NATIONAL ASPHALT PAVEMENT ASSOCIATION

Asphalt Pavement Industry Survey on

Recycled Materials and Warm-Mix Asphalt Usage 2018

Information Series 138

9th Annual Survey

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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 21.1 percent in 2018. In 2018, the estimated RAP tonnage used in asphalt mixtures was 82.2 million tons. This represents more than 4.1 million tons (23 million barrels) of asphalt binder conserved, along with the replacement of more than 78 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 1,053,000 tons in 2018 with the use of RAS increasing (11.6 percent) from 2017 to 2018.

The combined savings of asphalt binder and aggregate from using RAP and RAS in asphalt mixtures is estimated at more than $2.9 billion and some 62 million cubic yards of landfill space.

More than 1.8 million tons of other recycled materials were reported as being incorporated into nearly 12.3 million tons of asphalt pavement mixtures during the 2018 construction season, including recycled tire rubber, blast furnace slag, steel slag, and cellulose fibers.

The estimated total production of asphalt with WMA technologies during the 2018 construction season was 157.7 million tons more than half of which was produced at reduced temperatures. This was a 7 percent increase from the estimated 147.4 million tons of WMA in 2017, due to increased utilization reported for Other Agency sector tonnage for the year. Utilization of WMA technologies in 2018 was 839 percent more than the estimated 16.8 million tons in the 2009 construction season.

Asphalt produced with WMA technology made up 40.5 percent of the total estimated asphalt mixture market in 2018. Production plant foaming, representing nearly 63 percent of the market, is the most commonly used warm-mix technology; chemical additive technologies accounted for a little more than 34 percent of the market. Relatively minor differences were seen in which WMA technologies were used when production temperatures were or were not reduced.

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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
OGFC	Open-Graded Friction Course
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
RTR	Recycled Tire Rubber
SAPA	State Asphalt Pavement Association
SEAUPG	Southeastern Asphalt User/Producer Group
UPG	User/Producer Group
WMA	Warm-Mix Asphalt

On the Cover

To meet the needs of North Carolina Department of Transportation District 4, S.T. Wooten Corp. resurfaced and strengthened 13.5 miles of north- and south-bound I-795 in Wayne County, North Carolina, adding up to 4 inches of an intermediate course, topped with 2 inches of a surface mix and a ¾-inch open-graded friction course (OGFC). The asphalt pavement mixtures used on the project incorporated 30 percent RAP in the intermediate layer, 20 percent RAP in the surface layer, and 5 percent RAS in the OGCF.

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2018

Executive Summary

The results of the asphalt pavement industry survey for the 2018 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 use of WMA technologies by the asphalt pavement industry. For the 2018 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.

Asphalt mixture producers from 49 states, two U.S. territories, and the District of Columbia completed the 2018 construction season survey. A total of 272 companies with 1,328 production plants were represented in the survey.

A degree of fluctuation in year-to-year comparisons of data is influenced by which companies responded to the 2018 construction season survey versus prior year survey respondents. Respondents to the 2018 construction season survey increased by 35 companies compared to 2017. Of the companies responding to the 2018 survey, 82 did not respond to the 2017 construction season survey; also, 48 companies that did respond to the 2017 survey did not participate in the 2018 survey.

The following are highlights of the survey of usage during the 2018 construction season:

Reclaimed Asphalt Pavement

- Asphalt mixture producers remain the country's most diligent recyclers, with more than 97 percent of asphalt mixture reclaimed from old asphalt pavements being put back to use in new pavements and the remaining 3 percent being used in other civil engineering applications, such as unbound aggregate bases.
- The total estimated tons of RAP used in asphalt mixtures was 82.2 million tons in 2018. This is a nearly 7.9 percent increase from the 2017 construction season, and represents a nearly 46.8 percent increase from the total estimated tons of RAP used in 2009. Since 2009, total asphalt mixture tonnage has increased only 8.6 percent.
- The percentage of producers reporting use of RAP was at 97.4 percent of respondents, down 0.6 percent from 2017. Three producers reported landfilling a minor amount (12,120 tons, or 0.012 percent) of RAP during 2018.
- RAP usage during the 2018 construction season is estimated to have reduced the need for 4.1 million tons (23 million barrels) of asphalt binder and more than 78 million tons of aggregate with a total estimated value of more than $2.8 billion.
- The total estimated amount of RAP stockpiled nationwide at the end of the 2018 construction season was about 110.3 million tons.

- Fractionated RAP represents about 24 percent of RAP use nationwide, and the tons of RAP mixtures produced using softer binders are estimated at 20 percent while tons produced using recycling agents is estimated at 4 percent.
- Reclaiming 101.1 million tons of RAP for future use saved about 61.4 million cubic yards of landfill space, and more than $4.5 billion in gate fees for disposal in landfills.

Reclaimed Asphalt Shingles

- The total estimated tons of RAS used in asphalt mixtures rebounded 11.6 percent to an estimated 1.05 million tons in 2018. This reversed much of the drop in the use of RAS reported during the 2017 construction season, but is still about 45 percent below the 2014 peak level of reported usage.
- The total estimated amount of RAS stockpiled nationwide at the end of the 2018 construction season was about 1.4 million tons, a slight decrease from 2017.
- RAS usage during the 2018 construction season is estimated to have reduced the need for 210,600 tons (nearly 1.2 million barrels) of asphalt binder and about 527,000 tons of aggregate with a total estimated value of more than $107 million.
- Reclaiming 890,000 tons of unprocessed RAS for future use saved about 540,000 cubic yards of landfill space, and more than $49 million in gate fees for disposal in landfills.

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 and RAS used and the use of softer binders and/or recycling agents.
- Other recycled materials commonly reported as being used in asphalt mixtures during the 2018 construction season were recycled tire rubber, blast furnace slag, steel slag, and cellulose fibers. Recycled materials less commonly reported as being used in asphalt mixtures included fly ash, foundry sand, carbon fibers, crushed concrete aggregates, and start-up waste.
- Nearly 1.8 million tons of other recycled materials was reported as being used in nearly 12.3 million tons of asphalt mixtures by 79 companies in 31 states during the 2018 construction season.

Warm-Mix Asphalt Technologies

- The estimated total tonnage of asphalt pavement mixtures produced with WMA technologies for the 2018 construction season was 157.7 million tons. This was a 7 percent increase from the estimated 147.4 million tons of WMA in 2017, driven largely by increased WMA tonnage in the Other Agency sector, but changes to the reporting of WMA utilization at reduced temperatures from 2017 to 2018 may have also been a factor.
- Mixtures produced with WMA technologies made up 40.5 percent of the total estimated asphalt mixture market in 2018. About 50.5 percent (79.5 million tons) of these mixtures were produced with a temperature reduction of at least 10°F.
- Production plant foaming, representing nearly 63 percent of the market in 2018, remains the most commonly used warm-mix technology, despite decreasing about 1.5 percent since the 2017 construction season.
- Chemical additive technologies accounted for a little more than 34 percent of the market in 2018, an increase of 6.5 percent from their use in the 2017 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 68 percent of survey respondents produce asphalt with WMA technologies; 185 producers in 44 states, reported using WMA technologies.

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2018

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) technologies. 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 recycled tire rubber (RTR), steel and blast furnace slags, 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 et al., 2010; Copeland, 2011; 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 the growth in use of these sustainable practices by the road construction 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; 2017; Hansen et al., 2017; Williams et al., 2018). 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. Prior-year versions of this report are available at *https://goaspha.lt/IS138results*.

This report documents the results of the industry survey for the 2018 construction season, including the results, trends, and changes from 2009 through 2018. The survey methodology and survey instrument are included in Appendix A, and state-level data are included in Appendix B.

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 May 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 2018 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). However, 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 49 states, two U.S. territories, and the District of Columbia completed the survey for the 2018 construction season. A total of 272 companies with 1,328 production plants are represented in the 2018 survey. This is the largest number of companies and plants to participate in the survey since its inception. The reported total asphalt mixture tons for 2018 was 189.6 million tons, and the average tons produced per plant has continued to rise steadily since 2013.

A degree of fluctuation in year-to-year comparisons of data is influenced by which companies responded to the 2018 construction season survey versus prior-year survey respondents. For the 2018 construction season survey, there was a 12.4 percent increase in the total number of companies responding and a 14.6 percent increase in the number of plants; 29 percent of companies and more than 30 percent of the plants responding in 2018 did not participate in the 2017 survey. However, nearly 80 percent of the 2017 construction season respondents also completed the 2018 construction season survey. About 14 percent of responding companies, representing about 8 percent of the total reported tonnage, were not NAPA members.

Table 1 summarizes the number of asphalt mixture 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 1: Number of Companies Completing 2018 Construction Season Survey in Each State/Territory

State	Cos.	Prod. Plants	State	Cos.	Prod. Plants	State	Cos.	Prod. Plants
Alabama	9	49	Kentucky	10	51	Ohio	9	88
Alaska	*	*	Louisiana	4	4	Oklahoma	6	17
American Samoa	*	*	Maine	*	*	Oregon	4	14
Arizona	5	27	Maryland	11	25	Pennsylvania	8	46
Arkansas	7	29	Massachusetts	7	34	Puerto Rico	NCR	NCR
California	6	52	Michigan	5	40	Rhode Island	*	*
Colorado	3	15	Minnesota	5	28	South Carolina	6	24
Connecticut	3	15	Mississippi	9	29	South Dakota	NCR	NCR
Delaware	*	*	Missouri	9	32	Tennessee	5	40
District of Columbia	*	*	Montana	*	*	Texas	6	51
Florida	13	48	Nebraska	3	7	U.S. Virgin Islands	*	*
Georgia	6	46	Nevada	*	*	Utah	9	20
Guam	NCR	NCR	New Hampshire	4	16	Vermont	*	*
Hawaii	3	8	New Jersey	3	19	Virginia	7	36
Idaho	5	18	New Mexico	3	5	Washington	9	35
Illinois	12	25	New York	12	58	West Virginia	3	15
Indiana	7	54	North Carolina	7	62	Wisconsin	6	64
Iowa	4	16	North Dakota	*	*	Wyoming	*	*
Kansas	4	19	No. Mariana Islands	NCR	NCR	**Total†**	272	1,328

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

Table 2 summarizes the total number of companies and production plants responding in previous years, as well as the average tons of asphalt pavement mixture produced by each plant.

Table 2: Summary of Jurisdictions (States or Territories), Companies, and Production Plants Responding, 2009–2018

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	237	1,146	141,000
2018	52	272	1,328	143,000

Table 3 includes state-by-state 2018 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 49 percent of the estimated total tons for the 2018 construction season.

Table 3: Summary of 2018 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	6.7	5.0	75%	Montana	4.2	*	*
Alaska	2	*	*	Nebraska	3	0.6	20%
American Samoa	0.03	*	*	Nevada	3.6	*	*
Arizona	7.6	3.7	49%	New Hampshire	1.7	1.7	100%
Arkansas	5.4	3.1	57%	New Jersey	10.2	4.0	39%
California	27.7	10.8	39%	New Mexico	3.8	0.7	18%
Colorado	7.8	2.0	26%	New York	17	5.8	34%
Connecticut	4.9	2.2	45%	North Carolina	20	7.2	36%
Delaware	1.6	*	*	North Dakota	2.8	*	*
District of Columbia	1.5	*	*	No. Mariana Isl.	0.03	NCR	NCR
Florida	16	10.2	64%	Ohio	16.9	12.3	73%
Georgia	14.2	5.7	40%	Oklahoma	4.7	2.2	47%
Guam	0.12	NCR	NCR	Oregon	5.2	2.2	42%
Hawaii	1.1	0.7	64%	Pennsylvania	20	6.3	32%
Idaho	2.9	1.5	52%	Puerto Rico	1.7	NCR	NCR
Illinois	12.5	3.2	26%	Rhode Island	2.1	*	*
Indiana	12.5	8.3	66%	South Carolina	7.5	4.1	55%
Iowa	3.8	1.8	47%	South Dakota	2.2	NCR	NCR
Kansas	2.5	2.4	96%	Tennessee	8.9	5.7	64%
Kentucky	5.8	4.7	81%	Texas	17.2	7.2	42%
Louisiana	7.4	0.9	12%	U.S. Virgin Isl.	0.12	*	*
Maine	1.7	*	*	Utah	4	3.7	93%
Maryland	6.8	4.4	65%	Vermont	1.9	*	*
Massachusetts	6.5	5.0	77%	Virginia	11	5.1	46%
Michigan	14.3	8.8	62%	Washington	5.9	5.5	93%
Minnesota	10	6.5	65%	West Virginia	3.5	2.5	71%
Mississippi	5.5	3.9	71%	Wisconsin	12.5	9.2	74%
Missouri	6.5	3.8	58%	Wyoming	2.5	*	*
				Total	389.3	189.6†	49%

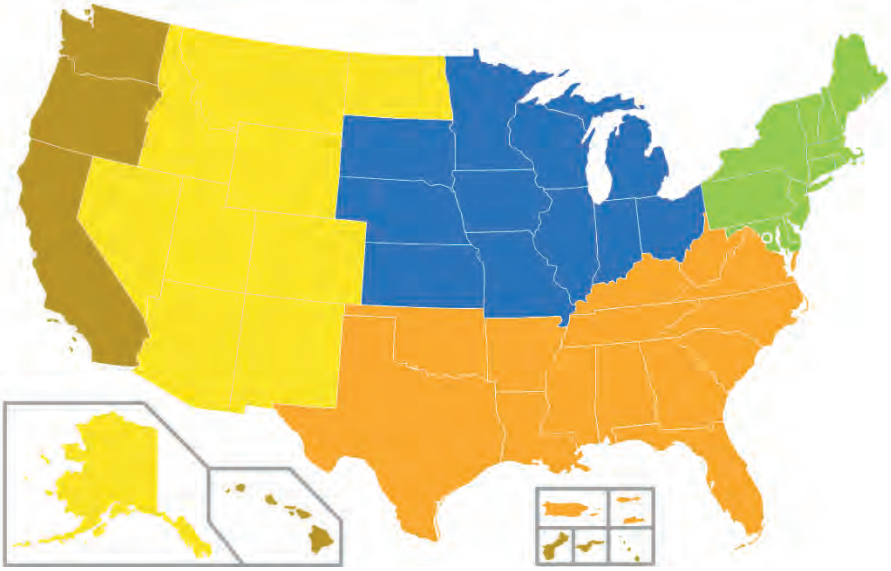
NCR No Companies Responding
* Fewer than 3 Companies Reporting
† Total Reported Tons includes values from state with fewer than 3 Companies Reporting
SAPA Estimated Tons
Numbers do not add up exactly due to rounding

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 increased from 2017 to 2018 with the largest increase in the Southeastern Asphalt User/Producer Group (SEAUPG) and the North Central Asphalt User/Producer Group (NCAUPG) regions and the smallest in the North East Asphalt User/Producer Group (NEAUPG) region. The combined Rocky Mountains Asphalt User/Producer Group (RMAUPG) and Pacific Coast Conference on Asphalt Specification (PCCAS) regions saw a notable increase in tonnage produced per plant, while the remaining regions were flat or saw a modest increase during the 2018 construction season.

