NATIONAL ASPHALT PAVEMENT ASSOCIATION

Asphalt Pavement Industry Survey on

Recycled Materials and Warm-Mix Asphalt Usage 2017

Information Series 138

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8th Annual Asphalt Pavement Industry Survey
IS 138
Produced July 2018

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
Information Series 138 (8th edition)		

4. Title and Subtitle	5. Report Date
Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2017	July 2018
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Brett A. Williams, Audrey Copeland, Ph.D., P.E., and T. Carter Ross	IS 138(8e)

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
National Asphalt Pavement Association 5100 Forbes Blvd. Lanham, MD 20706	**11. Contract or Grant No.** DTFH61-13-H-00027

12. Sponsoring Organization Name and Address	13. Type of Report and Period Covered
Federal Highway Administration Office of Preconstruction, Construction, and Pavements 1200 New Jersey Ave. SE Washington, DC 20590	Final Report; January–December 2017
	14. Sponsoring Agency Code FHWA-HI CP-40

15. Supplementary Notes

FHWA Agreement Officer's Representative: Matthew Corrigan, P.E.

16. Abstract

A shared goal of the Federal Highway Administration (FHWA) and the National Asphalt Pavement Association (NAPA) is to support and promote sustainable practices, such as the use of recycled materials and warm-mix asphalt (WMA). The use of recycled materials, primarily reclaimed asphalt pavement (RAP) and reclaimed asphalt shingles (RAS), in asphalt pavements conserves raw materials and reduces overall asphalt mixture costs, as well as reduces the stream of material going into landfills.

WMA technologies have been introduced to reduce production and compaction temperatures for asphalt mixtures, which reduces the energy needed and emissions associated with mixture production. Additional benefits include improved low-temperature compaction of asphalt mixtures leading to improved pavement performance, as well as a longer paving season. WMA was chosen for accelerated deployment in federal-aid highway, state department of transportation, and local road projects as part of FHWA's 2010 Every Day Counts initiative.

The objective of this survey, first conducted for the 2009 and 2010 construction seasons, is to quantify recycled materials used and WMA produced annually by the asphalt pavement industry to document the deployment of these technologies to understand where they are being used and where they are underutilized. Results show significant growth in the use of RAP, RAS, and WMA technologies since 2009, although the rate of year-over-year growth has generally slowed since 2013.

The asphalt industry remains the country's most diligent recycler with more than 99 percent of reclaimed asphalt pavement being put back to use. The average percentage of RAP used in asphalt mixtures has increased from 15.6 percent in 2009 to 20.1 percent in 2017. In 2017, the estimated RAP tonnage used in asphalt mixtures was 76.2 million tons. This represents more than 3.8 million tons (21.5 million barrels) of asphalt binder conserved, along with the replacement of more than 72 million tons of virgin aggregate. Similarly, the use of RAS in asphalt pavement mixtures has increased from 701,000 tons in 2009 to an estimated 944,000 tons in 2017; however, the use of RAS declined significantly (32 percent) from 2016 to 2017.

The combined savings of asphalt binder and aggregate from using RAP and RAS in asphalt mixtures is estimated at more than $2.2 billion.

More than 1.4 million tons of other recycled materials were reported as being incorporated into nearly 7.5 million tons of asphalt pavement mixtures during the 2017 construction season, including ground tire rubber, blast furnace slag, steel slag, and cellulose fibers.

The estimated total production of WMA for the 2017 construction season was 147.4 million tons. This was a 26 percent increase from the estimated 116.8 million tons of WMA in 2016, due largely to increased utilization reported for DOT and Commercial & Residential tonnage for the year. WMA utilization in 2017 was 777 percent more than the estimated 16.8 million tons in the 2009 construction season. WMA made up 38.9 percent of the total estimated asphalt mixture market in 2017. Production plant foaming, representing nearly 65 percent of the market, is the most commonly used warm-mix technology; chemical additive technologies accounted for a little more than 32 percent of the market.

17. Key Words	18. Distribution Statement
Reclaimed asphalt pavement, reclaimed asphalt shingles, warm-mix asphalt, ground tire rubber, slag, RAP, RAS, WMA, GTR, recycled materials	No restrictions.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified.	Unclassified.	46	NA

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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Suggested Citation:

Williams, B.A., A. Copeland, & T.C. Ross (2018). *Annual Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2017, 8th Annual Survey* (IS 138). National Asphalt Pavement Association, Lanham, Maryland. doi:10.13140/RG.2.2.30240.69129

List of Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
CCP	Coal Combustion Product
CCPR	Cold Central Plant Recycling
CIR	Cold In-Place Recycling
CRM	Crumb Rubber Modifier
DOT	Department of Transportation
FDR	Full-Depth Reclamation
FHWA	Federal Highway Administration
GTR	Ground Tire Rubber
HIR	Hot In-Place Recycling
HMA	Hot-Mix Asphalt
MWAS	Manufacturing Waste Asphalt Shingles
NAPA	National Asphalt Pavement Association
NCAT	National Center for Asphalt Technology
NCAUPG	North Central Asphalt User/Producer Group
NEAUPG	North East Asphalt User/Producer Group
NSA	National Slag Association
PCAS	Post-Consumer Asphalt Shingles
PCCAS	Pacific Coast Conference on Asphalt Specifications
RAP	Reclaimed Asphalt Pavement
RAS	Reclaimed Asphalt Shingles
RBR	Recycled Binder Ratio
RMA	Rubber Manufacturers Association
RMAUPG	Rocky Mountain Asphalt User/Producer Group
SAPA	State Asphalt Pavement Association
SEAUPG	Southeastern Asphalt User/Producer Group
UPG	User/Producer Group
WMA	Warm-Mix Asphalt

On the Cover

Working with District Two of the Idaho Transportation Department (ITD), Knife River Corp., Southern Idaho Division, used as much as 45 percent reclaimed asphalt pavement (RAP) in the 150,000 tons of asphalt mixture produced for a series of mill and overlay projects on US 12 and US 95 near Lewiston, Idaho. For the 4.05-mile segment of US 12,pictured, the contractor also used cement-reinforced asphalt base stabilization. Knife River and ITD won a NAPA 2017 Quality in Construction Green Paving Award for the project.

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2017

Executive Summary

The results of the asphalt pavement industry survey for the 2017 construction season show that asphalt mixture producers have a strong record of employing sustainable practices and continue to increase their use of recycled materials and warm-mix asphalt (WMA). The use of recycled materials, particularly reclaimed asphalt pavement (RAP) and reclaimed asphalt shingles (RAS), conserves raw materials and reduces overall asphalt mixture costs, allowing road owners to achieve more roadway maintenance and construction activities within limited budgets. WMA technologies can improve compaction at reduced temperatures, ensuring pavement performance and long life; conserve energy; reduce emissions from production and paving operations; and improve conditions for workers.

The objective of this survey, first conducted for the 2009 and 2010 construction seasons, was to quantify the use of recycled materials, primarily RAP and RAS, as well as the production of WMA by the asphalt pavement industry. For the 2017 construction season, the National Asphalt Pavement Association (NAPA) conducted a voluntary survey of asphalt mixture producers across the United States on tons produced, along with a survey of state asphalt pavement associations (SAPAs) regarding total tons of asphalt pavement mixture produced in their state. A degree of fluctuation in year-to-year comparisons of data is influenced by which companies responded to the 2017 construction season survey versus prior year survey respondents.

Asphalt mixture producers from all 50 states completed the 2017 construction season survey. A total of 238 companies with 1,158 production plants were represented in the survey.

The following are highlights of the survey of usage during the 2017 construction season:

Reclaimed Asphalt Pavement

- Asphalt mixture producers remain the country's most diligent recyclers, with more than 99 percent of asphalt mixture reclaimed from old asphalt pavements being put back to use in new pavements.
- The total estimated tons of RAP used in asphalt mixtures was 76.2 million tons in 2017. This is a 0.91 percent decrease from the 2016 construction season, but represents a greater than 36 percent increase from the total estimated tons of RAP used in 2009. During the same time frame, total asphalt mixture tonnage increased only 5.9 percent.
- The percentage of producers reporting use of RAP remained at 98 percent of respondents, as it was in 2016. Four producers reported landfilling a small amount (9,595 tons total) of RAP during 2017.
- RAP usage during the 2017 construction season is estimated to have reduced the need for 3.8 million tons (21.5 million barrels) of asphalt binder and more than 72 million tons of aggregate, with a total estimated value of more than $2.1 billion.
- The total estimated amount of RAP stockpiled nationwide at the end of the 2017 construction season was about 102.1 million tons.
- Fractionated RAP represents about 23 percent of RAP use nationwide, and the tons of RAP mixtures produced using softer binders are estimated at 18 percent while tons produced using recycling agents is estimated at 4 percent.

- Reclaiming 79.9 million tons of RAP for future use saved about 48.6 million cubic yards of landfill space.

Reclaimed Asphalt Shingles

- The total estimated tons of RAS used in asphalt mixtures decreased 32 percent to an estimated 944,000 tons in 2017. This downward trend in the use of RAS has persisted since 2015; still, the use of RAS in the 2017 construction season was 34 percent above the estimated 701,000 tons used in asphalt mixtures in 2009.
- The total estimated amount of RAS stockpiled nationwide at the end of the 2017 construction season was nearly 1.39 million tons.
- RAS usage during the 2017 construction season is estimated to have reduced the need for 188,000 tons (1.0 million barrels) of asphalt binder and nearly 472,000 tons of aggregate, with an estimated value of more than $74 million.

Other Findings

- The use of softer binders and recycling agents with mixtures incorporating RAP and RAS was reported nationwide. There was little correlation between the level of RAP used and the use of softer binders and/or recycling agents, but their use with RAS was more consistent.
- The most commonly reported factor limiting utilization of RAP and RAS was specification limits.
- Other recycled materials commonly reported as being used in asphalt mixtures during the 2017 construction season were ground tire rubber, blast furnace slag, steel slag, and cellulose fibers. Recycled materials less commonly reported as being used in asphalt mixtures included fly ash and foundry sand.
- Nearly 1.5 million tons of other recycled materials was reported as being used in nearly 7.5 million tons of asphalt mixtures by 58 companies in 26 states during the 2017 construction season.

Warm-Mix Asphalt

- The estimated total tonnage of asphalt pavement mixtures produced at reduced temperatures with WMA technologies for the 2017 construction season was 147.4 million tons. This was a 26 percent increase from the estimated 116.8 million tons of WMA in 2016, driven largely by increased WMA tonnage in the Commercial & Residential and the DOT sectors.
- WMA made up 38.9 percent of the total estimated asphalt mixture market in 2017.
- Production plant foaming, representing nearly 65 percent of the market in 2017, remains the most commonly used warm-mix technology, despite decreasing about 15.6 percent since the 2016 construction season.
- Chemical additive technologies accounted for a little more than 32 percent of the market in 2017, an increase of 52.4 percent from their use in the 2016 construction season.
- A gradual increase in the use of chemical additive WMA technologies and a decrease in plant-based foaming technologies been seen in the survey since 2011. A gradual increase in the use of chemical additive WMA technologies and a decrease in plant-based foaming technologies been seen in the survey since 2011.
- About 66 percent of respondents who produce WMA, 107 producers in 44 states, reported also using WMA technologies at HMA temperatures. An estimated 26–32 percent of these companies' HMA tons were produced with production plant foaming, and 16–20 percent were produced with chemical additive technologies.

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2017

Background

A shared goal of the Federal Highway Administration (FHWA) and the National Asphalt Pavement Association (NAPA) is to support and promote sustainable practices, such as incorporation of recycled materials in pavement mixtures and the use of warm-mix asphalt (WMA). Reclaimed asphalt pavement (RAP) is recycled at a greater rate than any other material in the United States and helps lower overall material costs, allowing road owners to achieve more roadway maintenance and construction activities within limited budgets. Another recycled material used in asphalt mixtures is reclaimed asphalt shingles (RAS) from both manufacturing waste (MWAS) and post-consumer asphalt shingles (PCAS). The use of RAP and RAS in asphalt pavements can reduce the amount of new asphalt binder and aggregates required in mixtures, which can help stabilize the price of asphalt mixtures and save natural resources. Other recycled materials commonly incorporated into asphalt pavements include ground tire rubber (GTR), steel slag, blast furnace slag, and cellulose fibers. By putting waste materials and byproducts to a practical use, the asphalt pavement industry helps reduce the amount of material going to landfills while improving the sustainability of asphalt mixtures.

WMA technologies reduce the mixing and compaction temperatures for asphalt mixtures. Environmental benefits include reductions in both fuel consumption and air emissions. Construction benefits include the ability to extend the paving season into the cooler months, haul material longer distances, improve compaction at lower temperatures, and use higher percentages of RAP (Prowell et al., 2012; West et al., 2014). As part of FHWA's original group of Every Day Counts initiatives, WMA was chosen in 2010 for accelerated deployment in federal-aid highway, state department of transportation (DOT), and local road projects (FHWA, 2013). In 2013, WMA was honored with the Construction Innovation Forum's NOVA Award for its engineering, economic, and environmental benefits (CIF, 2013).

FHWA works closely with the pavement industry through associations and other stakeholders to promote pavement recycling technologies and WMA. From 2007 to 2011, the American Association of State Highway and Transportation Officials (AASHTO) conducted a biennial survey of state DOTs' use of recycled materials (Copeland, 2011; Copeland et al., 2010; Pappas, 2011) and results were presented at FHWA Expert Task Group meetings. FHWA partners with NAPA to document industry use of RAP, RAS, other recycled materials, as well as WMA technologies used by asphalt mixture producers. These efforts have established a baseline for RAP, RAS, and WMA usage, and have tracked growth in the use of these sustainable practices in the highway industry since 2009.

FHWA first partnered with NAPA to capture annual RAP, RAS, and WMA use for the 2009 construction season (Hansen & Newcomb, 2011; Hansen & Copeland, 2013a; 2013b; 2014; 2015; 2017a; 2017b). Compared to the findings of the first survey (Hansen & Newcomb, 2011), asphalt mixture producers have shown significant growth in the use of these technologies, although the year-over-year rate of growth has slowed since the 2013 construction season. Since 2012, the survey has also asked about other recycled materials used in asphalt mixtures. This report documents the results of the industry survey for the 2017 construction season, including the survey methodology, results, trends, and changes from 2009 through 2017. The survey questions and state-level data are included in the appendixes.

Objective and Scope

The objective of this effort is to quantify the use of recycled materials and WMA technologies by the asphalt pavement industry. From January to April 2018, NAPA fielded a voluntary survey of asphalt mixture producers in the United States on tons produced, along with a survey of state asphalt pavement associations (SAPAs) regarding total tons of asphalt

pavement mixture produced in their state during the 2017 construction season. While keeping specific producer data confidential, NAPA staff compiled the amount of asphalt mixtures produced; the amount of RAP, RAS, and other recycled material used; and the amount of WMA produced in the United States. Not measured in this survey is the use of in-place asphalt pavement recycling techniques, such as full-depth reclamation (FDR), cold in-place recycling (CIR), and hot in-place recycling (HIR). Some cold central plant recycling (CCPR) of RAP may be included in Table 4 among the tons reported as "Used in Other" or "Used in Cold-Mix Asphalt."

Survey Methodology

The survey methodology used to collect and analyze the data in this report is detailed in Appendix A. Note that when reporting data at the state level, to keep specific producer information confidential, no state-specific results are provided in the tables or appendixes if fewer than three producers from that state responded to the survey. Information from states with fewer than three responding companies is included in the estimated national values, however.

Producer Survey Results

Asphalt mixture producers from all 50 states, the District of Columbia, and American Samoa completed the survey for the 2017 construction season. A total of 238 companies with 1,158 production plants are represented in the 2017 survey. This is a slight increase from the 2014–2016 construction season surveys, but a slight decrease in participation from 2013. The reported total asphalt mixture tons for 2017 was 163.0 million tons; despite fluctuations in the number of companies participating in the survey, the total tons reported has continued to increase each year. A degree of fluctuation in year-to-year comparisons of data is influenced by which companies responded to the 2017 construction season survey versus prior year survey respondents. Table 1 summarizes the number of asphalt mixture

Table 1: Number of Companies Completing 2017 Construction Season Survey in Each State/Territory

State	Cos.	Prod. Plants	State	Cos.	Prod. Plants	State	Cos.	Prod. Plants
Alabama	6	50	Kentucky	4	39	Ohio	7	74
Alaska	*	*	Louisiana	5	7	Oklahoma	5	18
American Samoa	*	*	Maine	3	17	Oregon	4	7
Arizona	3	8	Maryland	6	11	Pennsylvania	10	50
Arkansas	4	13	Massachusetts	8	29	Puerto Rico	NCR	NCR
California	6	39	Michigan	7	45	Rhode Island	*	*
Colorado	5	21	Minnesota	4	28	South Carolina	7	24
Connecticut	3	19	Mississippi	5	22	South Dakota	*	*
Delaware	*	*	Missouri	7	30	Tennessee	5	22
District of Columbia	*	*	Montana	*	*	Texas	7	48
Florida	5	28	Nebraska	3	8	U.S. Virgin Islands	NCR	NCR
Georgia	5	15	Nevada	3	4	Utah	9	19
Guam	NCR	NCR	New Hampshire	4	20	Vermont	*	*
Hawaii	3	8	New Jersey	3	19	Virginia	5	33
Idaho	6	19	New Mexico	3	6	Washington	7	33
Illinois	7	15	New York	11	72	West Virginia	4	15
Indiana	5	38	North Carolina	7	52	Wisconsin	4	63
Iowa	6	16	North Dakota	3	7	Wyoming	3	6
Kansas	3	17	No. Mariana Islands	NCR	NCR	**Total†**	238	1,158

NCR = No Companies Responding
* = Fewer than 3 Companies Reporting
† = Total includes companies/production plants from states with fewer than 3 companies reporting.

