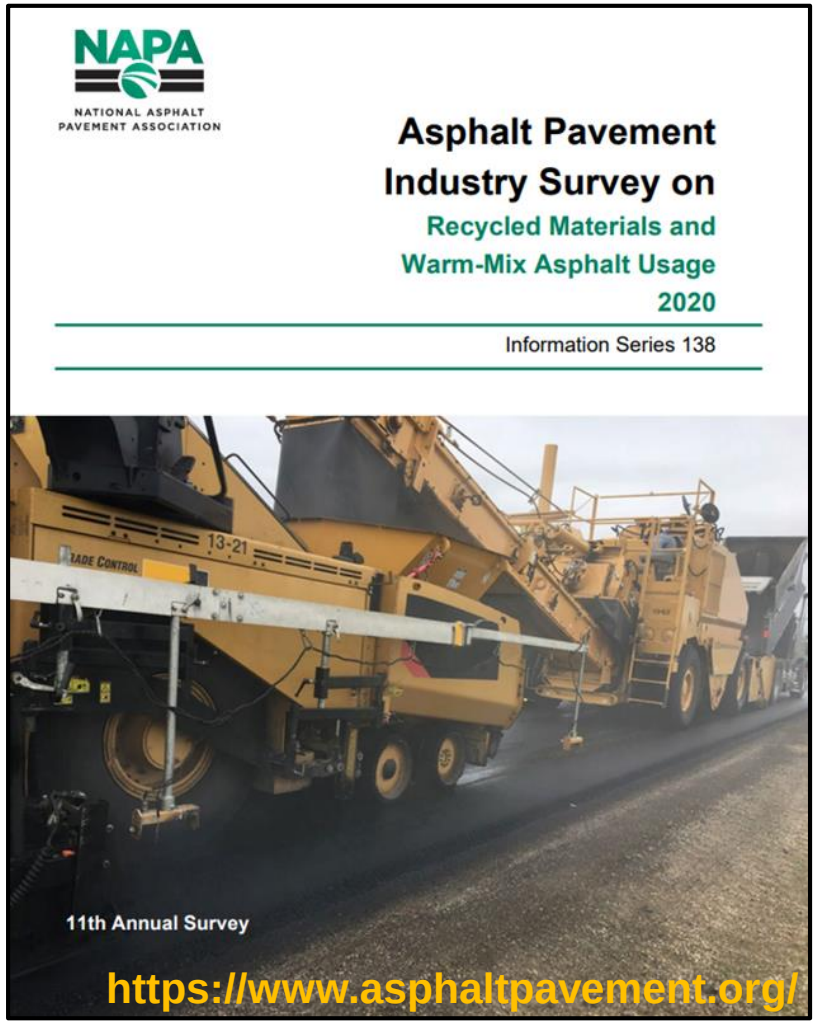
- Some State DOT Success at Higher Dosages.
- Task Objective: Visit High Dose States (up to 50% RAP) for Positive Practices & Lessons Learned.

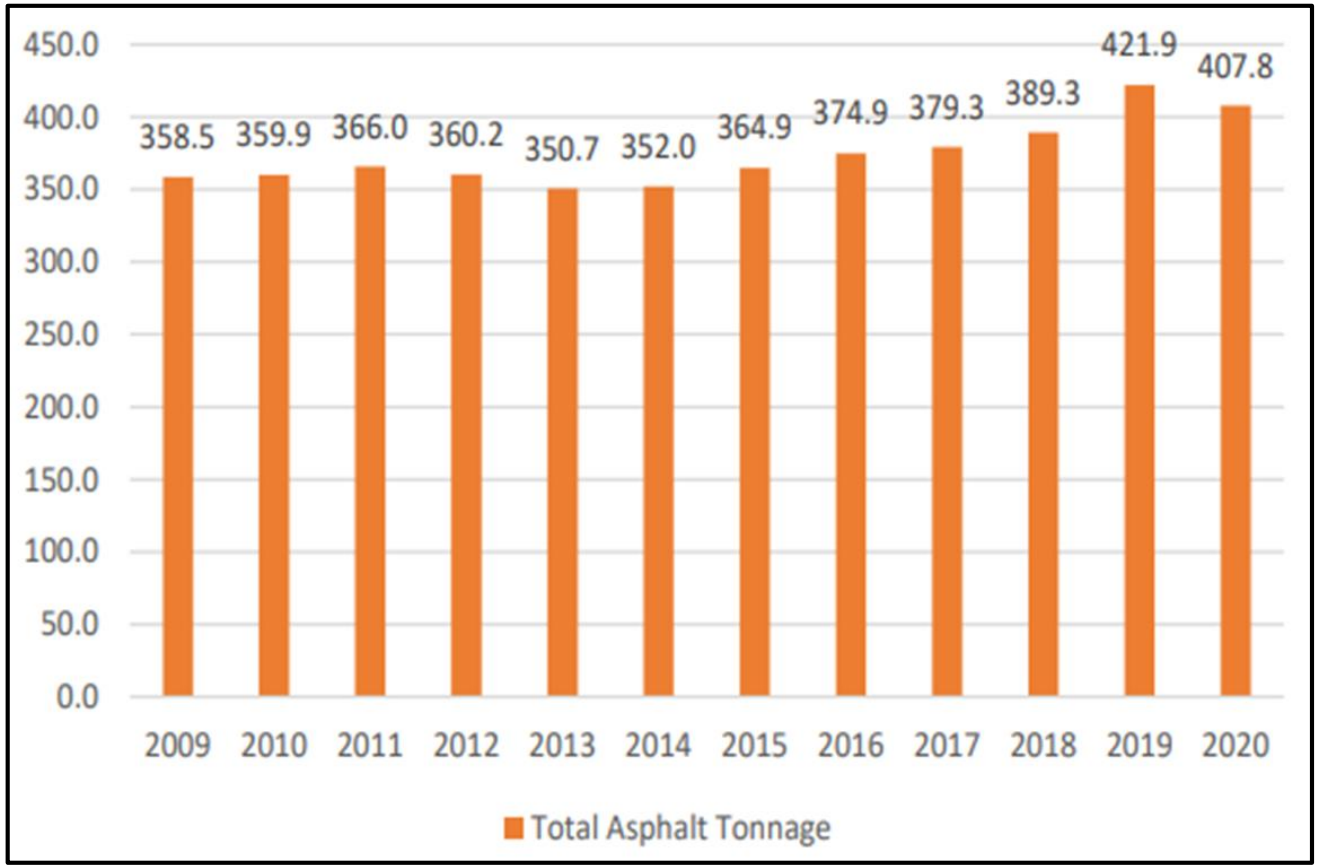
Why Responsibly Use High RAP?

- Optimize:
  - Use of Recycled Materials.
    - Environment: Conservation of Nature Resources, CO_2e.
  - Pavement Performance.
    - Equal Pavement Performance.
  - Cost.
    - Initial and Life Cycle.