NEAUPG		
Year	Plants	Tons/Plant
2009	232	123,000
2010	232	122,000
2011	195	115,000
2012	252	119,000
2013	258	111,000
2014	193	122,000
2015	207	137,000
2016	218	136,000
2017	239	142,000
2018	247	144,000

NCAUPG		
Year	Plants	Tons/Plant
2009	239	106,000
2010	239	106,000
2011	311	114,000
2012	298	116,000
2013	377	123,000
2014	374	136,000
2015	324	152,000
2016	313	136,000
2017	337	153,000
2018	373	153,000

SEAUPG		
Year	Plants	Tons/Plant
2009	348	106,000
2010	348	106,000
2011	406	114,000
2012	430	116,000
2013	434	113,000
2014	416	125,000
2015	402	129,000
2016	401	140,000
2017	386	134,000
2018	502	135,000



RMAUPG/PCCAS		
Year	Plants	Tons/Plant
2009	208	118,000
2010	208	112,000
2011	179	124,000
2012	161	113,000
2013	212	110,000
2014	202	122,000
2015	186	123,000
2016	214	128,000
2017	184	134,000
2018	206	157,000

Figure 1: Number of Production Plants Responding to Survey by User/Producer Group Region and Estimated Tonnage Per Plant, 2009–2018

Data Summary and National Estimates

Table 4: Summary of RAP, RAS, WMA Data

NATIONAL SUMMARY	Reported Values		Estimated Values	
	2017	2018	2017	2018
Tons of HMA/WMA Produced	Tons, Millions		Tons, Millions	
Total	163.0	189.6	379.4	389.3
DOT	71.0	78.1	165.2	160.4
Other Agency	39.9	50.9	92.7	104.6
Commercial & Residential	52.2	60.6	121.4	124.3
No. of Companies Reporting	237	272		
RAP	Tons, Millions		Tons, Millions	
Accepted	35.7	46.8	79.9	101.1
Used in HMA/WMA Mixtures	33.8	41.1	76.2	82.2
Used as Aggregate	1.4	2.9	3.4	6.4
Used in Cold-Mix Asphalt	0.1	0.1	0.3	0.3
Used in Other	0.1	0.9	0.2	2.0
Landfilled	0.0	0.0	0.0	0.0
Total Tons of RAP Stockpiled at Year-End	45.8	54.9	102.1	110.3
	Avg. % Used in Mixtures		Avg. % Used in Mixtures	
Average % for DOT Mixtures[1]	19.5%	20.2%		
Average % for Other Agency Mixtures[1]	19.1%	20.0%		
Average % for Commercial & Residential Mixtures[1]	21.7%	23.3%		
National Average All Mixtures Based on RAP Tons Used in HMA/WMA[2]			20.1%	21.1%
No. of Companies Reporting Using RAP	234	265		
RAS	Tons, Thousands		Tons, Thousands	
Unprocessed PCAS Shingles Accepted	254	254	591	534
Unprocessed MWAS Shingles Accepted	148	171	344	356
Processed Shingles Accepted	134	205	311	430
Used in HMA/WMA Mixtures	406	503	944	1,053
Used as Aggregate	15	24	36	50
Used in Cold-Mix Asphalt	0	0	0	0
Used in Other	0	0	0	0
Landfilled	0	0	0	0
Total Tons of RAS Stockpiled at Year-End	596	666	1,387	1,368
	Avg. % Used in Mixtures		Avg. % Used in Mixtures	
Average % for DOT Mixtures[1]	0.355%	0.286%		
Average % for Other Agency Mixtures[1]	0.188%	0.249%		
Average % for Commercial & Residential Mixtures[1]	0.221%	0.265%		
National Average All Mixtures Based on RAS Tons Used in HMA/WMA[2]			0.249%	0.271%
No. of Companies Reporting Using RAS	64	67		
WMA Technologies	% of Total Production		Tons, Millions	
Total Tons Produced With WMA Technology at Reduced Temperature[†]			147.4	79.5
Total Tons Produced With WMA Technology at HMA Temperatures[†]				78.2
DOT	42.2%	43.9%	69.6	69.3
Other Agency	31.7%	29.5%	29.4	46.5
Commercial & Residential	39.9%	26.6%	48.4	42.0
No. of Companies Reporting Using WMA Technologies	163	185		

[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.
[†] For the 2018 construction season, respondents were specifically asked to disaggregate use of WMA technology at HMA temperatures.

Table 4 summarizes the RAP, RAS, and WMA data from the 2018 construction season survey alongside data from the 2017 construction season survey (Williams et al., 2018) 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 section of 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 2018?” For the amount of RAS accepted, producers were asked “How many tons of shingles were accepted/delivered to your facilities in the state in 2018?” 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 tons of asphalt paving mixture produced for each sector using WMA technologies with a temperature reduction of 10°F to 100°F. In 2018 a separate question was asked for the first time about the percentage of tons of asphalt paving mixture produced for each sector with WMA technologies but without reducing production temperatures. These percentages were multiplied by the total mixture production for each sector to determine the total estimated tons of asphalt mixture produced using WMA technologies for each sector.

Total Asphalt Mixture Production

Table 4 includes the national summary of asphalt mixture production data from the 2017 and 2018 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.

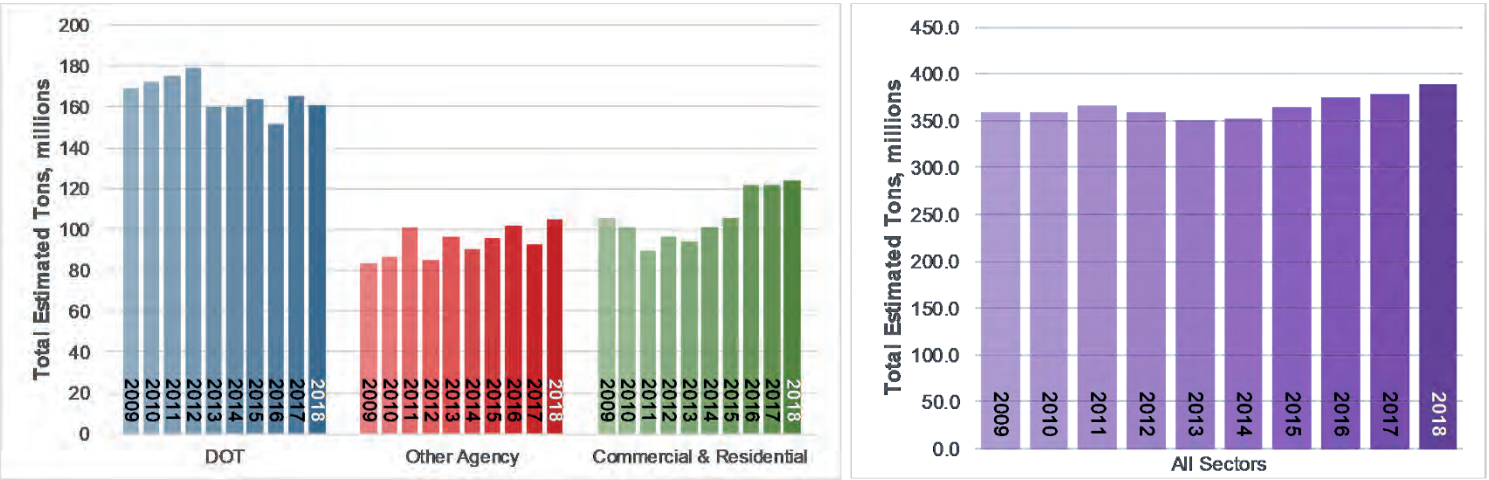


Figure 2: Estimated Total Asphalt Mixture Production by Sector (left) and in Total (right), 2009–2018

From 2017 to 2018, the estimated total amount of asphalt mixture produced in the United States increased from 379.4 million tons to 389.3 million tons, an increase of 2.6 percent.

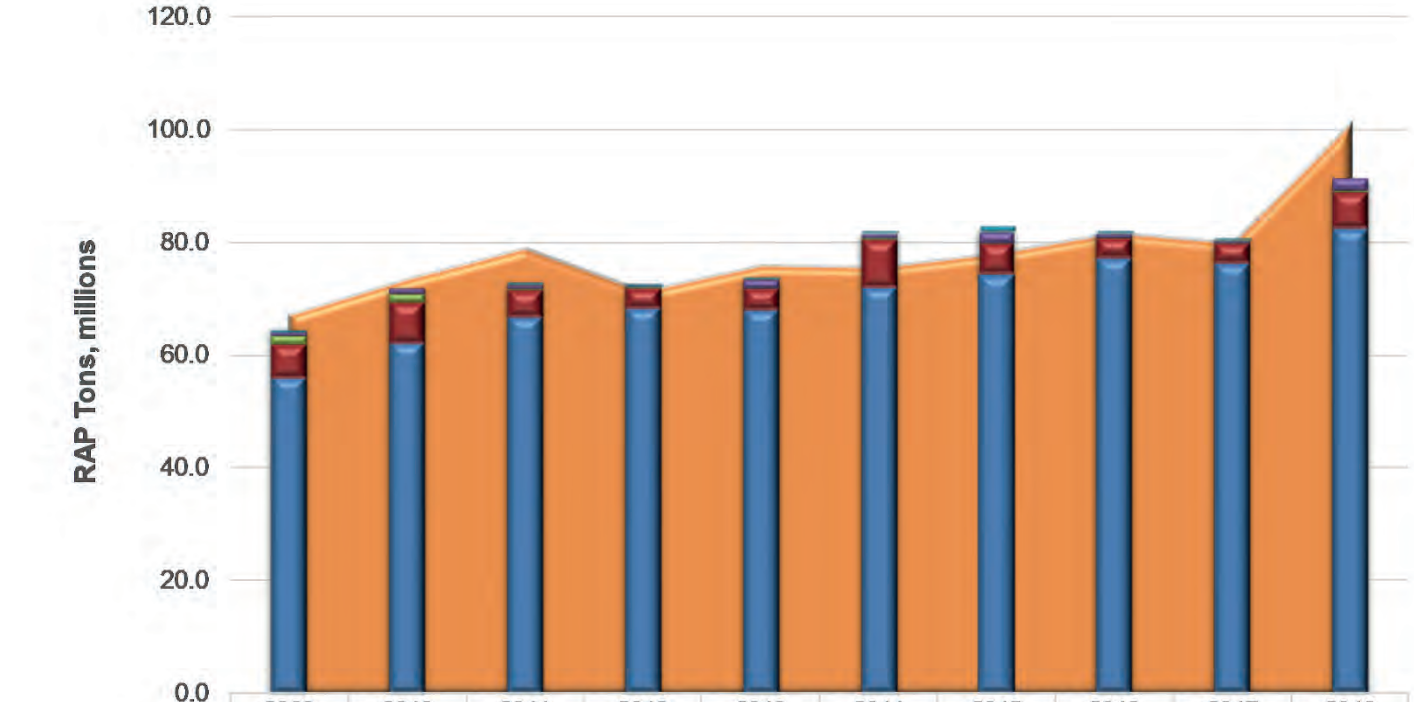
Asphalt pavement mixture producers' customers can be divided into two broad sectors: the private sector (Commercial & Residential) and the public sector (DOT or Other Agency). The "Other Agency" sector includes asphalt pavement mixtures produced for public works agencies; toll authorities; and city, 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 2017 construction season, asphalt mixture tonnage produced for the DOT sector in 2018 saw a decrease of 2.9 percent; however, mixture production for the Commercial & Residential sector increased by 2.4 percent, and the Other Agency sector grew significantly (12.8 percent) from 2017 to 2018.

Reclaimed Asphalt Pavement

Table 4 includes the national summary of RAP data from the 2017 and 2018 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 2018 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 CCPR or in-place recycling technologies.

From the 2017 to 2018 construction season, the amount of RAP used in HMA/WMA increased from 76.2 million to 82.2 million tons. The average percent RAP used in asphalt mixtures increased from 20.1 percent in 2017 to 21.1 percent in 2018. For 2018, more than 97 percent of companies responding to the survey reported using RAP. This was a slight decrease from the 98 percent of companies reporting using RAP in 2016 and 2017, 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.



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

Figure 3: Comparison of Tons of RAP Accepted and Tons of RAP Used or Landfilled (Million Tons), 2009–2018

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 115,000 tons per year. In 2018, just 12,120 tons, about 0.012 percent, of RAP was landfilled. The amount of RAP accepted during the 2018 construction season saved about 55.3 million cubic yards of landfill space.

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.

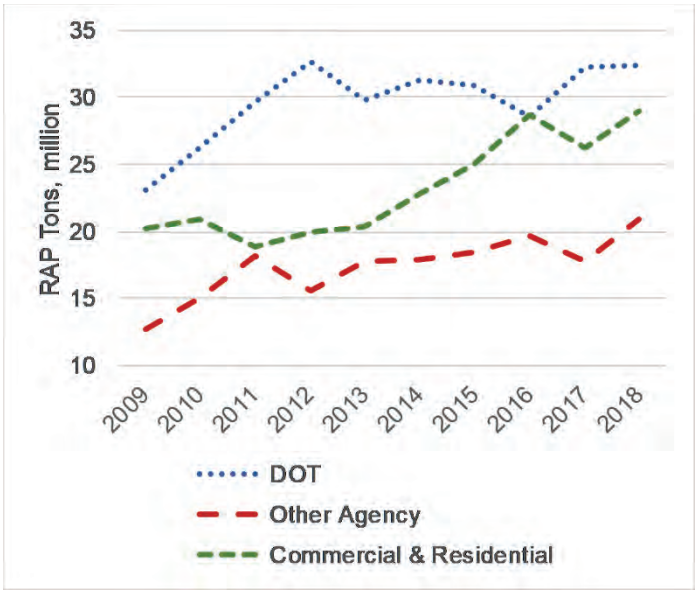


Figure 4: RAP Use by Sector (Million Tons)

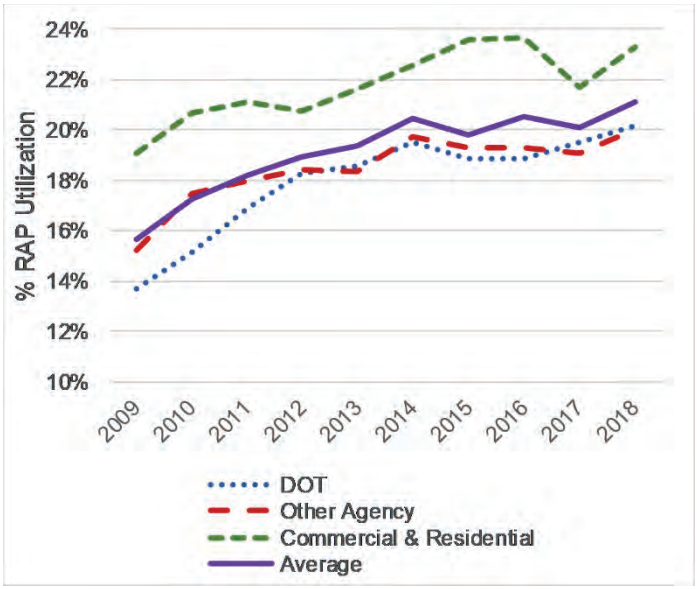


Figure 5: Average Percent RAP Used by Sector

Figure 5 shows the average percentage of RAP used by each sector and overall across all asphalt pavement mixtures. In 2018, the average percent RAP used by all sectors increased to a new high of 21.1 percent. Previously, the average percent RAP had seen steady growth from 2009 to 2014 before plateauing around 20 percent through 2017. Notable increases in the percent of RAP used were seen for each sector in 2018, with both the DOT and Other Agencies sectors seeing average percent RAP utilization of 20 percent or greater for the first time since this survey was initiated.

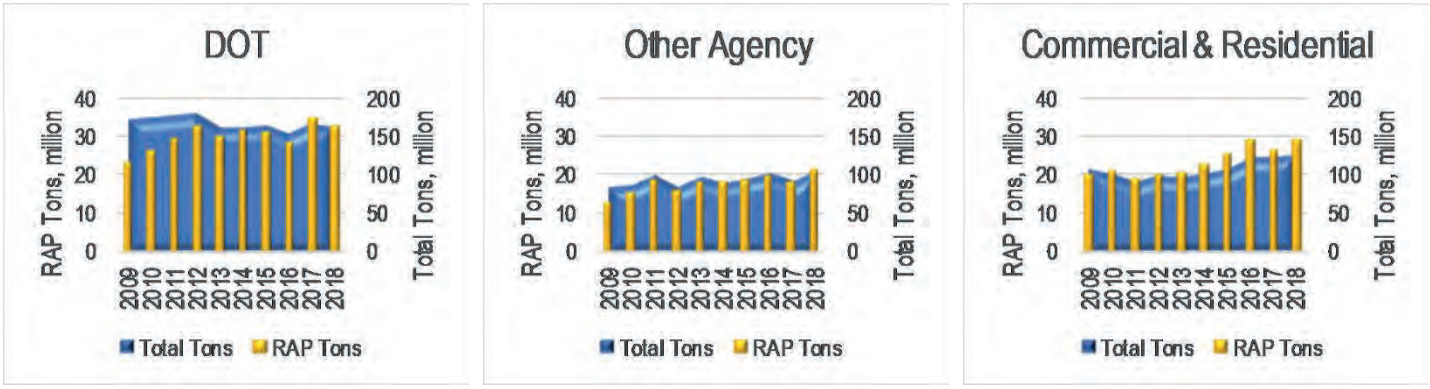


Figure 6: RAP Tons and Total Mixture Tons Comparison (Million Tons)

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 2018 construction season, the tons of RAP used in the DOT sector decreased from 2017 to 2018, but it increased for the Other Agency and Commercial & Residential sectors. The decreased percentage of RAP used in the DOT sector shown in Figure 5, combined with a decrease in the tons of mixture used for this sector shown in Figure 6, was offset by increases in the Other Agency

and Commercial & Residential sectors, resulting in an increase (1.0 percent) in the national average percentage of RAP used.

