Best Practices for Recycled Asphalt Pavements (RAP)

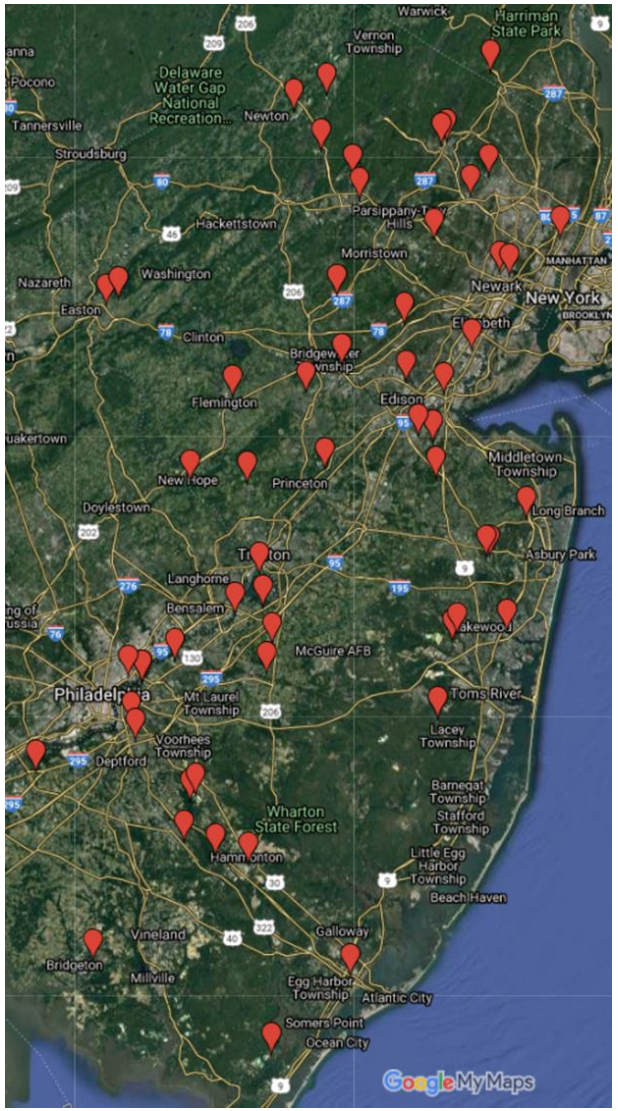
NJAPA

DEPARTMENT OF TRANSPORTATION
THE STATE OF NEW JERSEY

TILCON
A CRH COMPANY

RAP Discussion Outline

- Recycled Asphalt Pavement (RAP)
  - Basics and Use
  - Benefits
  - Processing & Management
  - Consistency
  - Performance
  - Future



Recycled Asphalt Pavement (RAP) Basics and Impact

RAP Basics

- Reclaimed Asphalt Pavement
  - Existing asphalt pavement material that is removed and reused.
- Sources of RAP:
  - Pavement Milling / Full-Depth Removal / Wasted plant material
- Consists of approximately:
  - 95% aggregate
  - 5% asphalt binder
- Has been used in asphalt mixes routinely since the 1970's
- First usage was in 1915!
- **Documented performance is as good or better than virgin mixes!**

RAP Use and Impacts (2019)

- 89.2 million tons of RAP were used in new pavements in 2019 in the United States
  - Over 99% of RAP removed is used in new pavements
- The average percentage of RAP used in asphalt mixtures has increased from 15.6 percent in 2009 to 21.1 percent in 2019.

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt

RAP Impacts (2019)

- Over $3.3 billion savings annually compared to the average cost of raw materials.

- Asphalt binders savings:
- ~ 24 million barrels
- ~ 3M tons
- ~ 1.1 **Billion** gallons
- >150K tanker trucks equivalent!

- Aggregate savings:
- ~ 84 million tons
- ~19,000 Olympic-size swimming pools equivalent!

- Landfill space reduction:
- ~ 60 million yd3
- ~15 AT&T stadiums equivalent

Data from Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt

Equivalents estimated.

U.S. RAP Survey Data

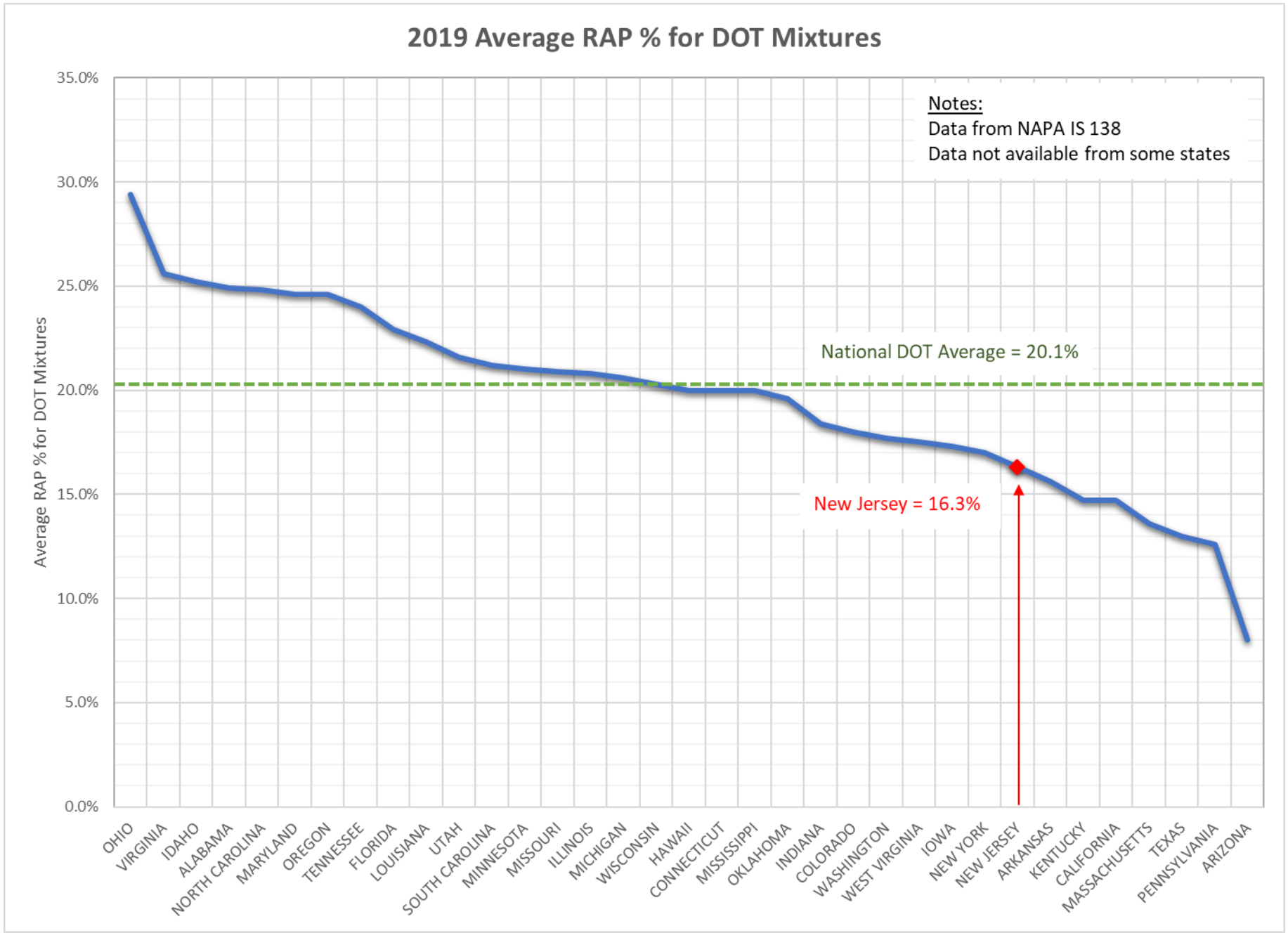
NATIONAL SUMMARY	Reported Values		Estimated Values	
	2018	2019	2018	2019
Tons of HMA/WMA Produced	Tons, Millions		Tons, Millions	
Total	189.6	161.7	389.3	421.9
DOT	78.1	63.2	160.4	164.8
Other Agency	50.9	42.2	104.6	110.2
Commercial & Residential	60.6	56.3	124.3	146.8
No. of Companies Reporting	272	212		
RAP	Tons, Millions		Tons, Millions	
Accepted	46.8	40.2	101.1	97.0
Used in HMA/WMA Mixtures	41.1	36.5	82.2	89.2
Used as Aggregate	2.9	1.7	6.4	3.8
Used in Cold-Mix Asphalt	0.1	0.1	0.3	0.3
Used in Other	0.9	0.6	2.0	1.4
Landfilled	0.0	0.1	0.0	0.1
Total Tons of RAP Stockpiled at Year-End	54.9	58.8	110.3	138.0
	Avg. % Used in Mixtures		Avg. % Used in Mixtures	
Average % for DOT Mixtures[1]	20.2%	20.1%		
Average % for Other Agency Mixtures[1]	20.0%	19.3%		
Average % for Commercial & Residential Mixtures[1]	23.3%	23.4%		

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt

New Jersey RAP Survey Data

NEW JERSEY	Reported Values		Estimated Values	
	2018	2019	2018	2019
Tons of HMA/WMA Produced	Tons, Millions		Tons, Millions	
Total	4.0	6.8	10.2	11.8
DOT	0.4	1.5	1.0	2.6
Other Agency	2.3	3.4	5.9	5.9
Commercial & Residential	1.3	1.9	3.3	3.3
No. of Companies Reporting	3	4		
RAP	Tons, Millions		Tons, Millions	
Accepted	1.5	2.5	3.8	4.3
Used in HMA/WMA Mixtures	0.7	1.4	1.8	2.4
Used as Aggregate	0.2	0.5	0.6	0.9
Used in Cold-Mix Asphalt	0.0	0.0	0.0	0.0
Used in Other	0.0	0.0	0.0	0.0
Landfilled	0.0	0.0	0.0	0.0
Total Tons of RAP Stockpiled at Year-End	4.24	6.32	10.81	11.04
	Avg. % Used in Mixtures		Avg. % Used in Mixtures	
Average % for DOT Mixtures[1]	13.3%	16.3%		
Average % for Other Agency Mixtures[1]	17.7%	17.5%		
Average % for Commercial & Residential Mixtures[1]	25.0%	24.0%		
State Average All Mixtures Based on RAP Tons Used in HMA/WMA[2]			17.5%	20.3%

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt


2019 Average RAP % for DOT Mixtures
Notes:
Data from NAPA IS 138
Data not available from some states
National DOT Average = 20.1%
New Jersey = 16.3%
Average RAP % for DOT Mixtures
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
OHIO
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MISSOURI
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MISSISSIPPI
OKLAHOMA
INDIANA
COLORADO
WASHINGTON
WEST VIRGINIA
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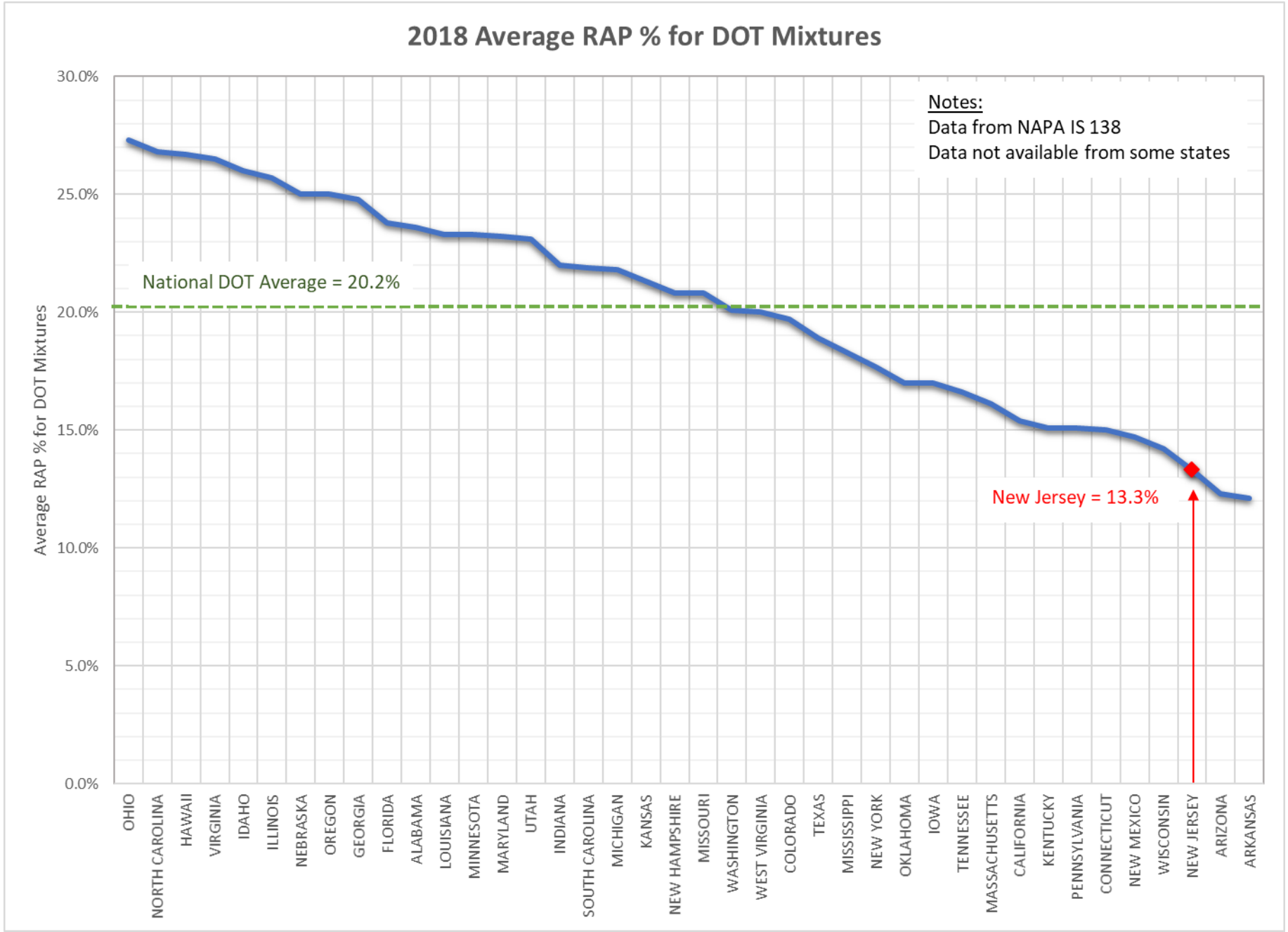
MASSACHUSETTS
TEXAS
PENNSYLVANIA
ARIZONA


