Information Series 138

Asphalt Pavement Industry Survey on

Recycled Materials and Warm-Mix Asphalt Usage 2015

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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 mix production. Additional benefits include improved compaction of asphalt mixtures leading to improved pavement performance, as well as a longer paving season. WMA was chosen for accelerated deployment in federal-aid highway, state department of transportation, and local road projects as part of FHWA's 2010 Every Day Counts initiative.

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

The asphalt industry remains the country's most diligent recycler with more than 99 percent of reclaimed asphalt pavement being put back to use. The average percentage of RAP used in asphalt mixtures has increased from 15.6 percent in 2009 to 20.3 percent in 2015. In 2015, the estimated RAP tonnage used in asphalt mixes was 74.2 million tons. This represents more than 3.7 million tons (21 million barrels) of asphalt binder conserved, along with the replacement of some 71 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 1.93 million tons in 2015, which is a slight (1.6 percent) decline from RAS tonnage in 2014.

The combined savings of asphalt binder and aggregate from using RAP and RAS in asphalt mixes is estimated at more than $2.6 billion.

More than 1.11 million tons of other recycled materials were reported as being incorporated into asphalt pavement mixtures during the 2015 construction season, included ground tire rubber, blast furnace slag, steel slag, and cellulose fibers.

The estimated total production of WMA for the 2015 construction season was 119.8 million tons. This was a greater than 5 percent increase from the estimated 113.8 million tons of WMA in 2014, and a more than 614 percent increase from the estimated 16.8 million tons in the 2009 construction season. WMA made up about one-third of the total estimated asphalt mixture market in 2015.

Plant foaming, representing 72 percent of the market, is the most commonly used warm-mix technology; chemical additive technologies accounted for a little more than 25 percent of the market.

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List of Abbreviations

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

On the Cover

Route 17 in Stafford County, Virginia, was widened in 2016 with more than 92,500 tons of warm-mix asphalt that incorporated 35 percent RAP in the base layer, 30 percent RAP in the intermediate layer, and 15 percent RAP in the surface course. Superior Paving Co. of Bristow, Virginia, won a NAPA 2016 Quality in Construction Green Paving Award for the project.

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2015

Executive Summary

The results of the asphalt pavement industry survey for the 2015 construction season show that asphalt mix 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, ensuring pavement performance and long life; conserve energy; reduce emissions from production and paving operations; and improve conditions for workers.

The objective of this survey, first conducted for the 2009 and 2010 construction seasons, was to quantify the use of recycled materials, primarily RAP and RAS, as well as the production of WMA by the asphalt pavement industry. For the 2015 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 mix producers from 48 states and one territory completed the 2015 construction season survey. A total of 214 companies/branches with 1,119 plants were represented in the survey.

The following are highlights of the survey of usage during the 2015 construction season:

- Asphalt mixture producers remain the country's most diligent recyclers, with more than 99 percent of asphalt mix reclaimed from old asphalt pavements being put back to use in new pavements.
- The total estimated tons of RAP used in asphalt mixes reached 74.2 million tons in 2015. This is a nearly 3 percent increase from the 2014 construction season, and represents a greater than 32 percent increase from the total estimated tons of RAP used in 2009. During the same time frame, total tonnage increased only 1.8 percent.
- The percent of producers reporting use of RAP decreased slightly from 100 percent of respondents in 2014 to 99 percent in 2015. Three producers reported landfilling a small amount of RAP during 2015.
- RAP usage during the 2015 construction season is estimated to have reduced the need for 3.7 million tons (21 million barrels) of asphalt binder and nearly 70.5 million tons of aggregate, with an estimated value in excess of $2.4 billion.
- The total estimated amount of RAP stockpiled nationwide at the end of the 2015 construction season was 85.1 million tons.
- Fractionated RAP represents about 23 percent of RAP use nationwide, and the tons of RAP mixtures produced using softer binders are estimated at 24 percent while tons produced using rejuvenators is estimated at 3 percent.
- The total estimated tons of RAS used in asphalt mixes decreased slightly (1.6 percent) to an estimated 1.93 million tons in 2015. Still, the use of RAS in the 2015 construction season increased 175 percent from the estimated 701,000 tons used in asphalt mixtures in 2009.