RAP Use in Each State

Table 5 and Figure 7 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 8 revisualizes the Table 5 data, showing the number of states with producers reporting average RAP percentages used at the various ranges by construction season from 2009 to 2018. 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; 29 states in 2016, decreasing to 24 states in 2017, and now peaking at 30 states in 2018. 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 relatively steady at 10 or 11 states in 2015 through 2017, before dropping to six states in 2018.

Table 5: Average Estimated RAP Percent

State	Average RAP Percent					State	Average RAP Percent				
	2014	2015	2016	2017	2018		2014	2015	2016	2017	2018
Alabama	23%	25%	24%	24%	26%	Montana	*	*	*	*	*
Alaska	*	*	*	*	*	Nebraska	33%	*	*	19%	26%
American Samoa	NCR	NCR	NCR	*	*	Nevada	18%	*	22%	12%	*
Arizona	14%	*	9%	10%	12%	New Hampshire	22%	19%	21%	22%	18%
Arkansas	14%	14%	10%	11%	12%	New Jersey	19%	*	19%	19%	18%
California	13%	16%	15%	18%	16%	New Mexico	*	NCR	22%	21%	19%
Colorado	21%	20%	24%	24%	20%	New York	14%	16%	16%	16%	17%
Connecticut	21%	*	21%	18%	15%	North Carolina	26%	26%	23%	18%	26%
Delaware	*	*	*	*	*	North Dakota	*	*	*	12%	*
Dist. of Columbia	NCR	NCR	NCR	*	*	No. Mariana Isl.	NCR	NCR	NCR	NCR	NCR
Florida	32%	33%	32%	35%	27%	Ohio	28%	28%	27%	28%	28%
Georgia	21%	*	27%	23%	25%	Oklahoma	16%	20%	17%	15%	17%
Guam	NCR	NCR	NCR	NCR	NCR	Oregon	28%	27%	22%	18%	27%
Hawaii	*	*	*	20%	23%	Pennsylvania	16%	15%	15%	15%	16%
Idaho	25%	25%	21%	27%	27%	Puerto Rico	NCR	*	NCR	NCR	NCR
Illinois	28%	25%	23%	25%	28%	Rhode Island	*	*	*	*	*
Indiana	29%	28%	22%	22%	24%	South Carolina	21%	19%	23%	21%	22%
Iowa	15%	13%	14%	11%	18%	South Dakota	*	NCR	*	*	NCR
Kansas	22%	17%	20%	19%	21%	Tennessee	14%	23%	21%	23%	18%
Kentucky	14%	15%	13%	24%	16%	Texas	15%	13%	13%	15%	17%
Louisiana	*	*	19%	21%	22%	U.S. Virgin Islands	NCR	NCR	NCR	NCR	*
Maine	21%	*	16%	20%	*	Utah	28%	25%	25%	22%	27%
Maryland	21%	23%	26%	23%	26%	Vermont	*	*	*	*	*
Massachusetts	17%	18%	18%	16%	16%	Virginia	27%	29%	28%	32%	28%
Michigan	32%	32%	32%	28%	28%	Washington	25%	25%	25%	20%	24%
Minnesota	24%	22%	21%	20%	25%	West Virginia	15%	14%	14%	18%	20%
Mississippi	17%	17%	19%	18%	20%	Wisconsin	*	16%	22%	16%	17%
Missouri	20%	23%	23%	23%	21%	Wyoming	*	*	10%	12%	*

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

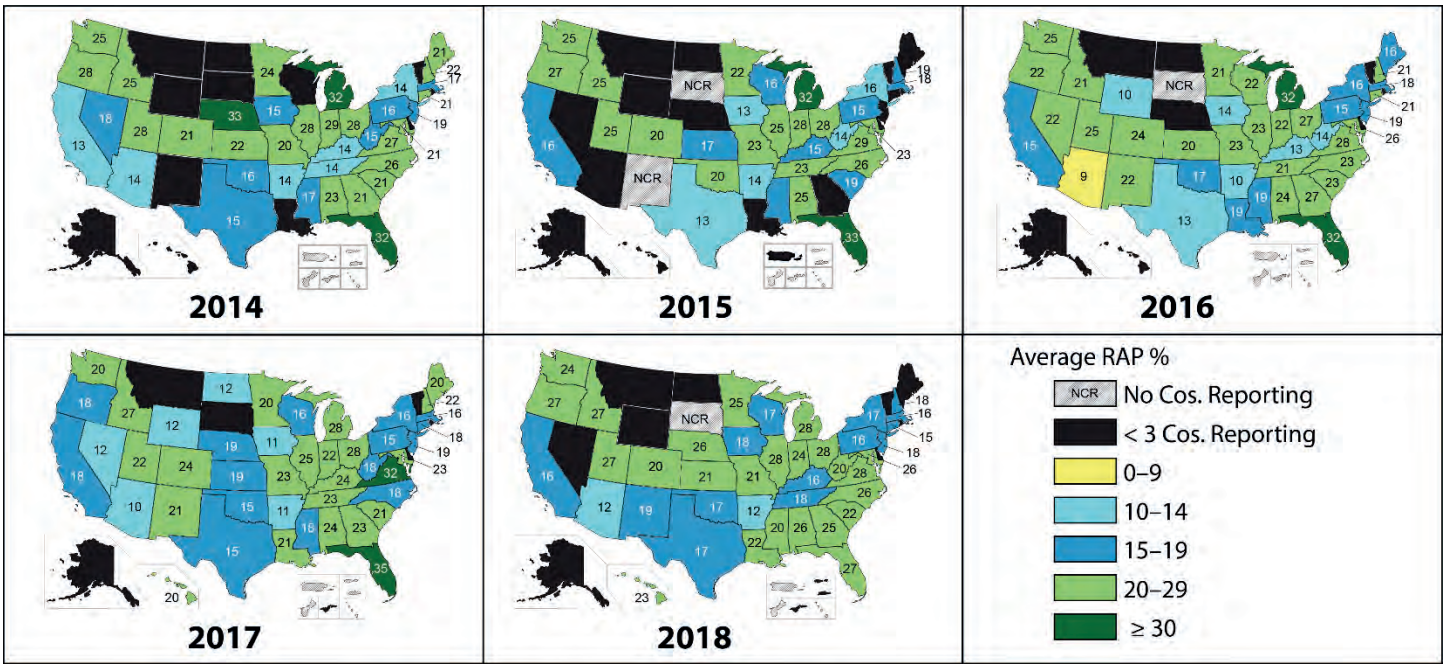


Figure 7: Estimated Average Percentage of RAP Used in Each State, 2014–2018

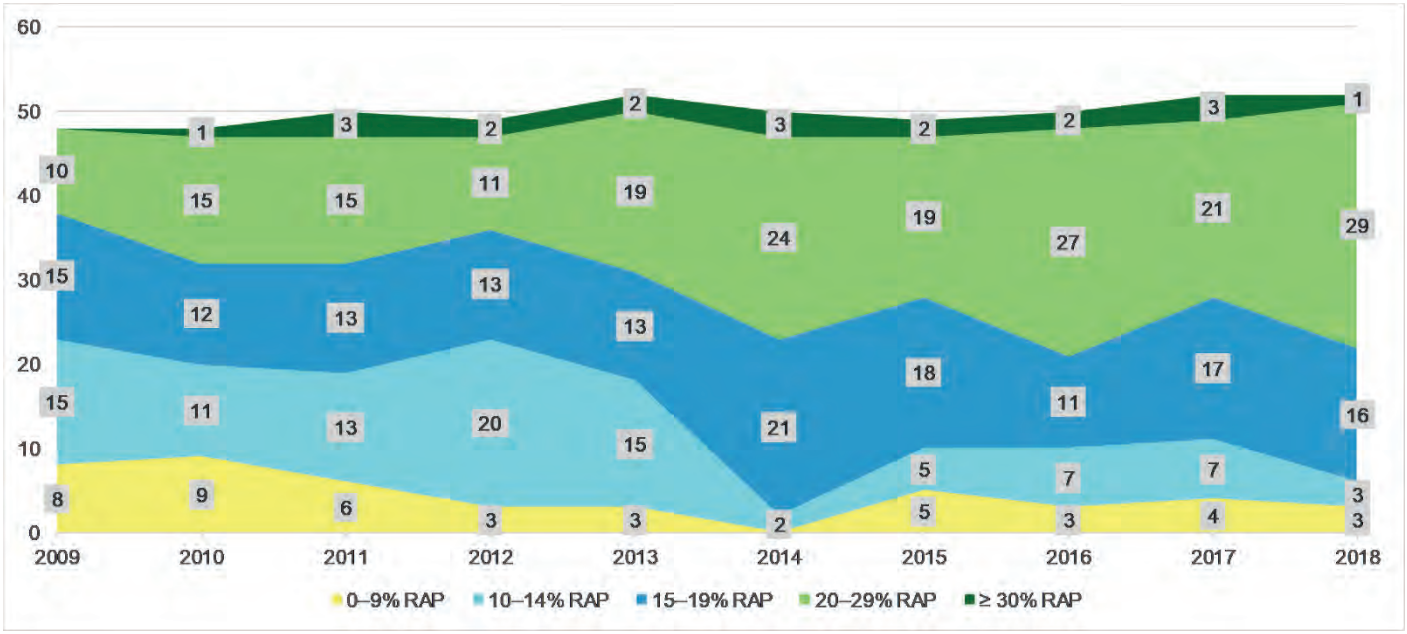


Figure 8: Number of States at Different Average Percentage of RAP Used in HMA/WMA Mixtures, 2009–2018

RAP Stockpiles

During the 2018 construction season, an estimated 101.1 million tons of RAP was accepted by asphalt mixture producers, and 90.9 million tons of RAP was used across all purposes during the year. In 2018, as in 2016, more RAP was received than was utilized, indicating an increase in producer inventory. By comparison, in 2012, 2014, and 2015, more RAP was used than was received, indicating producers were drawing upon stockpiled RAP. In 2017, RAP acceptance and use were about equal. In 2018, the estimated amount of RAP stockpiled nationwide increased to 110.31 million tons, an 8 percent increase from the 102.11 million tons of RAP stockpiled at the end of the 2017 construction season. This increase in stockpiled inventory is in line with the difference in the amount of RAP used and accepted. For 2018, 94.5 percent of producers reported having stockpiled RAP, up from 93.3 percent of producers in 2017. The reported RAP stockpiled represents about 1.4 years of inventory at 2018 utilization levels. Table 6 shows the reported and estimated amount of RAP stockpiled in each state at the end of the 2018 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)		Estimated Tons Stockpiled (Million)		State	Reported Tons Stockpiled (Million)		Estimated Tons Stockpiled (Million)	
	2017	2018	2017	2018		2017	2018	2017	2018
Alabama	1.94	1.80	2.78	2.41	Montana	*	*	*	*
Alaska	*	*	*	*	Nebraska	0.22	0.32	1.17	1.60
American Samoa	*	*	*	*	Nevada	0.05	*	0.12	*
Arizona	0.10	0.58	0.54	1.18	New Hampshire	1.01	0.15	1.23	0.15
Arkansas	0.20	0.30	0.64	0.52	New Jersey	5.91	4.24	15.05	10.81
California	0.60	1.52	2.63	3.90	New Mexico	0.10	0.14	0.31	0.78
Colorado	0.70	0.37	1.85	1.46	New York	1.07	2.02	2.40	5.92
Connecticut	1.14	1.00	1.97	2.22	North Carolina	1.02	1.14	2.55	3.17
Delaware	*	*	*	*	North Dakota	0.15	*	0.34	*
District of Columbia	*	*	*	*	No. Mariana Isl.	NCR	NCR	NCR	NCR
Florida	2.04	0.29	7.26	0.45	Ohio	3.58	8.15	4.58	11.20
Georgia	0.36	3.80	2.37	9.47	Oklahoma	0.36	0.36	0.72	0.77
Guam	NCR	NCR	NCR	NCR	Oregon	0.21	0.35	0.78	0.83
Hawaii	0.12	0.10	0.18	0.17	Pennsylvania	2.71	0.93	7.01	2.95
Idaho	0.53	0.73	0.86	1.41	Puerto Rico	NCR	NCR	NCR	NCR
Illinois	0.53	1.00	3.26	3.91	Rhode Island	*	*	*	*
Indiana	2.20	2.37	3.94	3.57	South Carolina	0.89	1.09	1.74	1.99
Iowa	0.22	0.12	0.51	0.25	South Dakota	*	NCR	*	NCR
Kansas	0.23	0.83	0.43	0.86	Tennessee	0.87	1.39	3.16	2.17
Kentucky	0.96	0.97	0.96	1.20	Texas	2.00	1.68	5.04	4.01
Louisiana	0.17	0.16	1.06	1.32	U.S. Virgin Islands	NCR	*	NCR	*
Maine	0.53	*	0.46	*	Utah	1.42	1.43	1.62	1.55
Maryland	0.71	1.02	2.29	1.58	Vermont	*	*	*	*
Massachusetts	0.56	1.28	0.72	1.66	Virginia	1.47	1.81	3.58	3.90
Michigan	3.42	3.17	5.18	5.15	Washington	0.87	1.02	1.18	1.09
Minnesota	1.15	2.13	1.31	3.28	West Virginia	0.32	0.56	0.55	0.78
Mississippi	0.16	0.49	0.27	0.69	Wisconsin	1.16	1.87	1.60	2.54
Missouri	1.51	1.55	2.53	2.65	Wyoming	0.02	*	0.40	*
					Total†	45.84	54.86	102.11	110.31

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

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 2018 data, with an example being Texas, which reports 63 percent of RAP being fractionated and averaging 17 percent RAP in mixtures, while Ohio reported only 7 percent of RAP being fractionated but averaged 28 percent RAP.