History of RAP Use:

2020 NAPA IS-138 Annual Survey: RAP, WMA, …





Source: 2020 NAPA IS-138 Annual Survey

2020 NAPA IS-138 Annual Survey - RAP

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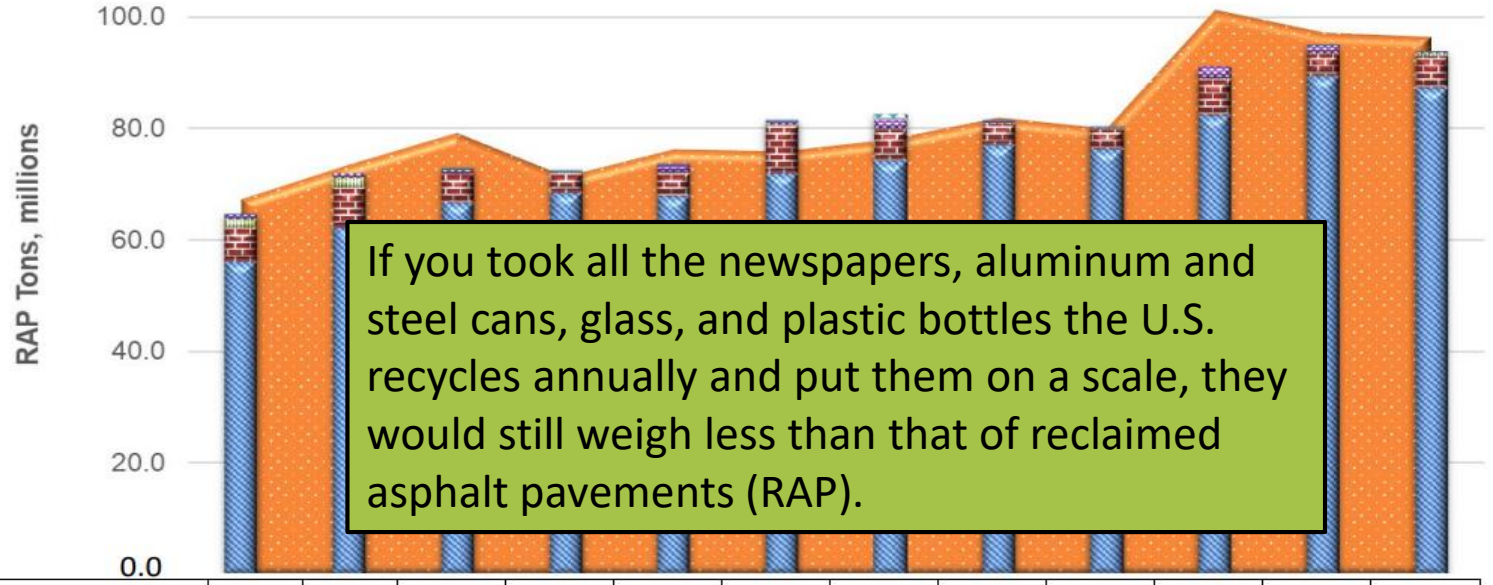

If you took all the newspapers, aluminum and steel cans, glass, and plastic bottles the U.S. recycles annually and put them on a scale, they would still weigh less than that of reclaimed asphalt pavements (RAP).

RAP	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Accepted	67.2	73.5	79.1	71.3	76.1	75.8	78.0	81.8	79.9	101.1	97.0	96.3
Landfilled	0.1	0.0	0.3	0.2	0.1	0.2	1.0	0.1	0.0	0.0	0.1	0.2
Used in Other	0.7	0.8	0.7	0.2	1.5	0.6	1.6	0.4	0.2	2.0	1.4	0.3
Used in Cold Mix	1.5	1.6	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4
Used in Aggregate	6.2	7.3	4.9	3.6	4.0	8.5	5.5	3.7	3.4	6.4	3.8	5.8
Used in HMA/WMA	56.0	62.1	66.7	68.3	67.8	71.9	74.2	76.9	76.2	82.2	89.2	87.0

Figure 3: Comparison of Tons of RAP Accepted and Tons of RAP Used or Landfilled (Million Tons), 2009–2020

Trends:

- Most recycled material.
- ≈93% of RAP put back in new asphalt mixture.
- Annual savings:
  - 4.4M tons of Asphalt (24M Barrels).
  - 82M tons of Aggregate.
  - $2.9 Billion.

Source: 2020 NAPA IS-138 Annual Survey

State DOTs Average Percent RAP

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Trends:

- 0-9%
- 10-14%
- 15-19%
- 20-29%
- ≥ 30%

- Steady @≈20%

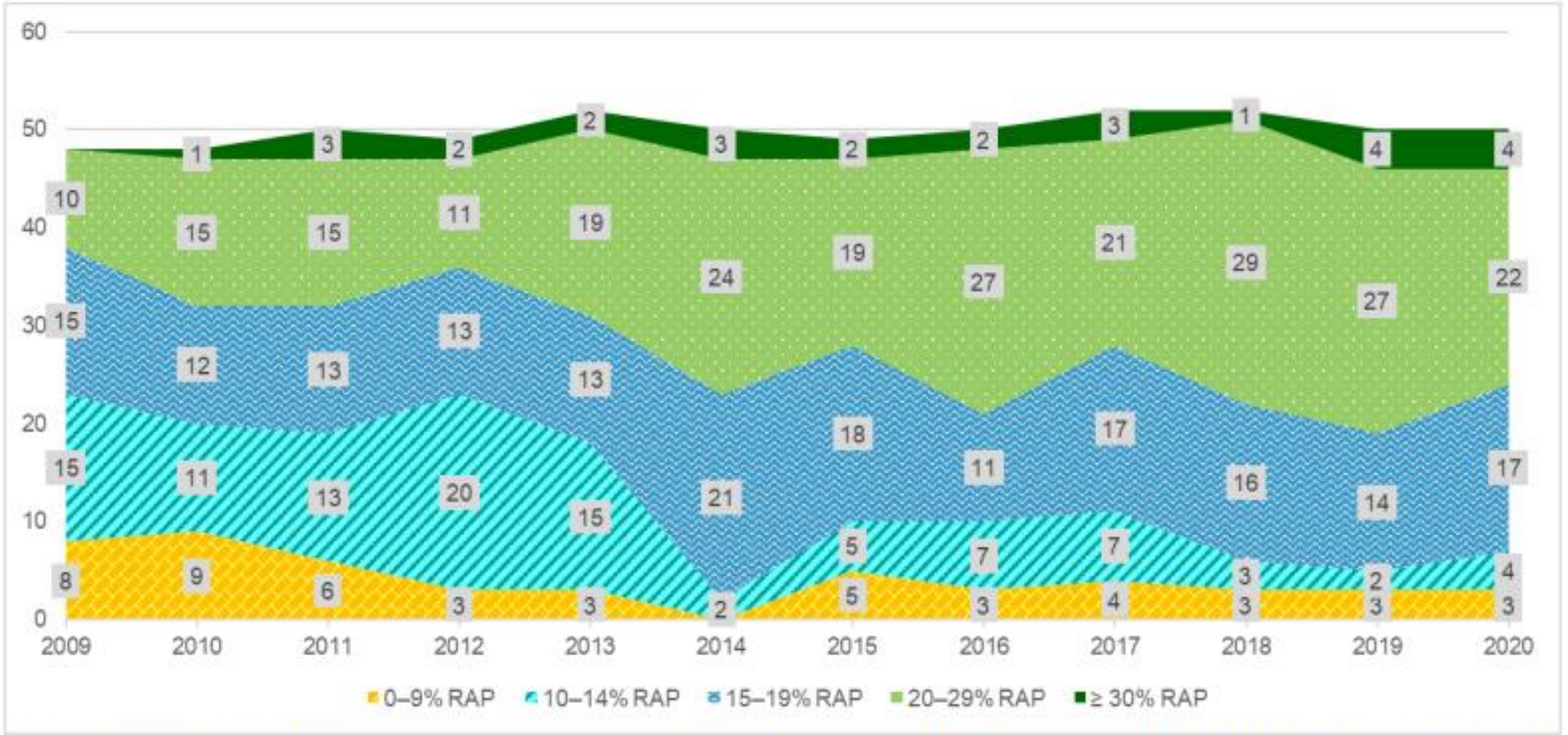
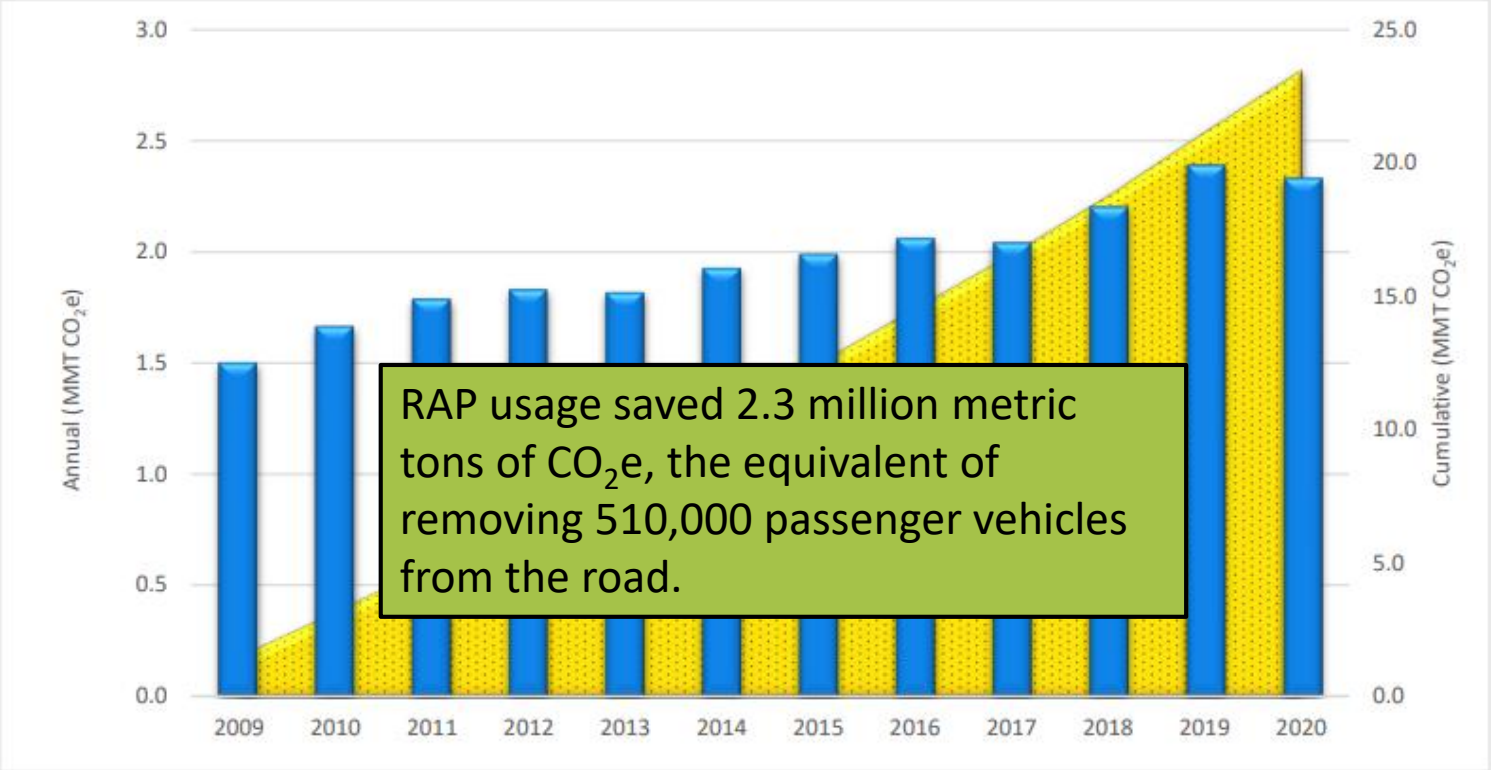


Figure 8: Number of States at Different Average Percentage of RAP Used in HMA/WMA Mixtures, 2009–2020

Source: 2020 NAPA IS-138 Annual Survey

Cumulative GHG Emissions Reduction from use of RAP in New Asphalt Mixtures



GHG Emissions	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cumulative	1.5	3.2	4.9	6.8	8.6	10.5	12.5	14.5	16.6	18.8	21.2	23.5
Annual	1.5	1.7	1.8	1.8	1.8	1.9	2.0	2.1	2.0	2.2	2.4	2.3

Figure 19: GHG Emissions Reduction from Use of RAP in New Asphalt Mixtures, 2009–2020

Trends:

- Steady Reduction of GHG Emissions (tons CO_2e).
  - 2020: 2.3 MM.
  - 2009: 1.5 MM.
  - 2009 to 2020: 23.5 MM.

Source: 2020 NAPA IS-138 Annual Survey

Virtual Site Visits

- **Florida DOT (FDOT)**:
  - Unlimited RAP use for some mixture types.
  - Several producers use 40% RAP, One uses 50% in unlimited RAP mixture type.
- **Nebraska DOT (NDOT):**
  - Averaged 39% RAP use for the past 6 years.
  - Typical RAP range 35 to 50%.
- **New Jersey (NJDOT):**
  - High RAP specification: Min 20% RAP surface mixtures; 30% intermediate and base mixtures using BMD approach.
- **South Carolina DOT (SCDOT):**
  - Some mixtures with 25 to 35% RAP.
  - Alternative RAP uses, e.g. full-depth reclamation (FDR).
- **Washington DOT (WSDOT):**
  - Up to 40% RBR (≤20% from RAS).
  - Uses BMD approach.
- **Wisconsin DOT (WisDOT):**
  - >95% of 2.8 million tons of asphalt contains RAP.
  - 40% RAP in some mixtures.