- RAS usage during the 2015 construction season is estimated to have reduced the need for 386,200 tons (2.1 million barrels) of asphalt binder and nearly 965,500 tons of aggregate, with an estimated value of about $194 million.
- Other recycled materials commonly used in asphalt mixtures during the 2015 construction season were ground tire rubber, blast furnace slag, steel slag, and cellulose fibers. Less commonly used recycled materials in asphalt mixtures included fly ash and foundry sand.
- The estimated total production of WMA for the 2015 construction season was 119.8 million tons. This was a greater than 5 percent increase from the estimated 113.8 million tons of WMA in 2014, and a more than 614 percent increase from the estimated 16.8 million tons in the 2009 construction season.
- WMA made up about one-third of the total estimated asphalt mixture market in 2015.
- Plant foaming, representing 72 percent of the market, is the most commonly used warm-mix technology; chemical additive technologies accounted for a little more than 25 percent of the market.

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2015

Background

A shared goal of the Federal Highway Administration (FHWA) and the National Asphalt Pavement Association (NAPA) is to support and promote sustainable practices, such as incorporation of recycled materials in pavement mixtures and the use of warm-mix asphalt (WMA). Reclaimed asphalt pavement (RAP) is recycled at a greater rate than any other material in the United States and helps lower overall material costs, allowing road owners to achieve more roadway maintenance and construction activities within limited budgets. Another recycled material used in asphalt mixtures is reclaimed asphalt shingles (RAS) from both manufacturing waste (MWAS) and post-consumer asphalt shingles (PCAS). The use of RAP and RAS in asphalt pavements can reduce the amount of new asphalt binder and aggregates required in mixes, which can help stabilize the price of asphalt mixtures and save natural resources. Other recycled materials commonly incorporated into asphalt pavements include ground tire rubber (GTR), steel slag, blast furnace slag, and cellulose fibers, among others. 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, and use higher percentages of RAP (Prowell et al., 2012). As part of FHWA's original group of Every Day Counts initiatives, WMA was chosen in 2010 for accelerated deployment in federal-aid highway, state department of transportation (DOT), and local road projects (FHWA, 2013). In 2013, WMA was honored with the Construction Innovation Forum's NOVA Award for its engineering, economic, and environmental benefits (CIF, 2013).

FHWA works closely with the pavement industry through associations and other stakeholders to promote pavement recycling technologies and WMA. From 2007 to 2011, the American Association of State Highway and Transportation Officials (AASHTO) conducted a biennial survey of state DOTs' use of recycled materials (Copeland, 2011; Copeland et al., 2010; Pappas, 2011). The results of the AASHTO survey 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 mix producers. These efforts have established a baseline for RAP, RAS, and WMA usage, and have tracked growth in the use of these sustainable practices in the highway industry since 2009.

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

Objective and Scope

The objective of this effort is to quantify the use of recycled materials and WMA technologies by the asphalt pavement industry. During 2016, NAPA conducted 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 2015 construction season. While keeping specific producer data confidential, NAPA staff compiled the amount of asphalt mixtures produced; the amount of RAP, RAS, and other recycled material used; and the amount of WMA produced in the United States. Not measured in this survey is the use of in-place asphalt pavement recycling techniques, such as full-depth reclamation (FDR), cold in-place recycling (CIR), and hot in-place recycling (HIR). Some cold central plant recycling (CCPR) of RAP may be included in Table 5 among the tons reported as "Used in Other" or "Used in Cold Mix."

Survey Methodology

The data are analyzed and summarized in this report. To accomplish this work, the following tasks were conducted:

1. Develop an online survey that enables an analysis of the quantities of recycled materials being used in asphalt mixtures, as well as the total amount of WMA produced nationally.
2. Conduct a voluntary survey of asphalt mix producers throughout the United States and follow up with verbal requests for information in locations where responses were low.
3. Estimate the total asphalt mixture market in each state or territory by using data provided by SAPAs and the U.S. Department of Transportation federal-aid highway apportionment to determine a weighting factor for each state and reconciling the total U.S. asphalt mix tonnage with national estimates.
4. Analyze and summarize the information nationally and by state and prepare a final report.