Table 7: Reported Percentage of RAP Fractionated, in Each State, 2017–2018

State	% Fractionated		State	% Fractionated		State	% Fractionated	
	2017	2018		2017	2018		2017	2018
Alabama	29%	16%	Kentucky	53%	42%	Ohio	25%	7%
Alaska	*	*	Louisiana	75%	95%	Oklahoma	65%	52%
American Samoa	*	*	Maine	27%	*	Oregon	3%	11%
Arizona	0%	10%	Maryland	0%	14%	Pennsylvania	5%	13%
Arkansas	0%	21%	Massachusetts	3%	14%	Puerto Rico	NCR	NCR
California	57%	28%	Michigan	24%	17%	Rhode Island	*	*
Colorado	22%	33%	Minnesota	10%	11%	South Carolina	50%	61%
Connecticut	0%	17%	Mississippi	25%	19%	South Dakota	*	NCR
Delaware	*	*	Missouri	10%	16%	Tennessee	55%	22%
Dist. of Columbia	*	*	Montana	*	*	Texas	39%	63%
Florida	28%	23%	Nebraska	0%	17%	U.S. Virgin Isl.	NCR	*
Georgia	8%	3%	Nevada	33%	*	Utah	8%	29%
Guam	NCR	NCR	New Hampshire	0%	0%	Vermont	*	*
Hawaii	67%	67%	New Jersey	12%	0%	Virginia	36%	26%
Idaho	17%	28%	New Mexico	37%	40%	Washington	14%	12%
Illinois	55%	39%	New York	14%	20%	West Virginia	4%	0%
Indiana	43%	69%	North Carolina	29%	21%	Wisconsin	4%	5%
Iowa	0%	1%	North Dakota	0%	*	Wyoming	50%	*
Kansas	5%	29%	No. Mariana Isl.	NCR	NCR			
						Average, Where Used†	23%	24%

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

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 30 states using 20 percent or more RAP, 22 of them report using softer binders and or recycling agents in a percentage of their RAP mixtures and eight 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, 2018

State	Softer Binder	Recyc. Agent	State	Softer Binder	Recyc. Agent	State	Softer Binder	Recyc. Agent
Alabama	0%	0%	Kentucky	22%	18%	Ohio	33%	0%
Alaska	*	*	Louisiana	25%	0%	Oklahoma	7%	0%
American Samoa	*	*	Maine	*	*	Oregon	3%	3%
Arizona	11%	0%	Maryland	19%	4%	Pennsylvania	13%	3%
Arkansas	14%	0%	Massachusetts	2%	0%	Puerto Rico	NCR	NCR
California	28%	8%	Michigan	35%	0%	Rhode Island	*	*
Colorado	25%	0%	Minnesota	28%	1%	South Carolina	29%	0%
Connecticut	0%	0%	Mississippi	0%	1%	South Dakota	NCR	NCR
Delaware	*	*	Missouri	35%	4%	Tennessee	5%	2%
Dist. of Columbia	*	*	Montana	*	*	Texas	38%	8%
Florida	55%	12%	Nebraska	17%	0%	U.S. Virgin Isl.	*	*
Georgia	14%	0%	Nevada	*	*	Utah	40%	12%
Guam	NCR	NCR	New Hampshire	0%	0%	Vermont	*	*
Hawaii	0%	0%	New Jersey	2%	0%	Virginia	5%	1%
Idaho	79%	2%	New Mexico	0%	0%	Washington	19%	9%
Illinois	23%	3%	New York	2%	8%	West Virginia	0%	0%
Indiana	8%	8%	North Carolina	19%	0%	Wisconsin	21%	3%
Iowa	19%	3%	North Dakota	*	*	Wyoming	*	*
Kansas	68%	15%	No. Mariana Isl.	NCR	NCR			
						Average, When Used†	20%	4%

NCR No Companies Responding for the State to the Survey

* Fewer than 3 Companies Reporting

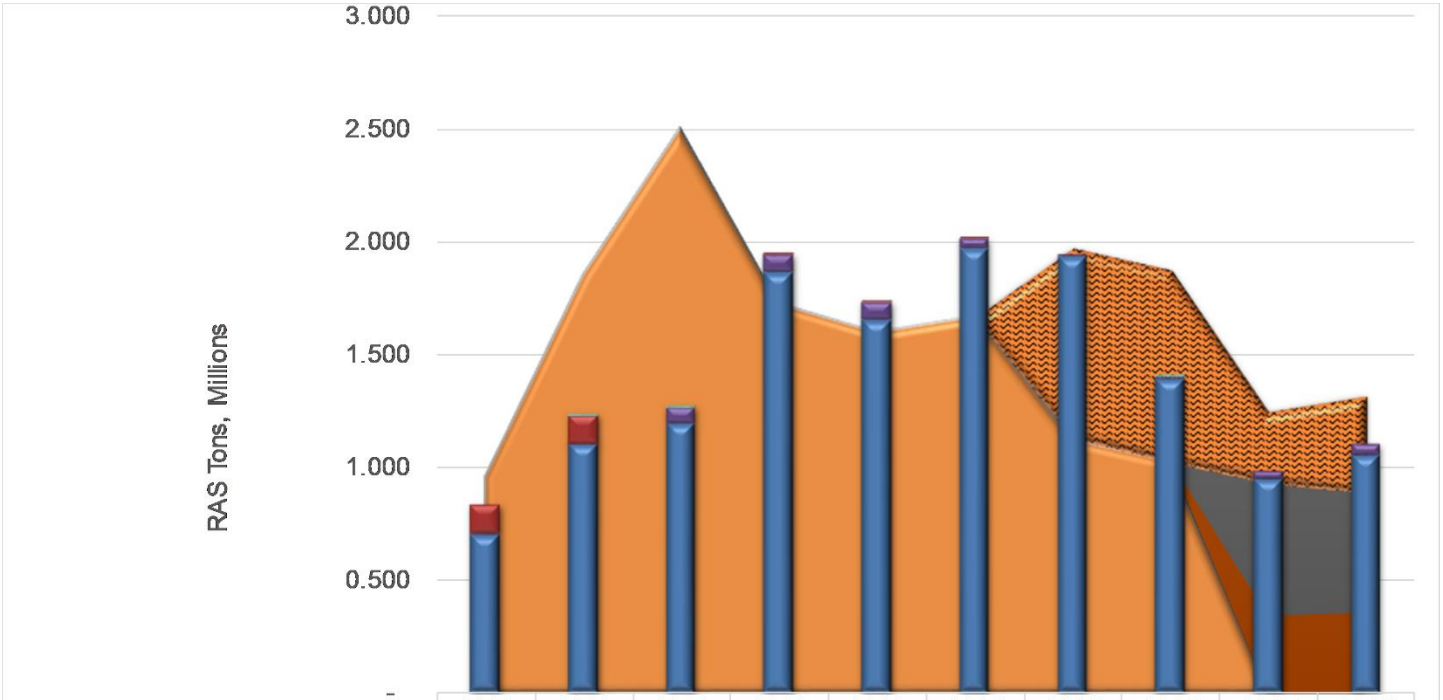
† Includes Values from States with Fewer than 3 Companies Reporting

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 20 percent during the 2018 construction season, which is up from 18 percent in the 2017 survey. The percentage of RAP mixtures incorporating recycling agents has fluctuated year to year with 4 percent in 2018, 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 2017 and 2018 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 9 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 2018 construction season surveys.

During the 2018 construction season, the total estimated amount of unprocessed and processed shingles received by producers was 1.32 million tons, which is more than combined amount of RAS used in asphalt mixtures (1,053,000 tons) and in aggregate (50,000 tons) used that year. This is a 5.9 percent increase from the 1.25 million total tons of RAS from all sources accepted during the 2017 construction season. The use of 1.053 million tons of RAS in asphalt pavement mixtures during 2018 is a 12.5% increase from the 980,000 tons used in 2017.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Processed Shingles Accepted	-	-	-	-	-	-	0.842	0.846	0.311	0.430
PCAS	-	-	-	-	-	-	-	-	0.591	0.534
MWAS	-	-	-	-	-	-	-	-	0.344	0.356
Unprocessed Shingles Accepted	0.957	1.851	2.500	1.724	1.599	1.664	1.129	1.027	-	-
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	0.050
Used in HMA/WMA	0.702	1.100	1.192	1.863	1.647	1.964	1.931	1.390	0.944	1.053

Figure 9: Comparison of Tons of RAS Accepted and Tons of RAS Used or Landfilled (Million Tons), 2009–2018. Processed RAS Acceptance First Tracked in 2015

As shown in Figure 9, from the 2012 to 2014 construction seasons, producers reported using RAS in greater quantities than they accepted. When this trend was first noticed, producers were contacted to confirm the reported 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?” Beginning with the 2017

construction season survey producers were asked to report the tons of unprocessed PCAS, unprocessed MWAS, and processed RAS accepted separately.

As seen in Table 4, there was a significant (38 percent) increase in the acceptance of processed shingles in 2018 compared to 2017, leading to a 6 percent increase in the total amount of RAS accepted during the 2018 construction season. However, the total estimated amount of unprocessed shingles accepted by producers declined 5 percent from 935,000 tons in 2017 to 890,000 tons in 2018. The drop in unprocessed shingles was due to a 9.6 percent decline in accepted PCAS, which fell from 591,000 tons in 2017 to 534,000 tons in 2018. Acceptance of MWAS, however, increased 3.5 percent during the same time period, rising from 344,000 tons in 2017 to 356,000 tons in 2018.

No RAS accepted by producers was reported as landfilled during the 2018 construction season. By accepting 890,00 tons of unprocessed RAS from both PCAS and MWAS sources, asphalt mixture producers saved about 540,000 cubic yards of landfill space.

According to the Asphalt Roofing Manufacturers Association (ARMA, 2015), about 13.2 million tons of waste shingles are generated annually — about 12 million tons of PCAS and 1.2 million tons of MWAS. Therefore, asphalt mixture producers in 2018 diverted about 10 percent of the total available supply of waste shingles from landfills.

The number of companies using RAS increased from 64 in 2017 to 67 during the 2018 construction season. The percentage of producers reporting use of RAS decreased from 27 percent of respondents in 2017 to 25 percent in 2018.

RAS Use by Sector

Figure 10 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 slight across-the-board increase in the tons of RAS used by DOTs from the 2017 to 2018 construction. All sectors saw increases in percentage and tonnage of RAS use from 2017 to 2018.

Figure 11 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 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

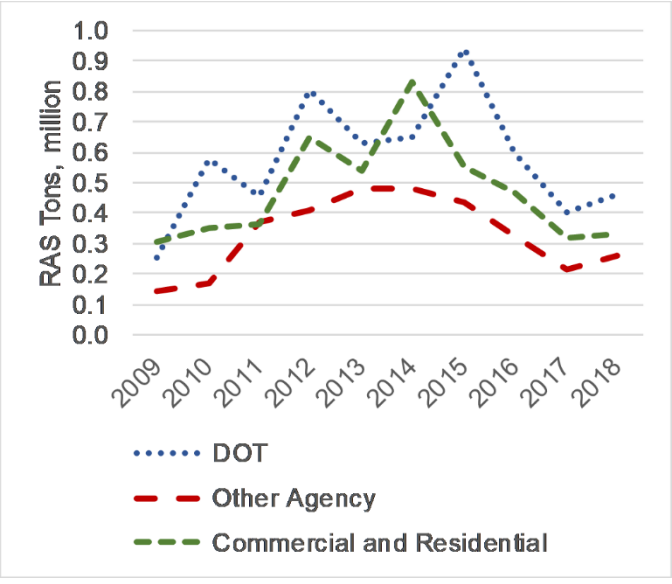


Figure 10: Estimated RAS Use by Sector (Million Tons)

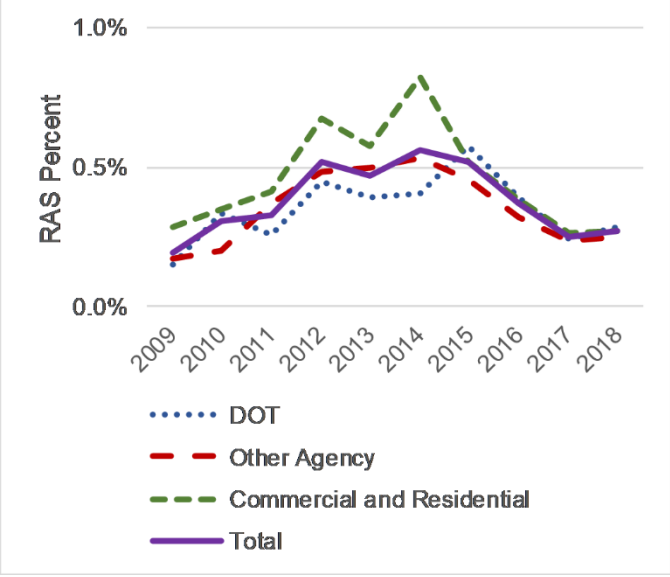


Figure 11: Average Percent RAS Used by Sector

in 2016 and continued into the 2017 season. The 2018 survey saw the decline bottoming out of this decline with a small increase in RAS use compared to 2017. The average percentage RAS peaked in 2012 at 0.56 percent in 2012 and started declining from 0.54 percent in 2014 to 0.24 percent in the 2017 construction season. 2018 saw a small rise in average percentage RAS to 0.27 percent.

In 2018, producers and SAPAs were asked which sectors allow RAS to be included in asphalt mixtures. Responses came from 48 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, 22 DOTs reportedly allow RAS in some asphalt pavement mixtures, and seven other DOTs allow it in all mixtures. These findings generally align the findings of a 2016 FHWA survey (Aschenbrener, 2017) examining DOT acceptance of the use of RAS. Aschenbrener (2017) also found that five state DOTs — District of Columbia, New Jersey, New York, Pennsylvania, and Massachusetts —allow only the use of MWAS in asphalt pavement mixtures. RAS use is allowed in some Other Agency sector mixtures in 34 states, with no additional states allowing RAS in all mixtures for that sector. Similarly, RAS is allowed in at least some Commercial & Residential sector mixtures in 37 states. There were no reports of states allowing RAS in all mixtures for all sectors, while nine states — Alaska, Arizona, Hawaii, Nevada, New Mexico, North Dakota, Rhode Island, West Virginia, and Wyoming — reportedly do not allow the use of RAS in mixtures for any sector.

Table 9: Sectors Allowing RAS, 2018

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	Some	None	None
Alaska	None	None	None	Nebraska	Some	Some	Some
American Samoa	DNA	DNA	DNA	Nevada	None	None	None
Arizona	None	None	None	New Hampshire	Some	Some	Some
Arkansas	Some	Some	Some	New Jersey	Some	None	None
California	None	Some	Some	New Mexico	None	None	None
Colorado	None	Some	Some	New York	All	Some	All
Connecticut	Some	Some	Some	North Carolina	All	Some	Some
Delaware	DNA	DNA	DNA	North Dakota	None	None	None
District of Columbia	DNA	DNA	DNA	No. Mariana Isl.	NCR	NCR	NCR
Florida	None	Some	Some	Ohio	Some	Some	Some
Georgia	None	Some	Some	Oklahoma	None	Some	Some
Guam	NCR	NCR	NCR	Oregon	Some	Some	Some
Hawaii	None	None	None	Pennsylvania	Some	None	All
Idaho	None	Some	Some	Puerto Rico	NCR	NCR	NCR
Illinois	All	Some	Some	Rhode Island	None	None	None
Indiana	All	Some	Some	South Carolina	Some	Some	Some
Iowa	All	Some	Some	South Dakota	None	Some	Some
Kansas	Some	Some	Some	Tennessee	Some	Some	Some
Kentucky	Some	Some	All	Texas	Some	Some	Some
Louisiana	DNA	DNA	DNA	U.S. Virgin Islands	DNA	DNA	DNA
Maine	Some	Some	Some	Utah	None	None	Some
Maryland	Some	Some	Some	Vermont	None	Some	Some
Massachusetts	Some	Some	Some	Virginia	Some	Some	Some
Michigan	Some	Some	Some	Washington	Some	Some	Some
Minnesota	All	Some	Some	West Virginia	None	None	None
Mississippi	None	None	Some	Wisconsin	All	Some	Some
Missouri	Some	Some	Some	Wyoming	None	None	None