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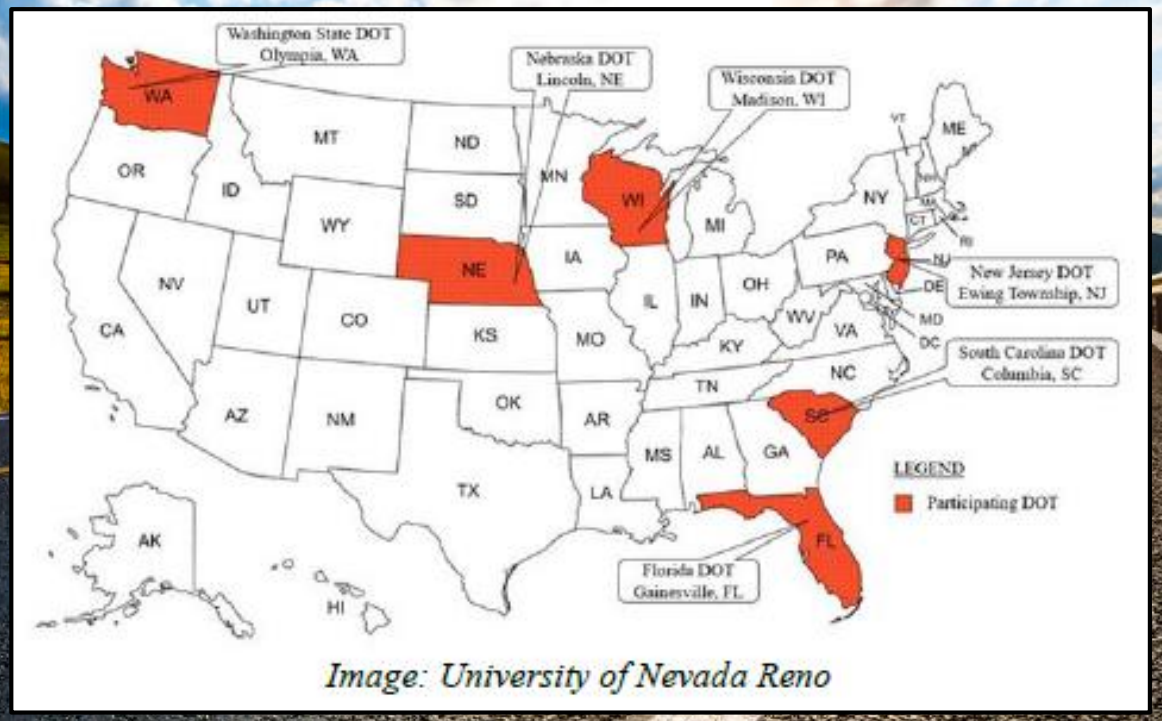
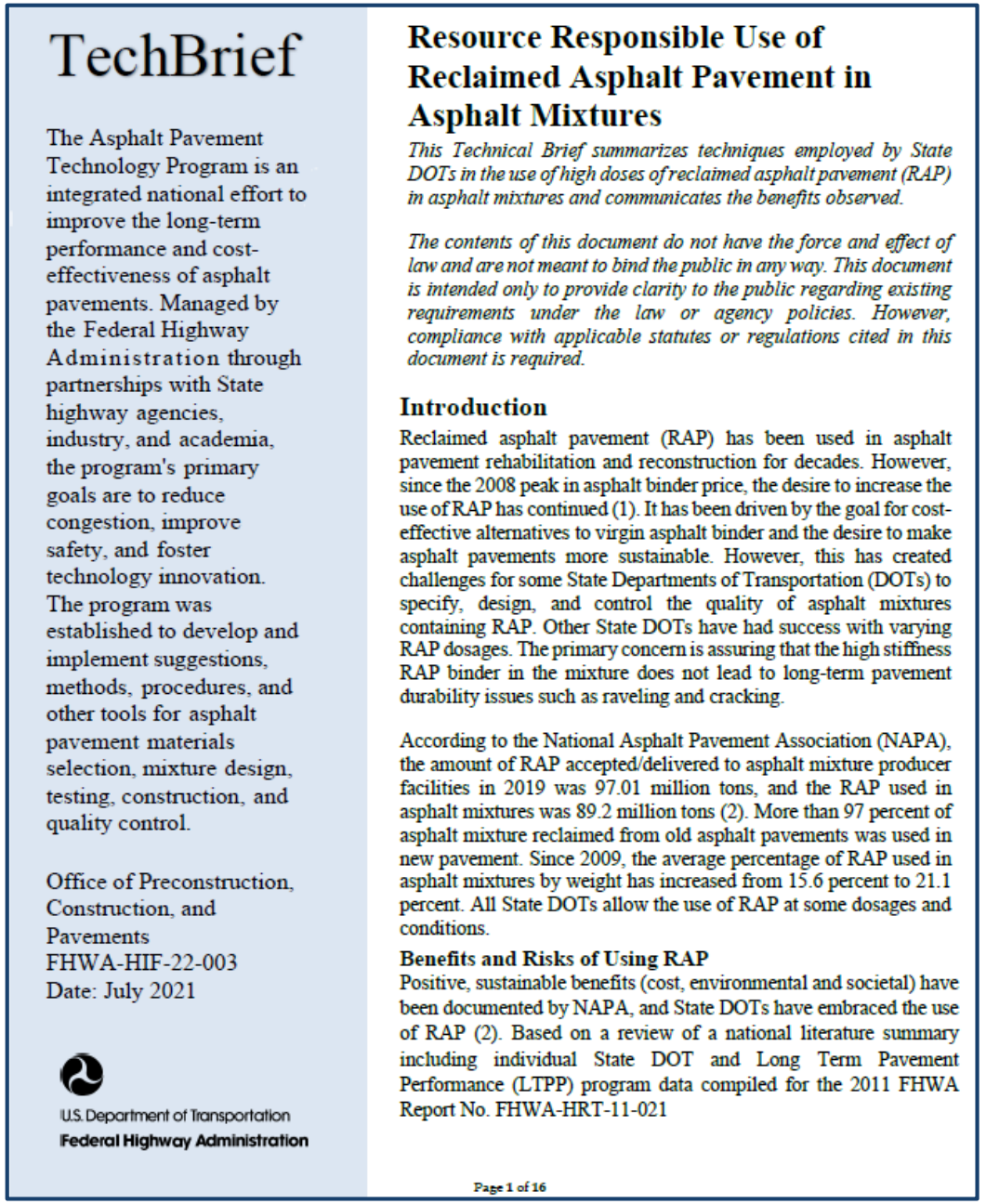


Image: University of Nevada Reno



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Benefits: Quantifying and Communicating