The survey was conducted using an online survey platform, SurveyMonkey®. Table 1 summarizes the questions asked in each section of the survey. Sections 1 through 4 have remained consistent from the 2009 to 2014 construction seasons. Additional questions (highlighted in yellow in Table 1) were added to Sections 2 through 4 for the 2015 construction season to gather additional information about the use of RAP, RAS, and WMA. Section 5 was added in the 2012 construction season survey to collect information on the use of other recycled material in asphalt mixtures. For 2015, the Section 5 question asking about specific recycled materials was modified to replace one user-provided response with cellulose fiber. A copy of the survey form used to gather information for the 2015 construction season is provided as Appendix A.

Producers were notified of the survey through several forums and electronic media. A notice was posted in NAPA's e-newsletter, *ActionNews*, informing members of the survey and asking for their participation. SAPAs solicited participation by placing notices on their websites and in their newsletters. Announcements were made at NAPA meetings, as well as at several state asphalt conferences. A press release was sent to construction industry trade media, and was published in print and online. Notices of the survey and links were shared through social media channels, including Twitter, Facebook, and LinkedIn.

Asphalt mixture producers then went to the SurveyMonkey website to complete the survey form. Some producers submitted PDF forms and the data were entered into SurveyMonkey by NAPA. Some multistate producers submitted data using a spreadsheet developed by NAPA. After the initial data was gathered and analyzed, anomalies in individual producer records were identified and reconciled.

To determine the estimated total amount of RAP and RAS used and WMA produced nationwide and in each state, the total amount of asphalt mix produced in each state needed to be determined. Total tonnage of asphalt mix produced represents both commercial (i.e., private sector) and governmental (i.e., DOT and Other Agency) tonnages. Estimated tonnages for each sector were provided by SAPAs for 33 states/territories, totaling about 294 million tons. This includes one SAPA that supplied an estimate of DOT-only tonnage. For this one state, total tonnage was estimated by dividing the DOT tonnage provided by the SAPA by the percent of DOT tons reported through the survey by asphalt mixture producers in that state.

Table 1: Survey Questions Summary (Questions Added in 2015 Highlighted in Yellow)

Section 1: General Information	Section 2: RAP	Section 3: RAS	Section 4: WMA	Section 5: Other Recycled Materials
Number of Plants	Tons Accepted	Tons Unprocessed Shingles Accepted	Average % Produced for DOT Tons	Were Other Recycled Materials Used (Y/N)
DOT Tons	Tons Used in HMA/WMA	Tons Processed Shingles Accepted	Average % Produced for Other Agency Tons	Other Recycled Materials Used (GTR, Steel Slag, Blast Furnace Slag, Cellulose Fiber, Up to Two User-Provided Responses)
Other Agency Tons	Tons Used in Aggregate	Tons Used in HMA/WMA	Average % Produced for Commercial & Residential Tons	Tons of HMA/WMA Produced Using Each Recycled Material
Commercial & Residential Tons	Tons Used in Cold Mix	Tons Used in Aggregate	Chemical Additive %	Tons of Each Other Recycled Product Used
	Tons Used in Other	Tons Used in Cold Mix	Additive Foaming %	
	Tons Landfilled	Tons Used in Other	Plant Foaming %	
	Average % for DOT Mixes	Tons Landfilled	Organic Additive %	
	Average % for Other Agency Mixes	Average % for DOT Mixes	Were WMA Additives Used to Produce Mixtures at HMA Temperatures (Y/N)	
	Average % for Commercial & Residential Mixes	Average % for Other Agency Mixes		
	Excess RAP (Y/N)	Average % for Commercial & Residential Mixes		
	Percentage of RAP Fractionated	Excess RAS (Y/N)		
	Percentage of RAP Mixtures Using Softer Asphalt Binder	What Sectors Allow RAS		
	Percentage of RAP Mixtures Using Rejuvenators	Estimated percent of RAS Binder Blending with New Asphalt Binder		
	Tons of RAP Stockpiled			