Table 2: Summary of Jurisdictions (States or Territories), Companies, and Production Plants Represented, 2009–2017

Year	No. Jurisdictions Reporting	No. of Companies Reporting	No. of Production Plants Represented in Survey	Average Tons Produced per Plant
2009	48	196	1,027	121,000
2010	48	196	1,027	117,000
2011	49	203	1,091	121,000
2012	49	213	1,141	122,000
2013	52	249	1,281	115,000
2014	50	228	1,185	127,000
2015	49	214	1,119	137,000
2016	50	229	1,146	136,000
2017	52	238	1,158	140,000

Table 3: Summary of 2017 Estimated and Reported Asphalt Mixture Tons in Each State

State	Tons, Millions		Reported % of Estimated	State	Tons, Millions		Reported % of Estimated
	Estimated	Reported			Estimated	Reported	
Alabama	7.0	4.9	70%	Montana	4.2	*	*
Alaska	5.1	*	*	Nebraska	2.8	0.5	18%
American Samoa	0.03	*	*	Nevada	3.4	1.3	38%
Arizona	6.5	1.2	18%	New Hampshire	3.0	2.5	83%
Arkansas	6.0	1.9	32%	New Jersey	10.2	4.0	39%
California	26.0	5.9	23%	New Mexico	3.0	0.9	30%
Colorado	5.3	2.0	38%	New York	16.5	7.3	44%
Connecticut	4.9	2.8	57%	North Carolina	16.0	6.4	40%
Delaware	1.5	*	*	North Dakota	2.7	1.2	44%
District of Columbia	1.4	*	*	Ohio	14.8	11.6	78%
Florida	16.5	4.6	28%	Oklahoma	4.8	2.4	50%
Georgia	14.6	2.2	15%	Oregon	5.4	1.4	26%
Hawaii	1.1	0.8	73%	Pennsylvania	19.8	7.7	39%
Idaho	2.8	1.7	61%	Puerto Rico	1.6	NCR	NCR
Illinois	13.0	2.1	16%	Rhode Island	2.0	*	*
Indiana	11.8	6.6	56%	South Carolina	7.6	3.9	51%
Iowa	3.9	1.6	41%	South Dakota	2.0	*	*
Kansas	2.0	1.1	55%	Tennessee	9.2	2.5	27%
Kentucky	4.4	4.4	100%	Texas	20.0	7.9	40%
Louisiana	7.8	1.2	15%	Utah	4.0	3.5	88%
Maine	1.7	2.0	118%	Vermont	1.9	*	*
Maryland	7.8	2.4	31%	Virginia	12.0	4.9	41%
Massachusetts	6.5	5.0	77%	Washington	6.0	4.5	75%
Michigan	13.7	9.0	66%	West Virginia	2.6	1.5	58%
Minnesota	6.9	6.0	87%	Wisconsin	12.0	8.7	73%
Mississippi	4.8	2.8	58%	Wyoming	2.5	0.1	4%
Missouri	6.5	3.9	60%	**Total**	379.4	163.0†	43%

NCR No Companies Responding

* Fewer than 3 Companies Reporting

† Total Reported Tons includes values from state with fewer than 3 Companies Reporting

SAPA Estimated Tons

Numbers do not add up exactly due to rounding

production companies and the number of production plants reporting for each state. Branches, subsidiaries, and operating units are counted as unique companies in Table 1 and throughout this report. Table 2 summarizes the total number of production plants responding in previous years.

Table 3 includes state-by-state 2017 construction season total estimated asphalt mixture tonnage, as estimated by the SAPA or from Equation A1 (see Survey Methodology in Appendix A); tonnage reported by survey respondents; and the percentage of reported tons included in estimated tons. The closer a state's percentage is to 100 percent indicates the completeness of reported tonnage compared to estimated tonnage. At the national level, survey responses make up 42.9 percent of the estimated total tons for the 2017 construction season.

Figure 1 shows the number of production plants, as well as the average tons produced per production plant, separated by User/Producer Group (UPG) region. The number of production plants responding from each UPG region showed a good deal of variability from 2016 to 2017, with notable increases in the North East Asphalt User/Producer Group (NEAUPG) and the North Central Asphalt User/Producer Group (NCAUPG) region, and declines in the combined Rocky Mountains Asphalt User/Producer Group (RMAUPG) and Pacific Coast Conference on Asphalt Specification (PCCAS) regions. Similarly, there is

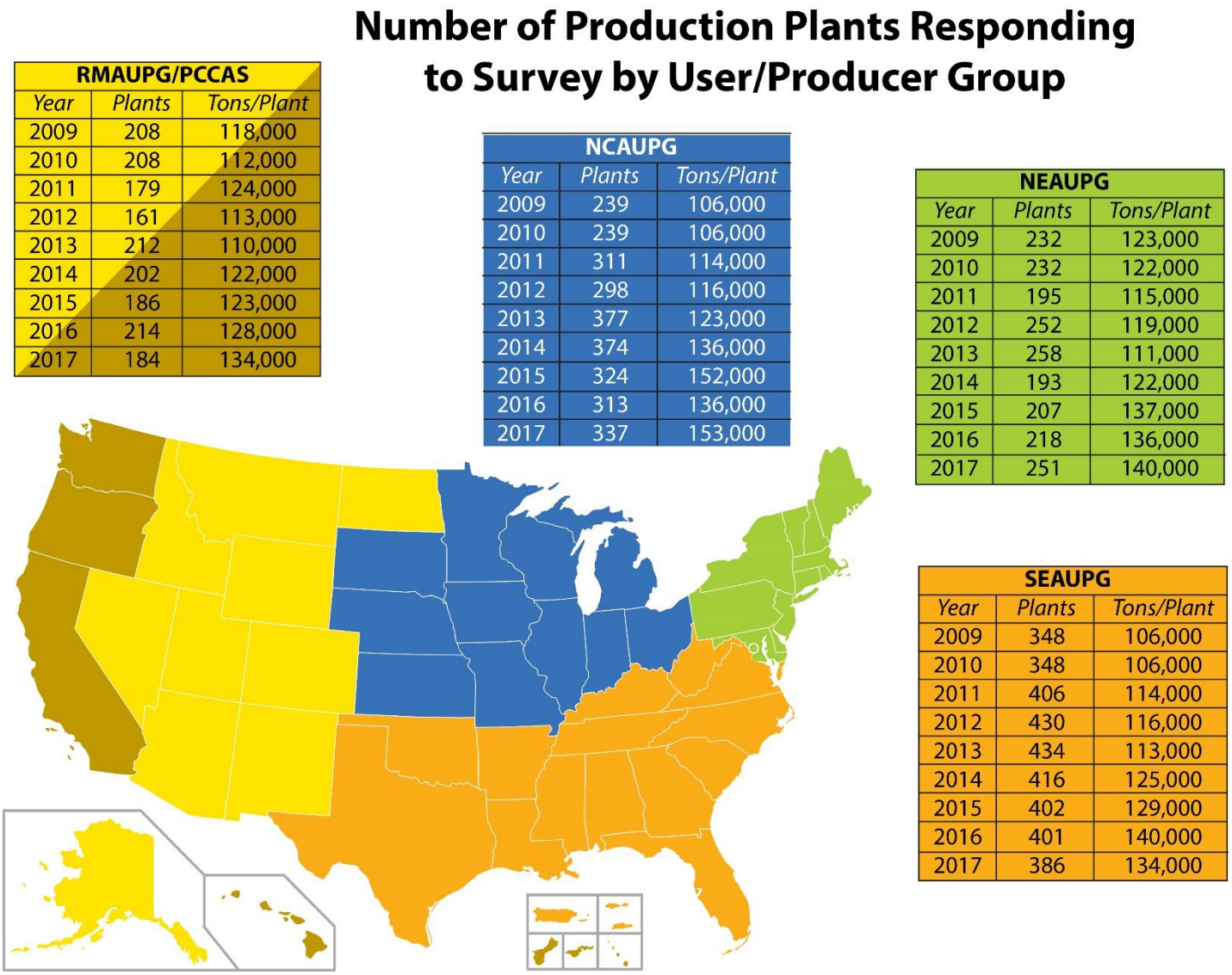


Figure 1: Number of Production Plants Responding to Survey by User/Producer Group Region and Estimated Tonnage, 2009–2017

variability in the tonnages reported for 2016 compared to previous years with NCEAUPG and NEAUPG seeing an increase in both tons per production plant and the number of production plants reporting, and the Southeastern Asphalt User/Producer Group (SEAUPG) seeing a decrease in both tons per production plant and the number of production plants reporting. The combined RMAUPG/PCCAS region had a decrease in participation in the survey with 184 production plants responding for the 2017 construction season.

Table 4 summarizes the RAP, RAS, and WMA data from the 2017 construction season survey alongside data from the 2016 construction season survey (Hansen& Copeland, 2017b) for comparison. The information requested in the survey is summarized in Appendix A. In the column labeled "Reported Values" are national summaries of the values from asphalt mixture producers completing the survey. The column labeled "Estimated Values" for the category labeled "Tons of HMA/WMA Produced" was determined as outlined in the Survey Methodology (Appendix A).

For the amount of RAP accepted, asphalt mixture producers were asked, "How many tons of removed asphalt pavement and asphalt millings were accepted/delivered to your facilities in the state in 2017?" For the amount of RAS accepted, producers were asked, "How many tons of shingles were accepted/delivered to your facilities in the state in 2017?" Producers were asked to report tons of unprocessed PCAS and unprocessed MWAS accepted/delivered, as well as tons of processed RAS acquired from shingle processors. These data are reported in Table 4 as the tonnage of material accepted. Producers were also asked for the tonnage of RAP and RAS used in the production of asphalt pavement mixtures, cold-mix asphalt, as aggregate, or for other purposes, such as in a chip seal. The tons of reclaimed material sent to landfills were also requested, along with the tons of material stockpiled at year-end.

For each state, the tons of RAS and RAP reported as accepted and used were multiplied by the ratio of total estimated production to total reported production, and these values were summed to arrive at the national estimated tons for these materials, which is reported in the "Estimated Values" column of Table 4.

To understand the average percentage of recycled material used in mixtures, producers were asked to report the percent of RAP or RAS averaged across all asphalt mixtures produced for each sector (DOT, Other Agency, Commercial & Residential). If precise data were not available, respondents were asked to provide their best estimate. These responses are reported in the "Average % Used in Mixtures" section of Table 4 for RAP and RAS. A "National Average All Mixtures Based on Tons Used in HMA/WMA" was calculated and reported in Table 4 for both RAP and RAS based on reported tonnage of each material used in HMA/WMA mixtures divided by the total reported tons produced. Producers were not asked about allowable RAP or RAS limits or binder replacement requirements, which can influence demand for mixtures that incorporate these materials.

Producers were asked to give their best estimate of the percentage of asphalt paving mixtures produced for each sector when WMA technology resulted in a temperature reduction of 10°F to 100°F. These percentages were multiplied by the total mixture production for each sector to determine the total estimated tons of WMA produced for each sector. The survey methodology was designed so that only mixtures produced at reduced temperatures are reported. Some WMA technologies are also used for construction benefits unrelated to the goal of reducing production temperatures; therefore, producers were also asked to estimate the percentage range of mixtures produced using WMA technologies at HMA temperatures.

Data Summary and National Estimates

Table 4: Summary of RAP, RAS, WMA Data

NATIONAL SUMMARY	Reported Values		Estimated Values	
	2016	2017	2016	2017
Tons of HMA/WMA Produced	Tons, Millions		Tons, Millions	
Total	155.8	163.0	374.9	379.4
DOT	62.9	71.0	151.5	165.2
Other Agency	42.4	39.9	102.1	92.7
Commercial & Residential	50.4	52.2	121.4	121.4
Companies Reporting	229	238		
RAP	Tons, Millions		Tons, Millions	
Accepted	35.6	35.7	81.8	79.9
Used in HMA/WMA Mixtures	32.8	33.8	76.9	76.2
Used in Aggregate	1.3	1.4	3.7	3.4
Used in Cold-Mix Asphalt	0.1	0.1	0.2	0.3
Used in Other	0.2	0.1	0.4	0.2
Landfilled	0.0	0.0	0.1	0.0
Total Tons of RAP Stockpiled at Year-End	41.2	45.8	93.6	102.1
	Avg. % Used in Mixtures		Avg. % Used in Mixtures	
Average % for DOT Mixtures[1]	19.3%	19.5%		
Average % for Other Agency Mixtures[1]	19.7%	19.1%		
Average % for Commercial & Residential Mixtures[1]	24.2%	21.7%		
National Average All Mixtures Based on RAP Tons Used in HMA/WMA[2]			20.5%	20.1%
Companies Reporting Using RAP	224	234		
RAS	Tons, Millions		Tons, Millions	
Unprocessed PCAS Shingles Accepted[3]	0.386	0.254	1.027	0.591
Unprocessed MWAS Shingles Accepted[3]		0.148		0.344
Processed Shingles Accepted	0.274	0.134	0.846	0.311
Used in HMA/WMA Mixtures	0.499	0.406	1.390	0.944
Used in Aggregate	0.004	0.015	0.009	0.036
Used in Cold-Mix Asphalt	0.000	0.000	0.000	0.000
Used in Other	0.000	0.000	0.000	0.000
Landfilled	0.002	0.000	0.005	0.000
Total Tons of RAS Stockpiled at Year-End	†	0.596	†	1.387
	Avg. % Used in Mixtures		Avg. % Used in Mixtures	
Average % for DOT Mixtures[1]	0.341%	0.355%		
Average % for Other Agency Mixtures[1]	0.274%	0.188%		
Average % for Commercial & Residential Mixtures[1]	0.334%	0.221%		
National Average All Mixtures Based on RAS Tons Used in HMA/WMA[2]			0.371%	0.249%
Companies Reporting Using RAS	76	64		
WMA	% of Total Production		Tons, Millions	
Total			116.8	147.4
DOT	36.3%	42.2%	50.7	69.6
Other Agency	32.4%	31.7%	31.5	29.4
Commercial & Residential	30.5%	39.9%	34.6	48.4
Companies Reporting Producing WMA	165	163		

[1] Average percent based on contractor's reported percentage for each sector, adjusted based upon reported tonnage.
[2] Average percent based on total reported tons of RAP or RAS used in HMA/WMA divided by reported total tons HMA/WMA produced.
[3] Prior to the 2017 construction season, unprocessed PCAS and MWAS Shingles were reported collectively.
† Question not asked in 2016.

Total HMA/WMA Production

Table 4 includes the national summary of asphalt mixture production data from the 2016 and 2017 construction season surveys. The information requested in the survey is detailed in Appendix A and summarized in Table A1, Section 2. State-level data are reported in Appendix B.

From 2016 to 2017, the estimated total amount of asphalt mixture produced in the United States increased from 374.9 million tons to 379.3 million tons, an increase of 1.2 percent.

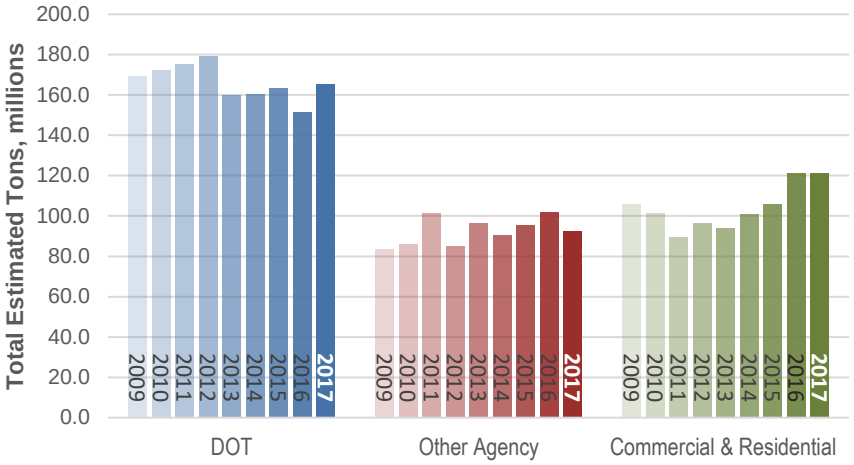


Figure 2: Estimated Total HMA/WMA Asphalt Mixture Production by Sector, 2009–2017

Asphalt pavement mixture producers' customers can be divided into two broad sectors: the private sector (Commercial & Residential) and the public sector (DOT or Other Agency). The "Other Agency" sector includes asphalt pavement mixtures produced for public works agencies; toll authorities; and city, county, and tribal transportation agencies, as well as the U.S. military and federal agencies, such as the Federal Aviation Administration, National Park Service, and U.S. Forest Service.

As seen in Figure 2, increases and decreases in total tonnage production estimates by sector have varied from year to year. Compared to the 2016 construction season, asphalt mixture tonnage produced for the DOT sector in 2017 saw an increase of 9.0 percent; however, mixture production for the Commercial & Residential sector was flat and the Other Agency sector decreased by just over 9.2 percent from 2016 to 2017.

Reclaimed Asphalt Pavement

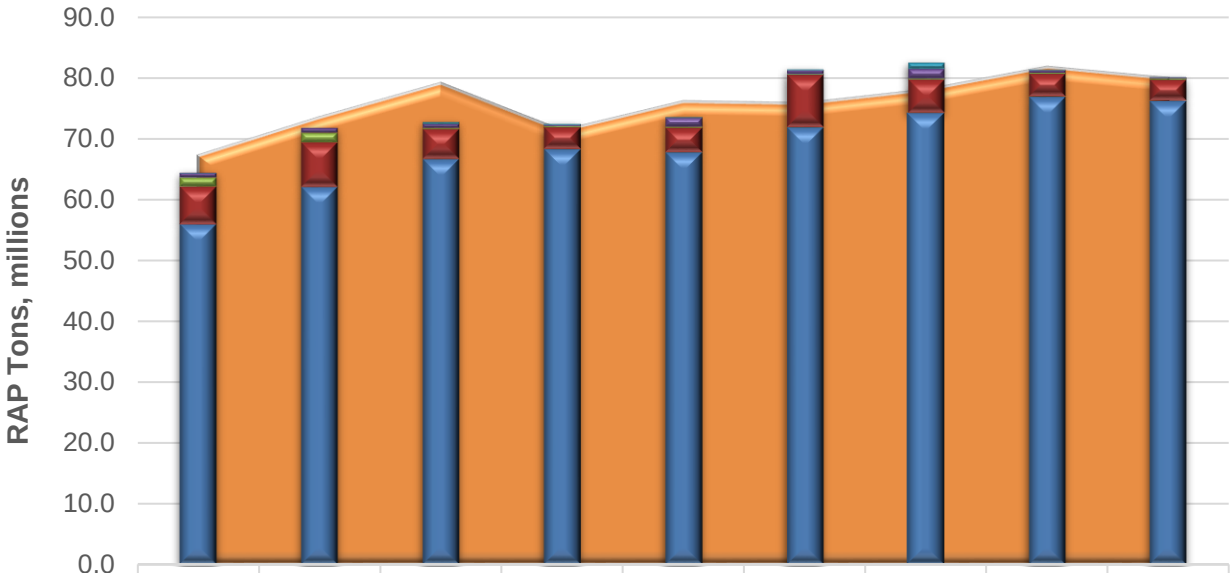
Table 4 includes the national summary of RAP data from the 2016 and 2017 construction season surveys. The information requested in the survey is detailed in Appendix A and summarized in Table A1, Section 2. State-level data is reported in Appendix B. Figure 3 is a visual representation of the estimated total tons of RAP used in asphalt mixtures, aggregate, cold-mix asphalt, and other uses, as well as the amount landfilled, from the 2009 to 2017 construction season surveys. The overwhelming majority of RAP is used in hot-mix asphalt (HMA) or warm-mix asphalt (WMA) mixtures, which is the most optimal use of RAP. The tons used in cold-mix asphalt data may include some CCPR of RAP, but the survey does not specifically record the use of in-place recycling technologies.