2018 Average RAP % for DOT Mixtures
Notes:
Data from NAPA IS 138
Data not available from some states
National DOT Average = 20.2%
New Jersey = 13.3%
Average RAP % for DOT Mixtures
30.0%
25.0%
20.0%
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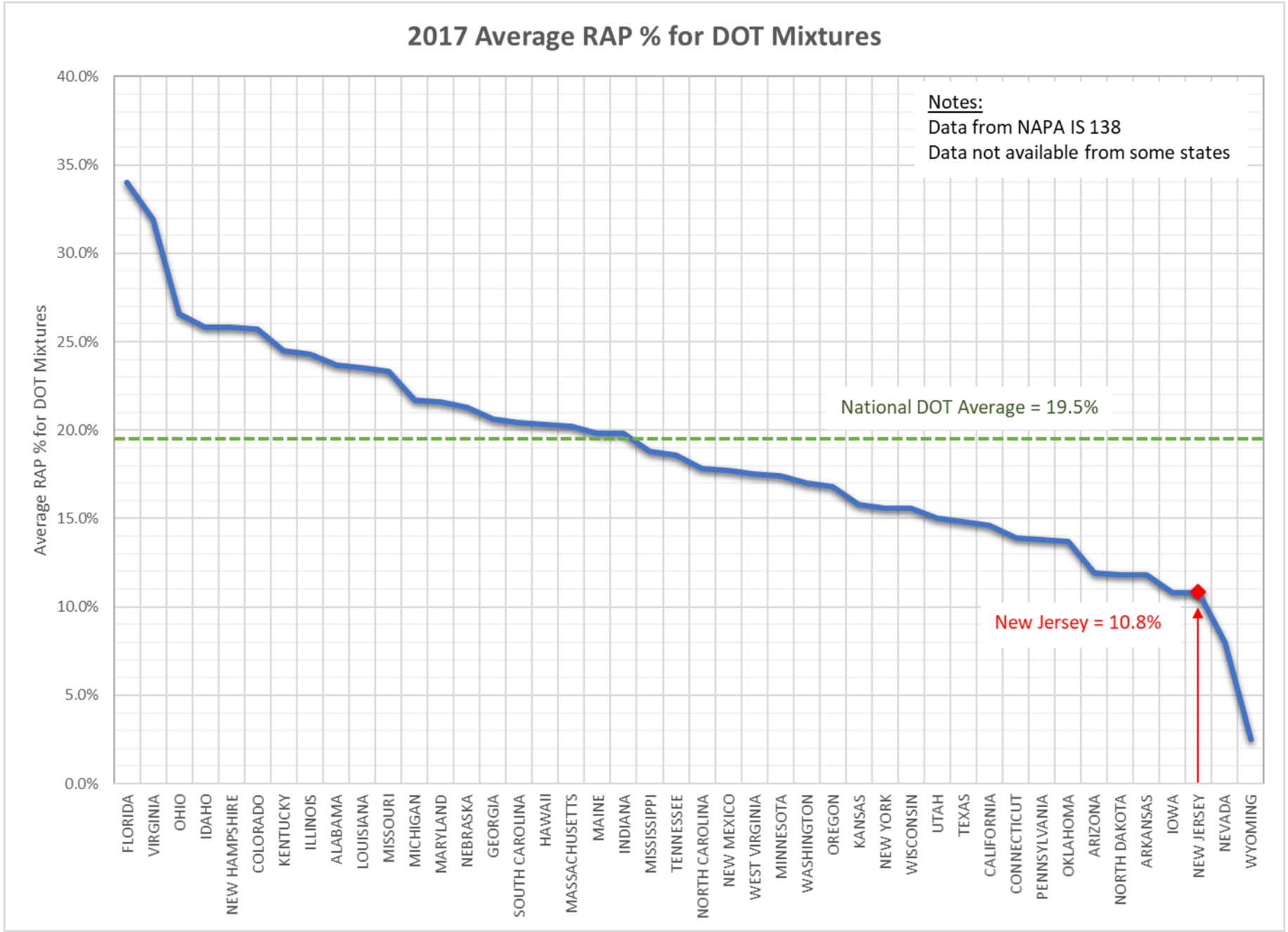
ARKANSAS


2017 Average RAP % for DOT Mixtures
Notes:
Data from NAPA IS 138
Data not available from some states
National DOT Average = 19.5%
New Jersey = 10.8%
Average RAP % for DOT Mixtures
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
FLORIDA
VIRGINIA
OHIO
IDAHO
NEW HAMPSHIRE
COLORADO
KENTUCKY
ILLINOIS
ALABAMA
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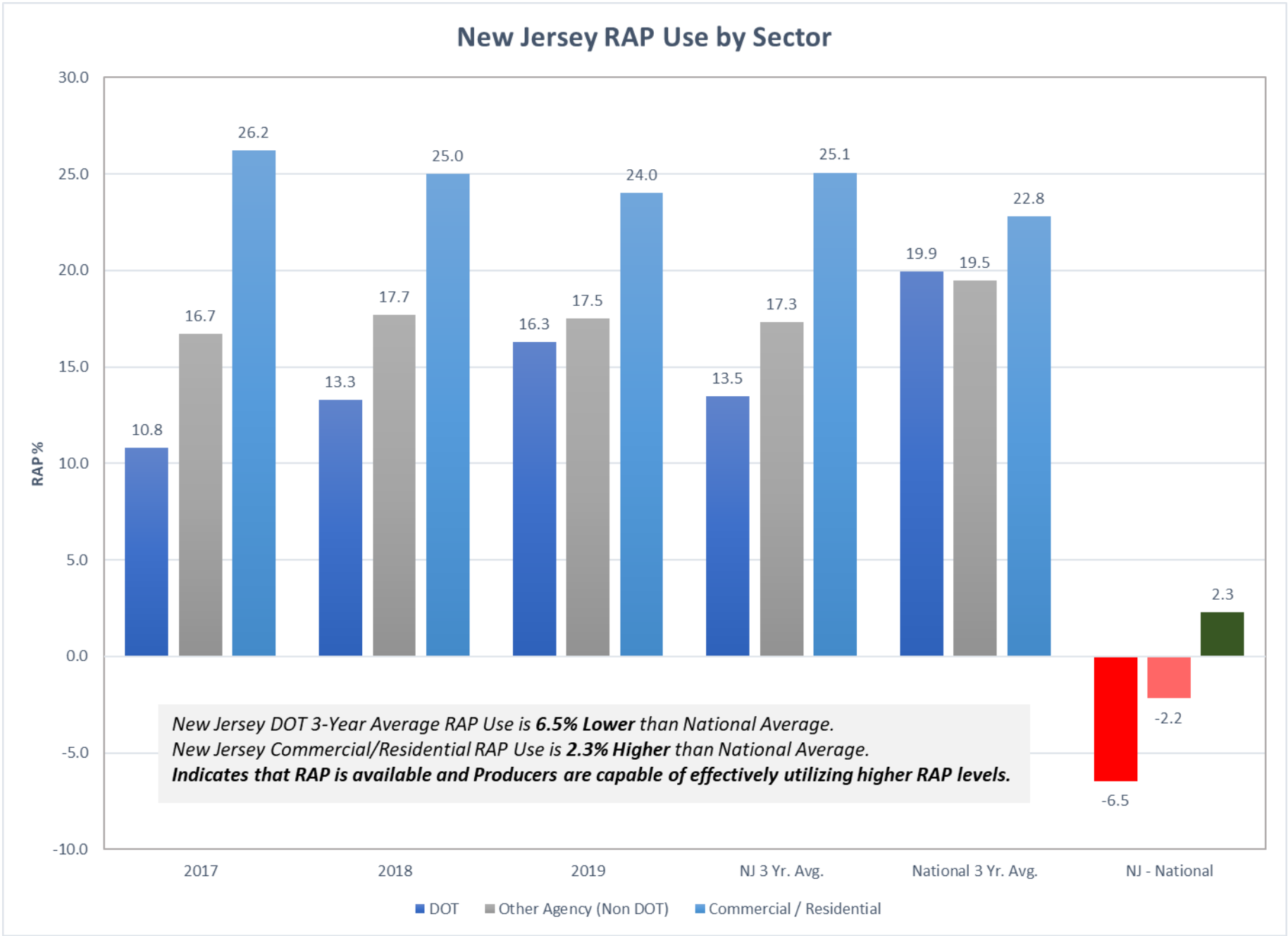


Source: NAPA IS 138 (2017, 2018, 2019)

New Jersey RAP Stockpiled

State	Reported Tons Stockpiled (Million) 2018	2019	Estimated Tons Stockpiled (Million) 2018	2019	State	Reported Tons Stockpiled (Million) 2018	2019	Estimated Tons Stockpiled (Million) 2018	2019
Alabama	1.80	0.80	2.41	1.62	Montana	*	*	*	*
Alaska	*	*	*	*	Nebraska	0.32	*	1.60	*
American Samoa	*	*	*	*	Nevada	*	*	*	*
Arizona	0.58	0.46	1.18	0.99	New Hampshire	0.15	*	0.15	*
Arkansas	0.30	0.18	0.52	0.48	New Jersey	4.24	6.32	10.81	11.04
California	1.52	0.69	3.90	2.29	New Mexico	0.14	*	0.78	*
Colorado	0.37	0.66	1.46	1.32	New York	2.02	1.20	5.92	3.14
Connecticut	1.00	0.20	2.22	0.44	North Carolina	1.14	1.63	3.17	3.16
Delaware	*	NCR	*	NCR	North Dakota	*	*	*	*
District of Columbia	*	*	*	*	No. Mariana Isl.	NCR	NCR	NCR	NCR
Florida	0.29	2.24	0.45	3.69	Ohio	8.15	6.37	11.20	11.07
Georgia	3.80	*	9.47	*	Oklahoma	0.36	0.39	0.77	1.10
Guam	NCR	NCR	NCR	NCR	Oregon	0.35	0.82	0.83	2.25
Hawaii	0.10	0.15	0.17	0.19	Pennsylvania	0.93	0.40	2.95	3.18
Idaho	0.73	0.98	1.41	1.80	Puerto Rico	NCR	NCR	NCR	NCR
Illinois	1.00	0.70	3.91	6.33	Rhode Island	*	*	*	*
Indiana	2.37	1.16	3.57	3.30	South Carolina	1.09	0.71	1.99	1.91
Iowa	0.12	0.34	0.25	1.38	South Dakota	NCR	NCR	NCR	NCR
Kansas	0.83	*	0.86	*	Tennessee	1.39	4.02	2.17	4.94
Kentucky	0.97	0.33	1.20	0.80	Texas	1.68	0.77	4.01	5.27
Louisiana	0.16	0.19	1.32	1.08	U.S. Virgin Islands	*	NCR	*	NCR
Maine	*	*	*	*	Utah	1.43	1.17	1.55	1.66
Maryland	1.02	0.16	1.58	0.68	Vermont	*	*	*	*
Massachusetts	1.28	0.54	1.66	1.65	Virginia	1.81	1.73	3.90	3.60
Michigan	3.17	14.75	5.15	28.12	Washington	1.02	1.26	1.09	1.79
Minnesota	2.13	1.50	3.28	2.93	West Virginia	0.56	0.33	0.78	0.66
Mississippi	0.49	0.43	0.69	0.57	Wisconsin	1.87	2.00	2.54	2.77
Missouri	1.55	1.66	2.65	4.13	Wyoming	*	*	*	*
					Total†	54.86	58.80	110.31	138.04

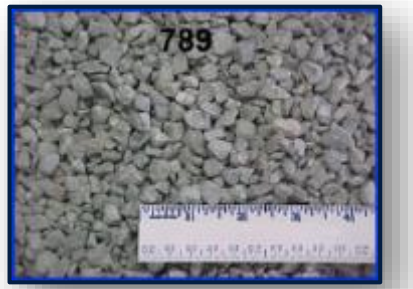
~8% of the total US stockpiled RAP. RAP is available for increased use!!

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt

RAP Benefits

Why Use Recycled Materials?

1. Compliance with FHWA Policies
2. Material supply issues
   - Diminishing reserves in some locations
   - Difficulty permitting new aggregate facilities
   - Past asphalt supply issues
3. Sustainability
   - Reduces impacts on landfills
   - Reduces energy costs and greenhouse gas emissions associated
   - Stewardship of our environment
4. Cost savings potential



FHWA Recycled Materials Policy

U.S. Department of Transportation
Federal Highway Administration

Pavements

Administrator's Message:

FHWA has established agency goals for enhancing the human and natural environment, increasing mobility, raising productivity, improving safety throughout the highway industry, and preserving national security. All of these goals are stated in our strategic plan, and we will ensure that the FHWA recycling policy and recycling programs are in alignment with those goals and underlying principles. This recycling policy statement is offered to advance the use of recycled materials in highway applications. It is intended to provide leadership, direction, and technical guidance to the transportation community for the use of recycling technology and materials in the highway environment.