To estimate the total tons in states where a SAPA estimate of total tonnage was not available, a power curve relationship based on an examination of the relationship between SAPA-estimated tons and federal-aid highway apportionment for those states was determined, resulting in Equation 1. This is the same methodology used to estimate tonnage in previous versions of this survey, and is detailed in Hansen & Newcomb (2011).

$$\text{Total Estimated Tons} = 0.0784 \times (\text{State Federal Apportionment})^{0.9058} \quad [1]$$

Appendix B and certain tables in this report detail survey responses and estimated values on a state-by-state basis. To keep specific producer data confidential, no state-specific information is provided in the tables or appendix if fewer than three producers from the state responded to the survey. Information from states with fewer than three responding companies is included in the estimated national values, however.

Survey Results

Asphalt mixture producers from 48 states and one territory completed the survey for the 2015 construction season, which is one fewer jurisdiction than in 2014. No plants in the District of Columbia, New Mexico, or South Dakota contributed data for 2015. A total of 214 companies/branches with 1,119 plants are represented in the 2015 survey. This is down slightly from the 2013 and 2014 construction season surveys, but is equal to or greater than other construction seasons surveyed. While the total number of companies/branches and plants represented in the survey decreased, the total tons reported increased from 151.0 million to 152.8 million tons. This may be due to a slight increase in total asphalt mix production and producers shutting down some less productive or less efficient plants. Table 2 summarizes the number of asphalt mix production companies/branches and the number of plants reporting for each state. Table 3 summarizes the total number of plants responding in previous years.

Table 2: No. of Companies/Branches Completing 2015 Construction Season Survey by State

State	Cos.	Plants	State	Cos.	Plants	State	Cos.	Plants
Alabama	4	34	Kentucky	6	44	Ohio	4	67
Alaska	*	*	Louisiana	*	*	Oklahoma	5	13
American Samoa	NCR	NCR	Maine	*	*	Oregon	4	12
Arizona	*	*	Maryland	6	17	Pennsylvania	8	33
Arkansas	6	18	Massachusetts	4	13	Puerto Rico	*	*
California	4	50	Michigan	5	38	Rhode Island	*	*
Colorado	4	21	Minnesota	7	27	South Carolina	5	10
Connecticut	*	*	Mississippi	3	18	South Dakota	NCR	NCR
Delaware	*	*	Missouri	4	18	Tennessee	8	56
District of Columbia	NCR	NCR	Montana	*	*	Texas	8	52
Florida	6	35	Nebraska	*	*	U.S. Virgin Islands	NCR	NCR
Georgia	*	*	Nevada	*	*	Utah	8	21
Guam	NCR	NCR	New Hampshire	3	11	Vermont	*	*
Hawaii	*	*	New Jersey	*	*	Virginia	7	39
Idaho	6	18	New Mexico	NCR	NCR	Washington	5	30
Illinois	15	35	New York	12	72	West Virginia	3	13
Indiana	4	36	North Carolina	8	56	Wisconsin	3	57
Iowa	6	18	North Dakota	*	*	Wyoming	*	*
Kansas	4	20	No. Mariana Islands	NCR	NCR			

NCR = No Companies/Branches Reporting * = Fewer than 3 Companies/Branches Reporting

Table 3: Summary of Jurisdictions (States or Territories), Companies/Branches, and Plants Represented, 2009–2015

Year	No. Jurisdictions Reporting	No. of Companies/Branches Reporting	No. of 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

Table 4 includes state-by-state 2015 construction season total estimated tonnage, as estimated by the SAPA or from Equation 1; tonnage reported by survey respondents; and the percent of reported tons included in estimated tons. The closer a state's percentage is to 100% indicates the completeness of reported tonnage compared to estimated tonnage.

At the national level, the survey responses make up 42 percent of the estimated total tons for the 2015 construction season.