From the 2016 to 2017 construction season, the amount of RAP used in HMA/WMA decreased slightly from 76.9 million to 76.2 million tons. The average percent RAP used in asphalt mixtures decreased marginally from 20.5 percent in 2016 to 20.1 percent in 2017. For 2017, 98 percent of companies responding to the survey reported using RAP. This was the case in 2016 as well, but is a slight decrease from the 100 percent of companies reporting using RAP in 2013 and 2014 and the 99 percent of companies reporting RAP use in the 2015 survey.

Placement of RAP in construction and demolition landfills is rare. Since the beginning of the survey in 2009, the average amount of RAP landfilled is less than 150,000 tons per year, or 0.2 percent. In 2015, the amount of RAP landfilled increased significantly to 1 percent due to three producers reporting sending RAP to a landfill. In 2017, the amount of

RAP landfilled was 0.04 percent, which is in line with previously recorded levels. Reclaiming 79.9 million tons of RAP for future use saved about 48.6 million cubic yards of landfill space in 2017.

Figure 3: Comparison of Tons of RAP Accepted and Tons of RAP Used or Landfilled (Million Tons), 2009–2017



	2009	2010	2011	2012	2013	2014	2015	2016	2017
Accepted	67.2	73.5	79.1	71.3	76.1	75.8	78.0	81.8	79.9
Landfilled	0.1	0.0	0.3	0.2	0.1	0.2	1.0	0.1	0.0
Used in Other	0.7	0.8	0.7	0.2	1.5	0.6	1.6	0.4	0.2
Used in Cold Mix	1.5	1.6	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Used in Aggregate	6.2	7.3	4.9	3.6	4.0	8.5	5.5	3.7	3.4
Used in HMA/WMA	56.0	62.1	66.7	68.3	67.8	71.9	74.2	76.9	76.2

RAP Use by Sector

Figure 4 shows the total estimated tons of RAP used in each sector. These values were calculated using the average percentages of RAP reported by producers for each sector and adjusted to account for differences between reported RAP tonnage and tons calculated from the percentage by sector.

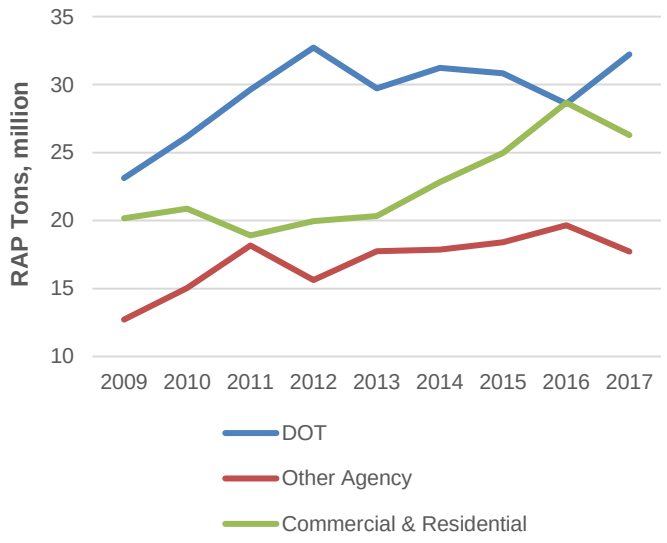


Figure 4: RAP Use by Sector (Million Tons)

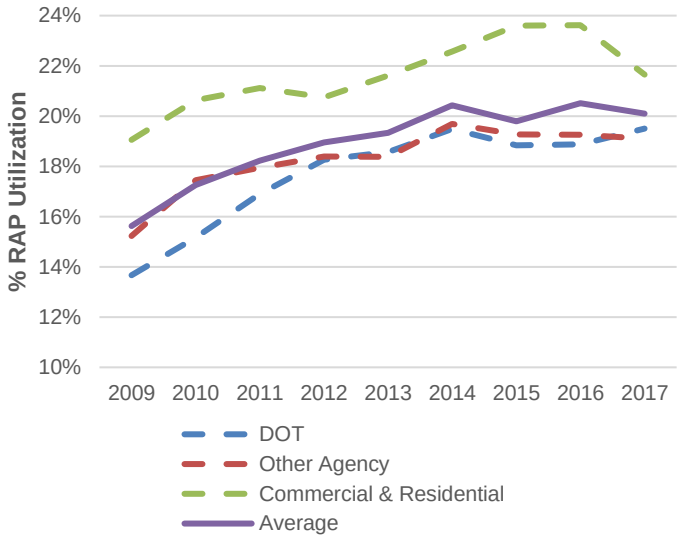


Figure 5: Average Percent RAP Used by Sector

Figure 5 shows the average percentage of RAP used by each sector and overall across all asphalt pavement mixtures. The average percent RAP used by all sectors has seen variable growth from 2009 to 2017. The change in total percentage of RAP use has seen a decreased growth rate from 2009 to 2017. The growth rate for 2016 to 2017 was negative, putting the total percentage of RAP utilized on level with timeframe of 2013 to 2014.

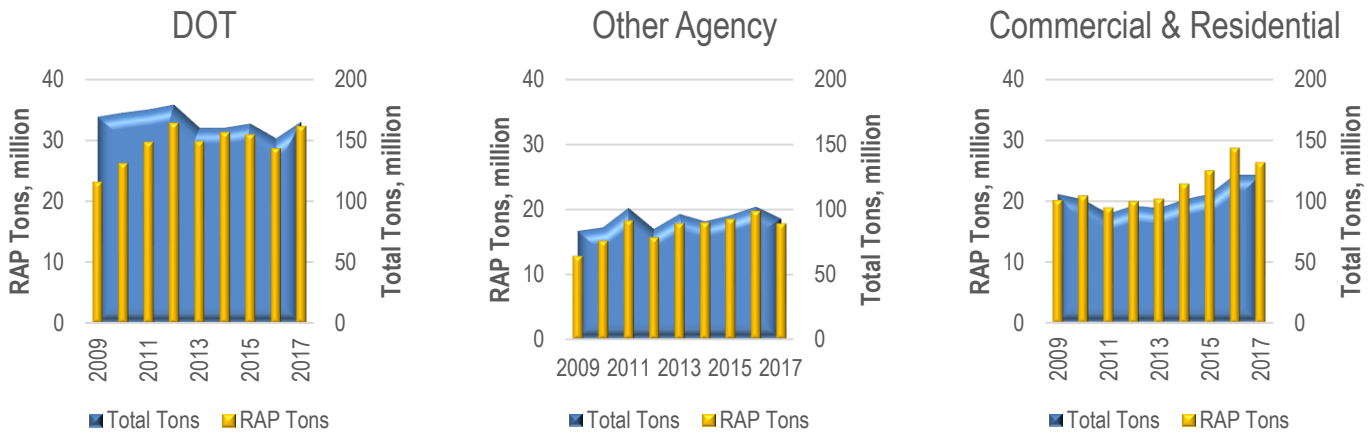


Figure 6: RAP Tons and Total Mixture Tons Comparison (Million Tons)

Since the 2012 construction season, the tonnage of RAP used by each sector has generally moved up or down with the total tonnage used by the sector, which is shown in Figure 6. For the 2017 construction season, the tons of RAP used in the DOT sector increased from 2016 to 2017, but it decreased for the Other Agency and Commercial & Residential sectors. The increased percentage of RAP used in the DOT sector shown in Figure 5, combined with an increase in the tons of mixture used for this sector shown in Figure 6, was not enough to offset declines in the Other Agency and Commercial & Residential sectors, resulting in a slight decrease (0.4 percent) in the national average percentage of RAP used.

RAP Use in Each State

Figure 7 and Table 5 show the average percentage of RAP used in HMA/WMA mixtures in each state by construction season based on reported RAP tons used in HMA/WMA mixtures and total reported tonnage. It should be noted that the accuracy of data for individual states varies depending on the number of responses received from producers in each state and the total number of tons accounted for in the responses.

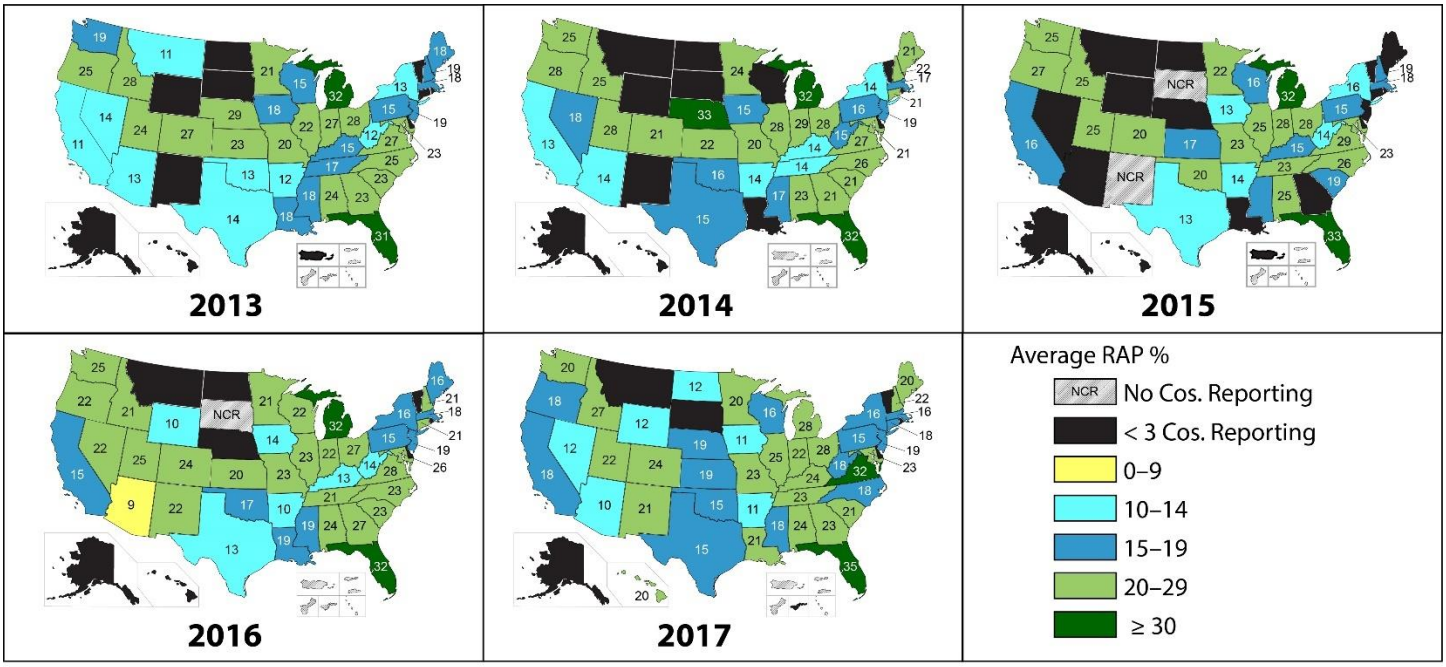


Figure 7: Estimated Average Percentage of RAP in Each State for Each Construction Season Survey, 2013–2017

Table 5: Average Estimated RAP Percent

State	Average RAP Percent					State	Average RAP Percent				
	2013	2014	2015	2016	2017		2013	2014	2015	2016	2017
Alabama	24%	23%	25%	24%	24%	Montana	11%	*	*	*	*
Alaska	*	*	*	*	*	Nebraska	29%	33%	*	*	19%
American Samoa	NCR	NCR	NCR	NCR	*	Nevada	14%	18%	*	22%	12%
Arizona	13%	14%	*	9%	10%	New Hampshire	19%	22%	19%	21%	22%
Arkansas	12%	14%	14%	10%	11%	New Jersey	19%	19%	*	19%	19%
California	11%	13%	16%	15%	18%	New Mexico	*	*	NCR	22%	21%
Colorado	27%	21%	20%	24%	24%	New York	13%	14%	16%	16%	16%
Connecticut	*	21%	*	21%	18%	North Carolina	25%	26%	26%	23%	18%
Delaware	*	*	*	*	*	North Dakota	*	*	*	*	12%
Dist. of Columbia	*	NCR	NCR	NCR	*	Ohio	28%	28%	28%	27%	28%
Florida	31%	32%	33%	32%	35%	Oklahoma	13%	16%	20%	17%	15%
Georgia	23%	21%	*	27%	23%	Oregon	25%	28%	27%	22%	18%
Hawaii	*	*	*	*	20%	Pennsylvania	15%	16%	15%	15%	15%
Idaho	28%	25%	25%	21%	27%	Puerto Rico	*	NCR	*	NCR	NCR
Illinois	22%	28%	25%	23%	25%	Rhode Island	*	*	*	*	*
Indiana	27%	29%	28%	22%	22%	South Carolina	23%	21%	19%	23%	21%
Iowa	18%	15%	13%	14%	11%	South Dakota	*	*	NCR	*	*
Kansas	23%	22%	17%	20%	19%	Tennessee	17%	14%	23%	21%	23%
Kentucky	15%	14%	15%	13%	24%	Texas	14%	15%	13%	13%	15%
Louisiana	18%	*	*	19%	21%	Utah	24%	28%	25%	25%	22%
Maine	18%	21%	*	16%	20%	Vermont	*	*	*	*	*
Maryland	23%	21%	23%	26%	23%	Virginia	27%	27%	29%	28%	32%
Massachusetts	18%	17%	18%	18%	16%	Washington	19%	25%	25%	25%	20%
Michigan	32%	32%	32%	32%	28%	West Virginia	12%	15%	14%	14%	18%
Minnesota	21%	24%	22%	21%	20%	Wisconsin	15%	*	16%	22%	16%
Mississippi	18%	17%	17%	19%	18%	Wyoming	*	*	*	10%	12%
Missouri	20%	20%	23%	23%	23%						

No Companies Reporting	< 3 Companies Reporting	0–9%	10–14%	15–19%	20–29%	≥ 30%

Figure 8 revisualizes the Table 5 data, showing the number of producers in each state reporting average RAP percentages at the various ranges by construction season from 2009 to 2017. The number of states with producers reporting average RAP percentages 20 percent or greater has increased significantly, rising from 10 states in 2009 to 27 states in 2014; peaking at 29 states in 2016, and decreasing to 24 states in 2017. The number of states with producers reporting RAP percentages less than 15 percent has decreased from 23 states in 2009 to just two states in 2014 and then remained steady at 10 states in 2015 and 2016, and rising to 11 states in 2017.

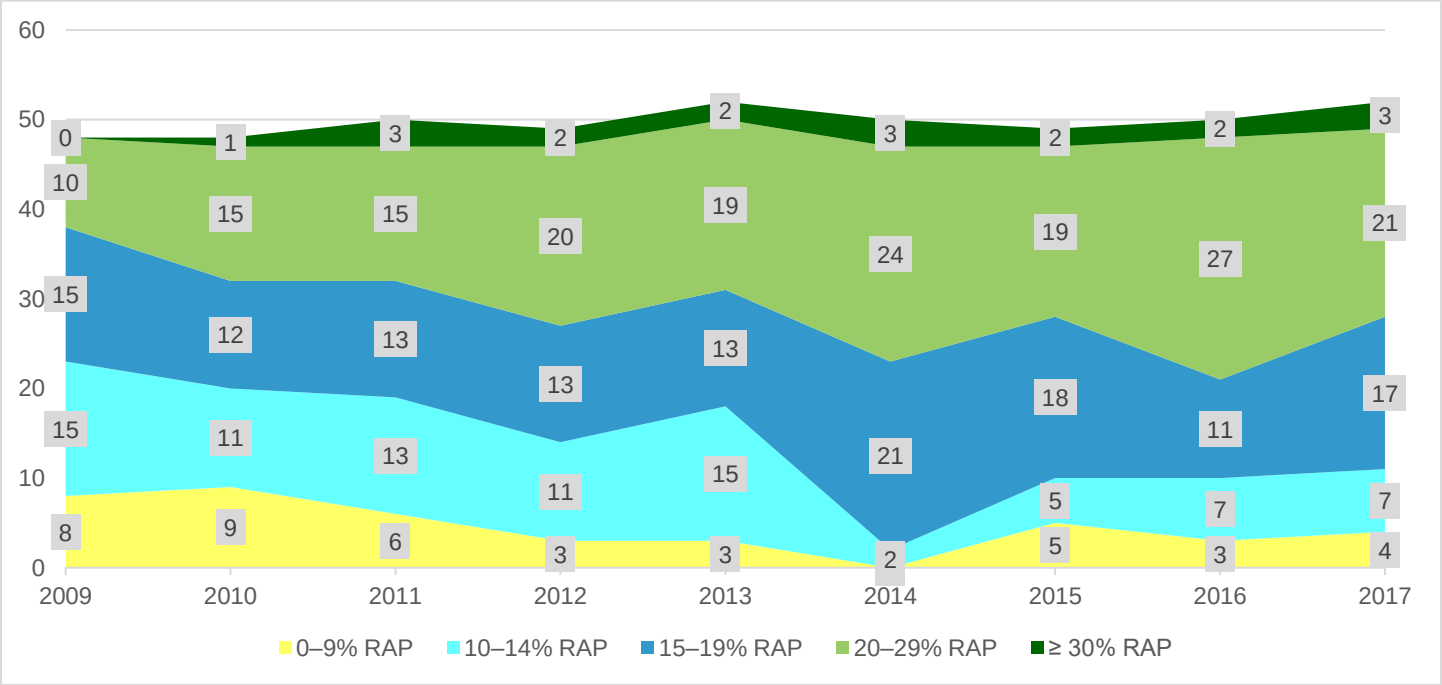


Figure 8: Number of States at Different Average RAP Percentages in HMA/WMA Mixtures, 2009–2017

Limitations on RAP Use

In the SAPA survey, state associations were asked "What limits the use of RAP in your state?" Respondents could provide up to five possible limiting factors. As can be seen in Figure 9, specification limits (38.5 percent) was the most commonly cited limiting factor in increasing the use of RAP followed by RAP availability (18.5 percent) and asphalt plant capabilities (15.4 percent). Specification limits are generally established by owner agencies based upon past experiences with the goal of ensuring future performance.