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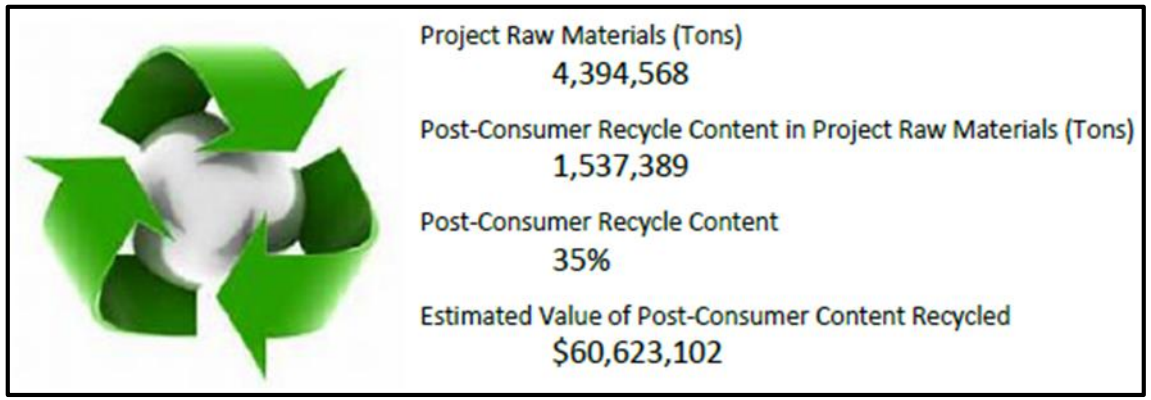
- Nebraska DOT
  - Recycling Goals, Quantities Stated & Cost Savings in Annual Report.
    - https://dot.nebraska.gov/media/3493/annual-report.pdf
  - Post-Consumer Labeling Plan Sets Since 2014.
  - Saving 2008 to 2020:
    - ≈9.2M tons aggregate recycled.
    - ≈ 498,000 tons asphalt binder recycled.
    - ≈ Cost saving of $408M.



Source: Nebraska DOT

- SCDOT
  - Estimate % cost saving from RAP as percent of mix cost paid.
  - Saving 2008 to 2013:
    - 9% to 16% of mix cost paid.
    - RAP mix savings ≈ $90.7 M.

Nebraska DOT
Pavement Performance Observations

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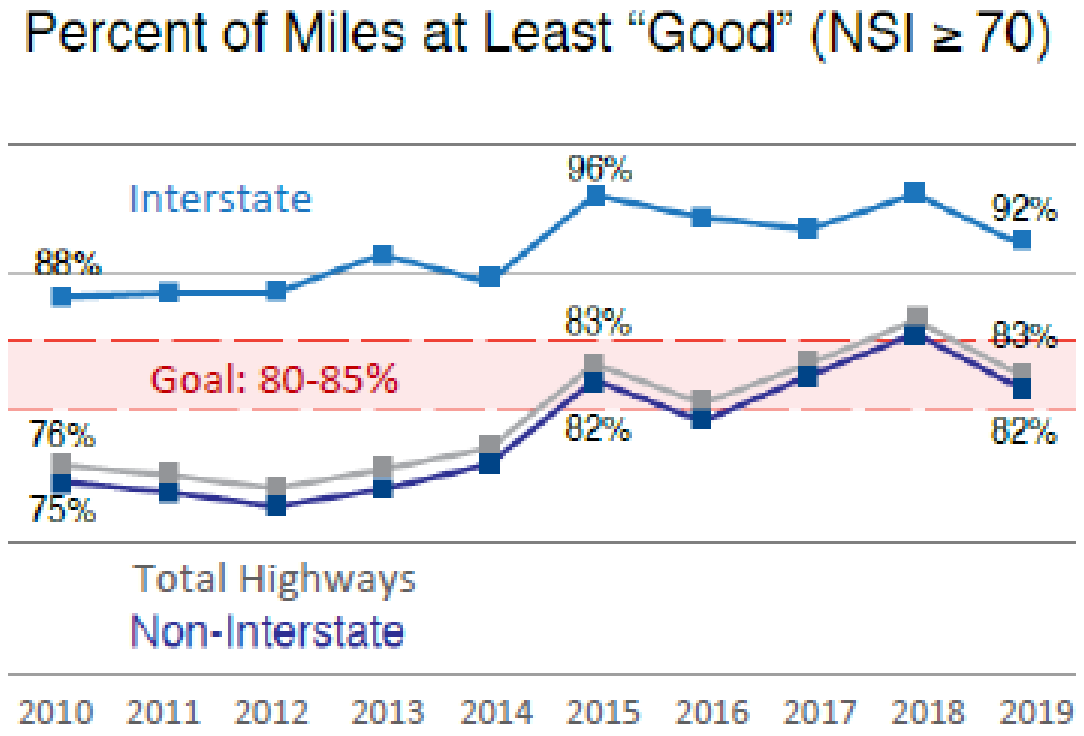
- Nebraska Serviceability Index (NSI):
  - Range = 0 to 100.
  - "Good" ≥ 70%.
- Goal 80 to 85% of Highway System "Good:"
  - 92% of Interstate System "Good."
  - 83% of Total Highway System "Good."
- NSI has Increased since High RAP Implementation in 2013.



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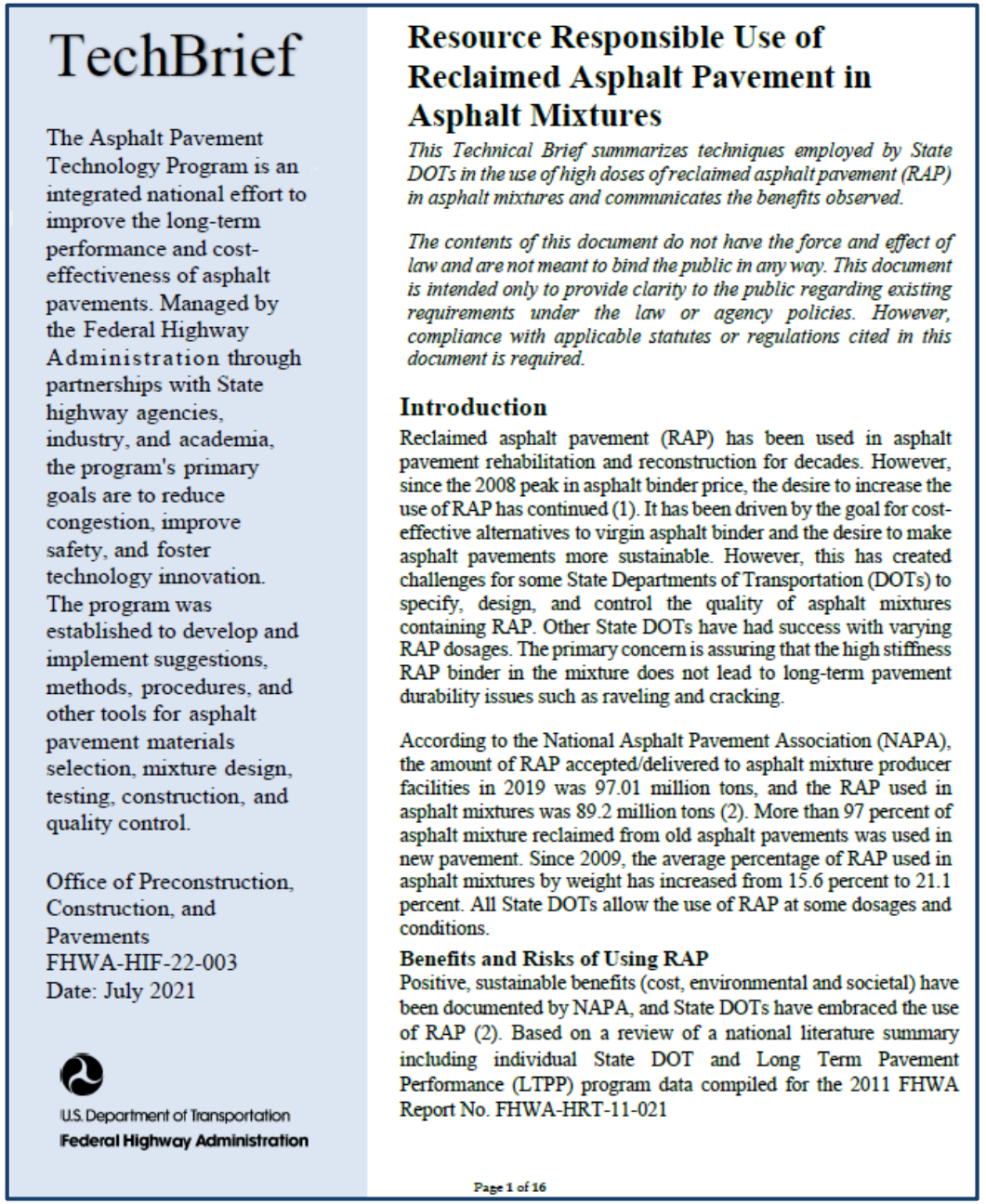