Table 4: Summary of 2015 Estimated and Reported Plant Mix Asphalt Tons by State

State	Tons, Millions		Reported % of Estimated	State	Tons, Millions		Reported % of Estimated
	Estimated	Reported			Estimated	Reported	
Alabama	7.50	3.73	50%	Montana	4.08	*	*
Alaska	4.71	*	*	Nebraska	3.03	*	*
Arizona	6.76	*	*	Nevada	3.53	*	*
Arkansas	3.20	1.87	58%	New Hampshire	1.77	1.30	73%
California	25.51	9.33	37%	New Jersey	8.66	*	*
Colorado	7.20	1.51	21%	New Mexico	3.50	NCR	NCR
Connecticut	3.10	*	*	New York	16.80	7.22	43%
Delaware	1.71	*	*	North Carolina	11.00	5.93	54%
District of Columbia	1.72	NCR	NCR	North Dakota	3.04	*	*
Florida	14.39	6.04	42%	Ohio	17.4	11.01	63%
Georgia	5.00	*	*	Oklahoma	6.28	2.06	33%
Hawaii	1.72	*	*	Oregon	4.85	1.67	34%
Idaho	3.98	1.06	27%	Pennsylvania	19.42	4.60	24%
Illinois	15.80	5.19	33%	Puerto Rico	1.00	*	*
Indiana	10.50	5.06	48%	Rhode Island	2.28	*	*
Iowa	3.60	1.47	41%	South Carolina	5.45	1.66	30%
Kansas	4.00	1.90	48%	South Dakota	2.05	NCR	NCR
Kentucky	6.50	4.09	63%	Tennessee	7.76	5.50	71%
Louisiana	4.00	*	*	Texas	20.00	8.27	41%
Maine	2.27	*	*	Utah	3.49	3.26	93%
Maryland	7.50	3.30	44%	Vermont	2.10	*	*
Massachusetts	6.20	2.86	46%	Virginia	12.50	6.75	54%
Michigan	12.60	7.07	56%	Washington	5.34	3.47	65%
Minnesota	13.50	6.14	45%	West Virginia	3.50	1.72	49%
Mississippi	4.50	2.09	46%	Wisconsin	11.00	8.15	74%
Missouri	6.00	1.61	27%	Wyoming	2.59	*	*
				Total	364.91	152.79†	42%

NCR No Companies Reporting

* Fewer than 3 Companies/Branches Reporting

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

SAPA Estimated Tons

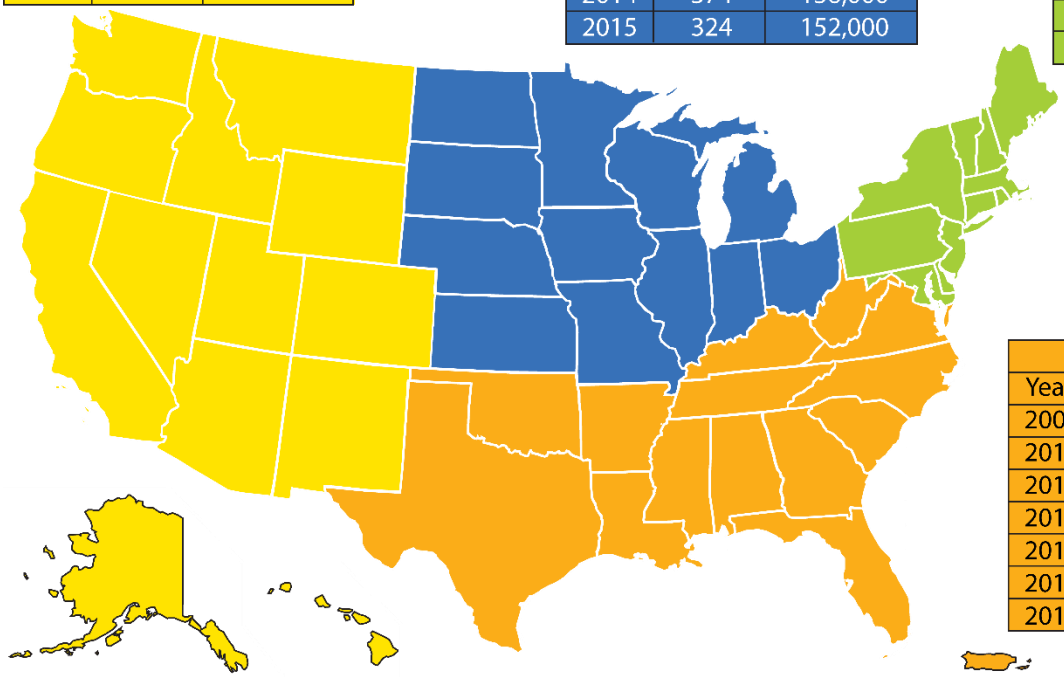
Figure 1 shows the number of plants, as well as the average tons produced per plant, separated by User/Producer Group (UPG) region. While the number of plants responding from each UPG region (apart from the North East Asphalt User/Producer Group), decreased from the 2014 to 2015 construction season, the tons per plant for all UPGs increased. Significant increases were noted for the North Central Asphalt User/Producer Group (NCAUPG) and North East Asphalt User/Producer Group (NEAUPG) regions.