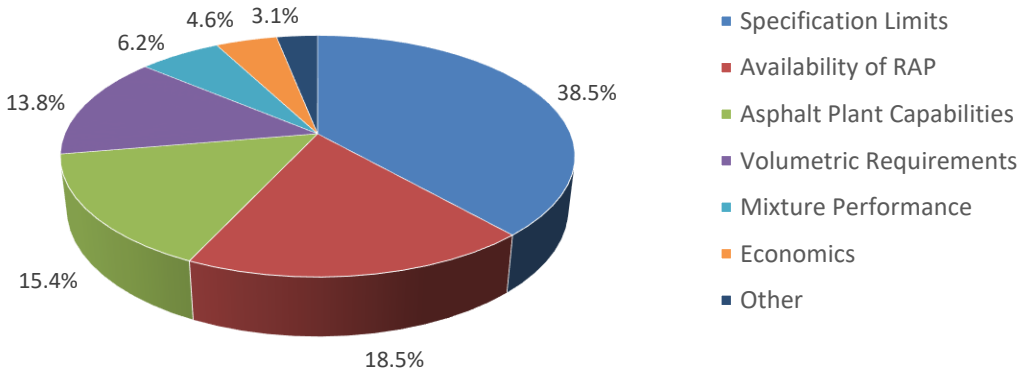


Figure 9: Reported Factors Limiting the Use of RAP, 2017

RAP Stockpiles

During the 2017 construction season, an estimated 79.9 million tons of RAP was accepted by asphalt mixture producers and the equivalent amount was used across all purposes during the year. In 2012, 2014, and 2015, more RAP was used than was received, indicating producers were drawing upon stockpiled RAP in those years. In 2016 more RAP was received than was utilized, indicating an increase in producer's inventory.

The estimated amount of RAP stockpiled nationwide increased by 9.1 percent from 93.59 million tons at the end of the 2016 construction season to 102.11 million tons at the end of the 2017 construction season. This increase is likely due, in part, to variation in which companies responded to the 2017 construction season survey versus prior year surveys. For 2017, 93.3 percent of producers reported having stockpiled RAP, up from 89.5 percent of producers in 2016.

Table 6 shows the reported and estimated amount of RAP stockpiled in each state at the end of the 2017 construction season. To calculate the estimated values, reported tons of RAP stockpiled were divided by the ratio of total reported tons of mixture produced to estimate tons of mixture produced. The total tonnage row in Table 6 includes stockpiled tonnages from states with fewer than three producers reporting.

Table 6: Reported Tons of RAP Stockpiled

State	Reported Tons Stockpiled (Million) 2016	Reported Tons Stockpiled (Million) 2017	Estimated Tons Stockpiled (Million) 2016	Estimated Tons Stockpiled (Million) 2017	State	Reported Tons Stockpiled (Million) 2016	Reported Tons Stockpiled (Million) 2017	Estimated Tons Stockpiled (Million) 2016	Estimated Tons Stockpiled (Million) 2017
Alabama	1.14	1.94	2.28	2.78	Montana	*	*	*	*
Alaska	*	*	*	*	Nebraska	*	0.22	*	1.17
American Samoa	NCR	*	NCR	*	Nevada	0.23	0.05	0.79	0.12
Arizona	0.36	0.10	1.05	0.54	New Hampshire	0.08	1.01	0.08	1.23
Arkansas	0.23	0.20	0.54	0.64	New Jersey	2.33	5.91	3.84	15.05
California	1.63	0.60	4.20	2.63	New Mexico	0.10	0.10	0.35	0.31
Colorado	0.72	0.70	2.28	1.85	New York	1.37	1.07	4.10	2.40
Connecticut	1.02	1.14	1.86	1.97	North Carolina	1.10	1.02	3.46	2.55
Delaware	*	*	*	*	North Dakota	*	0.15	*	0.34
District of Columbia	NCR	*	NCR	*	Ohio	2.17	3.58	3.96	4.58
Florida	1.08	2.04	3.02	7.26	Oklahoma	0.39	0.36	0.91	0.72
Georgia	5.27	0.36	7.58	2.37	Oregon	0.65	0.21	2.19	0.78
Hawaii	*	0.12	*	0.18	Pennsylvania	1.59	2.71	4.12	7.01
Idaho	0.34	0.53	0.73	0.86	Puerto Rico	NCR	NCR	NCR	NCR
Illinois	0.59	0.53	3.79	3.26	Rhode Island	*	*	*	*
Indiana	1.75	2.20	3.65	3.94	South Carolina	0.46	0.89	0.95	1.74
Iowa	0.42	0.22	0.76	0.51	South Dakota	*	*	*	*
Kansas	0.56	0.23	1.19	0.43	Tennessee	0.85	0.87	2.98	3.16
Kentucky	0.44	0.96	0.94	0.96	Texas	0.48	2.00	1.44	5.04
Louisiana	0.18	0.17	0.25	1.06	Utah	1.41	1.42	1.25	1.62
Maine	0.44	0.53	0.34	0.46	Vermont	*	*	*	*
Maryland	1.18	0.71	2.64	2.29	Virginia	2.20	1.47	3.57	3.58
Massachusetts	0.97	0.56	2.04	0.72	Washington	0.54	0.87	1.67	1.18
Michigan	1.80	3.42	4.26	5.18	West Virginia	0.13	0.32	0.24	0.55
Minnesota	0.93	1.15	2.61	1.31	Wisconsin	1.46	1.16	2.45	1.60
Mississippi	0.48	0.16	0.83	0.27	Wyoming	0.03	0.02	0.21	0.40
Missouri	1.11	1.51	3.84	2.53	**Total**†	41.15	45.84	93.59	102.11

NCR No Companies Responding

* Fewer than 3 Companies Reporting

† Includes Values from States with Fewer than 3 Companies Reporting

RAP Fractionation

Table 7 shows the average percentage of RAP fractionated into two or more sizes in each state, as reported by survey participants. **These results are representative *only* of the survey participants and do not completely reflect practices in a given state.** This also helps explain the state-level variability from year to year. Producers and SAPAs were not questioned about state specifications regarding fractionation and recycled material content.

Previous reports have shown that fractionation of RAP does not correlate to RAP utilization percentages. This holds true for the 2017 data, with an example being Oklahoma, which reports 65 percent of RAP being fractionated and averaging 15 percent RAP in mixtures, while Maryland reported no fractionation but averages 23 percent RAP.

Table 7: Reported Percentage of RAP Fractionated, in Each State, 2016–2017

State	% Fractionated		State	% Fractionated		State	% Fractionated	
	2016	2017		2016	2017		2016	2017
Alabama	13%	29%	Kentucky	75%	53%	Ohio	6%	25%
Alaska	*	*	Louisiana	80%	75%	Oklahoma	50%	65%
American Samoa	NCR	*	Maine	0%	27%	Oregon	7%	3%
Arizona	0%	0%	Maryland	0%	0%	Pennsylvania	2%	5%
Arkansas	1%	0%	Massachusetts	4%	3%	Puerto Rico	NCR	NCR
California	31%	57%	Michigan	20%	24%	Rhode Island	*	*
Colorado	71%	22%	Minnesota	3%	10%	South Carolina	63%	50%
Connecticut	0%	0%	Mississippi	27%	25%	South Dakota	*	*
Delaware	*	*	Missouri	32%	10%	Tennessee	22%	55%
Dist. of Columbia	NCR	*	Montana	*	*	Texas	15%	39%
Florida	6%	28%	Nebraska	*	0%	Utah	13%	8%
Georgia	1%	8%	Nevada	0%	33%	Vermont	*	*
Hawaii	*	67%	New Hampshire	0%	0%	Virginia	34%	36%
Idaho	12%	17%	New Jersey	16%	12%	Washington	0%	14%
Illinois	89%	55%	New Mexico	52%	37%	West Virginia	15%	4%
Indiana	72%	43%	New York	12%	14%	Wisconsin	14%	4%
Iowa	3%	0%	North Carolina	39%	29%	Wyoming	0%	50%
Kansas	3%	5%	North Dakota	*	0%			
						Average, Where Used†	23%	23%

NCR No Companies Responding

* Fewer than 3 Companies Reporting

† Includes Values from States with Fewer than 3 Companies Reporting

RAP Recycling Agent Use

Table 8 shows the percentage of reported tons of RAP-containing mixtures produced using softer binder or recycling agents in each state. **These results are representative *only* of the survey participants and do not completely reflect practices in a given state.** While there is no strong relationship between the amount of RAP mixtures using softer binder or recycling agents and percentage of RAP used by the state, it should be noted that of the 23 states using more than 20 percent RAP, 18 of them report using softer binders and or recycling agents in a percentage of their RAP mixtures and five of these states reported no use of softer binders or recycling agents in RAP mixtures.

Table 8: Percentage of RAP Mixes Using Softer Binder and/or Recycling Agents in Each State, 2017

State	Softer Binder	Recyc. Agent	State	Softer Binder	Recyc. Agent	State	Softer Binder	Recyc. Agent
Alabama	0%	0%	Kentucky	8%	26%	Ohio	30%	0%
Alaska	*	*	Louisiana	12%	0%	Oklahoma	19%	0%
American Samoa	*	*	Maine	2%	0%	Oregon	0%	0%
Arizona	23%	0%	Maryland	29%	16%	Pennsylvania	3%	8%
Arkansas	0%	0%	Massachusetts	5%	0%	Puerto Rico	NCR	NCR
California	21%	38%	Michigan	24%	0%	Rhode Island	*	*
Colorado	0%	0%	Minnesota	10%	1%	South Carolina	0%	0%
Connecticut	0%	0%	Mississippi	3%	0%	South Dakota	*	*
Delaware	*	*	Missouri	39%	6%	Tennessee	0%	22%
Dist. of Columbia	*	*	Montana	*	*	Texas	31%	0%
Florida	83%	0%	Nebraska	0%	0%	Utah	48%	0%
Georgia	0%	0%	Nevada	17%	0%	Vermont	*	*
Hawaii	0%	0%	New Hampshire	0%	25%	Virginia	14%	4%
Idaho	79%	3%	New Jersey	0%	0%	Washington	16%	7%
Illinois	14%	1%	New Mexico	8%	0%	West Virginia	3%	0%
Indiana	22%	0%	New York	4%	9%	Wisconsin	19%	5%
Iowa	21%	0%	North Carolina	44%	0%	Wyoming	0%	0%
Kansas	65%	3%	North Dakota	3%	0%			
						Average, When Used†	18%	4%

NCR No Companies Responding for the State to the Survey

* Fewer than 3 Companies Reporting

† Includes Values from States with Fewer than 3 Companies Reporting

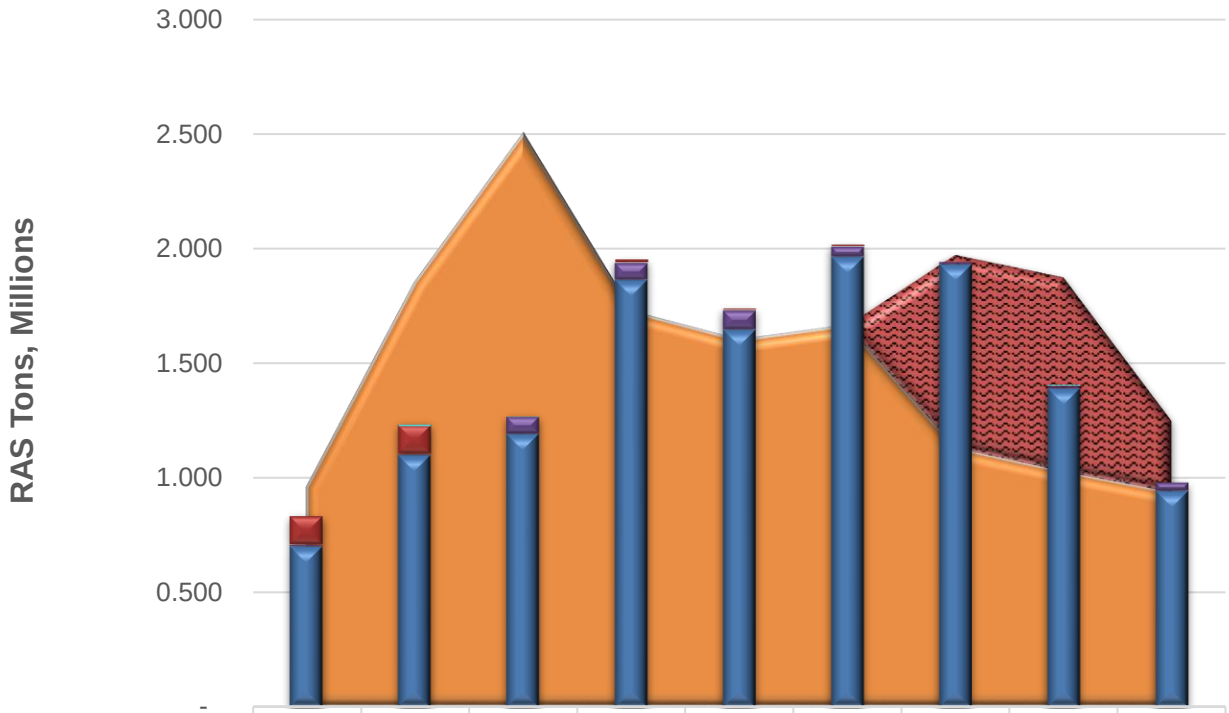
Although the data is highly dependent upon the companies responding to the survey each year, the average percentage of RAP mixtures incorporating softer binders was 18 percent during the 2017 construction season, which is down from 24 percent in the 2015 and 2016 survey. The percentage of RAP mixtures incorporating recycling agents has fluctuated year to year with 4 percent in 2017, 7 percent in 2016, and 3 percent in 2015.

Reclaimed Asphalt Shingles

Table 4 includes the national summary of RAS data from the 2016 and 2017 construction season surveys. The information requested in the survey is detailed in Appendix A and summarized in Table A1, Section 3. State-level data is reported in Appendix B. Producers and SAPAs were not asked about allowable RAS limits or binder replacement requirements for their states. Figure 10 is a visual representation of the estimated total tons of RAS used in asphalt mixtures, aggregate, cold-mix asphalt, and other uses, as well as the amount landfilled, from the 2009 to 2017 construction season surveys.

During the 2017 construction season, the total estimated amount of unprocessed and processed shingles received by producers was 1.246 million tons, which is more than combined amount of RAS used in asphalt mixtures (944,000 tons) and in aggregate (36,000 tons). This is a 32.1 percent decline from the 1.390 million total tons of RAS used in asphalt pavement mixtures during the 2016 construction season and it correlates with an across-the-board decrease in the use of RAS in asphalt pavement mixtures among all sectors. No RAS accepted by producers was reported as landfilled during the 2017 construction season.

As shown in Figure 10, beginning in the 2012 construction season, producers began reporting using RAS in greater quantities than they accepted. When this trend was first noticed, producers were contacted to confirm the reported



	2009	2010	2011	2012	2013	2014	2015	2016	2017
Processed Shingles Accepted	-	-	-	-	-	-	0.842	0.846	0.311
Unprocessed Shingles Accepted	0.957	1.851	2.500	1.724	1.599	1.664	1.129	1.027	0.935
Landfilled	-	0.007	0.000	-	-	-	-	0.005	-
Used in Other	0.123	0.125	-	0.012	0.005	0.006	-	-	-
Used in Cold Mix	-	-	-	-	-	-	-	-	-
Used in Aggregate	0.006	0.003	0.074	0.073	0.082	0.043	0.009	0.009	0.036
Used in HMA/WMA	0.702	1.100	1.192	1.863	1.647	1.964	1.931	1.390	0.944

Figure 10: Comparison of Tons of RAS Accepted and Tons of RAS Used or Landfilled (Million Tons), 2009–2017. Processed RAS Acceptance First Tracked in 2015

values. All producers contacted indicated they either had RAS stockpiled or were purchasing RAS from shingle processors. To capture the volume of processed shingles accepted by producers, the 2015 survey began asking producers "How many tons of processed shingles were accepted/delivered to your facilities in the state in 2015?"

During the 2017 construction season, the total estimated amount of unprocessed shingles accepted by producers declined 9 percent from 1.027 million tons in 2016 to 935,000 tons in 2016. There was an even more significant (63 percent) decrease in the acceptance of processed shingles in 2017 compared to 2016, which led to a 32 percent decrease in the total amount of RAS accepted during the 2017 construction season compared to 2016. To better characterize the source of unprocessed shingles (PCAS vs. MWAS), producers were asked to report in the 2017 construction season survey the tons of unprocessed PCAS, unprocessed MWAS, and processed RAS accepted separately. Of the unprocessed RAS accepted during 2017, about 63 percent (591,000 tons) was PCAS and 37 percent (344,000 tons) was MWAS.

The number of companies using RAS fell from 76 in 2016 to 64 during the 2017 construction season. The percentage of producers reporting use of RAS decreased from 33 percent of respondents in 2016 to 27 percent in 2017.

An estimated 13.2 million tons of waste shingles are produced annually;[1] therefore, asphalt mixture producers in 2017 accepted about 9 percent of the total available supply of waste shingles.

RAS Use by Sector

Figure 11 shows the total estimated amount of RAS used in each of the three sectors of the paving market. These values were calculated using the average percentages of RAS reported by producers for the sectors and adjusted to account for differences between reported RAS tonnage and tons calculated from the percentage by sector. There was a notable across-the-board decrease in the tons of RAS used by DOTs from the 2016 to 2017 construction. All sectors saw continued decreases in percentage and tonnage of RAS use from 2016 to 2017.