The FHWA policy is:

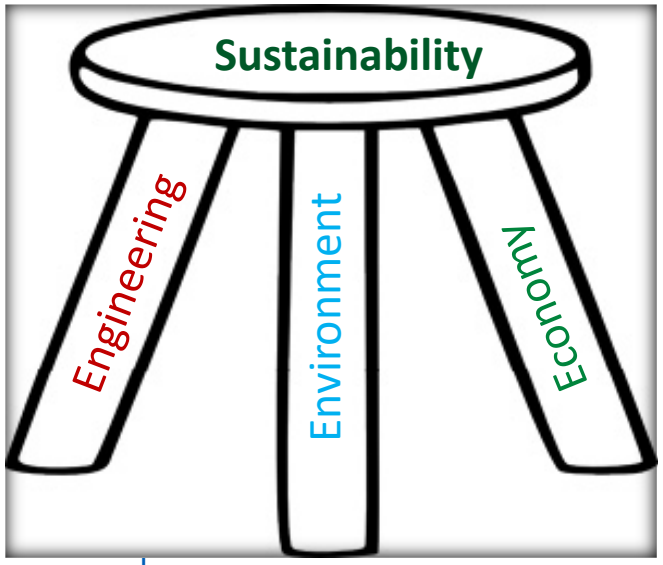
1. Recycling and reuse can offer engineering, economic and environmental benefits.
2. Recycled materials should get first consideration in materials selection.
3. Determination of the use of recycled materials should include an initial review of engineering and environmental suitability.
4. An assessment of economic benefits should follow in the selection process.
5. Restrictions that prohibit the use of recycled materials without technical basis should be removed from specifications.

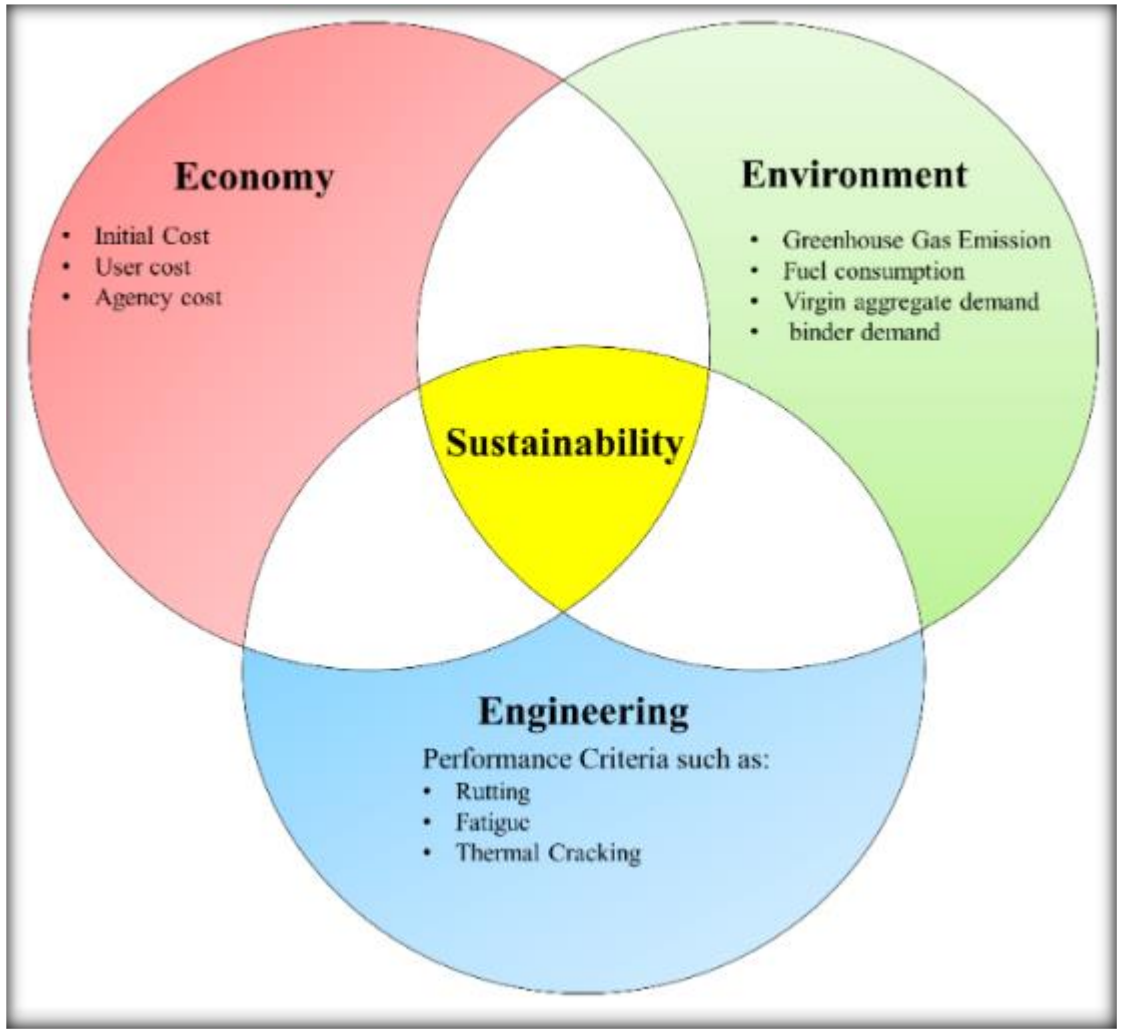
https://www.fhwa.dot.gov/legsregs/directives/policy/recmatpolicy.htm

CRH

Pavement Sustainability

"**Pavement Sustainability** is the optimal **balance** between engineering (performance), environmental, and economic aspects."





https://www.mdpi.com/2076-3298/6/6/73/htm

TechBrief

APRIL 2016 FHWA-HIF-16-012

STRATEGIES FOR IMPROVING SUSTAINABILITY OF ASPHALT PAVEMENTS

ABSTRACT

This Tech Brief summarizes guidance to the pavement community on sustainability considerations for asphalt pavement systems, as presented in greater detail in the recently published *Towards Sustainable Pavement Systems: A Reference Document* (FHWA 2015b). Sustainability considerations throughout the entire pavement life cycle are examined (from material extraction and processing through the design, construction, use, maintenance/rehabilitation, and end-of-life phases) and the importance of recognizing context sensitivity and assessing trade-offs in developing sustainable solutions is emphasized.

This Tech Brief focuses exclusively on sustainability considerations associated with asphalt-surfaced pavement structures and the materials used in their construction. For the purposes of this document, all permanent surfaces constructed with asphalt concrete are generically referred to as "asphalt" pavements.

The primary audience for this document is practitioners doing work within and for government transportation agencies, and it is intended for designers, maintenance, material and construction engineers, inspectors, and planners who are responsible for the design, construction and preservation of the nation's highway network.

INTRODUCTION

An increasing number of agencies, companies, organizations, institutes, and governing bodies are embracing principles of sustainability in managing their activities and conducting business. A sustainable approach focuses on the overarching goal of considering key environmental, social, and economic factors in the decision-making process. Sustainability considerations are not new and, in fact, have often been considered indirectly or informally. In recent years, significant efforts have been made to quantify sustainability effects and to incorporate more sustainable practices in a systematic and organized manner.

A companion Tech Brief (FHWA 2014) presents a summary of the application of sustainability concepts to pavements. It provides an introduction to these concepts and how they are applied as best practices in the industry, focusing on current and emerging technologies and trends.

A sustainable pavement is one that achieves its specific engineering goals, while, on a broader scale, (1) meets basic human needs, (2) uses resources effectively, and (3) preserves/restores surrounding ecosystems. Sustainability is context sensitive and thus the approach taken is not universal, but rather unique for each pavement application. Furthermore, a "sustainable pavement" as defined here is not yet fully achievable. Today it is an aspirational goal to be worked towards, and ultimately achieved at some point in the future as sustainability best practices continue to evolve.

U.S. Department of Transportation

Page 7: In general, ***recycled materials should be used for the <u>"highest use."</u>*** *Because the asphalt binder in RAP can replace the environmental burden of virgin asphalt production,* ***the <u>highest use</u> would be first as replacement for virgin asphalt and aggregate in new asphalt concrete****, followed by use in recycled cold-mix materials, followed by use as aggregate base or aggregate in concrete.*

Greenhouse Gas (GHG) Reduction w/ RAP (US Data)

Description	GHG Reduction (Burden)
Avoided Emissions	
Asphalt Binder Replacement	2.6
Aggregate Replacement	0.36
Transportation of Asphalt Binder and Aggregates	0.46
Subtotal Avoided Emissions	**3.4**
Emission Burdens	
RAP Processing	(0.11)
Transportation of RAP	(0.90)
Subtotal Emission Burdens	(1.0)
Net GHG Emissions Reduction	**2.4**
Equivalent Number of Passenger Vehicles[1]	**520,000**

1. Assumes that each vehicle emits 4.6 tonne CO_2e/yr (U.S. EPA, 2018).

RAP can substantially aid agency efforts at reducing GHG and targeted carbon reduction goals!

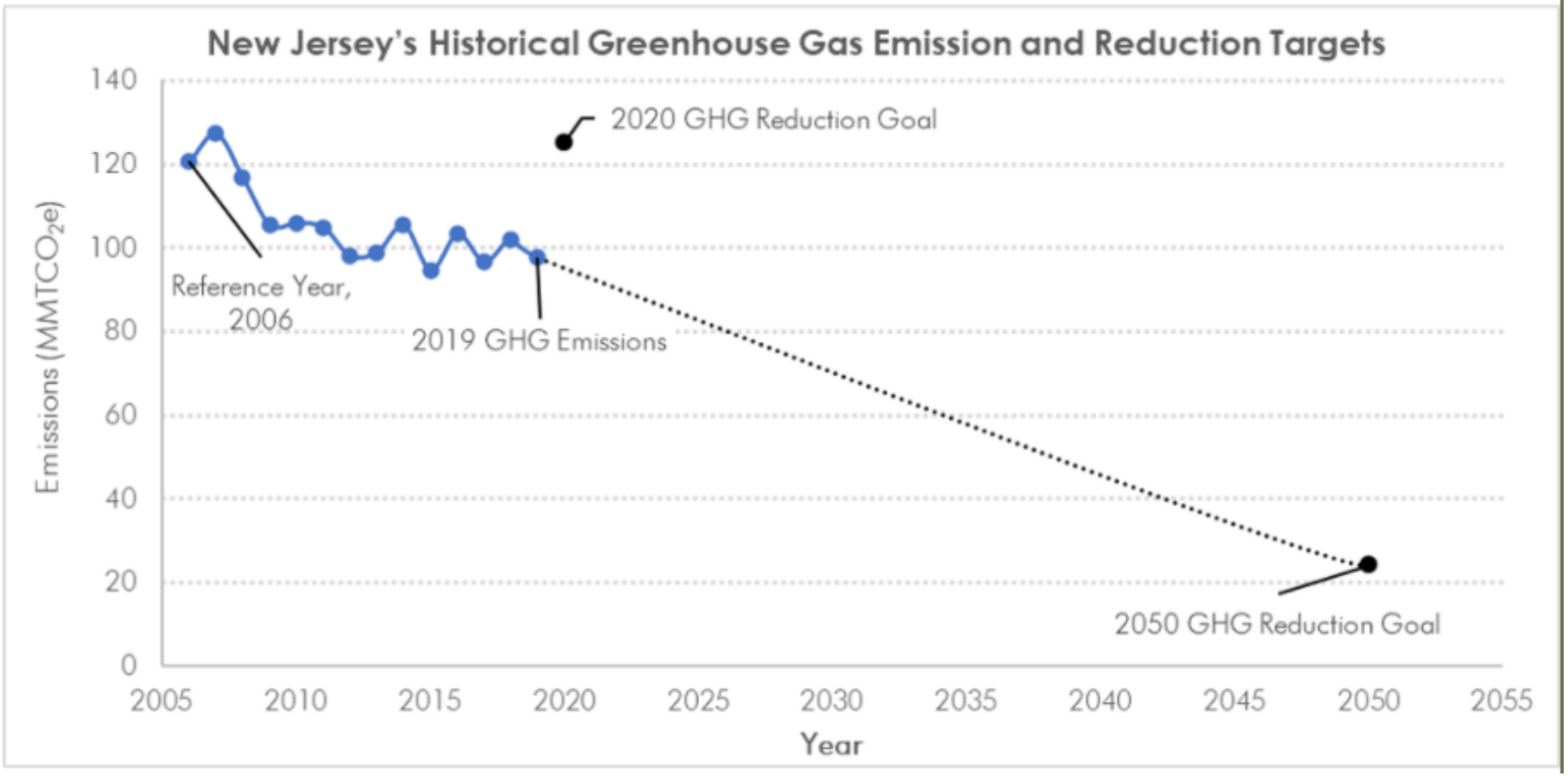
Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt

New Jersey GHG

Achieving New Jersey's Greenhouse Gas Reduction Goals

The Global Warming Response Act (GWRA) (P.L. 2007 c.112; P.L. 2018 c.197) establishes two greenhouse gas reduction goals for New Jersey:

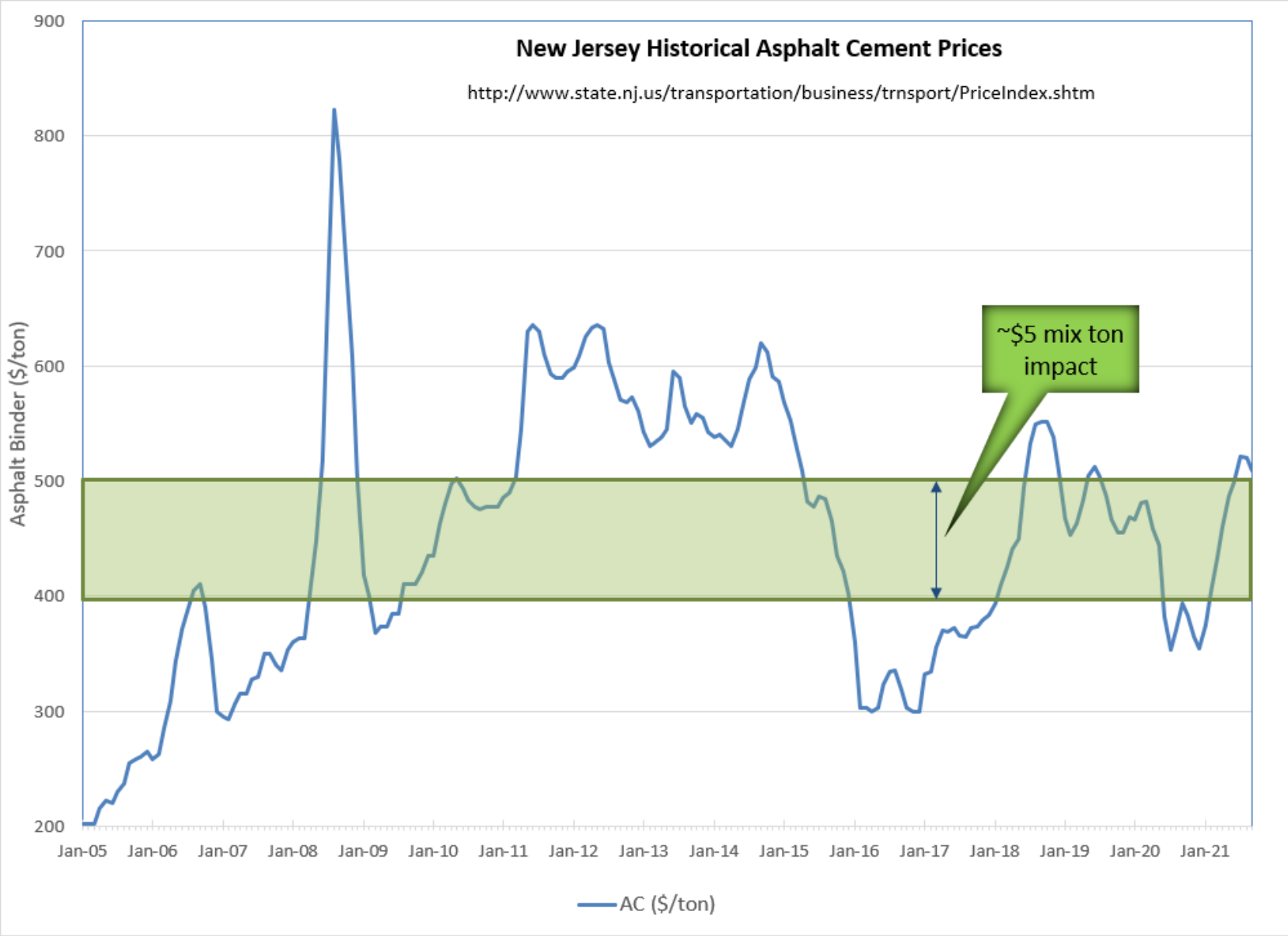
- Reduce statewide greenhouse gas emissions to 1990 levels (approximately 125 MMTCO2e) by the year 2020, and,
- Reduce statewide greenhouse gas emissions 80% below the 2006 level (approximately 24.1 MMTCO2e) by the year 2050.



https://www.nj.gov/dep/aqes/oce-ghgei.html

"Meeting the ambitious GWRA goal of reducing emissions 80% by 2050 will require an economy-wide transformation over the next 30 years that demands all economic sectors, levels of government, communities and individuals to accept and adopt changes that will reduce the adverse effects of climate change."

Asphalt Binder Considerations

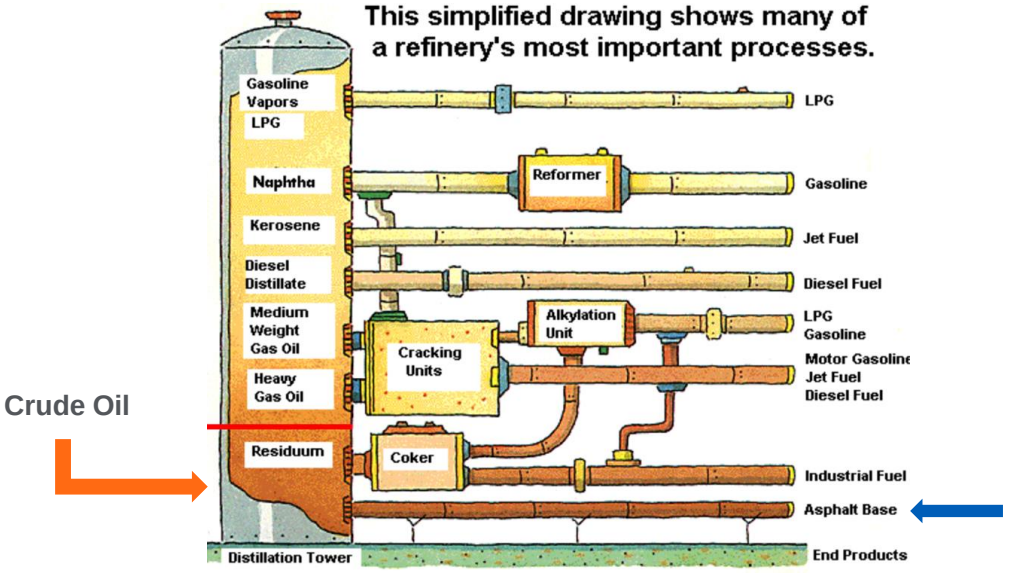


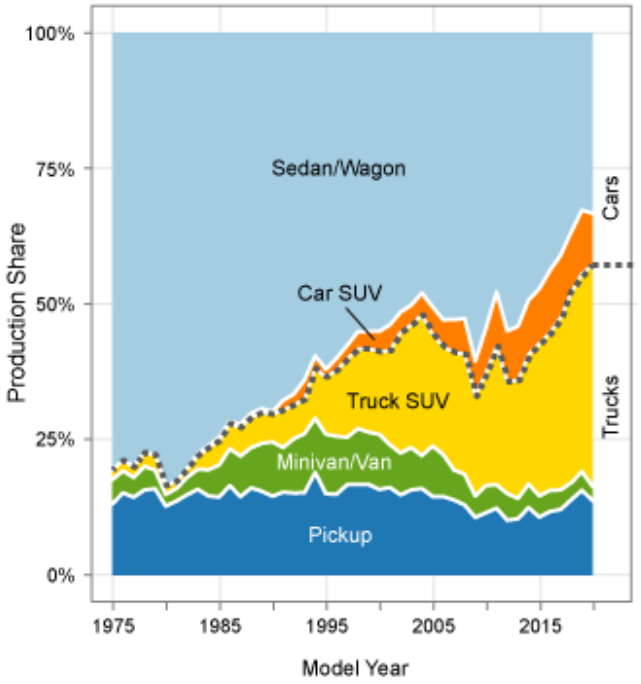
RAP use can help reduce exposure (agency and industry) to asphalt pricing volatility.

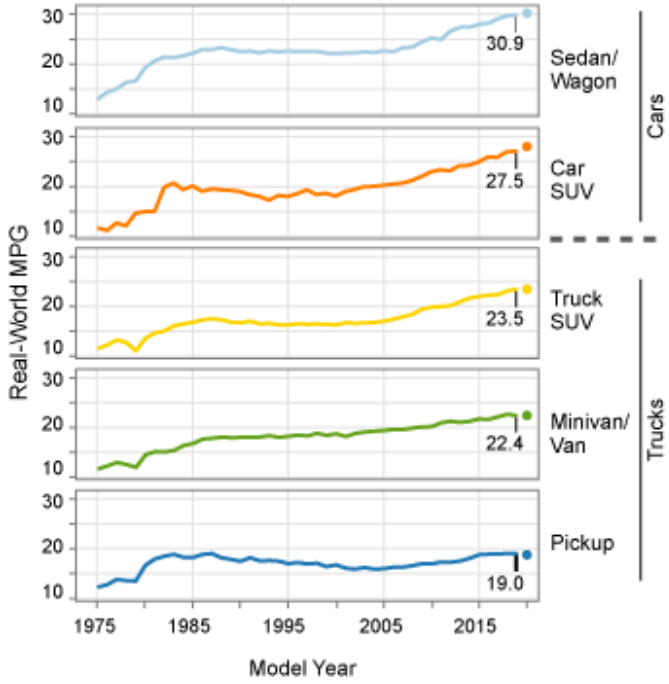
Asphalt Binder Future Supply Thoughts…

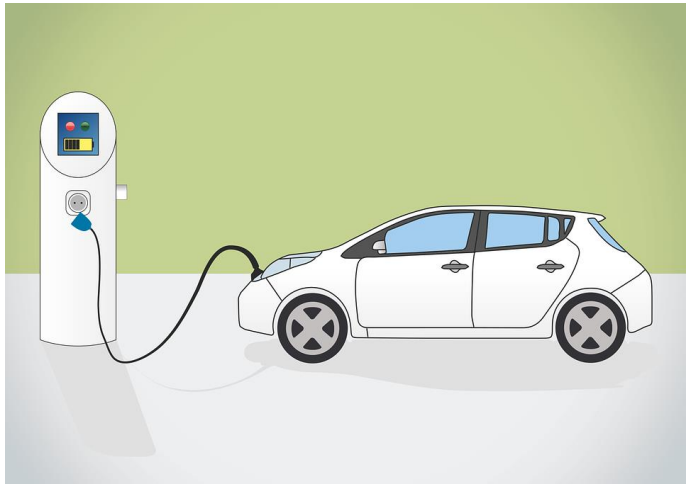
RAP use can help reduce exposure (agency and industry) to potential asphalt supply issue.

- Fuel economy standards increasing.
- Electrification of vehicles increasing.
- Carbon reduction efforts increasing.
- What will be the impact on petroleum supply?
  - Asphalt comes from petroleum?
  - What will the asphalt supply look like?





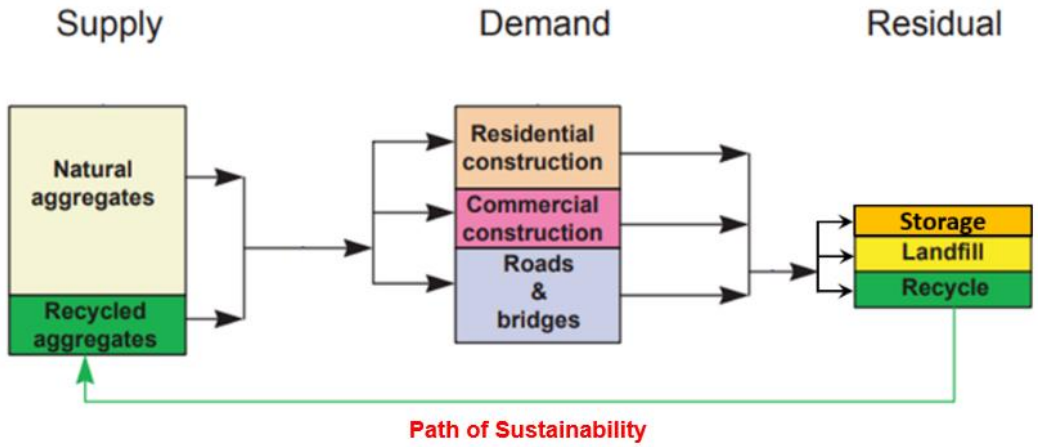


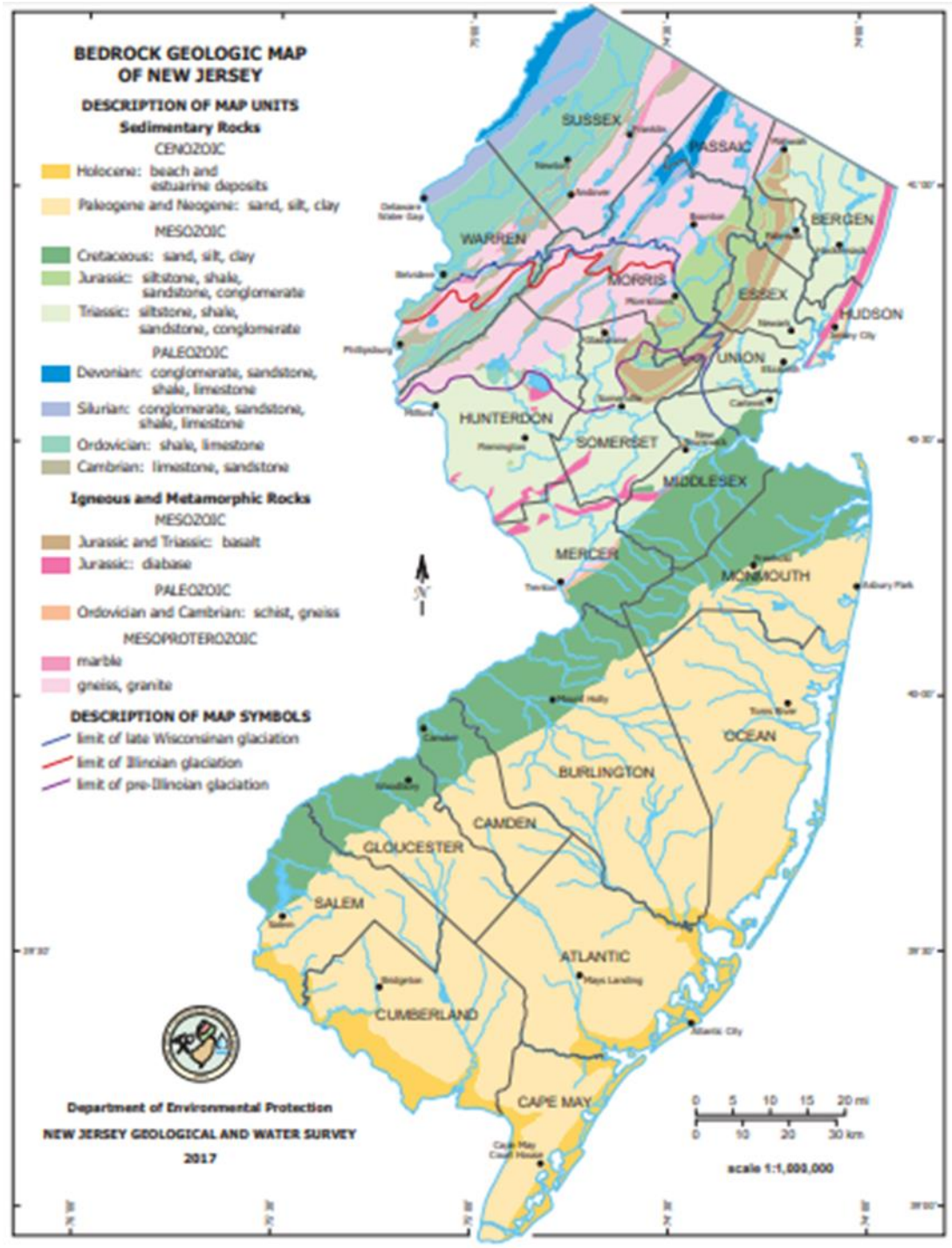


__By 2040__, electric vehicles could make up as much as __40 percent of the U.S. passenger vehicle fleet__ and 60 percent of sales, up from 2 percent of sales today, according to Bloomberg New Energy Finance. That would __erase demand for more than 3 million barrels of oil a day — or more than 20 percent of current transportation consumption.__
https://www.politico.com/story/2019/09/16/oil-industry-electric-car-1729429

Aggregate Supply Considerations

- Limited aggregate reserves for currently permitted facilities.
- Increased difficulty of permitting new facilities.
- At 20% RAP use, approximately 19 years worth of aggregate would be saved over the next 100 years.