Number of Plants Responding to Survey by User/Producer Group

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

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

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



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

Figure 1: Number of Plants Responding to Survey by User/Producer Group Regions and Estimated Tonnage, 2009–2015

Table 5 summarizes the RAP, RAS, and WMA data from the 2015 construction season survey alongside data from the 2014 construction season survey (Hansen & Copeland, 2015) for comparison. The information requested in the survey is summarized in Table 1 and detailed in Appendix A. The column labeled “Reported Values” in Table 5 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” were determined as outlined in the Survey Methodology.

For the amount of RAP accepted, asphalt mix producers were asked “How many tons of removed asphalt pavement and asphalt millings were accepted/delivered to your facilities in the state in 2015?” For the amount of RAS accepted, producers were asked “How many tons of unprocessed shingles (manufacturing waste and post-consumer/tear-off) were accepted/delivered to your facilities in the state in 2015?” For the 2015 construction season, producers were also asked how many tons of processed RAS was acquired from shingle processors. These data are reported in Table 5 as the tonnage of material accepted. Producers were also asked 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 was also requested.

For each state, the tons of RAS and RAP reported as accepted and used were multiplied by the ratio of estimated production to total 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 5.

To understand the average percentage of recycled material used in mixes, producers were asked to report the average recycled content of mixes produced for each sector (DOT, Other Agencies, Commercial & Residential). If precise data was not available, respondents were asked to provide their best estimate. These responses are reported in the "Average % Used in Mixes" section of Table 5 for RAP and RAS. To control for inaccuracies in producer estimates of sector-by-sector percentages, a "National Average All Mixes Based on Tons Used in HMA/WMA" was calculated and reported in Table 5 for both RAP and RAS based on reported tonnage of each material used in HMA/WMA mixes divided by the total reported tons produced. Producers were not asked about allowable RAP limits or binder replacement requirements, which can influence demand for mixes that incorporate these materials.

Producers were asked to give their best estimate of the percent of asphalt paving mixtures produced for each sector when WMA technology resulted in a temperature reduction of 10°F to 100°F. These percentages were multiplied by the total mix production for each sector to determine the total estimated tons of WMA produced for each sector. The survey methodology was designed so that only mixes produced at reduced temperatures are reported. Some WMA additives are also used for construction benefits unrelated to the goal of reducing production temperatures; therefore, for the 2015 construction season producers were also asked if they used WMA additives to produce mixtures at HMA temperatures.

Engineering Recycled Asphalt Mixtures for Quality

For more than three decades, two guiding principles of asphalt recycling have been: 1) mixtures containing RAP should meet the same requirements as mixes with all virgin materials, and 2) mixes containing RAP should perform equal to or better than virgin mixtures. 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 mixes have been successfully designed and produced for many years. The proof is in performance: a recent study comparing the performance of recycled versus virgin mixes 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 standard Superpave mix design procedures for each layer outperformed companion test sections with all virgin materials in all pavement performance measures.

However, as the amount and mix of recycled materials in asphalt pavement mixtures increase, additional considerations for material handling, mixture design, and quality testing become more important. In particular, RAP and RAS should be tested and classified to determine the amount and qualities of available asphalt cement. 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 mix design. In some cases, it may be necessary to make use of rejuvenators or a softer asphalt binder to ensure the final mix design delivers the desired level of product performance.