Figure 12 shows the average percentage of RAS used by each sector and overall across all asphalt pavement mixtures. These values were calculated using the average percentages of RAS reported for the different sectors and adjusted to account for differences between

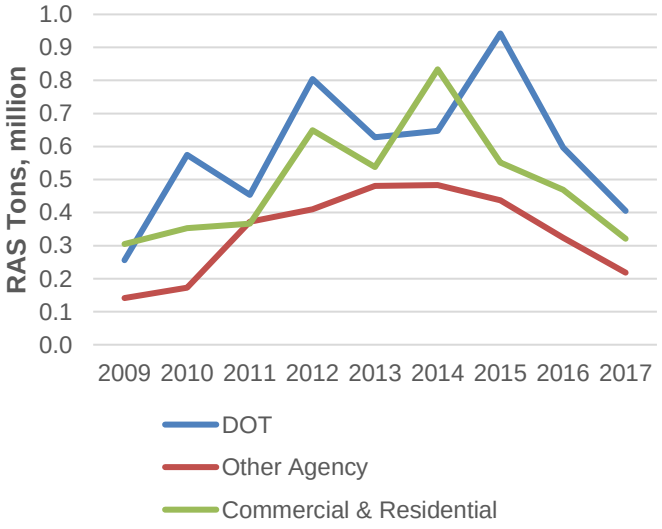


Figure 11: Estimated RAS Use by Sector (Million Tons)

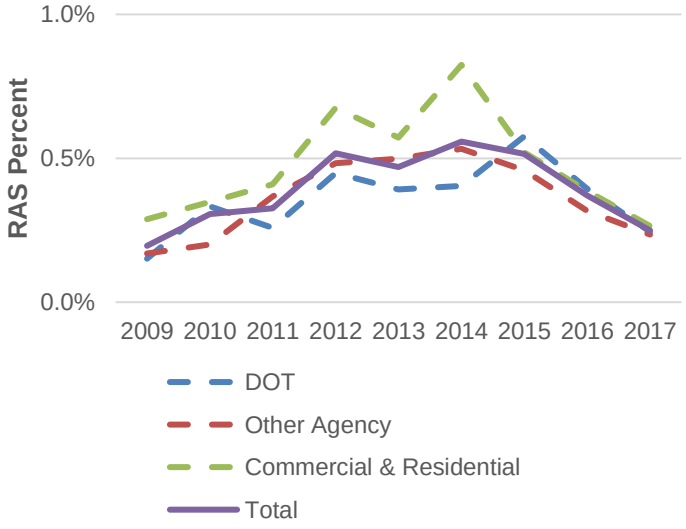


Figure 12: Average Percent RAS Used by Sector

[1] According to the Asphalt Roofing Manufacturers Association (ARMA, 2015), about 13.2 million waste shingles are generated annually — about 12 million tons of PCAS and 1.2 million tons of MWAS. This is an increase from the commonly cited figure of 11 million tons (NAHB, 1998), reflecting changes in housing stock and the housing market since 1998.

reported RAS tonnage and tons calculated from the percentage by sector. Although previous years' surveys saw relatively steady growth across all sectors from 2009 to 2014 with some year-to-year variation, there was a leveling of total RAS use from 2012 to 2015 until a notable decline began in the 2016 construction season and continued into 2017. The average percentage RAS peaked in 2012 at 0.56 percent in 2012 and started declining from 0.54 percent in 2014 and 2015 to 0.37 percent in 2016 and then again to 0.24 percent in the 2017 construction season.

In 2017, producers and SAPAs were asked which sectors allow RAS to be included in asphalt mixtures. Responses came from 47 states, and this information is summarized in Table 9. In cases where conflicting answers were provided, a middle ground was assumed with SAPA responses being given greater weight regarding the public sectors' RAS use and contractors' responses being given greater weight for the private sector. Most respondents reported that RAS is allowed in at least some mixtures and sectors. According to responses from producers and SAPAs, 25 DOTs reportedly allow RAS in some asphalt pavement mixtures, and seven other DOTs allow it in all mixtures. RAS use is allowed in some Other Agency sector mixtures in 31 states, with an additional two states allowing RAS in all mixtures for that sector. Similarly, RAS is allowed in at least some Commercial & Residential sector mixtures in 43 states. There were no reports of states allowing RAS in all mixtures for all sectors, while five states — Hawaii, North Dakota, Rhode Island, South Dakota, and Wyoming — reportedly do not allow the use of RAS in mixtures for any sector.

Table 9: Sectors Allowing RAS, 2017

State	RAS Allowed In?			State	RAS Allowed In?		
	DOT Mixtures	Other Agency Mixtures	Commercial & Residential Mixtures		DOT Mixtures	Other Agency Mixtures	Commercial & Residential Mixtures
Alabama	Some	Some	Some	Montana	None	None	All
Alaska	DNA	DNA	DNA	Nebraska	Some	Some	Some
American Samoa	DNA	DNA	DNA	Nevada	None	None	Some
Arizona	Some	Some	All	New Hampshire	None	None	Some
Arkansas	Some	Some	Some	New Jersey	Some	None	None
California	None	Some	Some	New Mexico	Some	Some	Some
Colorado	None	Some	Some	New York	Some	Some	All
Connecticut	Some	Some	Some	North Carolina	Some	Some	Some
Delaware	DNA	DNA	DNA	North Dakota	None	None	None
District of Columbia	DNA	DNA	DNA	Ohio	Some	Some	Some
Florida	None	None	Some	Oklahoma	Some	Some	Some
Georgia	None	None	Some	Oregon	Some	Some	Some
Hawaii	None	None	None	Pennsylvania	Some	Some	Some
Idaho	Some	Some	Some	Puerto Rico	NCR	NCR	NCR
Illinois	All	Some	Some	Rhode Island	None	None	None
Indiana	All	All	Some	South Carolina	Some	Some	Some
Iowa	All	All	Some	South Dakota	None	None	None
Kansas	Some	Some	Some	Tennessee	Some	Some	Some
Kentucky	Some	Some	All	Texas	Some	Some	Some
Louisiana	DNA	DNA	DNA	Utah	None	Some	Some
Maine	Some	None	Some	Vermont	Some	Some	Some
Maryland	Some	Some	All	Virginia	All	Some	Some
Massachusetts	Some	Some	Some	Washington	Some	Some	All
Michigan	Some	Some	Some	West Virginia	None	None	Some
Minnesota	All	Some	Some	Wisconsin	All	Some	Some
Mississippi	None	None	Some	Wyoming	None	None	None
Missouri	All	Some	Some				

DNA Did Not Answer
NCR No Companies Responding

Table 10: States With Reported RAS Use

State	RAS Used?								
	2009	2010	2011	2012	2013	2014	2015	2016	2017
Alabama	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Alaska	No	No	No	No	No	No	No	No	No
American Samoa	NCR	NCR	NCR	NCR	NCR	NCR	NCR	NCR	No
Arizona	No	No	No	No	No	No	No	No	No
Arkansas	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
California	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colorado	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Connecticut	No	No	No	No	Yes	Yes	Yes	Yes	Yes
Delaware	Yes	Yes	NCR	Yes	Yes	Yes	Yes	Yes	No
District of Columbia	NCR	NCR	NCR	NCR	No	NCR	NCR	NCR	No
Florida	Yes	Yes	No	No	Yes	Yes	Yes	No	No
Georgia	No	No	Yes	Yes	Yes	No	No	Yes	No
Hawaii	No	No	No	No	No	No	No	No	No
Idaho	No	No	No	No	No	No	No	No	No
Illinois	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Indiana	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Iowa	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kansas	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kentucky	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Louisiana	No	No	No	No	Yes	No	No	Yes	No
Maine	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Maryland	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Massachusetts	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Michigan	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Minnesota	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mississippi	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Missouri	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Montana	No	No	No	No	No	No	No	No	No
Nebraska	NCR	NCR	No	Yes	Yes	No	No	Yes	No
Nevada	No	Yes	No	No	No	No	No	Yes	Yes
New Hampshire	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
New Jersey	No	No	No	No	Yes	No	No	No	No
New Mexico	NCR	NCR	No	NCR	No	No	NCR	Yes	Yes
New York	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
North Carolina	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
North Dakota	NCR	NCR	No	NCR	No	No	No	No	No
Ohio	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Oklahoma	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Oregon	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pennsylvania	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Puerto Rico	No	No	No	No	No	NCR	No	NCR	NCR
Rhode Island	No	No	No	No	No	No	No	No	No
South Carolina	No	No	Yes	No	Yes	Yes	No	Yes	No
South Dakota	No	No	Yes	Yes	Yes	Yes	NCR	Yes	No
Tennessee	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Texas	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Utah	No	No	No	No	No	No	No	No	No
Vermont	No	No	No	Yes	Yes	Yes	Yes	No	Yes
Virginia	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Washington	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
West Virginia	Yes	Yes	No	No	No	No	No	No	No
Wisconsin	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wyoming	No	No	No	No	Yes	No	No	Yes	No

NCR	= No Companies Responding
Yes	= RAS Use Reported
No	= No RAS Use Reported

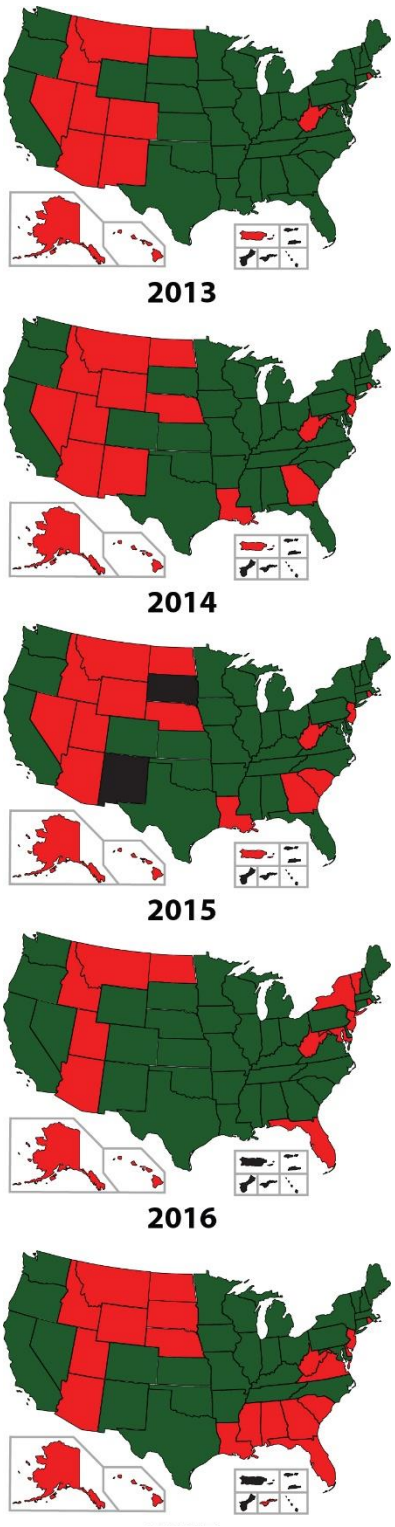


Figure 13: States with Companies Reporting Using RAS by Construction Season

RAS Use in Each State

Table 10 shows states where asphalt pavement mixture producers reported using RAS in 2009 through 2017. Figure 13 shows states where producers reported using RAS from 2013 through 2017. Red indicates a state where RAS use was not reported that construction season. The number of states where producers reported using RAS increased annually from 22 in 2009 to 38 in 2013, but decreased to 34 in 2014 and 32 in 2015. During the 2017 construction season, 29 states had asphalt mixture producers report RAS use. In Alabama, for the first time since 2009, no producers reported using RAS during the 2017 construction season.

RAS Stockpiles

During the 2017 construction season, RAS use continued to decline from its high of 1.964 million tons accepted and used in 2014. In 2017, 98 percent of the 64 producers using RAS reported having stockpiled RAS, compared to more than 91 percent of the 77 producers using RAS in 2016. In prior surveys, producers were only asked whether or not they had stockpiled RAS; in 2017, the survey first sought to quantify the amount of RAS stockpiled in each state and nationally.

Table 11 shows the reported and estimated amount of RAS stockpiled in each state at the end of the 2017 construction season. To calculate the estimated values, reported tons of RAS stockpiled were divided by the ratio of total reported tons of mix produced to estimated tons of mix produced. The total tonnage row in Table 11 includes stockpiled tonnages from states with fewer than three producers reporting.

Table 11: Reported Tons of RAS Stockpiled, 2017

State	Tons Stockpiled (Thousands)		State	Tons Stockpiled (Thousands)		State	Tons Stockpiled (Thousands)	
	Reported	Estimated		Reported	Estimated		Reported	Estimated
Alabama	0.0	0.0	Kentucky	5.5	5.5	Ohio	55.7	71.2
Alaska	*	*	Louisiana	0.0	0.0	Oklahoma	8.2	16.3
American Samoa	*	*	Maine	1.0	0.8	Oregon	3.2	12.3
Arizona	0.0	0.0	Maryland	10.5	33.8	Pennsylvania	69.5	179.4
Arkansas	38.7	121.6	Massachusetts	0.8	1.0	Puerto Rico	NCR	NCR
California	4.0	17.5	Michigan	1.5	2.3	Rhode Island	*	*
Colorado	7.8	20.7	Minnesota	25.3	28.8	South Carolina	0.0	0.0
Connecticut	0.0	0.0	Mississippi	0.0	0.0	South Dakota	*	*
Delaware	*	*	Missouri	78.7	132.0	Tennessee	54.6	198.3
Dist. of Columbia	*	*	Montana	*	*	Texas	22.6	57.1
Florida	9.5	33.9	Nebraska	3.3	17.7	Utah	0.0	0.0
Georgia	22.9	149.3	Nevada	0.2	0.4	Vermont	*	*
Hawaii	0.0	0.0	New Hampshire	0.0	0.0	Virginia	2.0	4.9
Idaho	0.0	0.0	New Jersey	0.0	0.0	Washington	2.9	3.9
Illinois	1.1	6.7	New Mexico	1.8	5.8	West Virginia	0.0	0.0
Indiana	13.8	24.6	New York	0.0	0.0	Wisconsin	45.7	62.7
Iowa	19.4	46.3	North Carolina	75.2	188.6	Wyoming	0.0	0.0
Kansas	11.0	20.5	North Dakota	0.0	0.0	**Total**†	596.2	1,387.0

NCR No Companies Responding for the State to the Survey

* Fewer than 3 Companies Reporting

† Includes Values from States with Fewer than 3 Companies Reporting

RAS Recycling Agent Use

Table 12 shows the percentage of reported tons of RAS-containing mixtures produced using softer binder or recycling agents in each state. **These results are representative *only* of the survey participants and do not completely reflect practices in a given state.** Unlike with RAP, there does appear to be a relationship between the amount of RAS mixtures using softer binder and/or recycling agents and percentage of RAS used by the state. In Figure 14, the trendline does not show a strong correlation, but there does appear to be an upward trend in RAS utilization when high quantities of softer binder and/or recycling agents are employed in a state.

Table 12: Percentage of RAS Mixtures Using Softer Binder and/or Recycling Agents in Each State, 2017

State	Softer Binder	Recyc. Agent	State	Softer Binder	Recyc. Agent	State	Softer Binder	Recyc. Agent
Alabama	0%	0%	Kentucky	0%	55%	Ohio	33%	0%
Alaska	*	*	Louisiana	0%	0%	Oklahoma	50%	0%
American Samoa	*	*	Maine	0%	0%	Oregon	0%	25%
Arizona	0%	0%	Maryland	25%	15%	Pennsylvania	10%	11%
Arkansas	0%	0%	Massachusetts	0%	0%	Puerto Rico	NCR	NCR
California	100%	0%	Michigan	33%	0%	Rhode Island	*	*
Colorado	0%	0%	Minnesota	5%	0%	South Carolina	0%	0%
Connecticut	0%	0%	Mississippi	0%	0%	South Dakota	*	*
Delaware	*	*	Missouri	62%	35%	Tennessee	0%	33%
Dist. of Columbia	*	*	Montana	*	*	Texas	35%	0%
Florida	0%	0%	Nebraska	0%	0%	Utah	*	*
Georgia	0%	0%	Nevada	0%	0%	Vermont	0%	0%
Hawaii	0%	0%	New Hampshire	0%	0%	Virginia	17%	17%
Idaho	0%	0%	New Jersey	0%	0%	Washington	0%	0%
Illinois	40%	0%	New Mexico	50%	0%	West Virginia	53%	0%
Indiana	25%	0%	New York	0%	0%	Wisconsin	0%	0%
Iowa	25%	0%	North Carolina	60%	0%	Wyoming	*	*
Kansas	100%	0%	North Dakota	0%	0%			
						Average, When Used†	44%	7%

NCR No Companies Responding for the State to the Survey

* Fewer than 3 Companies Reporting

† Includes Values from States with Fewer than 3 Companies Reporting

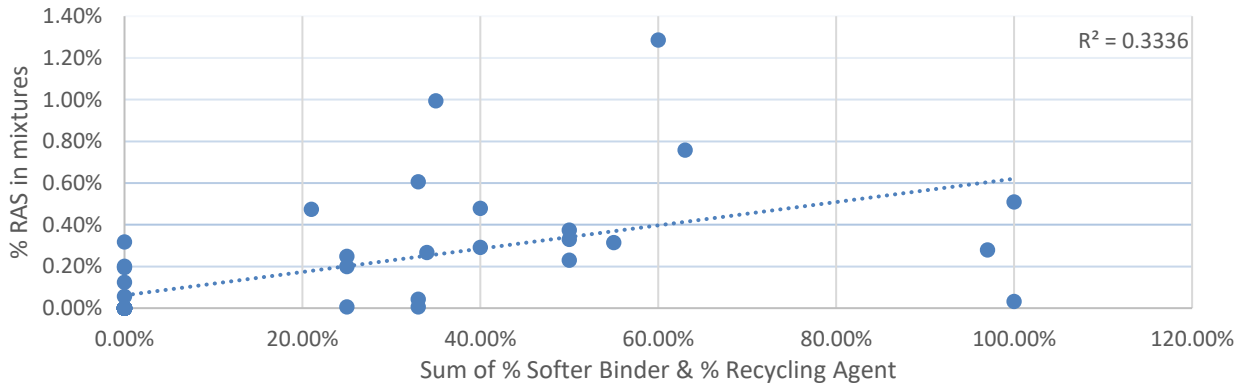


Figure 14: Scatter Plot Showing Use of Recycling Agents and Softer Binders Relative to Percentage of RAS Used in Asphalt Mixtures, 2017

Although the data is highly dependent upon the companies responding to the survey each year, in states where recycling agents are reportedly used, the average percentage of RAS mixtures incorporating softer binders was 44 percent during the 2017 construction season, while the percentage of RAS mixtures incorporating recycling agents was at 7 percent. In 2016, producers reported a lower average percentage (37 percent) of RAS mixtures incorporating softer binders, but a greater average percentage (19 percent) of RAS mixtures incorporating recycling agents, than in the 2017 construction season.