DNA Did Not Answer
NCR No Companies Responding

Table 10: States With Reported RAS Use, 2010–2018

State	RAS Used?								
	2010	2011	2012	2013	2014	2015	2016	2017	2018
Alabama	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Alaska	No	No	No	No	No	No	No	No	No
American Samoa	NCR	NCR	NCR	NCR	NCR	NCR	NCR	No	No
Arizona	No	No	No	No	No	No	No	No	No
Arkansas	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
California	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Colorado	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Connecticut	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Delaware	Yes	NCR	Yes	Yes	Yes	Yes	Yes	No	No
District of Columbia	NCR	NCR	NCR	No	NCR	NCR	NCR	No	No
Florida	Yes	No	No	Yes	Yes	Yes	No	No	Yes
Georgia	No	Yes	Yes	Yes	No	No	Yes	No	No
Guam	NCR	NCR	NCR	NCR	NCR	NCR	NCR	NCR	NCR
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	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kentucky	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Louisiana	No	No	No	Yes	No	No	Yes	No	No
Maine	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Maryland	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Massachusetts	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Michigan	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Minnesota	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mississippi	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Missouri	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Montana	No	No	No	No	No	No	No	No	No
Nebraska	NCR	No	Yes	Yes	No	No	Yes	No	No
Nevada	Yes	No	No	No	No	No	Yes	Yes	No
New Hampshire	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
New Jersey	No	No	No	Yes	No	No	No	No	No
New Mexico	NCR	No	NCR	No	No	NCR	Yes	Yes	No
New York	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
North Carolina	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
North Dakota	NCR	No	NCR	No	No	No	No	No	No
Northern Mariana Isl.	NCR	NCR	NCR	NCR	NCR	NCR	NCR	NCR	NCR
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	NCR	No	NCR	NCR	NCR
Rhode Island	No	No	No	No	No	No	No	No	No
South Carolina	No	Yes	No	Yes	Yes	No	Yes	No	No
South Dakota	No	Yes	Yes	Yes	Yes	NCR	Yes	No	NCR
Tennessee	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Texas	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
U.S. Virgin Islands	NCR	NCR	NCR	NCR	NCR	NCR	NCR	NCR	No
Utah	No	No	No	No	No	No	No	No	No
Vermont	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Virginia	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Washington	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
West Virginia	Yes	No	No	No	No	No	No	No	No
Wisconsin	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wyoming	No	No	No	Yes	No	No	Yes	No	No

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

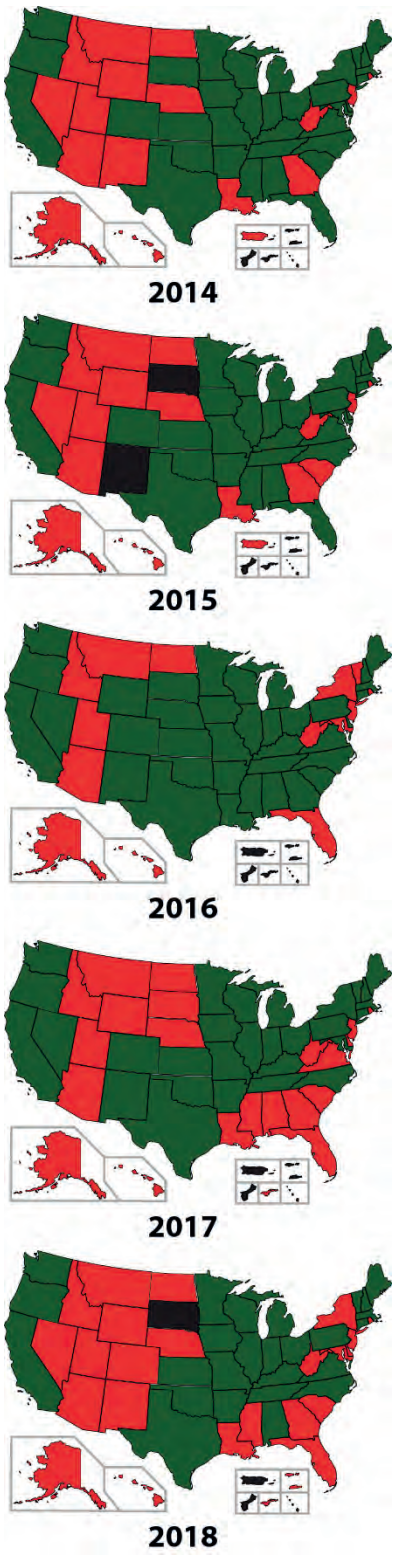


Figure 12: States with Companies Reporting RAS Use by Construction Season, 2014–2018

RAS Use in Each State

Table 10 shows states where asphalt pavement mixture producers reported using RAS in 2010 through 2018, and Figure 12 shows states where producers reported using RAS from 2014 through 2018. Red indicates a state where RAS use was not reported for 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, 32 in 2015, and 29 in 2017. During the 2018 construction season, asphalt mixture producers in 27 states report RAS use. Colorado producers for the first time since the 2013 survey reported not using RAS, while still reporting that RAS is allowed in Other Agency and Commerical and Residential sectors.

RAS Stockpiles

In 2018, 99 percent of the 67 producers using RAS reported having inventories of stockpiled RAS, compared to 98 percent of the 64 producers using RAS in 2017. Some 1.368 million tons of RAS was reported as stockpiled at year-end 2018, a slight (1.3 percent) decrease from the 1.387 million tons of RAS in stockpiles at the end of 2017. The reported RAS stockpiled represents about 1.3 years of inventory at 2018 utilization levels.

Table 11: Reported Tons of RAS Stockpiled, 2017–2018

State	Reported Tons Stockpiled (Thousands)		Estimated Tons Stockpiled (Thousands)		State	Reported Tons Stockpiled (Thousands)		Estimated Tons Stockpiled (Thousands)	
	2017	2018	2017	2018		2017	2018	2017	2018
Alabama	0.0	40.5	0.0	54.3	Montana	*	*	*	*
Alaska	*	*	*	*	Nebraska	3.3	4.4	17.7	22.0
American Samoa	*	*	*	*	Nevada	0.2	*	0.4	*
Arizona	0.0	0.0	0.0	0.0	New Hampshire	0.0	0.0	0.0	0.0
Arkansas	38.7	33.0	121.6	57.5	New Jersey	0.0	0.0	0.0	0.0
California	4.0	10.0	17.5	25.6	New Mexico	1.8	0.0	5.8	0.0
Colorado	7.8	7.2	20.7	28.1	New York	0.0	0.0	0.0	0.0
Connecticut	0.0	0.1	0.0	0.2	North Carolina	75.2	131.3	188.6	364.7
Delaware	*	*	*	*	North Dakota	0.0	*	0.0	*
District of Columbia	*	*	*	*	No. Mariana Isl.	NCR	NCR	NCR	NCR
Florida	9.5	1.0	33.9	1.6	Ohio	55.7	30.2	71.2	41.5
Georgia	22.9	0.0	149.3	0.0	Oklahoma	8.2	52.5	16.3	112.2
Guam	NCR	NCR	NCR	NCR	Oregon	3.2	1.9	12.3	4.5
Hawaii	0.0	0.0	0.0	0.0	Pennsylvania	69.5	33.9	179.4	107.6
Idaho	0.0	0.0	0.0	0.0	Puerto Rico	NCR	NCR	NCR	NCR
Illinois	1.1	1.0	6.7	3.9	Rhode Island	*	*	*	*
Indiana	13.8	9.0	24.6	13.6	South Carolina	0.0	2.5	0.0	4.6
Iowa	19.4	14.5	46.3	30.6	South Dakota	*	NCR	*	NCR
Kansas	11.0	2.0	20.5	2.1	Tennessee	54.6	9.6	198.3	15.0
Kentucky	5.5	15.3	5.5	18.9	Texas	22.6	32.6	57.1	77.9
Louisiana	0.0	0.0	0.0	0.0	U.S. Virgin Isl.	NCR	*	NCR	*
Maine	1.0	*	0.8	*	Utah	0.0	0.0	0.0	0.0
Maryland	10.5	3.0	33.8	4.6	Vermont	*	*	*	*
Massachusetts	0.8	25.0	1.0	32.5	Virginia	2.0	0.0	4.9	0.0
Michigan	1.5	1.5	2.3	2.4	Washington	2.9	7.2	3.9	7.7
Minnesota	25.3	25.0	28.8	38.5	West Virginia	0.0	0.0	0.0	0.0
Mississippi	0.0	0.1	0.0	0.1	Wisconsin	45.7	129.4	62.7	175.8
Missouri	78.7	42.4	132.0	72.5	Wyoming	0.0	*	0.0	*
					Total†	596.2	666.4	1,387.0	1,368.2

NCR No Companies Responding
* Fewer than 3 Companies Reporting
† Includes Values from States with Fewer than 3 Companies Reporting

Table 11 shows the reported and estimated amount of RAS stockpiled in each state at the end of the 2018 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.

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.** Similar to the RAP, there does not 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.

Table 12: Percentage of RAS Mixtures Using Softer Binder and/or Recycling Agents in Each State, 2018

State	Softer Binder	Recyc. Agent	State	Softer Binder	Recyc. Agent	State	Softer Binder	Recyc. Agent
Alabama	0%	0%	Kentucky	45%	90%	Ohio	71%	0%
Alaska	*	*	Louisiana	0%	0%	Oklahoma	63%	13%
American Samoa	*	*	Maine	*	*	Oregon	0%	100%
Arizona	0%	0%	Maryland	0%	0%	Pennsylvania	0%	0%
Arkansas	0%	0%	Massachusetts	0%	0%	Puerto Rico	NCR	NCR
California	100%	0%	Michigan	0%	0%	Rhode Island	*	*
Colorado	0%	0%	Minnesota	20%	0%	South Carolina	0%	0%
Connecticut	0%	0%	Mississippi	0%	0%	South Dakota	NCR	NCR
Delaware	*	*	Missouri	66%	8%	Tennessee	0%	0%
Dist. of Columbia	*	*	Montana	*	*	Texas	70%	0%
Florida	100%	0%	Nebraska	0%	0%	U.S. Virgin Isl.	*	*
Georgia	0%	0%	Nevada	*	*	Utah	0%	0%
Guam	NCR	NCR	New Hampshire	0%	0%	Vermont	*	*
Hawaii	0%	0%	New Jersey	0%	0%	Virginia	0%	0%
Idaho	0%	0%	New Mexico	0%	0%	Washington	33%	7%
Illinois	40%	7%	New York	0%	0%	West Virginia	0%	0%
Indiana	10%	0%	North Carolina	100%	0%	Wisconsin	55%	7%
Iowa	25%	5%	North Dakota	*	*	Wyoming	*	*
Kansas	67%	34%	No. Mariana Isl.	NCR	NCR			
						Average, When Used†	35%	11%

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, in states where RAS is reportedly used, the average percentage of RAS mixtures incorporating softer binders was 35 percent during the 2018 construction season, while the percentage of RAS mixtures incorporating recycling agents was at 11 percent. In 2017, producers reported a higher average percentage (44 percent) of RAS mixtures incorporating softer binders and a lower average percentage (7 percent) of RAS mixtures incorporating recycling agents, than in the 2018 construction season.

Potential for Increased RAP and RAS Use

For the 2018 construction season survey, SAPAs were asked if they felt there were opportunities for greater utilization of recycled materials, primarily RAP and RAS, in their state. Of the 26 SAPAs providing a response, 77 percent felt there was room to increase the use of these materials. The SAPAs were also asked to provide two ways agencies and industry could work to increase the utilization of recycled materials.

As can be seen in Figure 13, more than half of respondents felt increased levels of recycled materials could be achieved through the use of balanced mix design and mixture performance testing (29 percent) or by increasing recycled material content in lower pavement layers (23 percent). An additional 18 percent felt that increased fractionation of RAP would help increase RAP usage. Specification changes, improved recycled materials quality control, and binder grade bumping rounded out the responses.

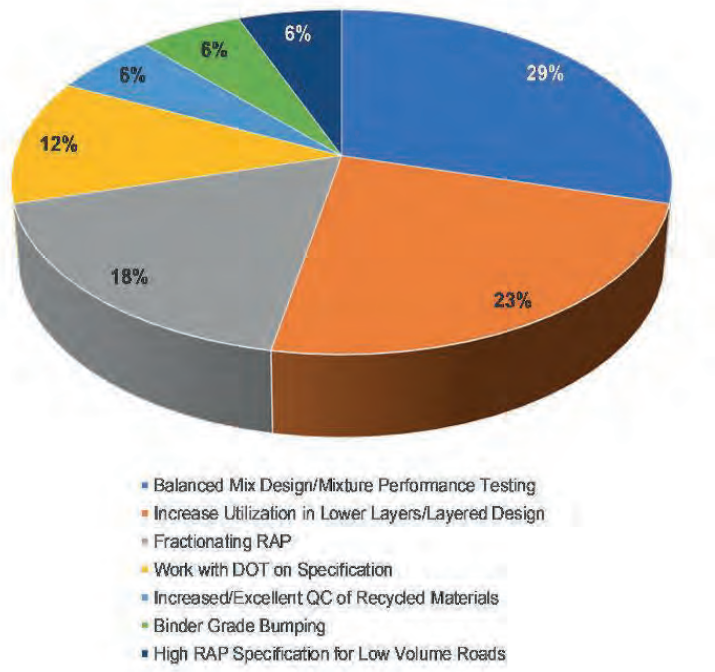


Figure 13: Reported Possible Means for Increasing Recycled Materials Use, 2018

This differs from the 2017 survey where respondents asked about what limits the use of RAP and RAS in their state and the most frequent responses were specification limits (39 percent for RAP; 47 percent for RAS) and the availability of RAP (19 percent) and RAS (13 percent).

The Importance of Engineering Recycled Asphalt Mixtures for Quality

For more than three decades, two guiding principles of asphalt recycling have been: asphalt mixtures containing recycled materials should 1) meet the same requirements as asphalt mixtures with all virgin materials, and 2) 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 129).

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 2018 construction season. In total, the use of RAP and RAS saved more than $2.9 billion during the 2018 construction season compared to the use of all virgin materials. This is $626 million more than in 2017 due primarily to increases in asphalt binder and aggregate prices (Table 14).

Table 13: Material Savings, 2017–2018

Material	Material Quantity, Million Tons		% Agg.	% AC	Aggregate Cost Savings, $ Billion		Asphalt Binder Cost Savings, $ Billion		Total Cost Savings, $ Billion	
	2017	2018			2017	2018	2017	2018	2017	2018
RAP	76.2	82.2	95	5	$0.736	$0.822	$1.488	$1.981	$2.224	$2.803
RAS	0.944	1.053	50*	20	$0.005	$0.006	$0.074	$0.101	$0.079	$0.107
Total					$0.741	$0.828	$1.561	$2.082	$2.303	$2.910

* 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 publicly available 2018 asphalt price indexes for 37 states (see Figure 14). The average price of unmodified asphalts from these states for 2018 was about $468.93 per ton, up from the 2017 average price of $361.93. Five of the states (Alabama, Florida, Louisiana, Tennessee, and Virginia) also provide price indexes for modified asphalts. The average modified asphalt prices from these states for 2018 was $595.98 per ton, up from $480.04 in 2017. Assuming 10 percent of asphalt mixtures use modified asphalt binders, the 2018 average price of asphalt binders used in asphalt mixtures was $481.90 per ton, up 23.4 percent from 2017.

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) increased to $10.80 per ton and Sand and Gravel (Construction) increased to $8.11 per ton for 2018 (USGS, 2019). 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 $10.53 per ton for the 2018 construction season, up 3.5 percent from 2017.

Table 14: Material Cost Factors, 2015–2018

Material		% of Market	Cost/Ton 2015	2016	2017*	2018
Asphalt	Unmodified	90	$468.45	$333.46	$361.93	$468.93
	Modified	10	$600.10	$466.16	$480.04	$595.98
	Weighted Average		$481.62	$346.73	$390.44	$481.90
Aggregate	Crushed Stone	90	$9.58	$10.11	$10.43	$10.80
	Sand and Gravel	10	$7.46	$7.77	$7.84	$8.11
	Weighted Average		$9.37	$9.88	$10.17	$10.53

*2017 cost per ton values updated from Williams et al. (2018) to reflect USGS (2019) estimates and expanded state asphalt price index data set.

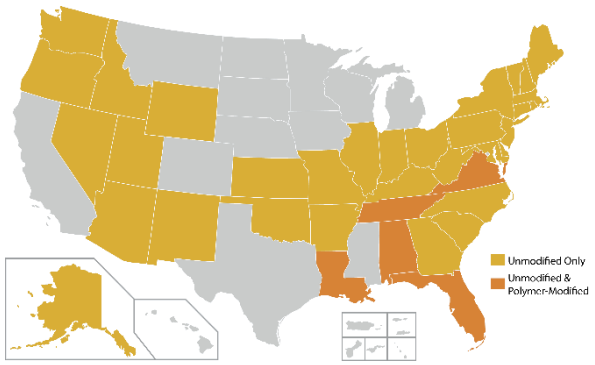


Figure 14: States With Publicly Available Asphalt Price Indexes, 2018

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.