For more information about processing and using reclaimed asphalt pavement and recycled asphalt shingles, consult the NAPA publication *Best Practices for RAP and RAS Management* (Quality Improvement Series No. 129) (West, 2016).

Table 5: Summary of RAP, RAS, WMA Data

	Reported Values		Estimated Values	
	2014	2015	2014	2015
Tons of HMA/WMA Produced	Tons, Millions		Tons, Millions	
Total	151.0	152.8	352.0	364.9
DOT	68.7	68.5	160.2	163.6
Other Agency	38.9	40.0	90.7	95.5
Commercial & Residential	43.3	44.3	101.1	105.8
Companies/Branches Reporting	228	214		
RAP	Tons, Millions		Tons, Millions	
Accepted	33.8	33.2	75.8	78.0
Used in HMA/WMA	32.2	32.7	71.9	74.2
Used in Aggregate	2.9	1.7	8.5	5.5
Used in Cold Mix	0.1	0.1	0.2	0.2
Used in Other	0.2	0.4	0.6	1.6
Landfilled	0.1	0.4	0.2	1.0
	Avg. % Used in Mixes		Avg. % Used in Mixes	
Average % for DOT Mixes[1]	19.6%	17.8%		
Average % for Other Agency Mixes[1]	19.8%	18.2%		
Average % for Commercial & Residential[1]	22.7%	22.3%		
National Average All Mixes Based on RAP Tons Used in HMA/WMA[2]	21.3%	21.4%	20.4%	20.3%
Companies/Branches Reporting Using RAP	228	211		
RAS	Tons, Millions		Tons, Millions	
Unprocessed Shingles Accepted	0.692	0.456	1.664	1.129
Processed Shingles Accepted	N/A	0.375	N/A	0.842
Used in HMA/WMA	0.809	0.819	1.964	1.931
Used in Aggregate	0.018	0.004	0.043	0.009
Used in Cold Mix	—	—	0	—
Used in Other	0.002	—	0.006	—
Landfilled	—	—	0	—
	Avg. % Used in Mixes		Avg. % Used in Mixes	
Average % for DOT Mixes[1]	0.72%	0.76%		
Average % for Other Agency Mixes[1]	0.95%	0.88%		
Average % for Commercial & Residential[1]	1.47%	1.06%		
National Average All Mixes Based on RAS Tons Used in HMA/WMA[2]			0.54%	0.54%
Companies/Branches Reporting Using RAS	87	89		
WMA	% of Total Production		Tons, Millions	
DOT	37.8%	37.4%	56.9	60.9
Other Agency	34.9%	34.0%	28.4	28.5
Commercial & Residential	29.4%	34.3%	28.5	30.4
Total			113.8	119.8
	% of WMA Production			
Chemical Additive %	15.0%	25.2%		
Additive Foaming %	0.0%	2.1%		
Plant Foaming %	84.5%	72.0%		
Organic Additive %	0.5%	0.7%		
Companies/Branches Reporting Using WMA	174	166		

[1] Average percent based on contractor's reported percentage for each sector.