Limitations on RAS Use

In the SAPA survey, state associations were asked "What limits the use of RAS in your state?" Respondents could provide up to five possible limiting factors. As can be seen in Figure 15, specification limits (47.3 percent) was the most commonly cited limiting factor in increasing the use of RAP followed by RAS availability (12.7 percent) and mixture performance (12.7 percent). Other (12.7 percent) responses received included lack of interest and/or perceptions of poor performance from owner agencies and/or producers, asphalt plant limitations, and local abundance of RAP. Specification limits are generally established by owner agencies based upon past experiences with the goal of ensuring future performance.

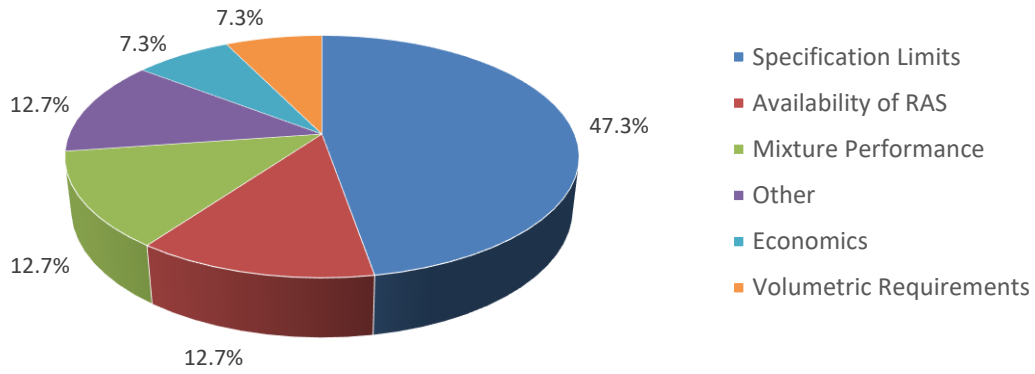


Figure 15: SAPA Reported Factors Limiting the Use of RAS, 2017

Cost Savings from RAP and RAS

The use of RAP and RAS both reduce the need for virgin materials, conserving valuable asphalt and aggregates. Beyond the environmental benefits of resource preservation, the use of RAP and RAS can help lower initial material costs for road construction, allowing road owners to achieve more roadway maintenance and construction activities within limited budgets. Table 13 summarizes the individual and cumulative savings from the use of RAP and RAS in asphalt mixtures realized during the 2017 construction season. In total, the use of RAP and RAS saved more than $2.2 billion during the 2017 construction season compared to the use of all virgin materials. This is about $43 million more than in 2016 due primarily to increases in asphalt binder and aggregate prices (Table 14).

Table 13: Material Savings, 2016–2017

Material	Material Quantity, Million Tons		% Agg.	% AC	Aggregate Cost Savings, $ Billion		Asphalt Binder Cost Savings, $ Billion		Total Cost Savings, $ Billion	
	2016	2017			2016	2017	2016	2017	2016	2017
RAP	76.9	76.2	95	5	$0.721	$0.734	$1.333	$1.393	$2.055	$2.127
RAS	1.39	0.944	50*	20	$0.007	$0.005	$0.096	$0.069	$0.103	$0.074
Total					$0.728	$0.739	$1.430	$1.462	$2.158	$2.201

* Includes granules and mineral filler

The estimated savings shown in Table 13 were based on the cost factors shown in Table 14. Asphalt binder prices were estimated based upon an average of available 2017 asphalt price indexes from 18 states (Arizona, Arkansas, Florida, Georgia, Illinois, Indiana, Louisiana, Maryland, Missouri, New Jersey, New Mexico, North Carolina, Ohio, Oklahoma, Oregon, Tennessee, Virginia, and Washington state). The average price of unmodified asphalts from these states for 2017 was about $353.14 per ton, up from the 2016 average price of $333.46. Four of the states (Florida, Louisiana, Tennessee, and Virginia) also included price indexes for modified asphalts. The average modified asphalt prices from these states for 2017 was $478.15 per ton, up from $466.16 in 2016. Assuming 10 percent of asphalt mixtures use modified asphalt binders, the 2017 average price of asphalt binders used in asphalt mixtures was $365.69 per ton, up 5 percent from 2016.

Most asphalt mixtures today use crushed stone as the primary aggregate, but they often include a small percentage of natural sand. The U.S. Geological Survey (USGS) reports the average price of Stone (Crushed) at $10.39 per ton, and Sand and Gravel (Construction) at $7.89 per ton for 2017 (USGS, 2018). Assuming the average asphalt pavement mixture contains 10 percent natural sand and 90 percent crushed stone, the average price of aggregate in an asphalt mixture was $10.14 per ton for the 2017 construction season, up 2.7 percent from 2016.

Table 14: Material Cost Factors, 2016–2017

Material		% of Market	Cost/Ton	
			2016*	2017
Asphalt	Unmodified	90	$333.46	$353.14
	Modified	10	$466.16	$478.59
	Weighted Average		$346.73	$365.69
Aggregate	Crushed Stone	90	$10.11	$10.39
	Sand and Gravel	10	$7.77	$7.89
	Weighted Average		$9.88	$10.14

* 2016 Aggregate costs updated based on USGS (2018)

Minor additional cost savings, not calculated for this report, are associated with the use of RAS in stone-matrix asphalt and other specialty asphalt mixtures where shingle fibers may potentially replace mineral or cellulose fibers.

Warm-Mix Asphalt

Table 4 includes the national summary of WMA data from the 2016 and 2017 construction season surveys. The information requested in the survey is detailed in Appendix A and summarized in Table A1, Section 4. State-level data is reported in Appendix B. Producers were asked primarily about their tons of asphalt mixture produced at reduced temperatures (at least a 10°F reduction from typical mixture production temperatures). Producers were also asked about the different WMA technologies used. In addition, because WMA technologies are sometimes used without a reduction in production temperatures, producers were asked about the production of asphalt pavement mixtures with WMA technologies at conventional HMA production temperatures.

The tonnage values provided in this section of the report and the WMA section of Table 4 are only tons of material produced at reduced temperatures. Tons of asphalt pavement mixture produced at conventional HMA temperatures, regardless of whether or not WMA technologies were used, are reported only as part of the total asphalt tonnage for the year.

The percentage of companies reporting the production of WMA saw rapid increases from the 2009 to 2011 construction seasons, but has held at between 69 and 79 percent of respondents from the 2011 to 2017 construction seasons, as shown in Figure 16. Increases in WMA tonnage as a percent of total tonnage have generally plateaued between 2013 and 2016, as seen in Figure 17. The 2017 construction season, however, saw a 26 percent increase in the production of WMA to 147.4 million tons, 38.9 percent of total asphalt pavement tonnage, with significant increases in the DOT and Commercial & Residential sectors. A total of 163 companies, 69 percent of respondents, reported using WMA technologies during the 2017 construction season.

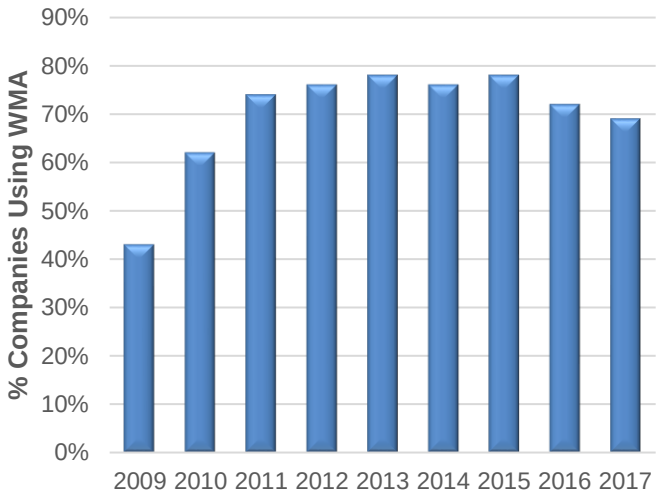


Figure 16: Percent of Companies Using WMA

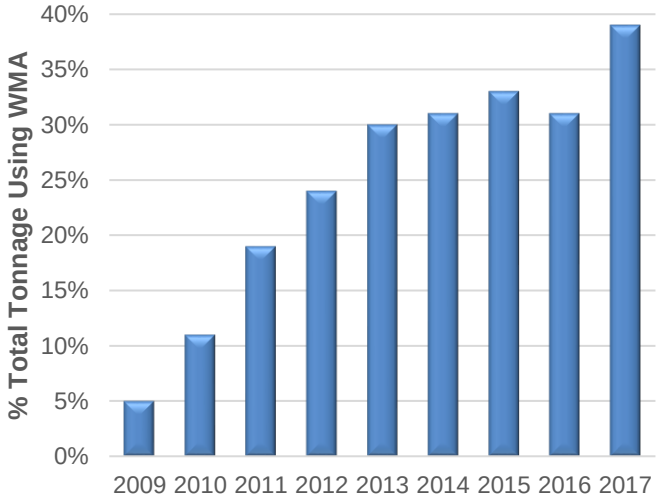
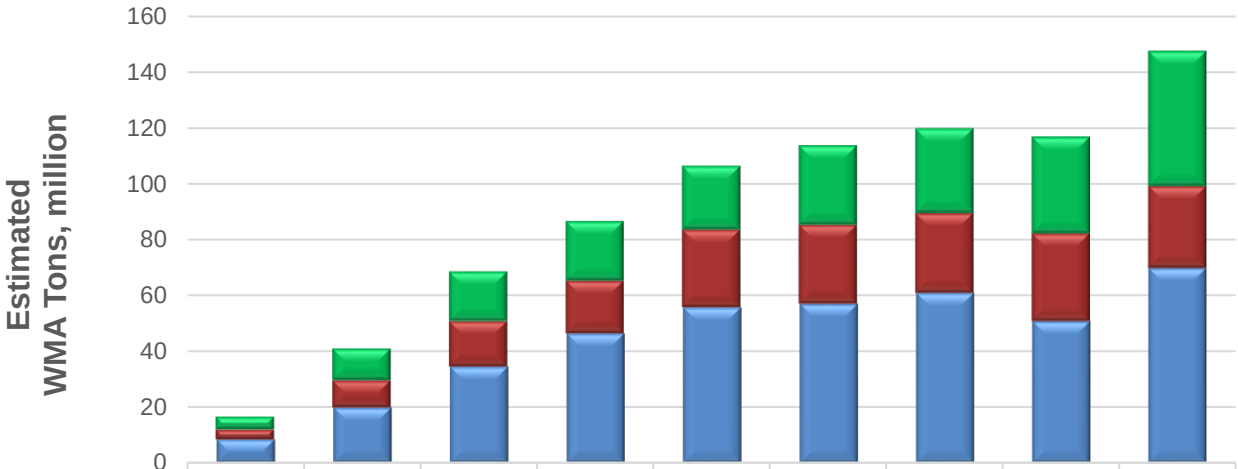


Figure 17: Percent Total Tonnage Produced Using WMA

WMA Use by Sector

Figure 18 shows a steady increase in the number of tons of WMA produced for each customer sector from 2011 to 2013, with modest increases continuing for the 2014 though 2015 construction seasons. For the 2016 construction season, WMA tonnage was down 2.5 percent from 2015. During 2017, growth in the production of WMA was driven by a 40 percent increase in WMA tonnage for the Commercial & Residential sector and a 37 percent increase in the DOT

sector mixtures; while the Other Agency sector was down 7 percent from the 2016 construction season. All in all, during the 2017 construction season, 42.2 percent of all DOT sector tonnage, 31.7 percent of Other Agency sector tonnage, and 39.8 percent of Commercial & Residential sector tonnage was produced using WMA technologies.



	2009	2010	2011	2012	2013	2014	2015	2016	2017
Commercial & Residential	4.6	11.3	17.8	21.4	22.8	28.5	30.4	34.6	48.4
Other Agency	3.6	9.8	16.3	18.9	27.9	28.4	28.5	31.5	29.4
DOT	8.6	20	34.6	46.4	55.7	56.9	60.9	50.7	69.7

Figure 18: Estimated Tons (Millions) of WMA by Sector, 2009–2017

WMA Use in Each State

Figure 19 shows the estimated percentage of total tons produced as WMA in each state. The national trend from 2009 through 2017 shows increased tons of asphalt mixture produced as WMA; however, a degree of fluctuation year-to-year

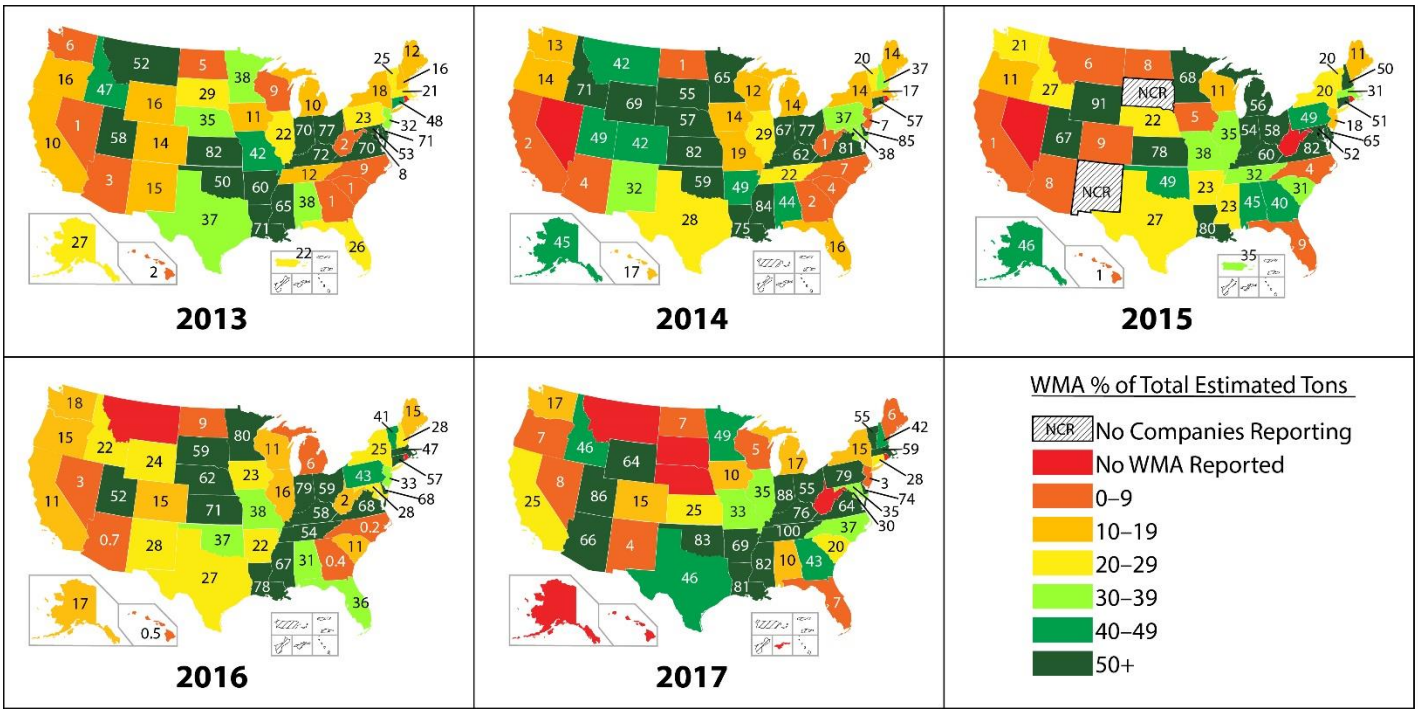


Figure 19: Estimated Percent of Total Production Using WMA in Each State, 2013–2017

is seen at the state level. The accuracy of data for individual states varies noticeably depending on the number of responses received from each state and the total number of tons represented by the respondents each year.

From 2016 to 2017, 19 states saw an increase of 10 percentage points or more in WMA production, while 12 states had a decrease of 10 percentage points or more. Ten states — Arizona, Arkansas, Georgia, North Carolina, Oklahoma, Pennsylvania, Tennessee, Utah, and Wyoming — had an increase of 30 percentage points or more in WMA production. Five states — Kansas, Minnesota, Nebraska, New Jersey, and South Dakota — had a decrease of 30 percentage points or more in WMA production.

WMA made up over half of the total asphalt mixture production in 16 states during 2017, and eight of these states — Indiana, Kentucky, Louisiana, Mississippi, Oklahoma, Pennsylvania, Tennessee, and Utah — reported WMA as 75 percent or more of total production in 2017. Notably, 100 percent of asphalt pavement mixture reported from Tennessee in 2017 was produced as WMA. Alaska, American Samoa, Hawaii, Montana, Nebraska, Rhode Island, South Dakota, and West Virginia did not report the production of WMA in 2017.

WMA Technologies

As Table 15 and Figure 20 show, production plant foaming remains the most commonly used technology for the production of WMA, being used for nearly 65 percent of the WMA produced in 2017. This is a decrease of about 15.6 percent from the 2016 construction season, however. The use of chemical additive technologies at 32.2 percent represents a 52.4 percent increase for the 2017 construction season compared to 2016. Organic additives make up the remainder of the market; there was negligible reported use of additive foaming technologies during 2017. The percentage of WMA produced with additive technologies has grown significantly since 2011 when they made up less than 5 percent of the WMA technologies used, and plant-based foaming has seen a general decrease in use since 2012.