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Design Considerations

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Criteria Commonly Used:

- Acceptable RAP Limits
- Project: Lift, Traffic, Mix Type
- Softer Binder
- Additional Asphalt

Criteria Sometimes Used:

- Recycling Agents
- Mixture Performance Test

Recycled Material Criteria by *Weight and RBR*

State	RAM Allowed (% by Weight)		RAM Allowed (by RBR)	
	RAS	RAP	RAS	RAP
FDOT	0%	0% or 0-20% or Unlimited		
NDOT	0%	0-35% or 20-35% or 0-55% or 35-65%		
NJDOT	0%	≥20% or ≥30%		
SCDOT			0.05	0.00-0.30 or 0.15-0.45 FRAP
WisDOT			0.20-0.25	0.25-0.40 RAP+FRAP or 0.25-0.35 RAS+RAP+FRAP
WSDOT			0.20	0.40 or 0.20 RAS+0.20RAP (0.40 total)

Rationale and Location for Using RAP

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- **FDOT %RAP =f(mix type, location, binder type, and geographic location):**

FDOT %RAP =f(mix type, location, binder type, and geographic location).

- Unlimited RAP:
  - Intermediate and base mixes with neat binders.
- 20% RAP:
  - Dense-graded friction course (DGFC) with granite aggregate.
  - All intermediate mixes with PG 76-22.
- 0% RAP:
  - OGFC, High Polymer (HP), or dense-graded friction course (DGFC) mixes with South Florida limestone.

Criteria for Use of Softer Binder

State	Softer Binder	Blending Chart	PG of Blended Asphalt
FDOT	One to two PG bumps down based on RAP dose.		
NDOT	Low PG bumped down one grade. Only MSCR grades are specified.		
NJDOT	PG64-22, Engineer may Direct Softer Grade.		
SCDOT			
WisDOT		Only to demonstrate that at higher RBR, blended binder meets the specified PG for the project per AASHTO M 332.	Only to demonstrate that at higher RBR, blended binder meets the specified (PG) for the project per AASHTO M 332
WSDOT			For all mixes containing RAS or > 20% RAP.

Additional Asphalt Content

State	FDOT	NDOT	NJDOT	SCDOT	WisDOT	WSDOT
Reduced N_{Design}		X	X	X	X	
Regressed Design %AV		1.5-4%		3.0-4.0%	≥3.0%	
Minimum %AC		X				
Minimum %VMA > AASHTO M323			+1.0%	+0.5%	+0.5%	
Asphalt Binder Separate Pay Item			X	X		
Performance Tests			Rutting, Cracking			Rutting, Cracking
Other			Max %Gsa	COAC	Gsb of RAM aggs	Gsb of RAM aggs

Use of Additives

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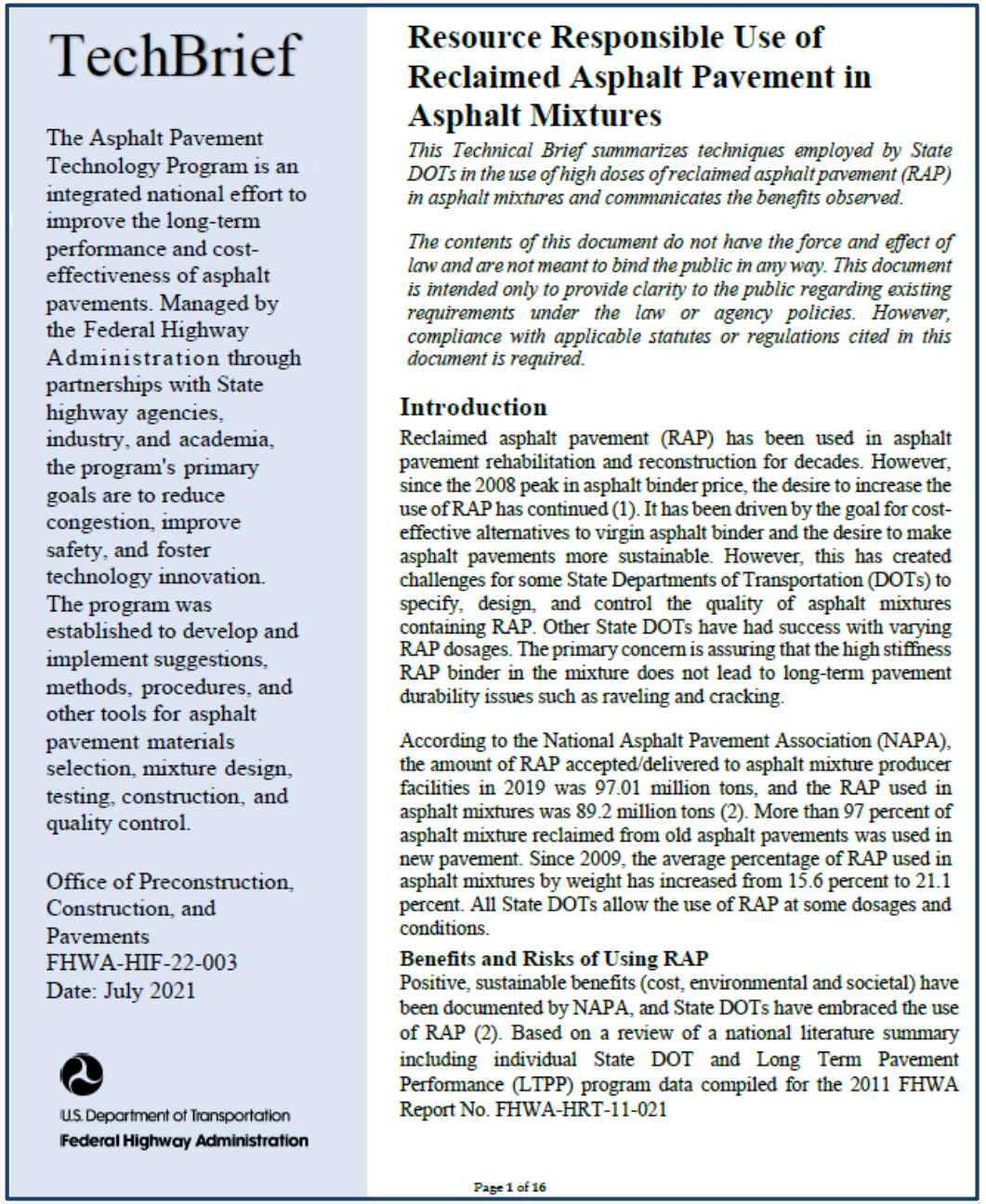
- Recycling Agents.
  - NJDOT and WSDOT allow recycling agents at Contractor's Option:
    - NJDOT to meet high RAP mixture performance test requirements.
    - WSDOT to meet blended binder (virgin, RAP, and recycling agent) PG requirements.