Additional cost savings are realized by diverting RAP and RAS from landfills. The national average gate fee for disposing of mixed construction and demolition (C&D) material in landfills is relatively close to the national average for municipal solid waste (MSW) landfill disposal (Tolaymat et al., 2017). Based upon a 2018 national average for MSW landfill gate fees of $55.11 per ton, not sending nearly 83 million tons of RAP and RAS to landfills (nearly 62 million cubic yards of material) saved about $4.6 billion dollars in gate fees, up from nearly $4 billion in 2017, due in part to a 6.3 percent increase in MSW gate fees from 2017 to 2018 (Staley et al., 2018).

Warm-Mix Asphalt Technology

Table 4 includes the national summary of WMA technology usage data from the 2017 and 2018 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 also asked about the different WMA technologies used.

Prior to the 2018 construction season, producers were asked to report primarily the use of WMA technologies to reduce production temperatures by at least 10°F from typical mixture production temperatures. However, because of potential compaction, antistrip, and workability benefits, the use of WMA technologies at HMA temperatures is common. To better understand the use of WMA technologies at different temperatures, the 2018 construction season survey asked additional questions to ensure disaggregation of WMA technology use at different temperatures. The results indicate that prior survey reports have better captured the use of WMA technologies than the use of WMA technologies at reduced temperature. Table 4 and this section report both aggregated data on the use of WMA technologies and disaggregated data on its use by mixture temperature where possible.

The percentage of companies reporting the use of WMA technologies saw rapid increases from the 2009 to 2011 construction seasons, but has held at between 68 and 78 percent of respondents from the 2011 to 2018 construction seasons, as shown in Figure 15. Increases in tonnage with WMA technologies as a percent of total tonnage have generally plateaued between 2013 and 2016, as seen in Figure 16. The 2018 construction season, however, had a 7 percent increase in the production of asphalt with WMA technologies to 157.7 million tons, 40.5 percent of total asphalt pavement tonnage. A total of 185 companies, 68 percent of respondents, reported using WMA technologies during the 2018 construction season.

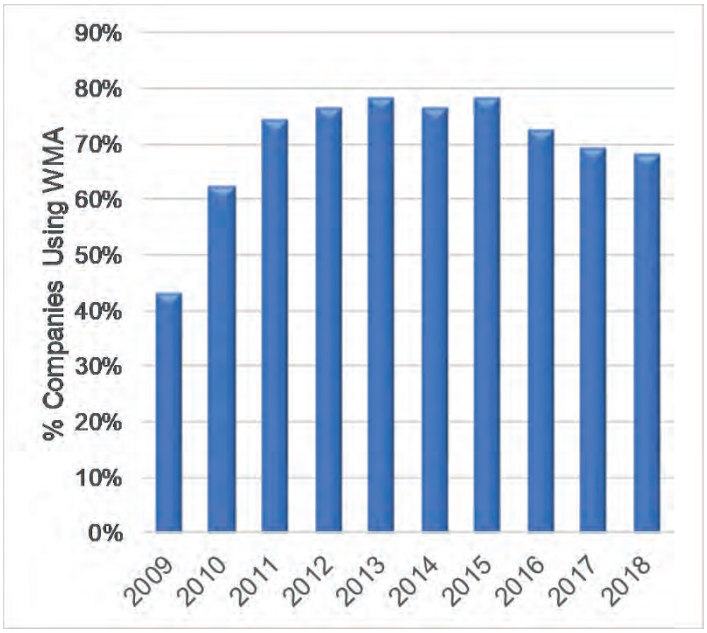


Figure 15: Percent of Companies Using WMA Technologies

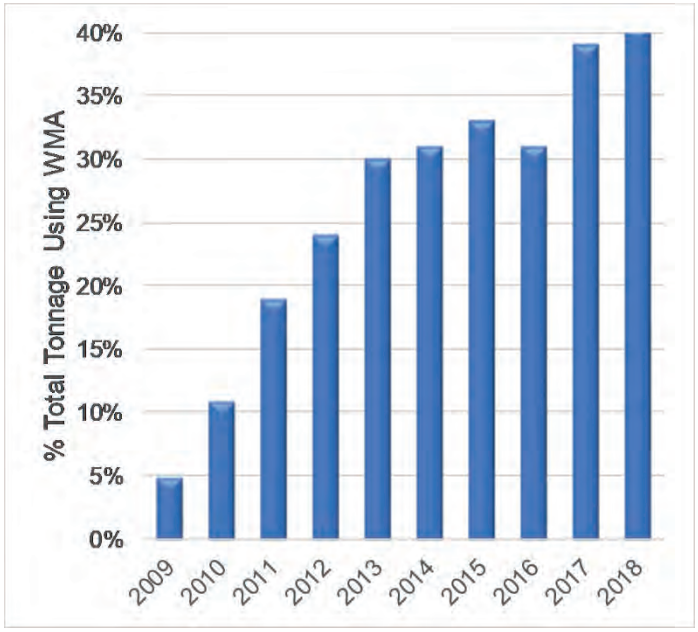
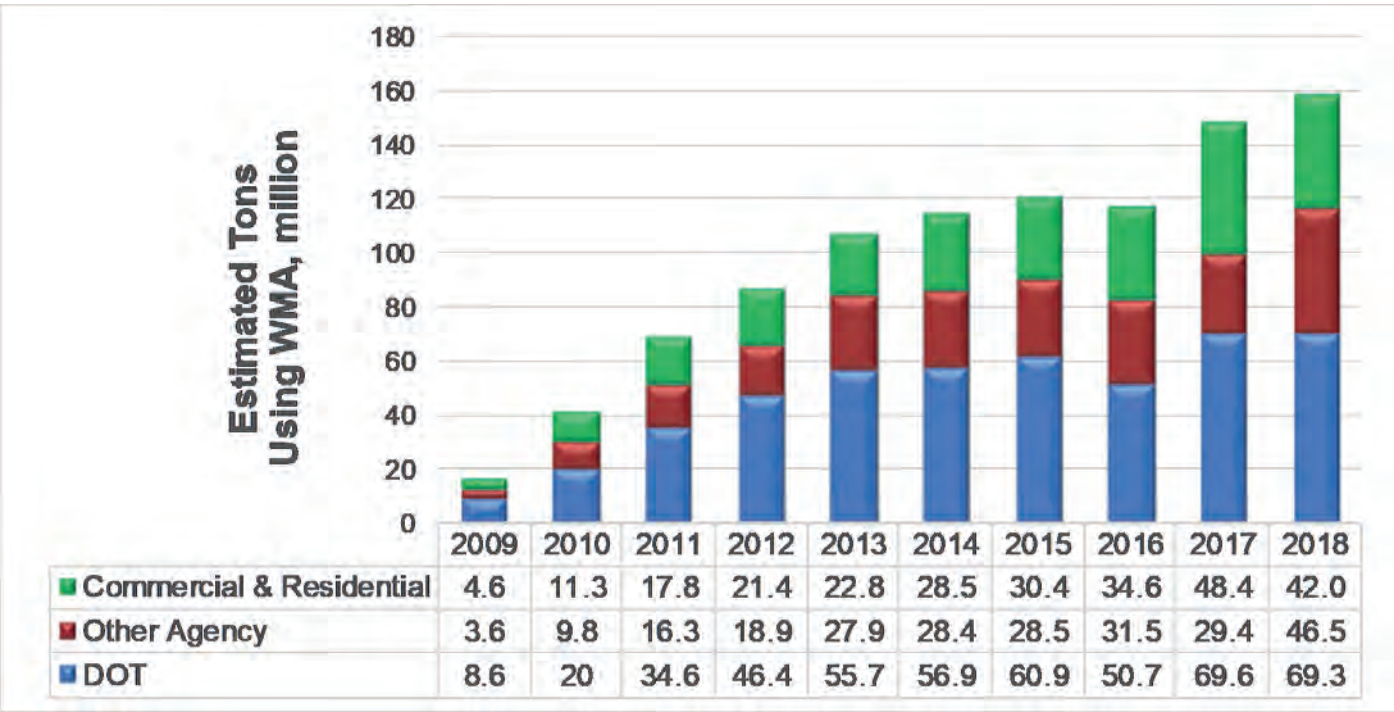


Figure 16: Percent Total Tonnage Produced Using WMA Technologies

WMA Technology Use by Sector

Figure 17 shows a steady increase in the number of tons of mixture produced using WMA technologies for each customer sector from 2011 to 2013, with use showing minor changes for the 2014 though 2016 construction seasons. In 2017, however, WMA technology use grew substantially due to notable increases in mixtures produced for the DOT and Commercial & Residential sectors. During 2018, growth in tonnage produced with WMA technologies was driven largely by a 58 percent increase in tons produced for the Other Agency sector. The Commercial & Residential sector was down 13 percent and the DOT sector was down less than a half percent from the 2017 construction season. All in all, during the 2018 construction season, 43.2 percent of all DOT sector tonnage, 44.5 percent of Other Agency sector tonnage, and 33.8 percent of Commercial & Residential sector tonnage was produced using WMA technologies.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Commercial & Residential	4.6	11.3	17.8	21.4	22.8	28.5	30.4	34.6	48.4	42.0
Other Agency	3.6	9.8	16.3	18.9	27.9	28.4	28.5	31.5	29.4	46.5
DOT	8.6	20	34.6	46.4	55.7	56.9	60.9	50.7	69.6	69.3

Figure 17: Estimated Tons (Millions) Produced With WMA Technologies by Sector, 2009–2018

WMA Technology Use in Each State

Figure 18 shows the estimated percentage of total tons produced as WMA in each state. The national trend from 2009 through 2018 shows increased tons of asphalt mixture produced with WMA technologies; however, a degree of fluctuation year-to-year 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 2017 to 2018, 20 states saw an increase of 10 percentage points or more in WMA production, while 13 states had a decrease of 10 percentage points or more. Nine states — Alabama, Connecticut, Florida, Illinois, Iowa, Kansas, Maine, Nebraska, and New Jersey — had an increase of 30 percentage points or more in mixture production with WMA technologies. Seven states — Arizona, Arkansas, Georgia, Oklahoma, Tennessee, Vermont, and Wyoming — had a decrease of 30 percentage points or more in mixture production with WMA technologies.

Mixture production with WMA technologies made up over half of the total asphalt mixture production in 23 states during 2018, five of these states — Idaho, Louisiana, Massachusetts, Mississippi, Oklahoma, and Utah — reported WMA as 75 percent or more of total production in 2018. Alaska, American Samoa, Hawaii, Montana, Rhode Island, Vermont, and West Virginia had no reported asphalt production with WMA technologies in 2018.

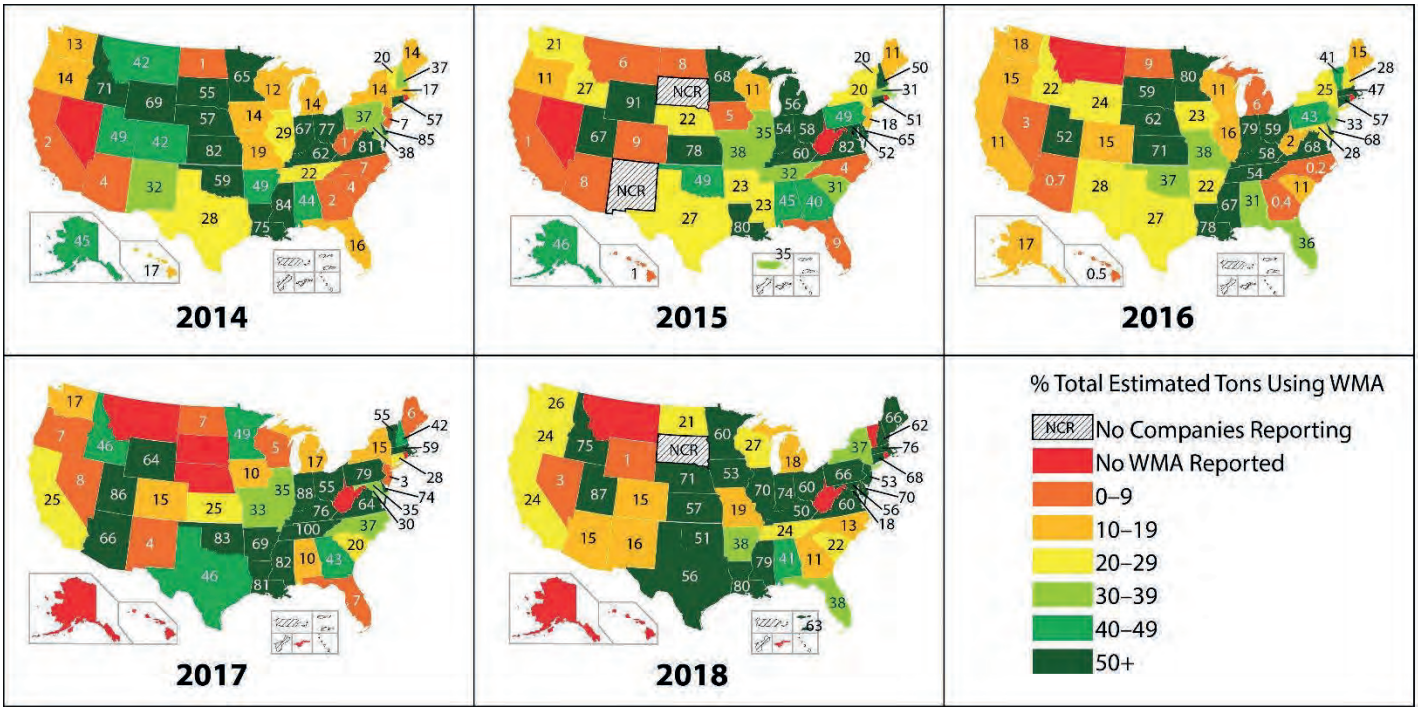


Figure 18: Estimated Percent of Total Production Using WMA Technologies in Each State, 2014–2018

WMA Technologies

As Table 15 and Figure 19 show, production plant foaming remains the most commonly used WMA production technology, being used for around 63 percent of the WMA produced in 2018. This is a decrease of about 2.3 percent from the 2017 season. However, the use of chemical additive technologies at 34.3 percent represents a 6.5 percent increase for the 2018 construction season compared to 2017. Organic additives represented 1.8 percent of the market. There was less than 1 percent reported use of additive foaming technologies during 2018. 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 over the same time period.