RAP Processing and Management

RAP Processing and Management General Steps

Steps for a **QUALITY** Product

1. Obtain the RAP
2. Crush / screen the RAP
3. Stockpile the RAP
4. Test the RAP as Stockpiled
5. Use the RAP
6. Test the RAP as Consumed

Obtain the RAP

- Pavement Milling
- Asphalt Pavement Removal
- Plant Waste

Pavement Milling

Asphalt Pavement Removal

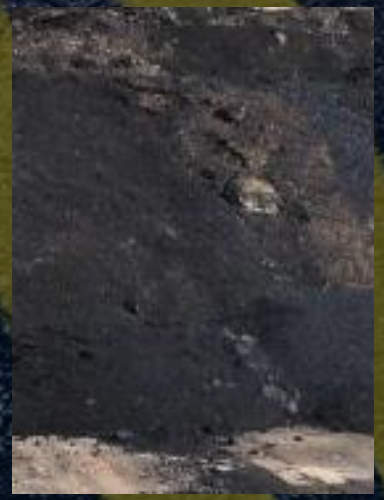
Plant Waste Material

Processing the RAP

- Effective processing begins with proper sorting and storage of RAP.
- Sort RAP appropriately for the desired end use. For example, keep millings separate from other sources.
  - Millings
  - General RAP
  - Agency RAP (approved source or classified)
    - Captive vs Replenished stockpiles
- Remove any potential non-RAP material prior to processing. Especially critical for returned asphalt pavement.

Millings

Broken Asphalt Pavement

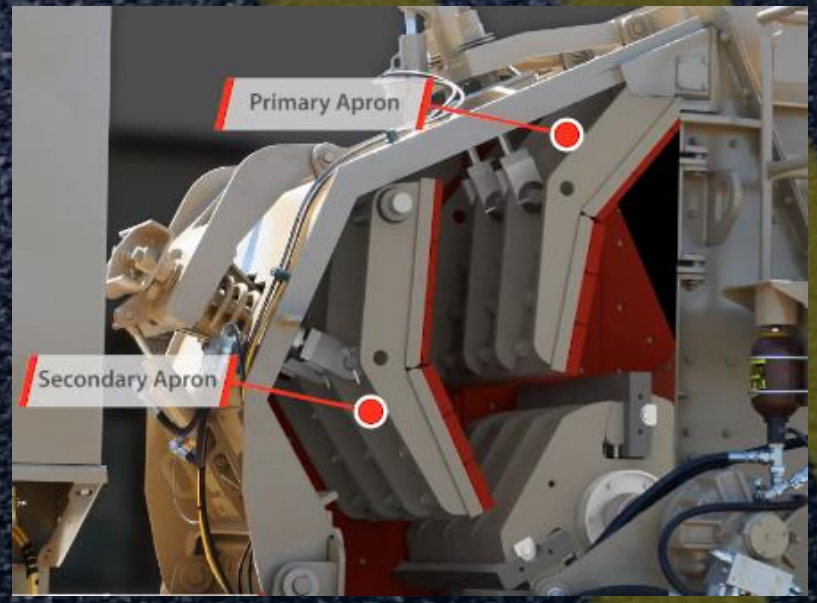


Plant Waste

Crushing / Screening the RAP

- Screen RAP prior to “crushing”. **Only crush the RAP that needs to be crushed!**
- Avoid breakdown and dust generation.
- Goals of RAP “Crushing”

1. Obtain correct top size
2. Break up the RAP, not crush the aggregate (avoid white rock) and dust generation.
3. Achieve a target grading (accuracy)
4. Achieve a consistent grading and binder content (precision)



Crushing / Screening / Stockpiling Operations

- Portable crusher / screening operations often used.
  - 3rd party crushers are very common.
- Horizontal shaft impactors often utilized
  - Varying rotor speed beneficial to break up, not crush, RAP.
  - Crushing the RAP aggregate is a huge negative
    - More water/binder absorption
    - More dust
    - Less binder content per RAP ton
- Screen set up to yield most desirable final product.
  - 5/8 to 1/2” top sieve most common

https://www.kpijci.com/equipment/crushing/andreas-hsi/

RAP Processing

Loading Portable Crusher

Portable Crusher (HSI)

RAP Processing

Screening / Conveyor


Stockpile Processed RAP

Miniature Stockpile
RAP Sampling

General RAP Stockpile Processing

General Stockpile Processing

Loading RAP Crusher (HSI)

Processing General RAP

Screen / Conveyor


Stockpiling

Processed RAP Stockpiles

Processed RAP Stockpile - Maine

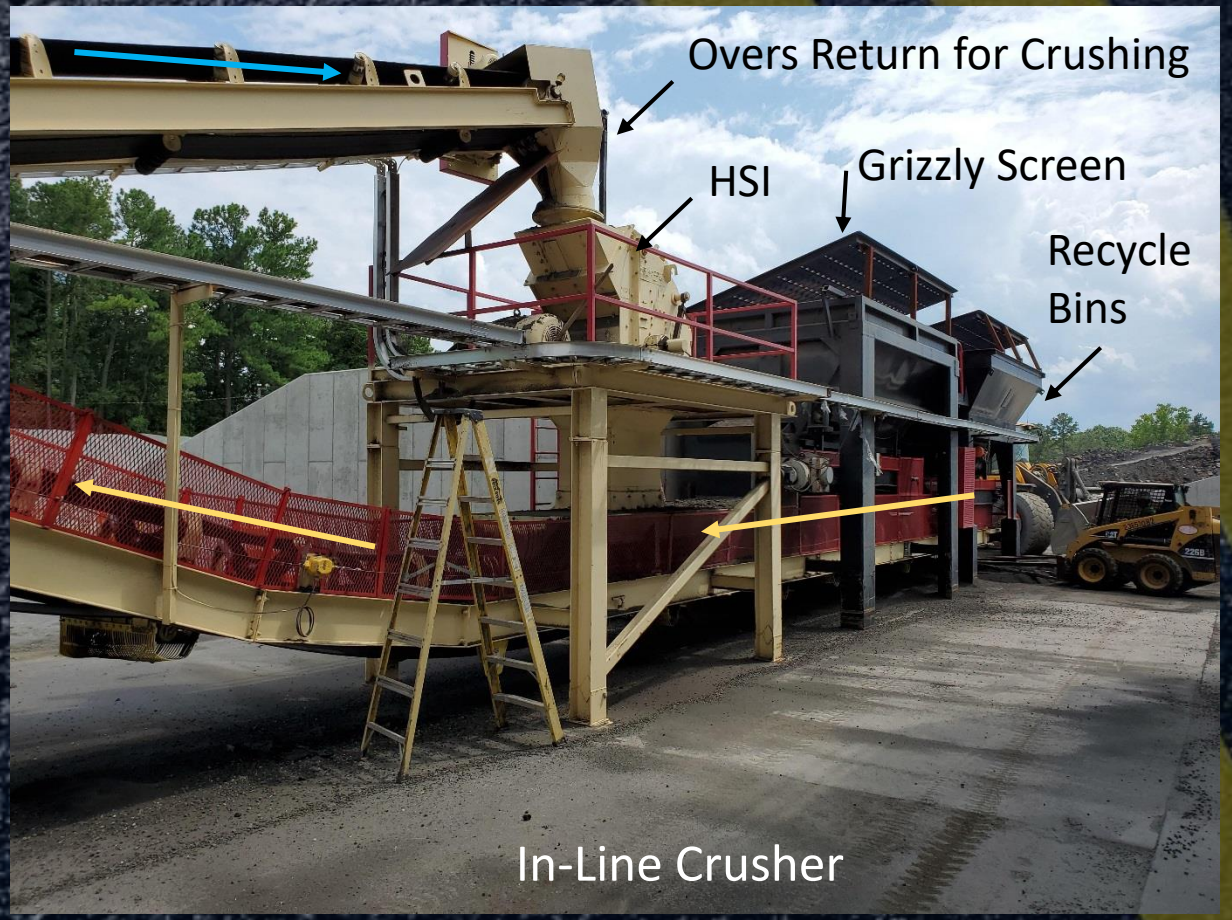
Processed RAP Stockpile - Maine

Processed RAP Stockpile - Texas

In-line RAP Crushing

- In-line RAP crushers are often used in areas of limited plant footprint area (no room for RAP processing/stockpiling)
- Can be used successfully, but it's important to understand the potential for and address changes in RAP gradation when these systems are used
- Ideally in-line crushing circuits will be designed to only break up agglomerations
- Cautions with in-line crushers
  - Crushed/screened RAP goes directly into plant.
  - Sample frequently to ensure consistency
  - Pay attention to feed to ensure uniformity

In-line RAP Crushing



Final RAP grading delivered into plant will be a blend of the RAP "unders" and the crushed RAP "overs".

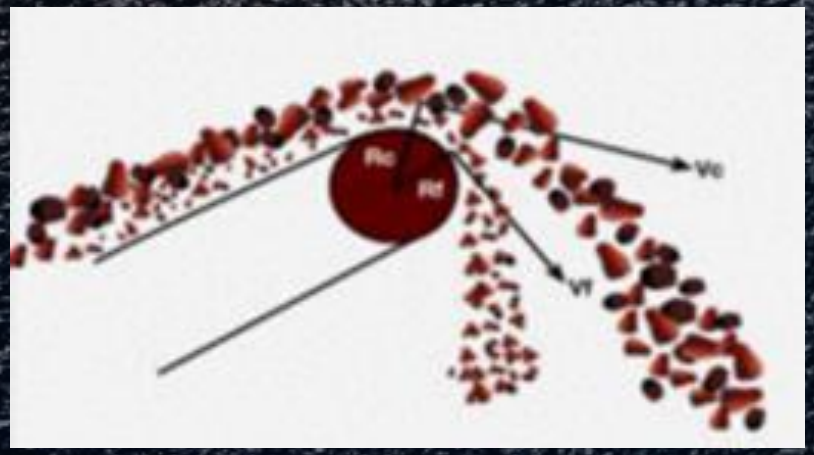
RAP Fractionating

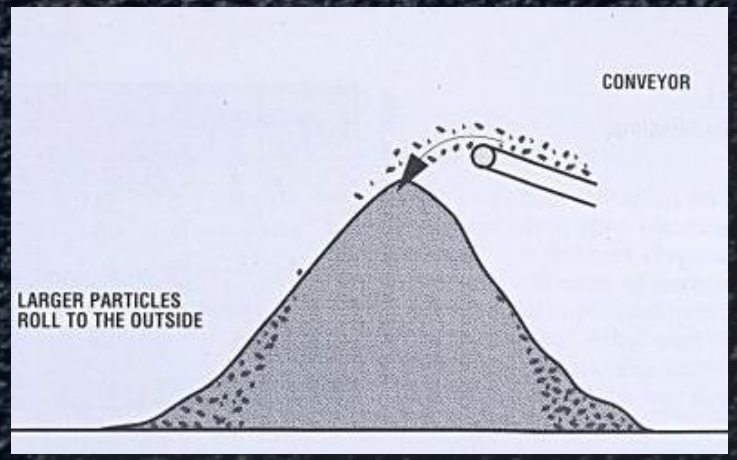
- **Screening RAP is <u>NOT</u> Fractionating RAP**
- Primary advantage of fractionating RAP is having stockpiles of different RAP sizes provide flexibility in meeting mix design requirements
- Typical Sizes
  - 3/4” – 3/8”
  - 3/8” – 3/16”
  - Minus 3/16”
- Fractionating increases RAP cost
- Evaluate benefit/cost ratio

- Fractionating should not be a blanket requirement!
- When should fractionating be considered:
  - Plant site has space for multiple RAP stockpiles
  - Problem meeting mix design requirements
  - Problem meeting project QC requirements

RAP Stockpiling

- Larger aggregate “likes to run” from smaller aggregate.
- Utilize leading stockpiling practices to reduce stockpile segregation.
- Segregation is most common when stockpiles are built using fixed conveyors that allow RAP to drop long distances
- Use of an indexing conveyor / radial stacker can be used to help eliminate pile segregation





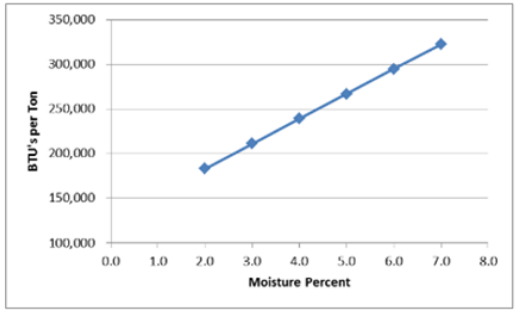
RAP Stockpile Moisture

- **Moisture control and monitoring is key.**
- Ideal case
  - Covered stockpile
  - Paved surface
  - Well drained
- Regardless, the moisture content must be routinely checked and the plant moisture setting adjusted if necessary.