Mixture Performance Tests

State	FDOT	NDOT	NJDOT	SCDOT	WisDOT	WSDOT
Rutting Test			APA	APA		HWT
Cracking Test			TxOL			IDT
Mixture Design			APA and TxOL	APA		HWT and IDT
Test Strip			APA and TxOL	APA		IDT
Production or Acceptance			APA and TxOL			1/10,000 tons
Test(s) of Interest	IDEAL-CT	HWT, SCB		HWT, IDEAL-CT	HWT, IDEAL-CT	HWT, IDT, IDEAL-CT



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Outline

U.S. Department of Transportation
Federal Highway Administration

- Introduction and Background
- Benefits and Communication
- Design Considerations
- Construction and QA
- Summary

https://www.fhwa.dot.gov/pavement/recycling/rap.cfm

Contractor Input on Successful RAP Use

- Contractors Focused On

State	FDOT	NDOT	NJDOT	SCDOT	WisDOT	WSDOT
Heat Transfer	X	X		X		
Moisture Control				X	X	
Dust Control	X	X			X	X
RAM Feed Bins	X	X		X		
Quantity Management				X		
Verifying %RAP	X	X		X	X	X
Millings in Mix Design		X			X	

Contractor Input on Successful RAP Use

U.S. Department of Transportation
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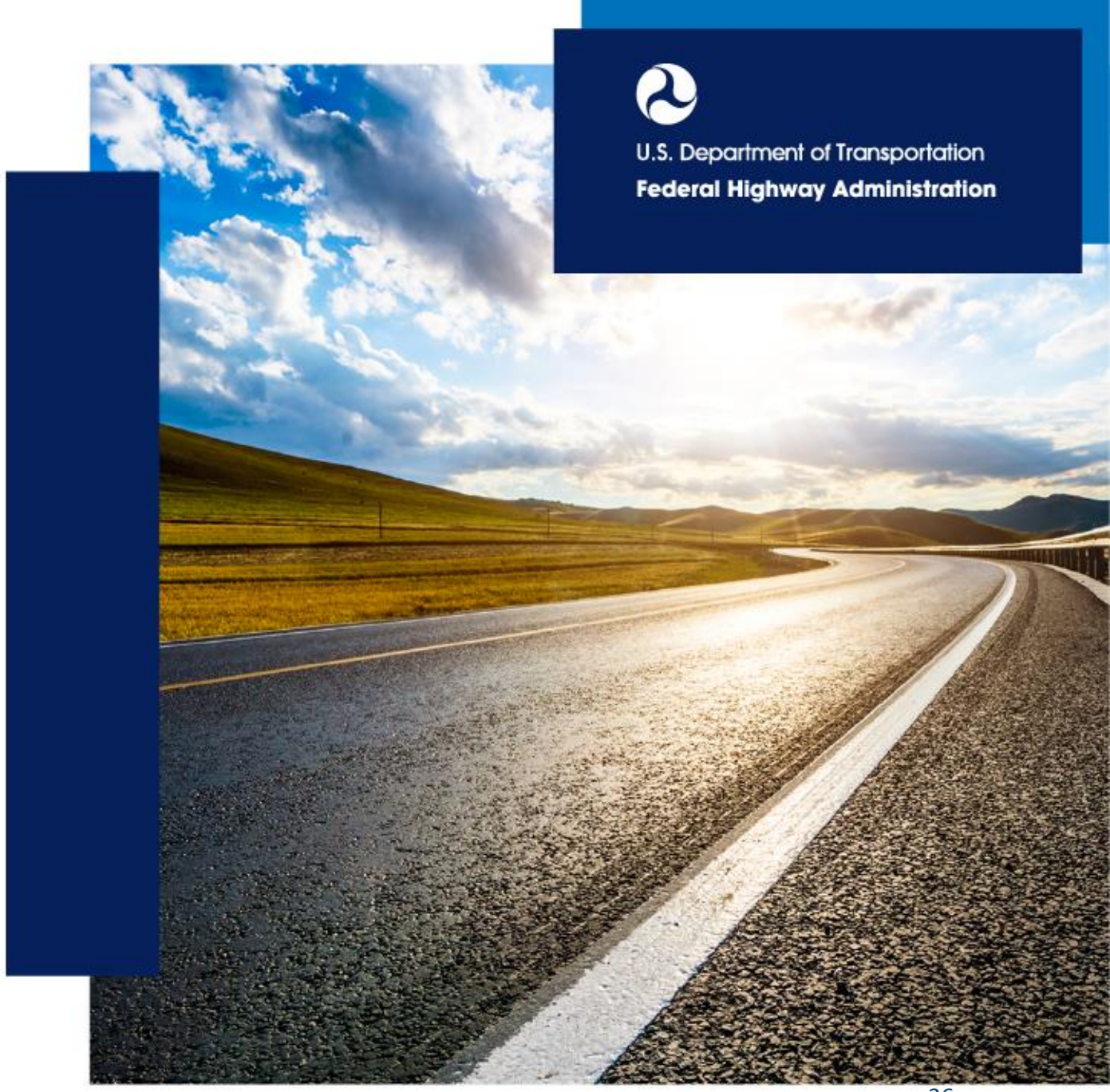
- Heat transfer.
  - Plant equipment.
  - RAP stockpile moisture.
    - Minimizing and monitoring especially in wet climates.
- Dust control.
  - Plant equipment.
    - Metering back or wasting baghouse fines accurately.
  - Controlling fines (material passing the #200 sieve) when producing aggregates.
    - Washing crusher fines.