Table 15: Percent Production of WMA Technologies, 2009–2018

WMA Technology	% Production									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Production Plant Foaming %	83.0%	92.0%	95.4%	88.3%	87.0%	84.5%	72.0%	76.9%	64.7%	63.2%
Additive Foaming %	2.0%	1.0%	0.2%	2.0%	0.3%	0.0%	2.1%	0.0%	0.0%	0.7%
Chemical Additive %	15.0%	6.0%	4.1%	9.4%	12.1%	15.0%	25.2%	21.1%	32.2%	34.3%
Organic Additive %	0.3%	1.0%	0.3%	0.2%	0.0%	0.5%	0.7%	1.9%	3.1%	1.8%

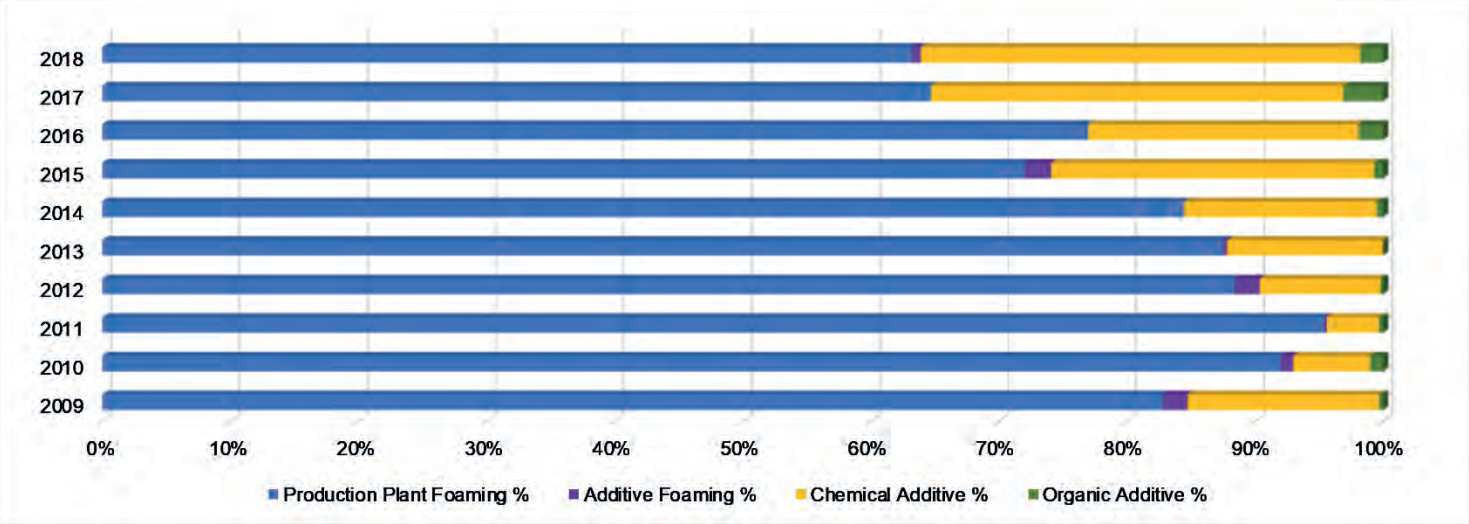


Figure 19: WMA Technologies Used as Percent of WMA Production, 2009–2018

Use of WMA Technologies at Different Temperatures

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 to report use of WMA technologies for asphalt production both at traditional HMA temperatures and at reduced temperatures. About 50.5 percent (79.5 million tons) of total tonnage produced using WMA technologies was produced with a temperature reduction of at least 10°F.

Of the respondents, 185 producers in 44 states, reported using WMA technologies. Of these, 97 producers reporting using WMA technologies at both reduced and HMA temperatures; 52 producers used WMA technologies only at reduced temperatures; and 36 producers reported using WMA technologies only at HMA temperatures.

Table 16 shows the percentage of reported tons produced using each WMA technologies at both reduced temperatures and at traditional HMA temperatures, along with the total tonnages produced with WMA technologies. For the most part, there is only minor variation in the utilization of different WMA technologies at different production temperatures. The producers reporting the use of WMA technologies at all temperatures typically did not report varying the technology by temperature. Therefore, much of the difference between the Reduced Temperatures and the HMA Temperatures columns in Table 16 is attributable to the technologies employed by producers that only utilize WMA technologies at either reduced temperatures or HMA temperatures.

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

Table 16: WMA Technologies Utilization Detail, 2018

WMA Technology	% of Market		
	Reduced Temperatures	HMA Temperatures	At All Temperatures
Chemical Additive	33.2%	35.4%	34.3%
Plant Foaming	64.7%	61.6%	63.2%
Additive Foaming	0.1%	1.3%	0.7%
Organic Additive	2.0%	1.6%	1.8%
2018 Tons (Millions)	79.5	78.2	157.7

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 2018 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 — recycled tire rubber (RTR), 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 79 companies from 31 states, 29 percent of survey respondents, reported using nearly 1.80 million tons of other recycled materials in nearly 12.3 million tons of asphalt mixtures during the 2018 construction season.

Recycled Tire Rubber

Table 17 summarizes reported information on the use of RTR, also referred to as ground tire rubber (GTR). Twenty-one producers from 11 states reported using RTR in some asphalt mixtures. Information about the use of RTR in surface treatments, such as chip seals, was not within the scope of this survey. About 59 percent of the total reported asphalt mixture tonnage produced using RTR came from California, where legislative mandates require the wide-spread use of RTR in asphalt pavements (Caltrans, 2017). The total reported tons of asphalt mixture using RTR jumped approximately 66 percent to 1,621,245 tons (about 0.86 percent of total reported tons for 2018) in the 2018 construction season survey, reflecting at least in part increased reporting of RTR use by California producers responding to the 2018 survey.

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

To give a picture of the total market size for RTR, the U.S. Tire Manufacturers Association (USTMA) reports that 24.2 percent of U.S. scrap tires were processed into an estimated 1 million tons of RTR in 2017. Of this, about 11.7 percent (118,900 tons) of RTR was used in asphalt pavement mixtures and surface treatments, such as seal coats, in 2017 (USTMA, 2018). USTMA conducts its scrap tire analysis biennially, so there is no data for 2018; however, using the 2017 USTMA estimate, the RTR use reported by 2018 construction season survey respondents makes up nearly 17 percent of the total RTR estimated by USTMA as used in asphalt pavement mixtures and surface treatments.

Table 17: Reported Tons of Asphalt Mixtures Using Recycled Tire Rubber and Reported Tons of RTR Used, 2014–2018

State	Reported Tons of Asphalt Mixtures Using RTR					Reported Tons of RTR Used				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Arizona	12,000	11,500	273,200	242,000	342,000	142	100	3,412	4,600	4,303
Arkansas	—	—	—	—	1,000	—	—	—	—	5
California	623,953	936,100	1,042,976	407,500	953,444	9,173	13,514	15,840	5,765	13,412
Delaware	—	—	8,000	—	2,500	—	—	40	—	10
Florida	198,046	110,000	32,288	22,392	9,895	419	356	135	145	136
Georgia	162,000	—	50,000	—	63,626	750	—	200	—	378
Illinois	—	3,500	15,500	—	125,000	—	36	79	—	750
Indiana	—	5,000	—	—	—	—	140	—	—	—
Kentucky	—	—	—	3,000	—	—	—	—	20	—
Louisiana	—	—	—	5,000	—	—	—	—	35	—
Massachusetts	81,882	79,680	71,500	145,333	77,000	1,146	1,090	841	1,603	710
Michigan	9,300	2,780	1,350	12,500	4,500	51	17	0.7	125	55
Missouri	—	—	—	100,000	36,000	—	—	—	1,500	260
Nevada	—	—	—	23,000	—	—	—	—	275	—
New Hampshire	50,000	8,400	365	—	—	780	114	—	—	—
New Mexico	—	—	15,000	—	—	—	—	—	—	—
Ohio	23,000	6,000	—	6,300	—	150	60	—	65	—
Oregon	—	5,000	6,000	—	—	—	—	—	—	—
Pennsylvania	—	—	5,260	—	—	—	—	25	—	—
South Carolina	—	—	10,000	—	—	—	—	18	—	—
Tennessee	—	—	10,000	—	—	—	—	50	—	—
Texas	40,000	50,000	—	11,000	6,280	200	—	—	40	98
Utah	—	3,500	—	—	—	—	61	—	—	—
Virginia	—	—	—	1,200	—	—	—	—	13	—
Washington	—	6,500	—	—	—	—	—	—	—	—
Wisconsin	—	5,000	—	—	—	—	30	—	—	—
Total	1,200,181	1,234,960	1,541,439	974,725	1,621,245	12,811	17,518	20,641	14,186	20,117
No. of Companies	19	22	26	19	21					

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. Producers in 12 states reported using steel slag, and in eight states reported using blast furnace slag during the 2018 construction season; in six of these states — Alabama, Indiana, Michigan, Missouri, Ohio, and Tennessee — producers reported using 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, n.d.), as seen in Figure 20.

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 21, but since 2017 reported slag utilization has rebounded significantly. This rebound in slag utilization is likely the fluctuating number of companies reporting slag use and the specific companies that did or did not participate in each survey. Missouri had consistently reported the use of a modest amount of foundry sand each year of the survey prior to this year.

The U.S. Geologic Survey estimates that about 17.6 million tons of slag was sold in 2018 (USGS, 2019). About 11.8 percent of this (2.07 million tons) is used in asphalt pavement mixtures (van Oss, 2017). With 1.75 million tons of slag materials reported as being used in asphalt mixtures during the 2018 construction season, this survey captures nearly 85 percent of total slag estimated to be used in asphalt pavement mixtures. For the states reporting slag use, slightly more than 21 percent of their total reported asphalt pavement mixture tonnage includes steel and/or blast furnace slag. According to the American Foundry Society, between 4 million and 7 million tons of foundry sand are available for recycling annually (AFS, n.d.), which means only a 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, 2014–2018

State & Material	Reported Tons of Mixture Using Material					Reported Tons of Material Used				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Steel Slag										
Alabama	837,083	400,000	475,000	755,764	985,000	112,480	95,000	55,000	164,229	195,500
Arkansas	84,900	229,800	60,210	49,005	148,533	12,735	60,000	9,109	10,238	26,658
Illinois	56,407	70,000	5,271	10,000	4,002	21,991	19,000	2,600	8,100	869
Indiana	111,800	245,000	140,000	132,500	328,214	41,500	90,000	64,000	45,929	110,777
Iowa	57,689	27,623	—	25,000	75,000	9,432	4,111	—	4,500	13,000
Kentucky	125,000	—	—	45,853	—	15,000	—	—	4,603	—
Michigan	754,131	1,549,291	—	367,652	1,847,249	136,382	225,819	—	259,252	225,818
Minnesota	238,000	268,000	134,000	140,000	115,000	34,000	37,500	17,800	28,500	20,000
Mississippi	—	22,803	35,000	—	5,000	—	3,000	500	—	250
Missouri	—	—	—	—	38,599					6,431
Ohio	185,125	220,000	85,000	145,868	145,000	60,133	40,000	18,000	30,556	30,000
Tennessee	—	40,000	—	—	30,000	—	8,000	—	—	3,000
Washington	416,000	305,000	—	413,000	395,000	60,000	56,700	—	53,300	48,000
Total	2,866,135	3,382,517	934,481	2,064,642	4,116,597	503,653	639,130	167,009	609,207	680,303
No. of Companies	15	19	12	18	23					
Blast Furnace Slag										
Alabama	100,000	15,000	210,000	177,933	375,000	10,000	10,000	30,000	39,379	85,500
Illinois	40,000	20,000	—	—	—	10,000	15,000	—	—	—
Indiana	375,000	—	1,007,000	1,001,700	1,660,356	150,000	—	179,900	336,413	548,431
Iowa	15,000	—	—	—	—	1,500	—	—	—	—
Kentucky	828,243	100,000	500,000	600,000	150,000	191,067	25,000	80,000	100,000	30,000
Michigan	329,000	500,000	—	393,239	470,015	43,750	2,000	—	156,741	110,220
Mississippi	—	—	—	11,534	—	—	—	—	1,150	—
Missouri	—	—	—	—	1,630	—	—	—	—	489
Ohio	794,6000	884,000	696,219	660,395	595,263	145,105	208,268	176,333	164,861	149,580
Tennessee	—	—	—	—	60,000	—	—	—	—	6,000
West Virginia	1,065,382	748,922	695,572	150,000	1,052,500	190,000	183,357	100,987	22,500	137,958
Wisconsin	—	5,500	—	—	—	—	795	—	—	—
Total	3,547,225	2,273,422	3,108,791	2,994,801	4,364,764	741,422	444,420	567,220	821,044	1,068,178
No. of Companies	21	12	13	13	18					
Foundry Sand										
Missouri	22,310	10,000	15,960	10,000	—	2,231	500	1,596	1,000	—
Texas	—	—	—	—	50,000	—	—	—	—	4,800

— = No Use Reported

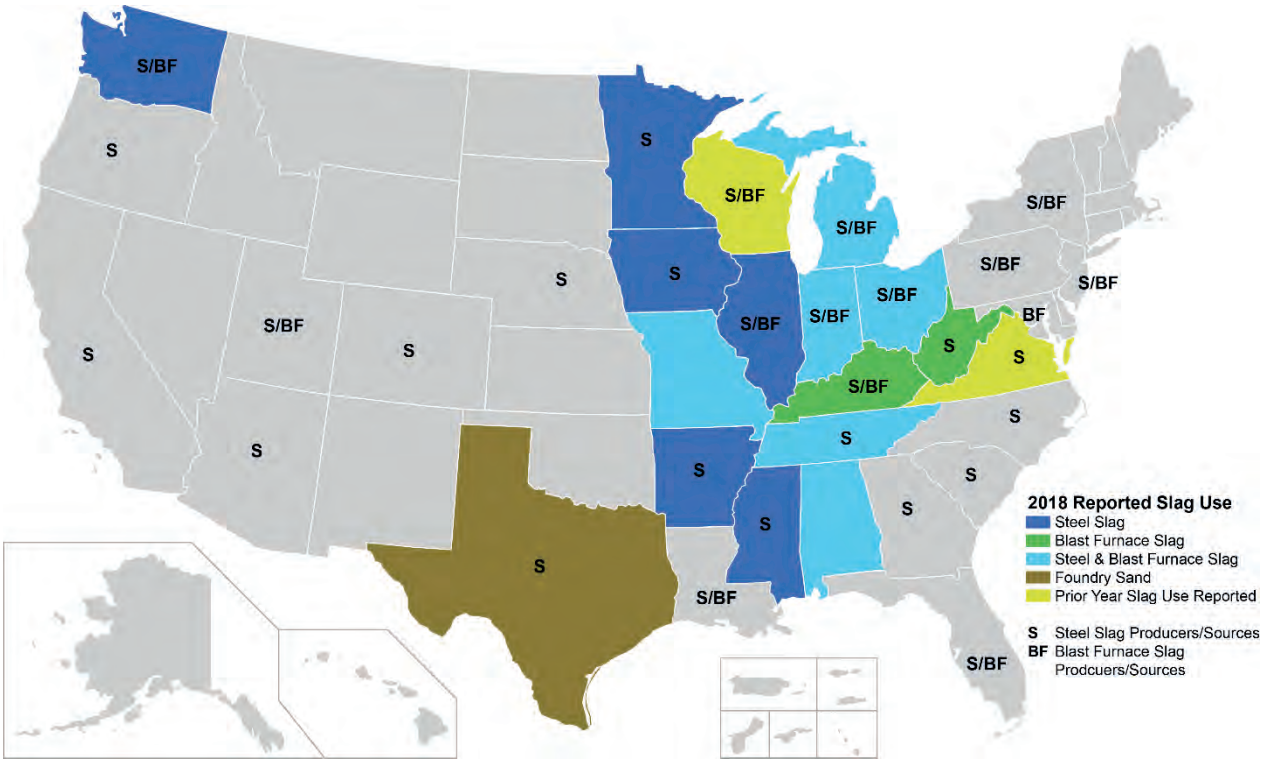


Figure 20: States Reporting Steel and/or Blast Furnace Slag Use and Slag Producers/Sources, 2018

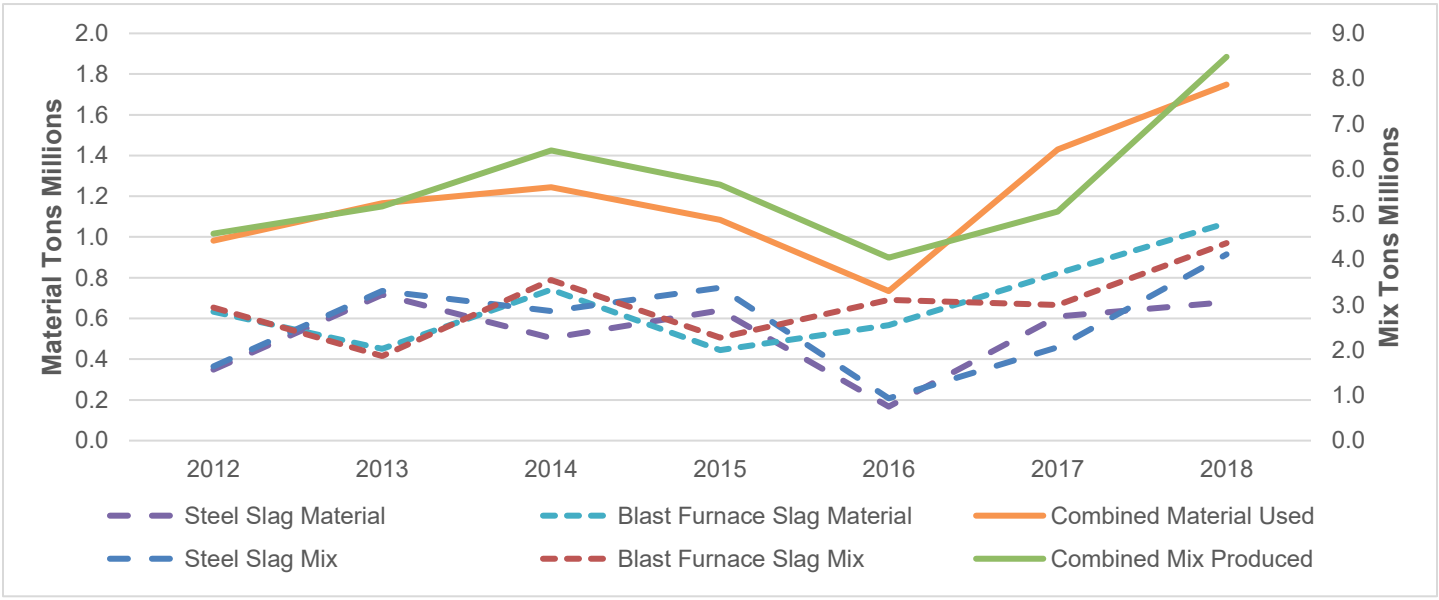


Figure 21: Steel and Blast Furnace Slag Use, 2012–2018

Recycled Fibers

Table 19 summarizes the use of various types of recycled fibers used in asphalt mixtures. For the 2018 construction season, producers reporting using recycled cellulose fibers, as well as recycled carbon fiber recovered from aerospace-grade composite waste materials. In 2016 a small amount of recycled poly fibers were reported. 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 2018 construction season, producers from 22 states reported using more than 8,700 tons of recycled fibers in more than 1.8 million tons of asphalt pavement mixture.