Water Quantities on a Stockpile During a Rain Event

- The amount of water falling on a stockpile during a rain event is very significant.
  - Example: 100 ft. x 100 ft. stockpile will collect 26 tons of water after a 1” rainfall event.
  - This water must either be 1) drained out or 2) dried out.

Stockpile Footprint (sf)	Approximate Dimensions, ft	Water Tonnage Over Footprint After Given Rainfall Events (in)			
		0.5	1	2	3
5000	70 x 70	7	13	26	39
10000	100 x 100	13	26	52	78
15000	125 x 125	20	39	78	117
20000	140 x 140	26	52	104	156
25000	160 x 160	33	65	130	195
30000	175 x 175	39	78	156	234



1% change in moisture equals a ~24,000 BTU change per ton of mix

- ***Best Solution: Keep Water Out Of The Stockpile w/ Coverings!***

RAP Sampling

Miniature Stockpile
RAP Sampling

Sample Splitting

Samples Drying

Miniature Stockpile
RAP Sampling

RAP Testing

- Accurate test results starts with **proper sampling and reduction**
- RAP properties / testing
  - Asphalt binder content
  - Particle size grading
  - Aggregate specific gravity
  - True PG classification


Miniature Stockpile RAP Sampling


Sample Splitting


http://pavementinteractive.org/index.php?title=Image:No_slump.jpg

RAP Binder True Grading

- Extraction, recovery and true grading of the RAP binder will provide **an indication** of the RAP stiffness and allow for the **estimation** of the overall composite PG binder classification. Assumes total blending, but worthwhile.
- Provide insight on how the mix design can be engineered to provide the desired performance.
- Base asphalt, in-place service duration, and climate are drivers of grade.

Table 1-5. RAP binder critical temperatures from regional testing and analyses.

Location of Study	No. of Stockpile Samples Analyzed	Parameter	Critical Temperature, °C		
			Avg.	Std. Dev.	Range
Alabama	36	T_{crit} High	91.7	5.2	84.4 to 105.5
		T_{crit} Intermediate	34.1	4.9	25.2 to 42.9
		T_{crit} Low	-12.5	3.7	+0.4 to -21.6
Florida	21	T_{crit} High	94.8	4.6	87.1 to 106.1
		T_{crit} Intermediate	32.3	3.3	24.5 to 38.5
		T_{crit} Low	-15.8	3.2	-9.8 to -23.2
Indiana	33	T_{crit} High	90	5.0	83 to 103
		T_{crit} Low	-11	3.1	0 to -21
Wisconsin	13	T_{crit} High	82.8	3.7	73.5 to 87.1
		T_{crit} Intermediate	26.9	2.3	20.9 to 29.4
		T_{crit} Low	-21.8	2.3	-18.8 to -27.9

Superpave Asphalt Binder Grading Summary
AASHTO M320

Original Binder				
Test, Method			**Test Results**	**Specification**
Rotational Viscosity @ 135°C, AASHTO T 316, PaS			6.821	≤ 3 PaS
Dynamic Shear Rheometer AASHTO T 315				
Test Temperature, °C	G*, kPa	Phase Angle δ, °	G* / sinδ, kPa	
106	1.07	84.0	1.08	≥ 1.00 kPa
112	0.59	85.4	0.59	
Rolling Thin Film (RTFO) Aged Binder, AASHTO T 240				
Mass Change, %			na	≤ 1.00%
Dynamic Shear Rheometer AASHTO T 315				
Test Temperature, °C	G*, kPa	Phase Angle δ, °	G* / sinδ, kPa	
100	3.01	79.8	3.05	≥ 2.20 kPa
106	1.57	82.0	1.59	
Dynamic Shear Rheometer AASHTO T 315*				
Test Temperature, °C	G*, kPa	Phase Angle δ, °	G* sinδ, kPa	
40	6833	43.8	4728	≤ 5,000 kPa
37	9719	41.4	6423	
Bending Beam Rheometer (BBR) AASHTO T313*				
Test Temperature, °C			RAP	
0	Stiffness, Mpa		163	≤ 300 Mpa
	m-value		0.309	≥ 0.300
-6	Stiffness, Mpa		284	
	m-value		0.267	
True Grade	103.0 -11.3			
PG Grade	**100 - 10**			

RAP Testing Frequency and Variability Guidelines

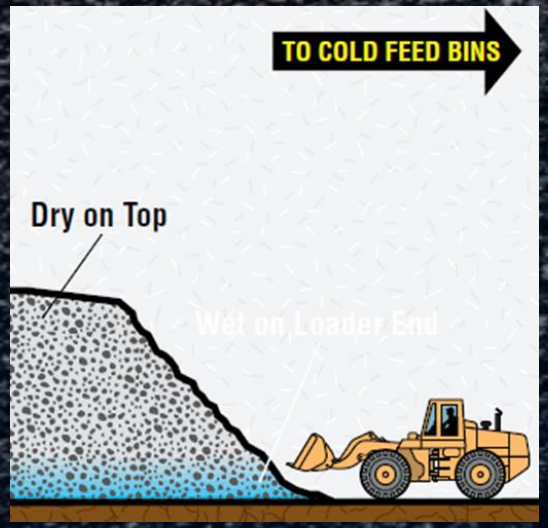
- Testing frequency will vary based on intended application.
- 1 sample per 1,000 ton consumed is typical
- 10 tests recommended to “categorize” a stockpile.
- **Goal should be to have as low a variability as possible.**
- Amount of RAP used will be driven in part by it’s variability!
  - If you have high variability RAP there are two choices.
    1. Use less of it!
    2. Improve the consistency!

RAP Property	Maximum Std. Dev. (%)
Asphalt Content	0.5
% Passing Median Sieve	5.0
% Passing 0.075 mm Sieve	1.5

https://www.asphaltpavement.org/PDFs/EngineeringPubs/QIP129_RAP_-_RAS_Best_Practices_lr.pdf

RAP Loading to Plant

- Use leading practice for stockpile loadout.
- Specifically, keep bucket off the ground to reduce moisture and potential contaminants.
- Consistent recycled bin feed.

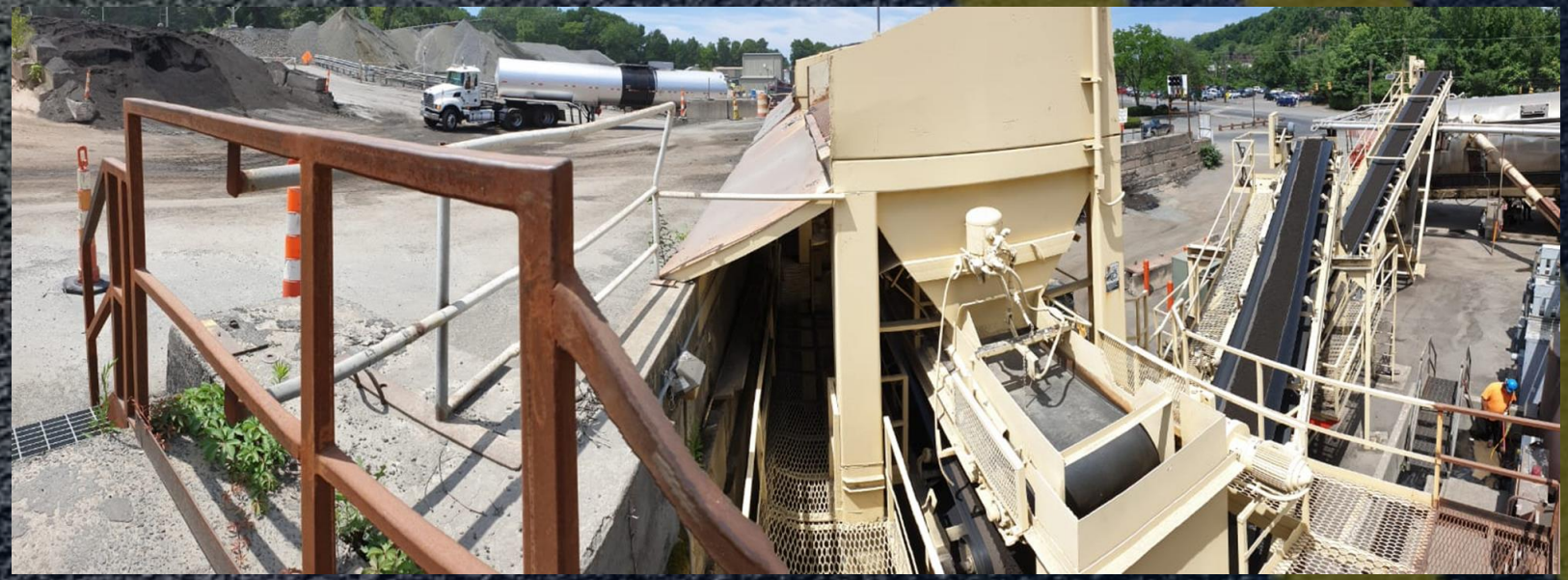


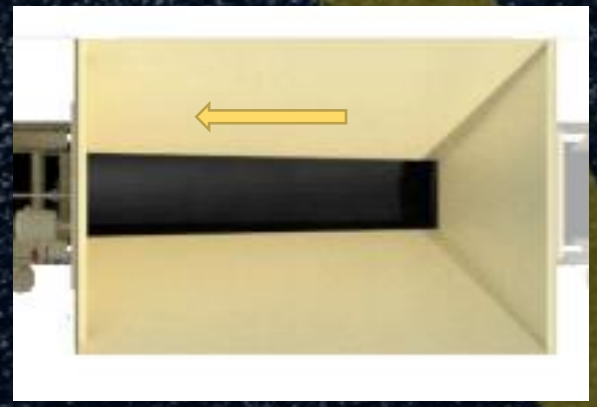

Plant RAP Stockpile Loadout


Loading RAP Bin

Recycle Bins

- Grizzly (oversize)
- No flow switches
- Steeper sides
- Bin vibrators
- Air cannons





https://www.astecinc.com/images/file/literature/Astec-Cold-Feed-Bins-EN.pdf

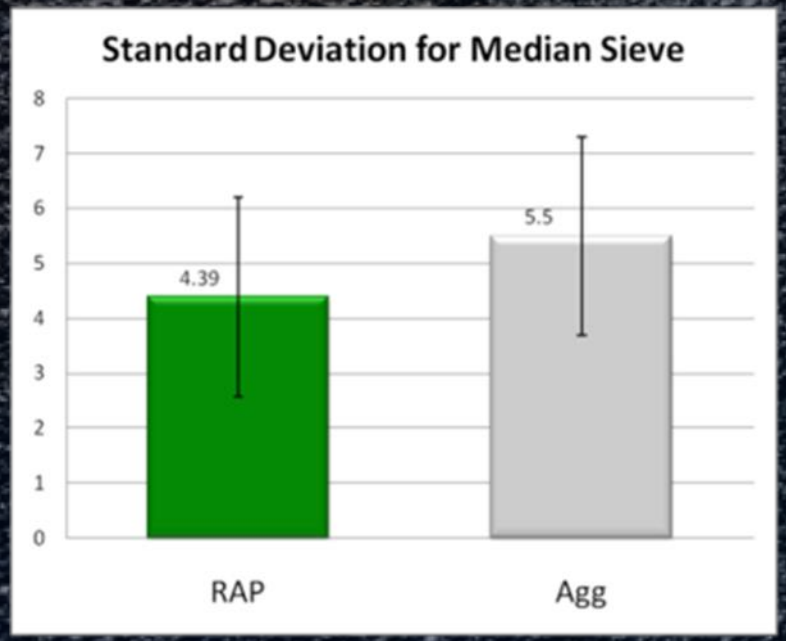
https://almix.com/recycled-material-handling

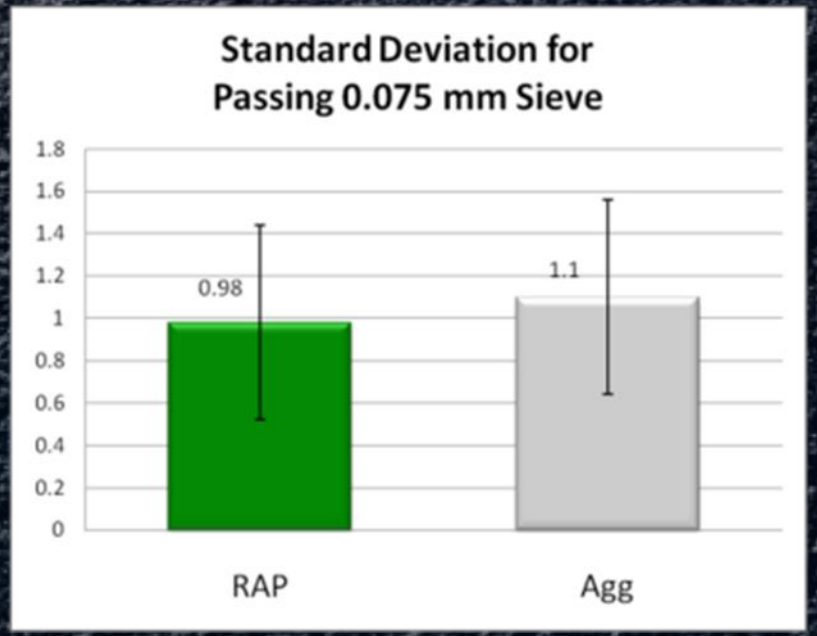
RAP Consistency


Consistency is better than perfection. We can all be consistent-perf ection is impossible.
Michael Hyatt
quotefancy