Table 15: WMA Technologies Used as Percent of WMA Production, 2009–2017

WMA Technology	% of WMA Production								
	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production Plant Foaming %	83.0%	92.0%	95.4%	88.3%	87.0%	84.5%	72.0%	76.9%	64.7%
Additive Foaming %	2.0%	1.0%	0.2%	2.0%	0.3%	0.0%	2.1%	0.0%	0.0%
Chemical Additive %	15.0%	6.0%	4.1%	9.4%	12.1%	15.0%	25.2%	21.1%	32.2%
Organic Additive %	0.3%	1.0%	0.3%	0.2%	0.0%	0.5%	0.7%	1.9%	3.1%

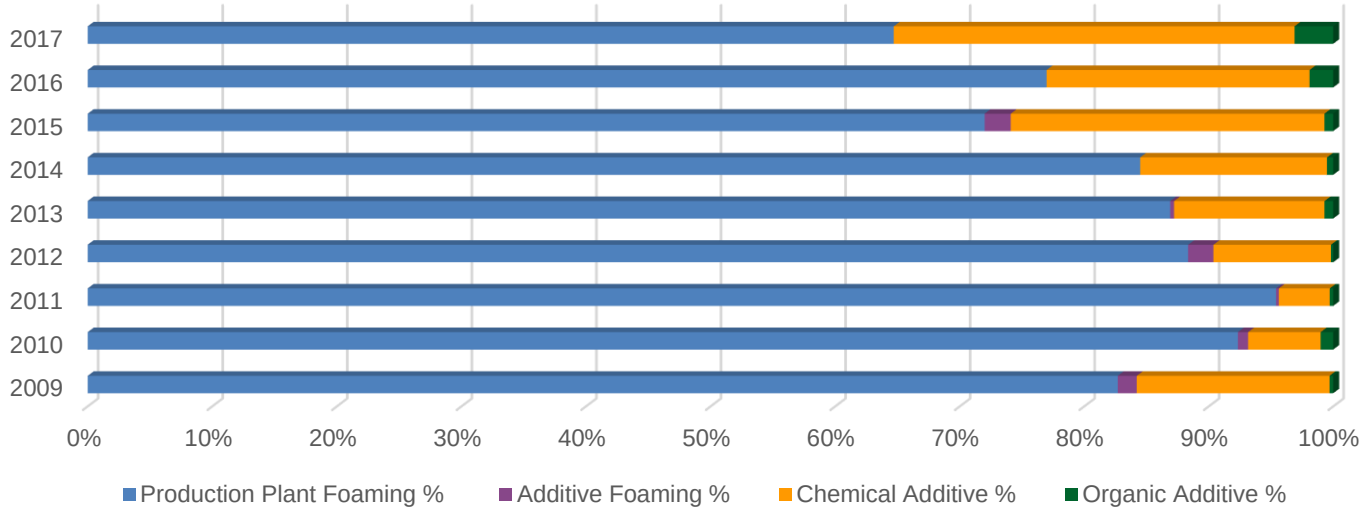


Figure 20: WMA Technologies Used as Percent of WMA Production, 2009–2017

Use of WMA Technologies in HMA

WMA additives can have compaction, workability, antistrip, and other benefits that encourage their use even when a reduction in production temperature is not sought or achieved by the producer. For this reason, producers were asked if they use WMA additives to produce asphalt mixtures at HMA temperatures. One hundred and seven producers in 43 states, about 66 percent of respondents who produce WMA, reported using WMA additives at HMA temperatures, including one respondent who did not produce reduced-temperature asphalt pavement mixtures but did use WMA additive technologies at HMA temperatures.

In the 2017 construction season survey, respondents were asked for the first time to estimate the percentage of HMA produced with each WMA technology. Because the focus of this survey is quantifying the production of reduced-temperature asphalt mixtures, producers were asked to estimate the percentage range of HMA tonnage produced using WMA technologies, instead of providing estimates of HMA tons produced with WMA technologies.

A national average of the responses is shown in Table 16.

Table 16: Percent of HMA Production Produced Using WMA Technologies, 2017

WMA Technology	% of HMA Production (Range)
Production Plant Foaming %	26–32%
Additive Foaming %	0–0.3%
Chemical Additive %	16–20%
Organic Additive %	1–2%

Producers reporting using production plant foaming WMA technologies to produce HMA in 38 states; additive foaming in one state; chemical additives in 22 states; and organic additives in six states. In 21 states, the use of multiple types of WMA technologies was reported in the production of HMA.

Other Recycled Materials

Starting with the 2012 construction season survey, a series of questions was asked about the use of other recycled materials in asphalt mixtures. The information requested in the survey is detailed in Appendix A and summarized in Table A1, Section 5.

Producers were asked how many tons of mixture were produced that incorporated other recycled materials, as well as how many tons of specific materials were used in mixture production during the 2017 construction season. In some cases, respondents provided only the tons of asphalt mixture produced using other recycled materials or only the tons of the other recycled materials used, not both. Four recycled materials — ground tire rubber (GTR), steel slag, blast furnace slag, and cellulose fibers — were specifically listed in the survey. Respondents could specify up to two additional recycled materials used in mixtures.

Because the response rate to these questions about other recycled materials was expected to be low and because producers may not track the use of these materials, state and national estimates of total quantities used for these materials were not calculated. **All values in this section are reported values *only* and do not represent estimates of the total quantity of these materials used in each state or nationally.** Year-to-year variation in reported values is entirely dependent upon the makeup of the respondents to each year's survey. Where available, third-party data is referenced to provide an understanding of the estimated total usage of these materials.

A total of 58 companies from 26 states, about 24 percent of survey respondents, reported using nearly 1.5 million tons of other recycled materials in nearly 7.5 million tons of asphalt mixtures during the 2017 construction season.

Ground Tire Rubber

Table 17 summarizes reported information on the use of ground tire rubber. Nineteen producers from 12 states reported using GTR in some asphalt mixtures. Information about the use of GTR in surface treatments, such as chip seals, was not within the scope of this survey. About two-fifths of the total reported asphalt mixture tonnage produced using GTR came from California, where legislative mandates require the wide-spread use of GTR in asphalt pavements (Caltrans, 2017). The total reported tons of asphalt mixture using GTR declined approximately 35 percent to 979,225 tons in the 2017 construction season survey, due at least in part to a decrease in the number of California producers responding to the 2017 survey.

While the tonnage produced that incorporates GTR is relatively straightforward to track and report, the tons of GTR used is harder to document due to different methods of producing mixtures that incorporate GTR — the wet process, which uses GTR as an asphalt binder modifier, and the dry process, which incorporates GTR as a fine aggregate (Bahia, 2011) — and the likelihood that GTR is either preblended with binder at the terminal or blended onsite by a third party. Given these factors, producer reports of tons of GTR used versus tons of asphalt mixture produced using GTR were given a heightened level of scrutiny to determine if the reported data was within a reasonable range. When reported tons of GTR fell outside the expected range, producers were contacted to obtain correct values.

To give a picture of the total market size for GTR, the U.S. Tire Manufacturers Association (USTMA) reports that 24.2 percent of U.S. scrap tires were processed into an estimated 1.013 million tons of GTR in 2017. Of this, about 11.7 percent (118,900 tons) of GTR was used in asphalt pavement mixtures and surface treatments, such as seal coats, in 2017 (USTMA, 2018). The GTR use reported by 2017 construction season survey respondents makes up nearly 12 percent of the total GTR estimated by USTMA as used in asphalt pavement mixtures and surface treatments during 2017.

Table 17: Reported Tons of Asphalt Mixtures Using Ground Tire Rubber and Reported Tons of GTR Used, 2013–2017

State	Reported Tons of Asphalt Mixtures Using GTR					Reported Tons of GTR Used				
	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Arizona	26,300	12,000	11,500	273,200	242,000	380	142	100	3,412	4,600
California	523,213	623,953	936,100	1,042,976	407,500	3,748	9,173	13,514	15,840	5,765
Delaware	—	—	—	8,000	—	—	—	—	40	—
Florida	250,779	198,046	110,000	32,288	22,392	531	419	356	135	145
Georgia	65,000	162,000	—	50,000	—	260	750	—	200	—
Illinois	4,500	—	3,500	15,500	—	20	—	36	79	—
Indiana	13,000	—	5,000	—	—	30	—	140	—	—
Kentucky	—	—	—	—	3,000	—	—	—	—	20
Louisiana	104,395	—	—	—	5,000	550	—	—	—	35
Maine	14,000	—	—	—	—	219	—	—	—	—
Massachusetts	24,897	81,882	79,680	71,500	145,333	324	1,146	1,090	841	1,603
Michigan	12,000	9,300	2,780	1,350	12,500	71	51	17	0.7	125
Missouri	50,000	—	—	—	100,000	180	—	—	—	1,500
Nevada	—	—	—	—	23,000	—	—	—	—	275
New Hampshire	28,000	50,000	8,400	365	—	358	780	114	—	—
New Mexico	—	—	—	15,000	—				—	—
New York	10	—	—	—	—	—	—	—	—	—
Ohio	1,500	23,000	6,000	—	6,300	8	150	60	—	65
Oregon	—	—	5,000	6,000	—	—	—	—	—	—
Pennsylvania	18,000	—	—	5,260	—	140	—	—	25	—
Puerto Rico	10,000	NCR	—	NCR	NCR	170	NCR	—	NCR	NCR
South Carolina	—	—	—	10,000	—	—	—	—	18	—
Tennessee	—	—	—	10,000	—	—	—	—	50	—
Texas	50,000	40,000	50,000	—	11,000	—	200	—	—	40
Utah	—	—	3,500	—	—	—	—	61	—	—
Virginia	—	—	—	—	1,200	—	—	—	—	13
Washington	—	—	6,500	—	—	—	—	—	—	—
Wisconsin	—	—	5,000	—	—	—	—	30	—	—
Total	1,195,594	1,200,181	1,234,960	1,541,439	974,725	6,989	12,811	17,518	20,641	14,186
No. of Companies	29	19	22	26	19					

NCR = No Companies Responding

— = No Use Reported

Steel & Blast Furnace Slag

Table 18 summarizes the reported use of steel slag and blast furnace slag in asphalt mixtures. Ten states reported using steel slag, and seven states reported using blast furnace slag during the 2017 construction season; of these five states — Alabama, Indiana, Kentucky, Michigan, and Ohio — reporting both. Also reported in Table 18 is the use of foundry sand, another byproduct material generated by metal-casting processes at foundries. Not surprisingly, the reported use of slags in asphalt pavement mixtures is most common in regions with steel and iron production industries and thus a relatively available supply of slag aggregates (NSA, 2017b), as seen in Figure 21.

While the total tons of asphalt mixture and materials for each slag type vary from year to year, there was a downward trend in the reported combined use of both slags for 2014 through 2016, as illustrated in Figure 22, but 2017 shows a rebound in slag utilization. This rebound in slag utilization is likely the result of the number of companies reporting slag use and which companies did or did not participate in the 2016 and 2017 surveys. Missouri has consistently reported the use of a modest amount of foundry sand each year of the survey.

The National Slag Association estimates that more than 20 million tons of slag is produced and marketed annually (NSA, 2017a). About 11.8 percent of this (2.63 million tons) is used in asphalt pavement mixtures (van Oss, 2017). With 1,430,251 tons of slag reported as being used in asphalt mixtures during the 2017 construction season, this survey captures about 60.6 percent of total slag estimated to be used in asphalt pavement mixtures. For the states reporting slag use, 5 percent of their total reported asphalt pavement mixture tonnage includes steel and/or blast furnace slag. According to the Industrial Resources Council, more than 9 million tons of foundry sand are produced annually (IRC, n.d.), which means only a very small portion of its potential use in asphalt pavement mixtures is captured by this survey.

Table 18: Reported Tons for Steel Slag, Blast Furnace Slag, & Foundry Sand and Tons of Asphalt Mixture Using Each Material, 2013–2017

State & Material	Reported Tons of Mixture Using Material					Reported Tons of Material Used				
	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Steel Slag										
Alabama	750,000	837,083	400,000	475,000	755,764	165,000	112,480	95,000	55,000	164,229
Arkansas	25,000	84,900	229,800	60,210	49,005	2,500	12,735	60,000	9,109	10,238
Illinois	43,700	56,407	70,000	5,271	10,000	16,300	21,991	19,000	2,600	8,100
Indiana	161,115	111,800	245,000	140,000	132,500	61,985	41,500	90,000	64,000	45,929
Iowa	97,500	57,689	27,623	—	25,000	10,200	9,432	4,111	—	4,500
Kentucky	508,000	125,000	—	—	45,853	173,265	15,000	—	—	4,603
Michigan	750,000	754,131	1,549,291	—	367,652	95,000	136,382	225,819	—	259,252
Minnesota	200,000	238,000	268,000	134,000	140,000	30,000	34,000	37,500	17,800	28,500
Mississippi	—	—	22,803	35,000	—	—	—	3,000	500	—
Ohio	185,319	185,125	220,000	85,000	145,868	79,085	60,133	40,000	18,000	30,556
Tennessee	—	—	40,000	—	—	—	—	8,000	—	—
Washington	586,000	416,000	305,000	—	413,000	82,954	60,000	56,700	—	53,300
Total	3,306,634	2,866,135	3,382,517	934,481	2,064,642	716,289	503,653	639,130	167,009	609,207
No. of Companies	24	15	19	12	18					
Blast Furnace Slag										
Alabama	110,000	100,000	15,000	210,000	177,933	12,500	10,000	10,000	30,000	39,379
Illinois	—	40,000	20,000	—	—	—	10,000	15,000	—	—
Indiana	116,500	375,000	—	1,007,000	1,001,700	57,000	150,000	—	179,900	336,413
Iowa	5,000	15,000	—	—	—	500	1,500	—	—	—
Kentucky	16,000	828,243	100,000	500,000	600,000	7,500	191,067	25,000	80,000	100,000
Michigan	700,000	329,000	500,000	—	393,239	107,000	43,750	2,000	—	156,741
Mississippi	—	—	—	—	11,534	—	—	—	—	1,150
Ohio	416,250	794,6000	884,000	696,219	660,395	110,613	145,105	208,268	176,333	164,861
Virginia	—	—	—	—	—	—	—	—	—	—
West Virginia	504,704	1,065,382	748,922	695,572	150,000	155,032	190,000	183,357	100,987	22,500
Wisconsin	—	—	5,500	—	—	—	—	795	—	—
Total	1,868,454	3,547,225	2,273,422	3,108,791	2,994,801	450,145	741,422	444,420	567,220	821,044
No. of Companies	17	21	12	13	13					
Foundry Sand										
Missouri	15,130	22,310	10,000	15,960	10,000	1,514	2,231	500	1,596	1,000

— = No Use Reported

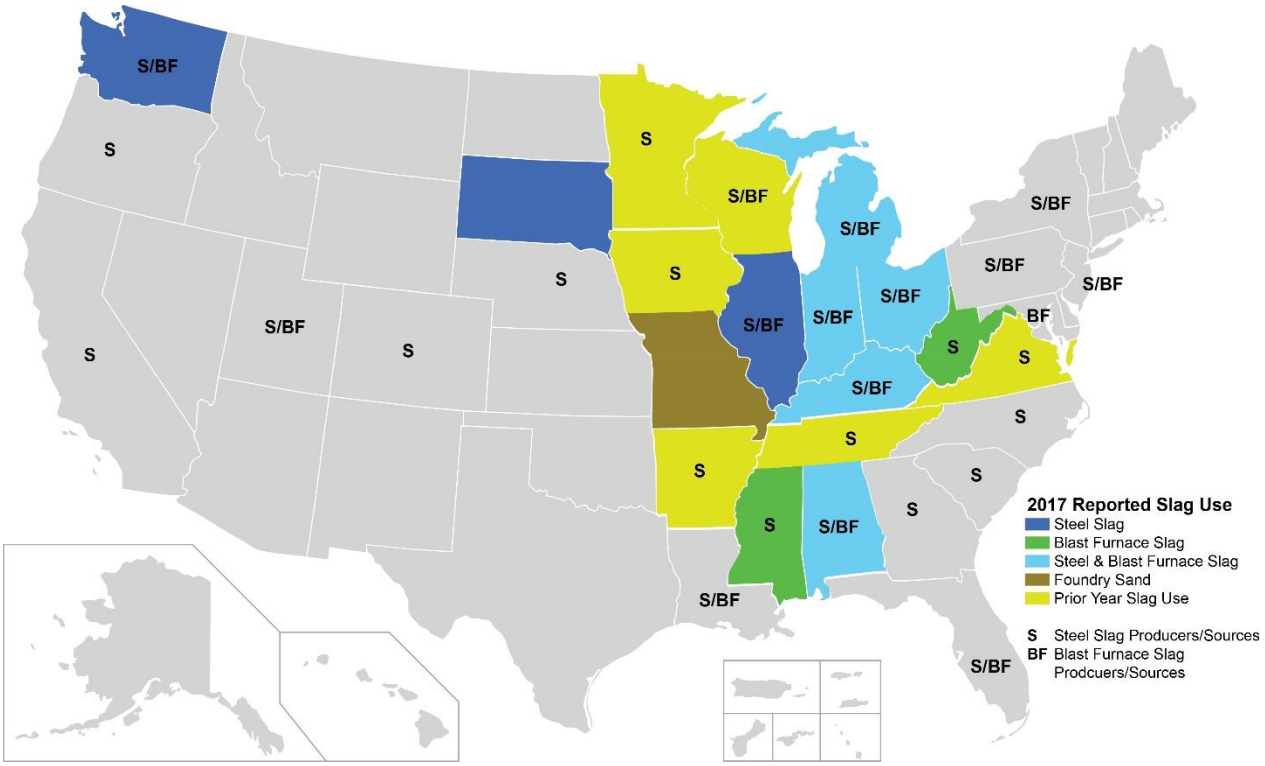


Figure 21: States Reporting Steel and/or Blast Furnace Slag Use and Slag Producers/Sources

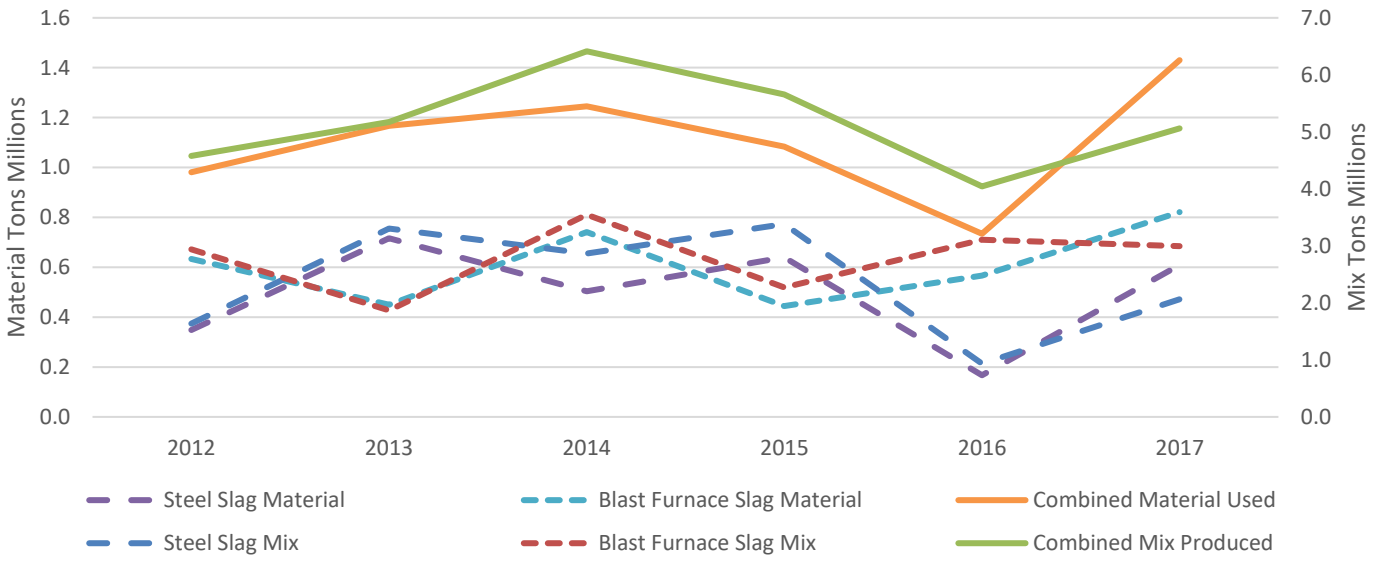


Figure 22: Steel and Blast Furnace Slag Use, 2013–2017

Coal Combustion Products

Several waste and by-products associated with the burning of coal to produce electricity, including fly ash, bottom ash, boiler slag and flue-gas desulfurization (FGD) materials, are used in asphalt pavement mixtures as a cost-effective mineral filler that can help increase mixture stiffness and reduce asphalt drain down. In the 2017 construction season survey, fly ash was the only of these coal combustion products (CCP) reported as being used, as shown in Table 19. In previous survey years, limited use of bottom ash was reported in 2012 and 2015.