Table 19: Recycled Fibers, 2014–2018

State & Material	Reported Tons of Mixture Produced Using Recycled Fibers*					Reported Tons of Other Recycled Fibers*				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Cellulose Fibers										
Alabama	—	100,000	—	193,268	196,000	—	500	—	720	655
Alaska	—	1,000	—	—	—	—	—	—	—	—
Arkansas	—	—	—	—	250	—	—	—	—	1
California	—	—	—	—	36,865	—	—	—	—	55
Connecticut	—	—	—	—	500	—	—	—	—	2
Delaware	—	—	20,000	—	12,000	—	—	60	—	36
Dist. of Columbia	—	—	—	—	1,006	—	—	—	—	5
Florida	73,600	92,000	94,903	165,863	193,450	311	147	71	663	362
Georgia	—	—	—	—	370,934	—	—	—	—	1,170
Idaho	—	—	—	—	1,500	—	—	—	—	5
Illinois	—	126,150	—	—	—	—	240	—	—	—
Indiana	—	22,000	—	—	—	—	1	—	—	—
Kentucky	—	—	—	—	35,000	—	—	—	—	105
Louisiana	1,500	22,260	—	—	—	30	45	—	—	—
Maryland	120,000	85,000	100,000	125,000	138,000	360	230	300	373	414
Massachusetts	—	—	2,000	—	—	—	—	3	—	—
Michigan	—	—	—	145,200	151,728	—	—	—	84	231
Minnesota	—	—	—	—	14,000	—	—	—	—	22
Mississippi	—	—	53,998	40,173	60,000	—	—	153	121	400
Missouri	—	56,000	—	60,000	136,000	—	100	—	180	3,108
New Jersey	—	5,000	—	—	—	—	—	—	—	—
New York	700	1,605	1,640	—	500	1	—	9	—	1
North Dakota	—	—	65,000	—	—	—	—	195	—	—
Ohio	—	10,220	3,000	6	16,750	—	90	—	0	50
Oregon	—	20,000	—		—	—	8	—		—
Pennsylvania	—	12,952	45,000	21,000	84,300	—	—	90	88	211
South Carolina	—	20,000	—	—	—	—	—	—	—	—
Tennessee	—	175,940	127,845	113,000	27,000	—	80	201	300	180
Texas	36,000	50,300	—	20,000	79,700	44	15	—	60	554
Utah	—	—	122,317	120,696	149,135	—	—	570	336	746
Virginia	74,000	61,000	30,000	—	116,000	120	183	90	—	348
Washington	—	—	—	—	5,000	—	—	—	—	100
Carbon Fibers										
Washington	—	—	—	—	2,000	—	—	—	—	50
Poly Fibers										
Maine	—	—	—	—	—	—	—	2	—	—
New Hampshire	—	—	—	—	—	—	—	5	—	—
Vermont	—	—	—	—	—	—	—	3	—	—
Total	305,800	861,427	665,703	1,004,206	1,825,618	866	1,643	1,754	2,925	8,761
No. of Companies	10	18	28	20	43					

*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

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 2018 construction season survey, fly ash was the only of these coal combustion products (CCP) reported as being used, as shown in Table 20. In previous survey years, limited use of bottom ash was reported in 2012 in South Dakota and in 2015 in Texas.

To give a picture of the total use of CCP in asphalt pavement mixtures, the American Coal Ash Association found that some 59,317 tons of fly ash, no bottom ash, no boiler slag, and 7,019 tons of FGD material from dry scrubbers were used as mineral filler in asphalt in 2017 (ACAA, 2018). Assuming utilization of CCP in asphalt pavement mixtures remained steady,[1] fly ash usage reported for the 2018 construction season survey is about 20.3 percent of total fly ash used as a mineral filler in asphalt pavements; however, only a very small amount (0.155 percent) of the 38.2 million tons of fly ash produced in 2017 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 20: Reported Tons of Asphalt Mixtures Using Coal Combustion Products and Reported Tons of CCP Used, 2014–2018

State & Material	Reported Tons of Asphalt Mixtures Using CCP*					Reported Tons of CCP Used*				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Fly Ash										
Alabama	—	—	—	58,253	160,000	—	—	—	2,625	5,100
Georgia	—	—	—	—	3,068	—	—	—	—	53
Illinois	—	—	—	95,750	—	—	—	—	1,500	
Michigan	—	50,000	—	—	—	—	—	—	—	—
Mississippi	15,000	—	19,000	141,767	—	600	—	750	4,253	—
Missouri	—	—	—	60,000	—	—	—	—	4,000	—
Tennessee	—	15,940	—	—	—	—	616	—	—	—
Texas	20,000	—	30,000	20,000	110,000	1,000	—	—	600	3,300
Wisconsin	26,000	102,500	160,000	40,000	60,000	1,500	6,150	9,500	4,000	3,600
Bottom Ash										
Texas	—	1,000	—	—	—	—	1,000	—	—	—
Total (All CCP)	61,000	169,440	209,000	415,770	333,068	3,100	7,766	10,250	16,978	12,053
No. of Companies	3	4	3	10	5					

*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 21 summarizes other recycled materials reported as used in asphalt mixtures, including crushed concrete aggregates and plant start-up waste during the 2018 construction season. In previous years, producers have also reported the use of recycled glass and petroleum-contaminated soil in asphalt pavement mixtures.

Table 21: Other Recycled Materials, 2014–2018

State & Material	Reported Tons of Mixture Produced Using Other Recycled Material*					Reported Tons of Other Recycled Material Used*				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Crushed Concrete Aggregates										
Florida	—	—	—	—	10,000	—	—	—	—	1,000
Petroleum-Contaminated Soil										
Massachusetts	—	35,000	—	—	—	—	1,050	—	—	—
Plant Start-Up Waste										
Missouri	—	—	—	—	15,000	—	—	—	—	4,000
Recycled Glass										
Florida	—	1,000	—	—	—	—	200	—	—	—
Total	—	36,000	—	—	25,000	—	1,250	—	—	5,000

*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

[1] ACAA typically reports prior-year production and usage of CCP in the fourth quarter of the following year. Therefore, in this report, ACAA CCP usage data from 2017 is compared to reported CCP usage in asphalt mix production during the 2018 construction season.

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 2018 construction season. Asphalt mixture producers from 49 states, two territories, and the District of Columbia completed the 2018 survey. Responses came from 272 companies with data from 1,328 production plants. Data collected was compared to annual data from previous surveys since the 2009 construction season.

The survey findings for 2018 regarding the use of RAP, RAS, and WMA are summarized in Table 4.

Comparing the 2018 results to 2017 construction season, estimated total asphalt mixture production saw a slight increase from 379.4 million tons to 389.3 million tons, a 2.6 percent increase. DOT tonnage was down 2.9 percent, but this was offset by a 12.8 percent increase in tonnage for the Other Agency sector, and a 2.4 percent increase in tonnage for the Commercial & Residential sector for 2017 to 2018.

The use of RAP has risen dramatically since the 2009 construction season survey; year-over-year growth slowed through 2017, but 2018 saw a 7.9 percent increase over 2017.

The 2018 construction season survey shows:

Reclaimed Asphalt Pavement

- The total estimated tons of RAP used in asphalt mixtures reached 82.2 million tons in 2018. This represents a greater than 46.8 percent increase in the total estimated tons of RAP used in 2009. During the same time frame, total asphalt mixture tonnage increased only 8.6 percent.
- The percentage of producers reporting use of RAP was 97.4 percent of respondents which is down 0.6 percent from 2016 and 2017.
- The average percent RAP used by all sectors has seen variable growth from 2009 to 2018. The average estimated percentage of RAP used in asphalt mixtures has increased from 15.6 percent in 2009 to 21.1 percent in 2018.
- Companies reporting having stockpiled RAP on hand at year-end increased slightly from 93.3 percent in 2017 to 94.5 percent in 2018. In total, producers accepted an estimated 101.1 million tons and used an estimated 90.9 million tons in 2018.
- Reclaiming 101.1 million tons of RAP for future use saved about 61.4 million cubic yards of landfill space.
- The total estimated amount of RAP stockpiled nationwide at the end of the 2018 construction season was 110.3 million tons.
- Producers from 40 states reported fractionating RAP. Nationally, a reported 24 percent of RAP is fractionated.
- Producers from 35 states reported using softer binders and 22 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.

Reclaimed Asphalt Shingles

- Use of both recycled MWAS and PCAS in asphalt mixtures increased (11.6 percent) from an estimated 944,000 tons in 2017 to 1.05 million tons in 2018.
- The amount of unprocessed RAS accepted by asphalt mixture producers decreased from 935,000 tons in 2017 to 890,000 tons in 2018. An estimated 430,000 tons of processed RAS was also accepted by producers, which was about 119,000 tons more processed RAS than was accepted in 2017. The combined amount of unprocessed and processed RAS accepted in 2018 was 1.32 million tons, which was 217,000 tons more RAS than was used for all purposes during the 2018 construction season.

- Of the unprocessed RAS accepted by producers in 2018, 534,000 tons was PCAS and 356,000 tons was MWAS.
- Of the RAS used in 2018, more than 96 percent was used in asphalt mixtures. The remainder was combined with aggregates. No producers reported landfilling of RAS during the 2018 construction season.
- The percent of producers reporting use of RAS decreased from 26.9 percent of respondents in 2017 to 24.6 percent in 2018.
- The total estimated amount of RAS stockpiled nationwide at the end of the 2018 construction season was nearly 1.37 million tons.
- Accepting 890,00 tons of unprocessed RAS from both PCAS and MWAS sources diverted about 540,000 cubic yards of material from landfills.
- The number of states with producers reporting RAS use decreased to 27 states in 2018. Colorado producers for the first time since the 2013 survey reported not using RAS, but did report that RAS is still allowed in asphalt mixtures by the Other Agency and Commercial & Residential sectors.
- Commercial & Residential sectors allow the use of RAS in most states, 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 nine states reportedly do not approve the use of RAS in asphalt pavement mixtures for any sector.
- Producers from 15 states reported using softer binders and nine states reported using recycling agents in RAS mixtures.

Material Cost Savings

- The use of RAP and RAS saved more than $2.9 billion during the 2018 construction season compared to the use of all virgin materials. This is about $626 million more savings realized than in 2017. These savings help reduce material costs for asphalt pavement mixtures, allowing road owners to achieve more roadway maintenance and construction activities within limited budgets.
- The diversion of RAP and RAS from landfills during the 2018 construction season save more than 61 million cubic yards of space in C&D landfills, as well as nearly $4.6 billion in gate fees associated with the disposal of RAP and RAS.

Other Recycled Materials

- A reported total of nearly 1.8 million tons of other recycled materials was used in nearly 12.3 million tons of asphalt mixtures by 79 companies in 31 states during the 2018 construction season.
- Twenty-one producers from 11 states reported use of recycled tire rubber (RTR) in asphalt mixtures during the 2018 construction season. The total reported tons of asphalt mixture using RTR increased 66 percent from 2017 to 1,621,000 tons in the 2018 construction season.
- Producers in 12 states reported use of steel or blast furnace slags, and one state reported the use of foundry sand in 2018. Compared to reported use in 2017, the reported tons of mixtures including steel slag and mixtures including blast furnace slag increased dramatically during the 2018 construction season. Reported use of these materials was concentrated along the Mississippi and Ohio River Valleys, where much of U.S. steel and iron production is concentrated.
- Producers in four states reported using fly ash in asphalt mixtures in 2018. Fly ash was the only coal combustion product (CCP) reported as being used in asphalt pavement mixtures during the 2018 construction season.
- Producers in 23 states reported use of more than 8,000 tons of recycled cellulose fiber in more than 1.8 million tons of asphalt pavement mixtures during 2018.

Warm Mix Asphalt

The use of WMA technologies continues to increase since 2009. The 2018 construction season survey shows:

- The estimated total tonnage of asphalt pavement mixtures produced with WMA technologies for the 2018 construction season was about 157.7 million tons. This was a 7 percent increase from the estimated 147.4 million tons of mixture produced with WMA technologies in 2017 and a more than 839 percent increase from the estimated 16.8 million tons in the 2009 construction season.
- Mixtures produced with WMA technologies made up 40.5 percent of the total estimated asphalt mixture market in 2018. About 50.5 percent (79.5 million tons) of these mixtures were produced with a temperature reduction of at least 10°F.
- In addition, producers using WMA technologies in five states — Idaho, Louisiana, Massachusetts, Mississippi, Oklahoma, and Utah — reported producing more than 75 percent of their total tonnage with WMA technologies.
- Production plant foaming, representing just over 63 percent of the market in 2018, remains the most commonly used warm-mix technology, despite decreasing about 33.8 percent since its peak in the 2011 construction season.
- Chemical additive technologies accounted for a little more than 34 percent of the market in 2018, an increase of 6.5 percent from their use in the 2017 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.
- There appears to be little variation in the use of WMA technology based upon production temperature.
- About 68 percent of survey respondents reported producing asphalt mixture with WMA technologies; 185 producers in 44 states reported using WMA technologies.

Conclusions

The 2018 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 has slowed.

The amount of RAP received was 10.2 million tons more than what producers utilized during the 2018 construction season, with 94.5 percent of producers indicated they have stockpiled RAP on hand. With an estimated 110.3 million tons of RAP stockpiled nationwide at year-end 2018, an 8 percent increase over year-end 2017 inventories, 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 11.5 percent increase in 2018 in asphalt pavement mixtures; by accepting 1.320 million tons of waste shingles during 2018, producers diverted about 10 percent of the nation’s available waste shingles for use in asphalt mixtures. An estimated 1.37 million tons of RAS was stockpiled nationwide at year-end 2018. 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 2018 construction season, slags and other metal foundry byproducts were reported in 13 states, RTR use was reported in 11 states, recycled cellulose use was reported in 23 states, and fly ash use in four states.

The tonnage of asphalt pavement mixtures produced with WMA technologies saw a 7 percent increase during the 2018 construction season with a total production of 157.7 million tons, which represents 40.5 percent of total estimated asphalt mixture production for the year. Producers in Alaska, American Samoa, Hawaii, Montana, Rhode Island, Vermont, and West Virginia reported not producing mixtures with WMA technologies in 2018.

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