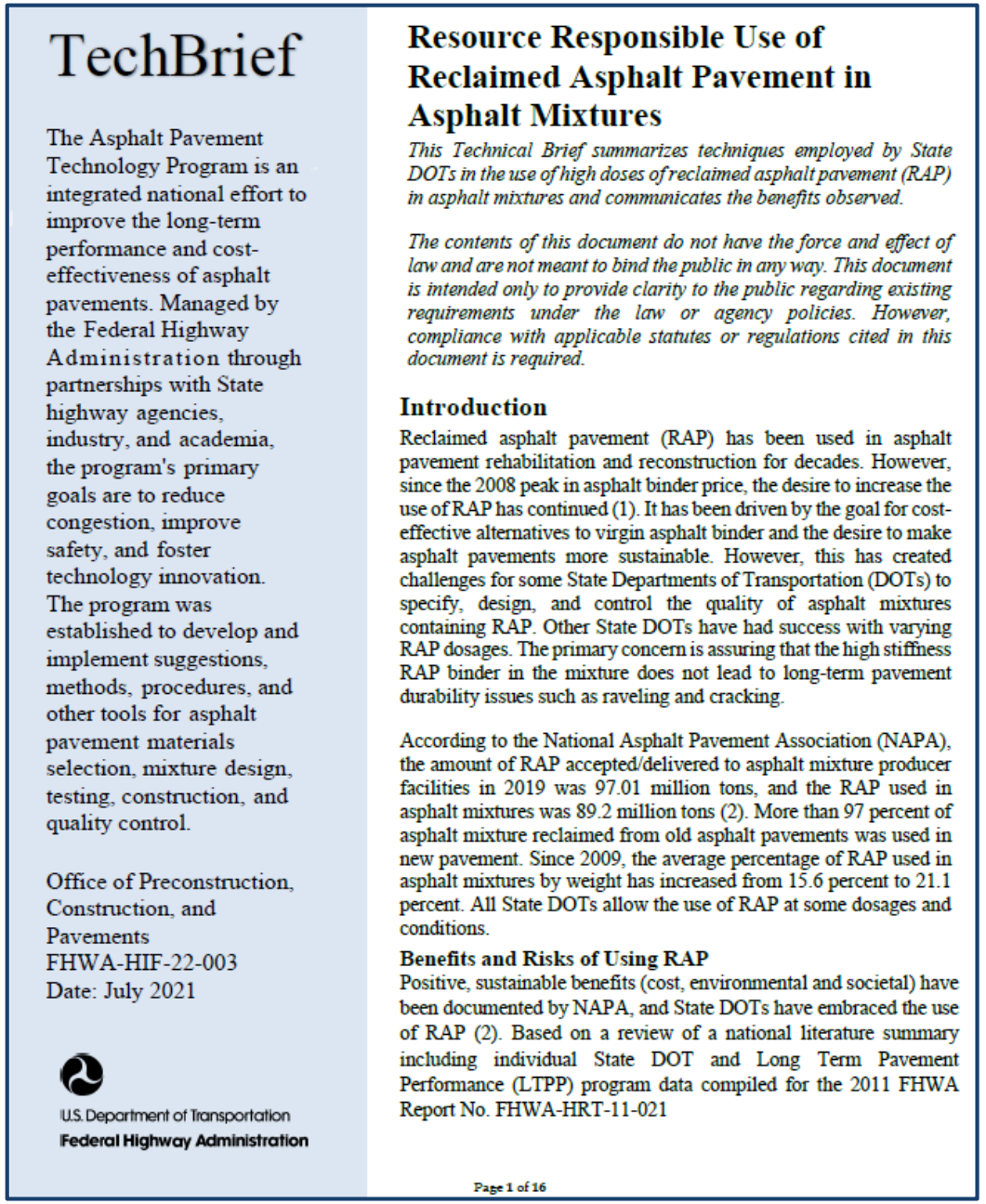
QC, RAP Processing, and Handling

- Contractor process control and QC.
  - Each asphalt plant has an on-site QC lab.
- Dedicated RAP stockpiles (FDOT, SCDOT, WSDOT).
- Blending, screening, and crushing over-size materials for consistency (FDOT, SCDOT, WisDOT, WSDOT).
- Allowing fractionation of RAP (FDOT, SCDOT, WisDOT).

Quality Assurance

- PWL acceptance specifications (FDOT, WisDOT, WSDOT).
- Mixture performance tests during test strips and acceptance (NJDOT, WSDOT).





TechBrief

The Asphalt Pavement Technology Program is an integrated national effort to improve the long-term performance and cost-effectiveness of asphalt pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, industry, and academia, the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement suggestions, methods, procedures, and other tools for asphalt pavement materials selection, mixture design, testing, construction, and quality control.

Office of Preconstruction, Construction, and Pavements
FHWA-HIF-22-003
Date: July 2021

U.S. Department of Transportation
Federal Highway Administration

Resource Responsible Use of Reclaimed Asphalt Pavement in Asphalt Mixtures

This Technical Brief summarizes techniques employed by State DOTs in the use of high doses of reclaimed asphalt pavement (RAP) in asphalt mixtures and communicates the benefits observed.

The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. This document is intended only to provide clarity to the public regarding existing requirements under the law or agency policies. However, compliance with applicable statutes or regulations cited in this document is required.

Introduction

Reclaimed asphalt pavement (RAP) has been used in asphalt pavement rehabilitation and reconstruction for decades. However, since the 2008 peak in asphalt binder price, the desire to increase the use of RAP has continued (1). It has been driven by the goal for cost-effective alternatives to virgin asphalt binder and the desire to make asphalt pavements more sustainable. However, this has created challenges for some State Departments of Transportation (DOTs) to specify, design, and control the quality of asphalt mixtures containing RAP. Other State DOTs have had success with varying RAP dosages. The primary concern is assuring that the high stiffness RAP binder in the mixture does not lead to long-term pavement durability issues such as raveling and cracking.

According to the National Asphalt Pavement Association (NAPA), the amount of RAP accepted/delivered to asphalt mixture producer facilities in 2019 was 97.01 million tons, and the RAP used in asphalt mixtures was 89.2 million tons (2). More than 97 percent of asphalt mixture reclaimed from old asphalt pavements was used in new pavement. Since 2009, the average percentage of RAP used in asphalt mixtures by weight has increased from 15.6 percent to 21.1 percent. All State DOTs allow the use of RAP at some dosages and conditions.

Benefits and Risks of Using RAP

Positive, sustainable benefits (cost, environmental and societal) have been documented by NAPA, and State DOTs have embraced the use of RAP (2). Based on a review of a national literature summary including individual State DOT and Long Term Pavement Performance (LTPP) program data compiled for the 2011 FHWA Report No. FHWA-HRT-11-021

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Summary

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- NAPA reports about 20% RAP typical, participating State DOTs reported success with 30-50% RAP.
- Sustainable benefits: *Cost, Environmental & Societal.*
- Good pavement performance accomplished through:
  - Regular review of DOT specifications, mixture design procedures, & performance test methods.
  - Monitoring pavement performance.
  - Working with asphalt producers for improvement.
  - Performing research as a basis for changes.

Resource Responsible use of Materials for Flexible Pavement Systems

Thank You

Q & A

Tech Brief

FHWA-HIF-22-003

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