RAP Consistency Relative to Virgin Aggregates

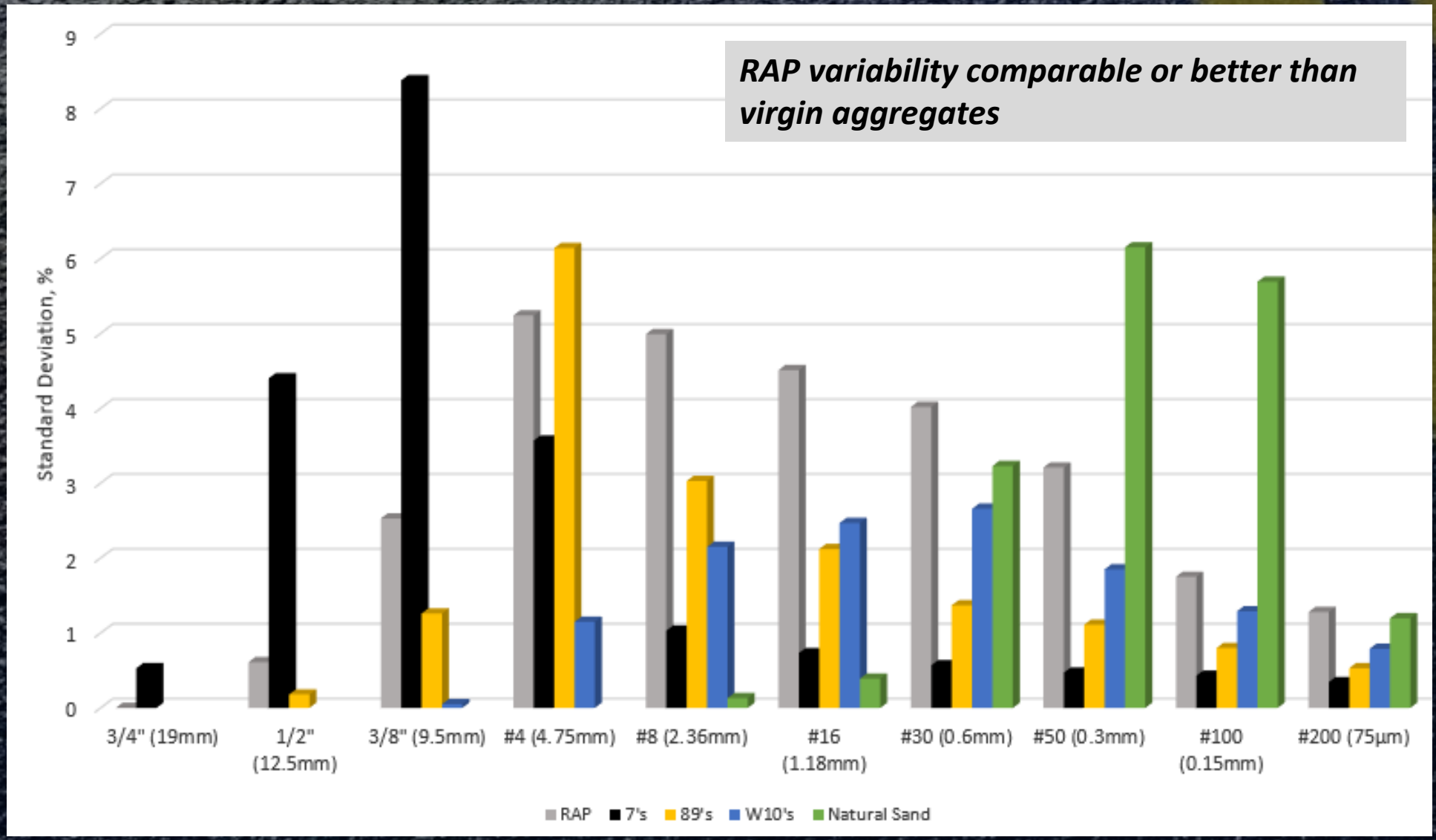
- NCAT study evaluated 74 RAP stockpiles in 14 states, and 60 virgin aggregate stockpiles in 6 states
- RAP was found to have lower grading variability
- Is this surprising? Probably not, RAP has been sized and processed more than virgin aggregate



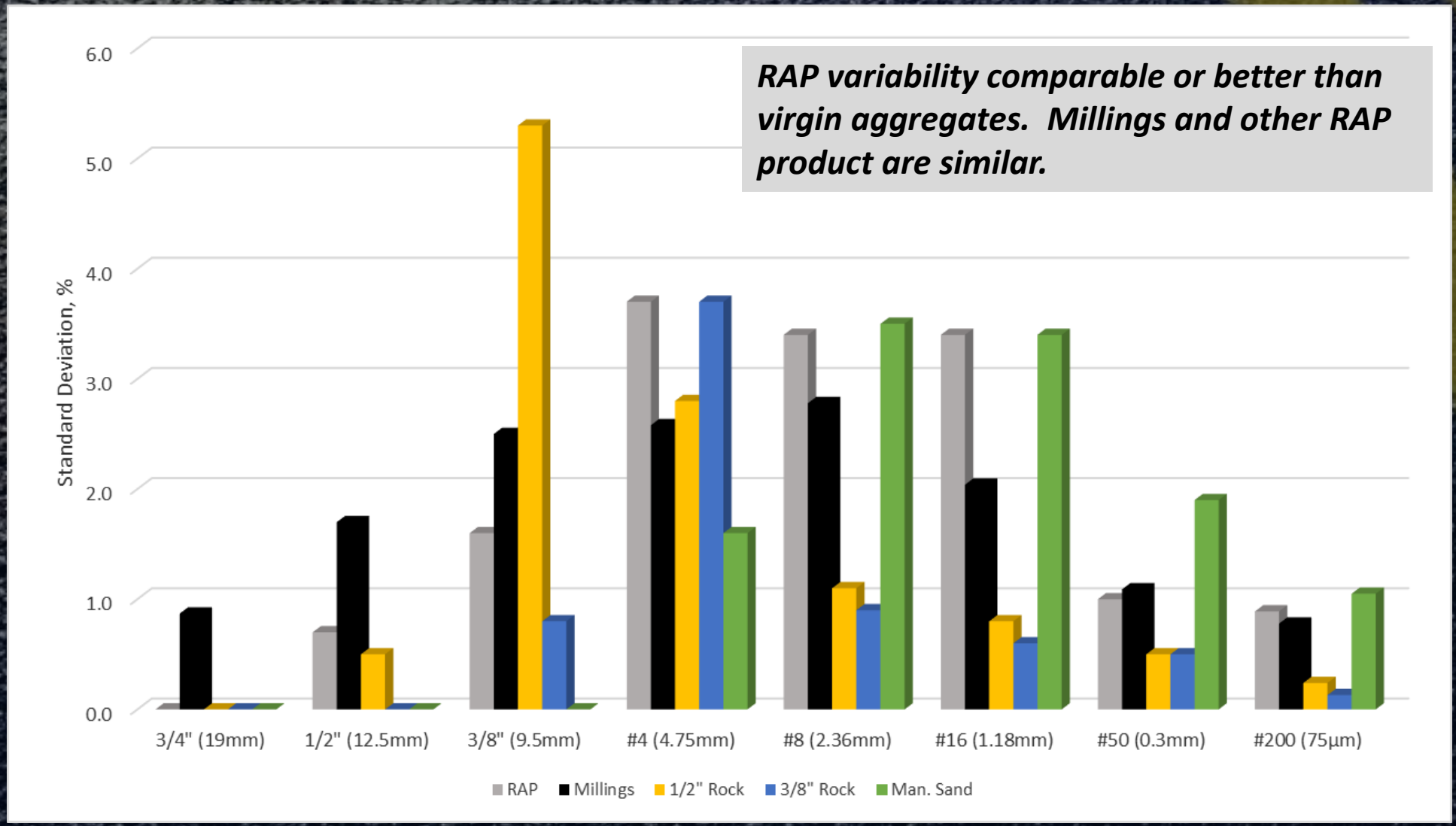


http://www.eng.auburn.edu/research/centers/ncat/rap/files/meetings/10-08/ncat-survey-summary.pdf

Example Variability Data – RAP vs Aggregate

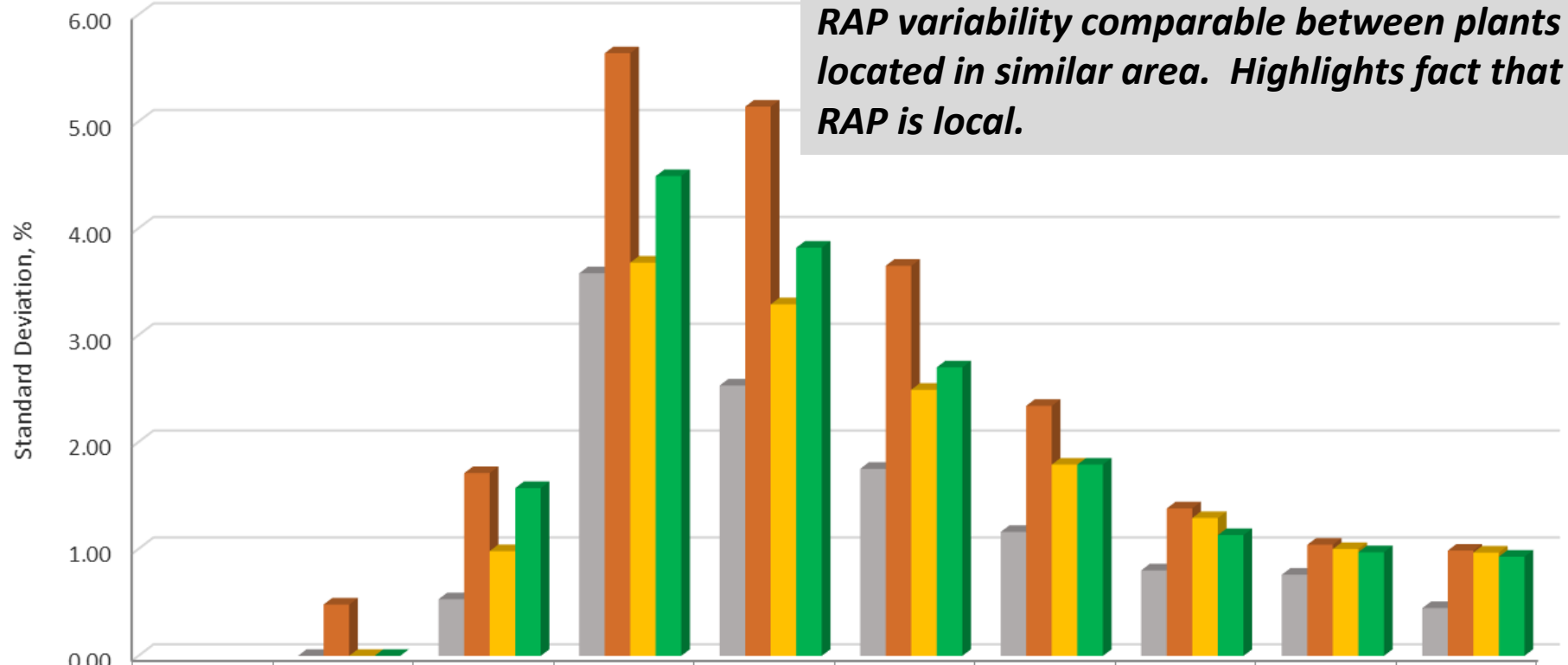


Example Variability Data – General RAP, Millings vs Aggregate



RAP Variability Data – Multi Plant RAP

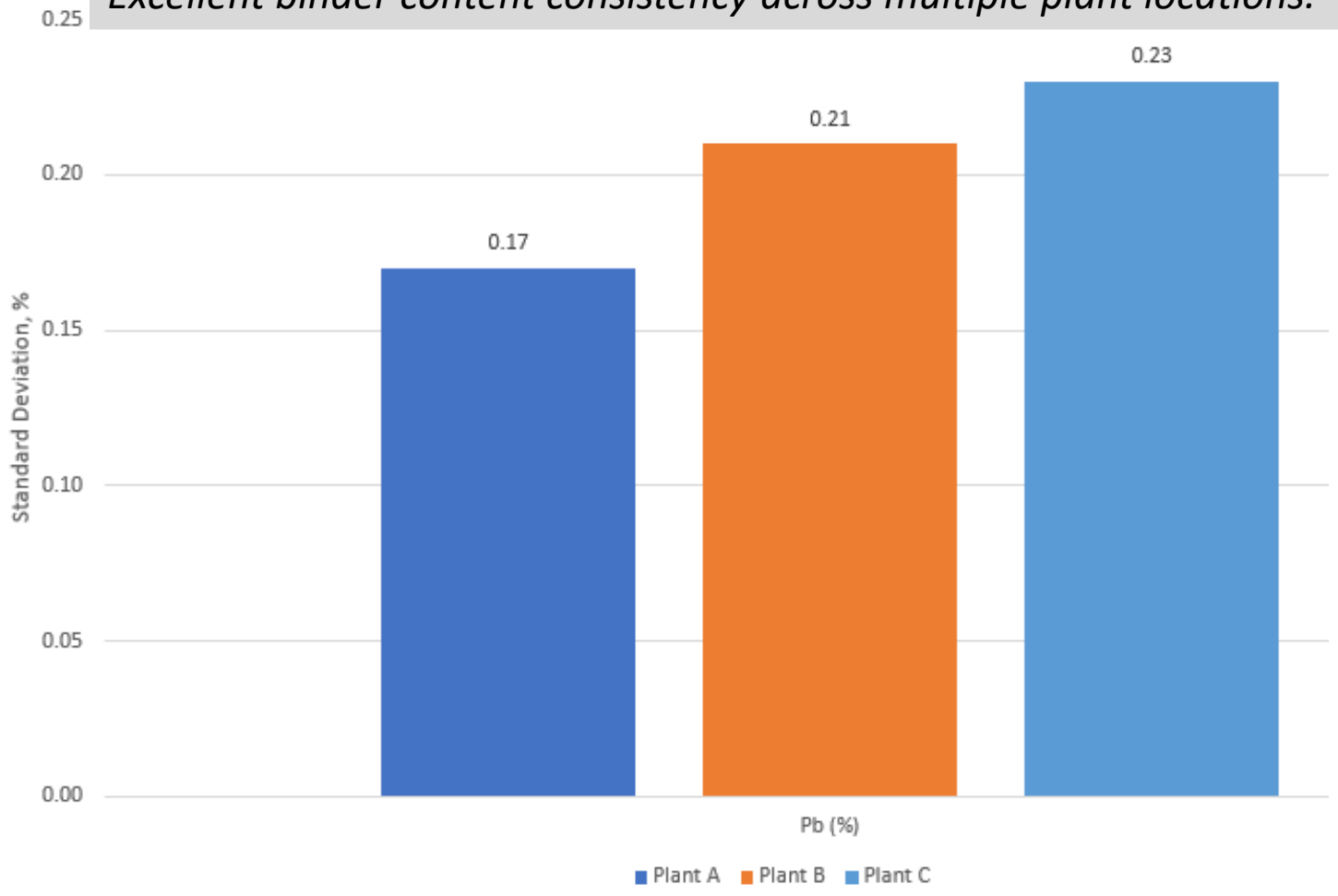
RAP variability comparable between plants located in similar area. Highlights fact that RAP is local.