To give a picture of the total use of CCP in asphalt pavement mixtures, the American Coal Ash Association found that some 40,969 tons of fly ash, no bottom ash, 10,592 tons of boiler slag, and 8,912 tons of flue-gas desulfurization (FGD) material from dry scrubbers were used as mineral filler in asphalt in 2016 (ACAA, 2017). Assuming utilization of CCP in asphalt pavement mixtures remained steady, fly ash usage reported for the 2017 construction season survey makes up 41 percent of fly ash used in asphalt pavements during the 2017 construction season; however, only a very small amount (0.045 percent) of the 37.8 million tons of fly ash produced in 2016 was used in asphalt mixtures, according to ACAA (2017). Unlike with slags, there is no apparent correlation between the location of coal-fired power plants and the use of CCP in asphalt pavement mixtures.

Table 19: Reported Tons of Asphalt Mixtures Using Coal Combustion Products and Reported Tons of CCP Used, 2013–2017

State & Material	Reported Tons of Asphalt Mixtures Using CCP*					Reported Tons of CCP Used*				
	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Fly Ash										
Alabama	—	—	—	—	58,253	—	—	—	—	2,625
Illinois	—	—	—	—	95,750	—	—	—	—	1,500
Michigan	—	—	50,000	—	—	—	—	—	—	—
Mississippi	50,000	15,000	—	19,000	141,767	2,500	600	—	750	4,253
Missouri	—	—	—	—	60,000	—	—	—	—	4,000
Tennessee	—	—	15,940	—	—	—	—	616	—	—
Texas	25,000	20,000	—	30,000	20,000	1,700	1,000	—	—	600
Wisconsin	—	26,000	102,500	160,000	40,000	—	1,500	6,150	9,500	4,000
Bottom Ash										
Texas	—	—	1,000	—	—	—	—	1,000	—	—
Total (All CCP)	75,000	61,000	169,440	209,000	415,770	4,200	3,100	7,766	10,250	16,978
No. of Companies	2	3	4	3	10					

*Not all producers reporting tonnages of mixtures using other recycled materials provided quantities of recycled materials used and vice versa.
NCR = No Companies Responding
— = No Use Reported

Other Recycled Materials

Table 20 summarizes other recycled materials used in asphalt mixtures. For the 2017 construction season, only the use of cellulose fibers was reported. In previous years, producers have also reported the use of poly fibers, recycled glass, and petroleum-contaminated soil in asphalt pavement mixtures. The reported use of cellulose fiber has increased significantly since 2015, due to the specific request for data about cellulose fiber beginning with the 2015 construction season survey. As explained in Appendix A, in previous years, reporting data about cellulose fiber use was at the discretion of the respondent. During the 2017 construction season, producers from 11 states reported using nearly 3,000 tons of recycled cellulose fiber in over a million tons of asphalt pavement mixture.

Table 20: Other Recycled Materials

State & Material	Reported Tons of Mixture Produced Using Other Recycled Material*					Reported Tons of Other Recycled Material Used*				
	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Cellulose Fiber										
Alabama	—	—	100,000	—	193,268	—	—	500	—	720
Alaska	—	—	1,000	—	—	—	—	—	—	—
Delaware	—	—	—	20,000	—	—	—	—	60	—
Florida	20,204	73,600	92,000	94,903	165,863	71	311	147	71	663
Georgia	43,000	—	—	—	—	129	—	—	—	—
Illinois	—	—	126,150	—	—	—	—	240	—	—
Indiana	6,000	—	22,000	—	—	60	—	1	—	—
Louisiana	31,651	1,500	22,260	—	—	63	30	45	—	—
Maryland	145,000	120,000	85,000	100,000	125,000	440	360	230	300	373
Massachusetts	—	—	—	2,000	—	—	—	—	3	—
Michigan	—	—	—	—	145,200	—	—	—	—	84
Minnesota	5,000	—	—	—	—	15	—	—	—	—
Mississippi	—	—	—	53,998	40,173	—	—	—	153	121
Missouri	—	—	56,000	—	60,000	—	—	100	—	180
New Jersey	—	—	5,000	—	—	—	—	—	—	—
New York	—	700	1,605	1,640	—	—	1	—	9	—
North Dakota	—	—	—	65,000	—	—	—	—	195	—
Ohio	—	—	10,220	3,000	6	—	—	90	—	0
Oregon	—	—	20,000	—		—	—	8	—	
Pennsylvania	—	—	12,952	45,000	21,000	—	—	—	90	88
South Carolina	—	—	20,000	—		—	—	—	—	
Tennessee	—	—	175,940	127,845	113,000	—	—	80	201	300
Texas	30,600	36,000	50,300	—	20,000	90	44	15	—	60
Utah	—	—	—	122,317	120,696	—	—	—	570	336
Virginia	—	74,000	61,000	30,000	—	—	120	183	90	—
Total	281,455	305,800	861,427	665,703	1,004,206	868	866	1,643	1,744	2,925
No. of Companies	10	10	18	25	20					
Poly Fibers										
Maine	—	—	—	—	—	—	—	—	2	—
New Hampshire	—	—	—	—	—	—	—	—	5	—
Vermont	—	—	—	—	—	—	—	—	3	—
Total	—	—	—	—	—	—	—	—	10	—
Petroleum-Contaminated Soil										
Massachusetts	—	—	35,000	—	—	—	—	1,050	—	—
Recycled Glass										
Florida	—	—	1,000	—	—	—	—	200	—	—

*Not all producers reporting tonnages of mixtures using other recycled materials provided quantities of recycled materials used and vice versa.
NCR = No Companies Responding; — = No Use Reported

Summary and Conclusions

The objective of this survey was to quantify the use of recycled materials and WMA produced by the asphalt pavement mixture production industry during the 2017 construction season. Asphalt mixture producers from all 50 states, the District of Columbia, and American Samoa completed the 2017 survey. Responses came from 238 companies with data from 1,158 production plants. Data collected was compared to annual data from previous surveys since the 2009 construction season.

The survey findings for 2017 regarding the use of RAP, RAS, and WMA are summarized in Table 4.

Comparing the 2017 results to 2016 construction season, estimated total asphalt mixture production saw a slight increase from 374.9 million tons to 379.4 million tons, a 1.2 percent increase. DOT tonnage was up 9 percent, but this was offset by a 9.2 percent decrease in tonnage for the Other Agency sector, while tonnage for the Commercial & Residential sector was flat for 2016 to 2017.

The use of recycled material has risen dramatically since the 2009 construction season survey; although, year-over-year growth has slowed in recent years. The 2017 construction season survey shows:

Reclaimed Asphalt Pavement

- The total estimated tons of RAP used in asphalt mixtures reached 76.2 million tons in 2017. This represents a greater than 36 percent increase in the total estimated tons of RAP used in 2009. During the same time frame, total asphalt mixture tonnage increased only 5.9 percent.
- The percentage of producers reporting use of RAP remained constant at 98 percent of respondents for 2016 and 2017.
- The average percent RAP used by all sectors has seen variable growth from 2009 to 2017. The average estimated percentage of RAP used in asphalt mixtures has increased from 15.6 percent in 2009 to 20.1 percent in 2017.
- Companies reporting having stockpiled RAP on hand at year-end increased slightly from 89.5 percent in 2016 to 93.3 percent in 2017. In total, producers accepted and used about the same amount of RAP (an estimated 79.9 million tons) in 2017.
- Reclaiming 79.9 million tons of RAP for future use saved about 48.6 million cubic yards of landfill space.
- The total estimated amount of RAP stockpiled nationwide at the end of the 2017 construction season was 102.1 million tons.
- Producers from 36 states reported fractionating RAP. Nationally, a reported 23 percent of RAP is fractionated.
- Producers from 31 states reported using softer binders and 15 states reported using recycling agents in RAP mixtures. There was little correlation between the percentage of RAP used in asphalt pavement mixtures and the use of softer binders and/or recycling agents in a given state.
- When asked about limiting factors in the use of RAP, the top-three responses were specification limits (38.5 percent), RAP availability (18.5 percent), and asphalt plant capabilities (15.4 percent).

Reclaimed Asphalt Shingles

- Use of both recycled MWAS and PCAS in asphalt mixtures decreased significantly (32.1 percent) from an estimated 1.39 million tons in 2016 to 944,000 tons in 2017. Declines were seen in the use of RAS in mixtures for all three sectors, continuing a trend evident since 2015.

- The amount of unprocessed RAS accepted by asphalt mixture producers decreased from 1.03 million tons in 2016 to 935,000 tons in 2017. An estimated 311,000 tons of processed RAS was also accepted by producers, which was about 535,000 tons less processed RAS than was accepted in 2016. The combined amount of unprocessed and processed RAS accepted in 2017 was 1.25 million tons, which was 266,000 tons more RAS than was used for all purposes during the 2017 construction season.
- Of the unprocessed RAS accepted by producers in 2017, 591,000 tons was PCAS and 344,000 tons was MWAS.
- Of the RAS used in 2017, more than 96 percent was used in asphalt mixtures. The remainder was combined with aggregates. No producers reported landfilling of RAS during the 2017 construction season.
- The percent of producers reporting use of RAS decreased from 33.6 percent of respondents in 2016 to 26.9 percent in 2017.
- The total estimated amount of RAS stockpiled nationwide at the end of the 2017 construction season was nearly 1.39 million tons.
- The number of states with producers and SAPAs reporting RAS use decreased to 29 states in 2017. Alabama producers for the first time in this survey reported not using RAS.
- When asked about limiting factors in the use of RAS, the top-three responses were specification limits (47.3 percent), RAS availability (12.7 percent), and mixture performance (12.7 percent).
- Most states allow the use of RAS in Commercial & Residential sector mixtures, with more limited use in DOT and Other Agency public sector mixtures, according to producer and SAPA reports. No states reportedly allow the use of RAS in all mixes for all sectors, and five states reportedly do not approve the use of RAS in asphalt pavement mixtures for any sector.
- Producers from 16 states reported using softer binders and seven states reported using recycling agents in RAS mixtures.

Material Cost Savings

- The use of RAP and RAS saved more than $2.2 billion during the 2017 construction season compared to the use of all virgin materials. This is about $400 million more savings realized than in 2016. These savings help reduce material costs for asphalt pavement mixtures, allowing road owners to achieve more roadway maintenance and construction activities within limited budgets.

Other Recycled Materials

- A reported total of nearly 1.5 million tons of other recycled materials was used in nearly 7.5 million tons of asphalt mixtures by 58 companies in 26 states during the 2017 construction season.
- Nineteen producers from 12 states reported use of ground tire rubber (GTR) in asphalt mixtures during the 2017 construction season, which was fewer producers than in 2016. The total reported tons of asphalt mixture using GTR dropped 35 percent from 2016 to 979,000 tons in the 2017 construction season.
- Producers in 12 states reported use of steel or blast furnace slags, and one state reported the use of foundry sand in 2017. Compared to reported use in 2016, the reported tons of mixtures including steel slag increased dramatically during the 2016 construction season, but there was a slight decrease in the tons of asphalt pavement mixture incorporating blast furnace slag. Reported use of these materials was greatest along the Mississippi and Ohio River Valleys, where much of U.S. steel and iron production is concentrated.

- Producers in six states reported using fly ash in asphalt mixtures in 2017. Fly ash was the only coal combustion product (CCP) reported as being used in asphalt pavement mixtures during the 2017 construction season.
- Producers in 11 states reported use of nearly 3,000 tons of recycled cellulose fiber in more than 1 million tons of asphalt pavement mixtures during 2017.

Warm Mix Asphalt

The use of WMA continues to increase since 2009. The 2017 construction season survey shows:

- The estimated total tonnage of asphalt pavement mixtures produced at reduced temperatures with WMA technologies for the 2017 construction season was about 147.4 million tons. This was a 26 percent increase from the estimated 116.8 million tons of WMA in 2016 and more than 777 percent increase from the estimated 16.8 million tons in the 2009 construction season.
- WMA was 38.9 percent of the total estimated asphalt mixture market in 2017.
- Of the Tennessee producers using WMA technologies, 100 percent of the tons of asphalt pavement they produced in 2017 were produced at reduced temperatures as WMA.
- In addition, producers using WMA technologies in seven additional states — Indiana, Kentucky, Louisiana, Mississippi, Oklahoma, Pennsylvania, and Utah — reported producing more than 75 percent of their total tonnage at reduced temperatures as WMA.
- Production plant foaming, representing nearly 65 percent of the market in 2017, remains the most commonly used warm-mix technology, despite decreasing about 15.6 percent since the 2016 construction season.
- Chemical additive technologies accounted for a little more than 32 percent of the market in 2017, an increase of 52.4 percent from their use in the 2016 construction season.
- A gradual increase in the use of chemical additive WMA technologies and a decrease in plant-based foaming technologies been seen in the survey since 2011.
- About 66 percent of respondents who produce WMA, 107 producers in 44 states, reported also using WMA technologies at HMA temperatures. An estimated 26–32 percent of these companies' HMA tons were produced with production plant foaming, and 16–20 percent were produced with chemical additive technologies.

Conclusions

The 2017 survey results show that the asphalt pavement mixture production industry has a strong record of sustainable practices and continues to innovate through the use of recycled materials and WMA. Since the initial industry survey of the 2009 construction season, producers have significantly increased their use of recycled materials and WMA; however, since the 2013 survey, indicators are that the rate of increase of adoption is slowing and/or plateauing.

The amount of RAP received was nearly equivalent to what producers utilized during the 2017 construction season, but 93.3 percent of producers indicated they have stockpiled RAP on hand. With an estimated 102.1 million tons of RAP stockpiled nationwide at year-end 2017, a 9.1 percent increase over year-end 2016, opportunities remain to increase the amount of RAP used in asphalt mixtures through engineering, performance-based specifications, education, improved RAP processing, production equipment, and procedures.

RAS use saw a 32.1 percent decrease in 2017 in asphalt pavement mixtures; however, by accepting 1.246 million tons of waste shingles during 2017, producers diverted about 9 percent of the nation's available waste shingles for use in asphalt mixtures. An estimated 1.4 million tons of RAS was stockpiled nationwide at year-end 2017. As with RAP,

performance-based specifications, education, improved processing, production equipment, and procedures will help increase the amount and percentages of RAS used in asphalt mixtures.

The asphalt pavement mixture production industry repurposes many products from other industries. The survey shows that, for the 2017 construction season, slags and other metal foundry byproducts were reported in 13 states, GTR use was reported in 12 states, recycled cellulose use was reported in 11 states, and fly ash use in six states.

The tonnage of asphalt pavement mixtures produced at reduced temperatures with WMA technologies saw a 26 percent increase during the 2017 construction season with a total production of 147.4 million tons, which represents 38.9 percent of total estimated asphalt mixture production for the year. Producers in Alaska, American Samoa, Hawaii, Montana, Nebraska, Rhode Island, South Dakota, and West Virginia reported not producing WMA in 2017.

The Importance of Engineering Recycled Asphalt Mixtures for Quality

For more than three decades, two guiding principles of asphalt recycling have been: 1) asphalt mixtures containing RAP should meet the same requirements as asphalt mixtures with all virgin materials, and 2) asphalt mixtures containing RAP should perform equal to or better than asphalt mixtures with all virgin materials. This is at the heart of the "Three E's of Recycling," which state that recycled materials should provide Environmental, Economic, and Engineering benefits.

Quality recycled mixtures have been successfully designed and produced for many years. When successfully engineered, designed, produced, and constructed, the proof is in performance. A recent study comparing the performance of recycled versus virgin mixtures based on Long-Term Pavement Performance (LTPP) data from 16 U.S. states and two Canadian provinces shows that overlays containing at least 30 percent RAP performed equal to overlays using virgin mixtures (Carvalho et al., 2010; West et al., 2011). At the NCAT Test Track, test sections containing 50 percent RAP using Superpave mixture design procedures for each layer outperformed companion test sections with all virgin materials in all pavement performance measures.

However, as the amount of recycled materials in asphalt pavement mixtures increase, additional considerations for material handling, engineering, mixture design, quality, and performance testing become more important. In particular, RAP and RAS should be tested and classified to determine the amount, properties, and quality of available asphalt binder. The absorbability of RAP aggregate should also be tested and determined. These values have an impact on pavement performance and are important to assess when developing a high recycled content mixture design. In some cases, it may be necessary to make use of recycling agents or a softer asphalt binder to ensure the final mixture design delivers the desired level of product performance.

For more information about processing and using reclaimed asphalt pavement and recycled asphalt shingles, consult the NAPA publication *Best Practices for RAP and RAS Management* (Quality Improvement Series No. 129).

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