	3/4" (19mm)	1/2" (12.5mm)	3/8" (9.5mm)	#4 (4.75mm)	#8 (2.36mm)	#16 (1.18mm)	#30 (0.6mm)	#50 (0.3mm)	#100 (0.15mm)	#200 (75µm)
Plant A		0.0	0.5	3.6	2.5	1.8	1.2	0.8	0.8	0.4
Plant B		0.5	1.7	5.6	5.1	3.7	2.3	1.4	1.0	1.0
Plant C		0.0	1.0	3.7	3.3	2.5	1.8	1.3	1.0	1.0
Plant D		0.0	1.6	4.5	3.8	2.7	1.8	1.1	1.0	0.9

RAP Variability Data – Binder Content

Excellent binder content consistency across multiple plant locations.



“Better” RAP Impact

- **What is “better” RAP?**
  1. Higher stockpile binder content.
  2. More consistent aggregate grading.
  3. More consistent residual binder grading.
  4. Less / more consistent P200.

Tips…

1. Monitor in-coming RAP to limit contamination
2. Segregate RAP sources
3. Process / screen / crush correctly
   - Don’t crush RAP that doesn’t need crushing.
   - Too much dust generated, lower binder %
4. Fractionate if it makes sense
   - Can you make one fraction work and have outlet for other fractions?

Managing Your RAP: “Better” RAP Impact

- Case 1: Increase Residual RAP Binder Content by 0.1% w/ no add $.

RAP IMPACT ON BINDER REPLACEMENT AND COST		
Mix Design Binder %	5.0	
Virgin Binder, $ / ton	500.00	
Virgin Aggregate, $ / ton	15.00	
RAP Used, %	20.0	
RAP Cost / RAP Ton, $	5.00	5.00
RAP Stockpile Binder, %	5.00	5.10
Binder Replacement, %	20.00	20.40
Materials Cost, $ / mix ton	32.40	32.30
Binder Replacement % Impact		0.40
Mix Materials Cost Impact / Ton		$ (0.097)

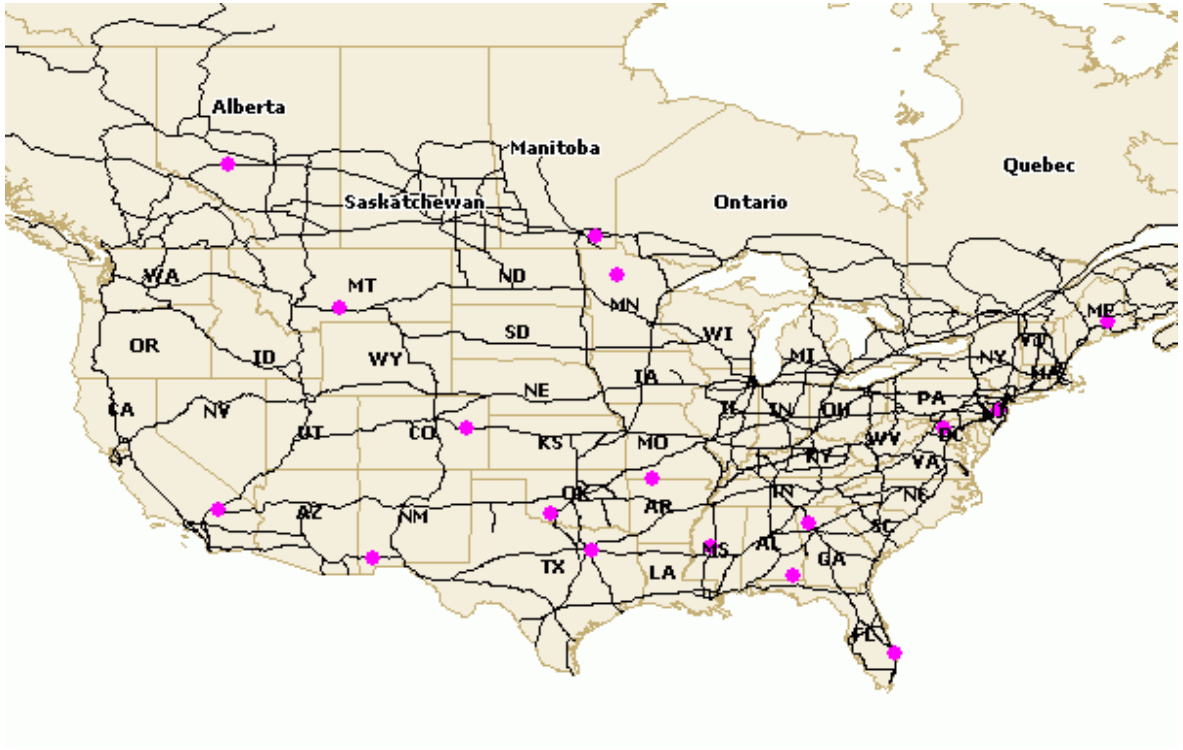
- Case 2: Increase Residual RAP Binder Content by 0.5% w/ +$3 cost.

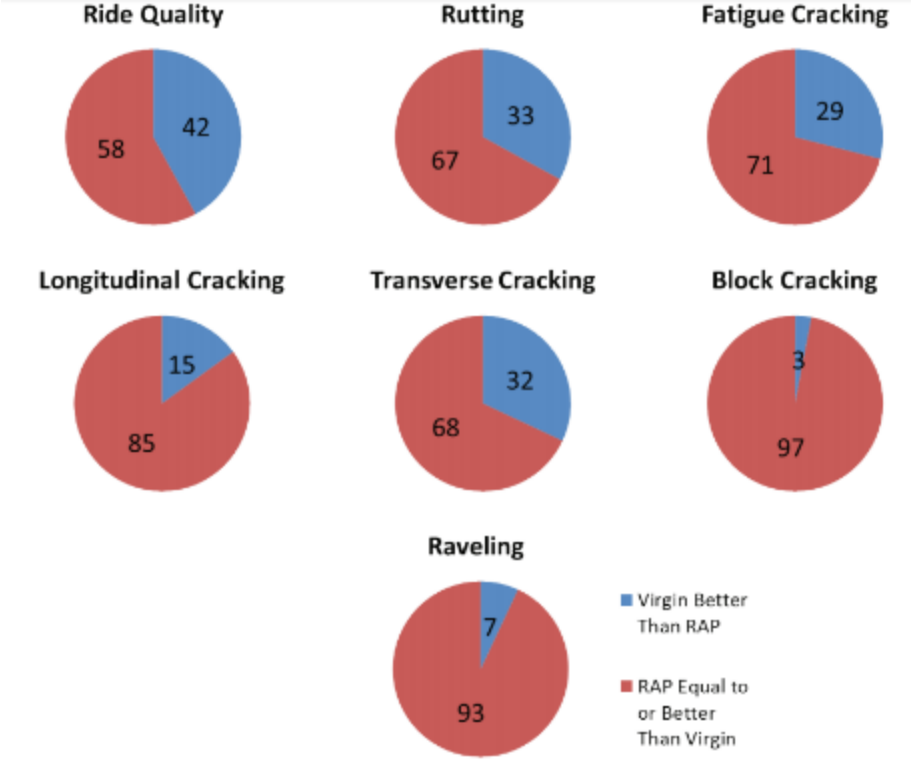
RAP IMPACT ON BINDER REPLACEMENT AND COST		
Mix Design Binder %	5.0	
Virgin Binder, $ / ton	500.00	
Virgin Aggregate, $ / ton	15.00	
RAP Used, %	20.0	
RAP Cost / RAP Ton, $	5.00	8.00
RAP Stockpile Binder, %	5.00	5.50
Binder Replacement, %	20.00	22.00
Materials Cost, $ / mix ton	32.40	31.92
Binder Replacement % Impact		2.00
Mix Materials Cost Impact / Ton		$ (0.485)

RAP Mix Performance

LTPP SPS-5 Performance

- LTPP SPS-5 sections (18 total) across the United States and Canada
- NCAT concluded that “RAP mixes performed better than or equal to virgin mixes for the majority of the data obtained. It can be concluded that in most cases, **using at least 30 percent recycled materials in asphalt pavement can provide the same overall performance as virgin pavement.”**





http://driveasphalt.org/assets/content/resources/SR213_-_RAP-RAS_Synthesis-lr.pdf

NCAT Test Track RAP Performance

- Results from the 2006 NCAT test track cycle show that **mixes designed with up to 45 percent RAP can provide improved rutting resistances with minimal cracking.**
- *"Although the cracks are low-severity cracks that would not even be detected with automated pavement evaluation systems, the amount of cracking in the sections is related to the virgin binder grades, with stiffer grades exhibiting cracking before softer grades."*
- http://www.ncat.us/files/reports/2012/rep12-10.pdf

Table 3.1 Observed Cracking for the 2006 High RAP Content Experiment

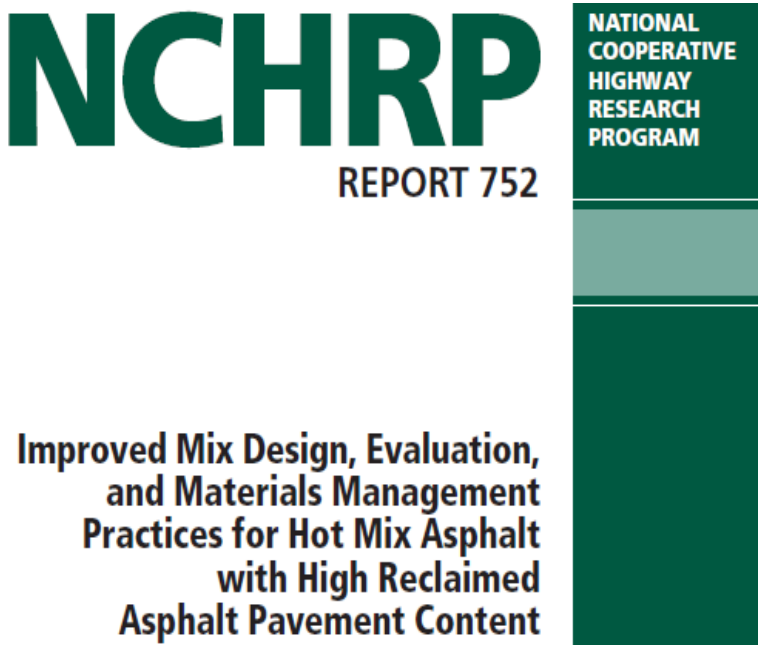
Test Section	RAP Content[1]	RAP Binder Percentage[2]	Virgin Binder Grade	Date of First Crack	ESALs at First Crack	Total Length of Cracking after 2 Cycles
W4	20%	17.6%	PG 67-22	no cracking		
W3	20%	18.2%	PG 76-22	4/7/2008	6,522,440	34.0
W5	45%	42.7%	PG 58-28	8/22/2011	19,677,699	3.5
E5	45%	41.0%	PG 67-22	5/17/2010	13,360,016	13.9
E6	45%	41.9%	PG 76-22	2/15/2010	12,182,331	53.9
E7	45%	42.7%	PG 76-22+S[3]	1/28/2008	5,587,906	145.5

[1] RAP content as a percentage of the total aggregate
[2] The percentage of RAP binder relative to the total binder content
[3] This virgin binder contained 1.5% Sasobit.

NCAT Test Track RAP Performance

- NCHRP Report 752 states that ***"Numerous studies of in-service pavements containing up to 50 percent RAP have shown that high RAP content mixtures can provide performance similar to virgin mixes.*** *Good performance with high RAP content mixes has been reported in projects with diverse climates and traffic."*

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_752.pdf



RAP Future

Performance Testing and Balanced Mix Design

- Performance Testing and Balanced Mix Design are KEYS.
- Many questions arise during mix design.
  - What is the …
    - Gsb of the aggregate, RAP?
    - Stiffness of the virgin, RAP binder, composite binder?
    - Blending of the virgin and RAP binder?
  - You will **NEVER** know all the answers, all the time!
- ***Avoid the recipe that may not yield the desired product!***
- ***Innovate and engineer the mix for the performance that's required.***

Summary

- Using RAP offers substantial benefits and is encouraged for pavement sustainability and environmental stewardship
  - Less natural resources utilized and lower greenhouse gas emissions
- RAP can be processed and managed to be a highly consistent product which results in a consistent asphalt mixture.
- **Future will demand innovation and quality from the industry.**
- ***Innovative BMD approaches will be the key!!!***

Thank You / Questions

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