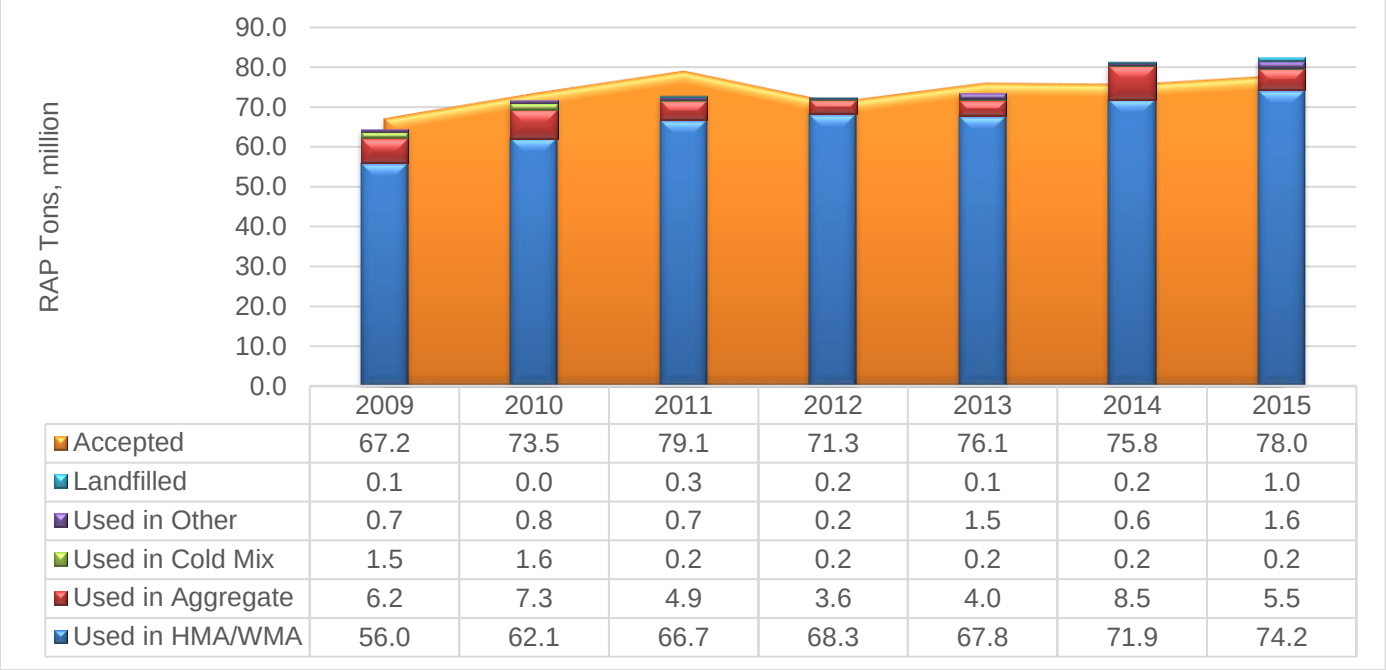
[2] Average percent based on total reported tons of RAP or RAS used in HMA/WMA divided by reported total tons HMA/WMA produced.

Reclaimed Asphalt Pavement

Table 5 includes the national summary of RAP data from the 2014 and 2015 construction season surveys. The information requested in the survey is detailed in Appendix A and summarized in Table 1, Section 2. State-level data is reported in Appendix B. Figure 2 is a visual representation of the estimated total tons of RAP used in asphalt mixes, aggregate, cold mix, and other uses, as well as the amount landfilled, from the 2009 to 2015 construction season surveys. The overwhelming majority of RAP is used in hot-mix asphalt (HMA) or warm-mix asphalt (WMA), which is the most optimal use of RAP. The tons used in cold mix data may include some cold central plant recycling of RAP, but is not intended to record the use of in-place recycling technologies.

From the 2014 to 2015 construction season, the amount of RAP used in HMA/WMA increased from 71.9 million to 74.2 million tons. The average percent RAP used in mixes decreased from 20.4 percent in 2014 to 20.3 percent in 2015. For 2015, 99 percent of companies/branches responding to the survey reported using RAP. This is a very slight decrease from the 100 percent of companies/branches reporting using RAP in 2013 and 2014.

Placement of RAP in construction and demolition landfills is rare. Since the beginning of the survey in 2009, the average amount of RAP landfilled is less than 150,000 tons per year, or 0.2 percent. For 2015, the amount of RAP landfilled increased significantly to 1 percent. It should be noted that only three producers reported sending RAP to a landfill.



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

Figure 2: Comparison of Tons of RAP Accepted and Tons of RAP Used or Landfilled (Million Tons), 2009–2015

RAP Use by Sector

Asphalt pavement mix 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 mix produced for public works agencies, including 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.

Figure 3 shows the total estimated amount 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 shows the average percentage of RAP used by each sector and total percentage of RAP used. The average percent RAP used by all sectors has seen variable growth from 2009 to 2015. The change in total percentage of RAP use has seen a decreased growth rate from 2009 to 2015. The growth rate decreased from 1.8 percent between 2009 and 2010 to 0.1 percent between 2014 and 2015.

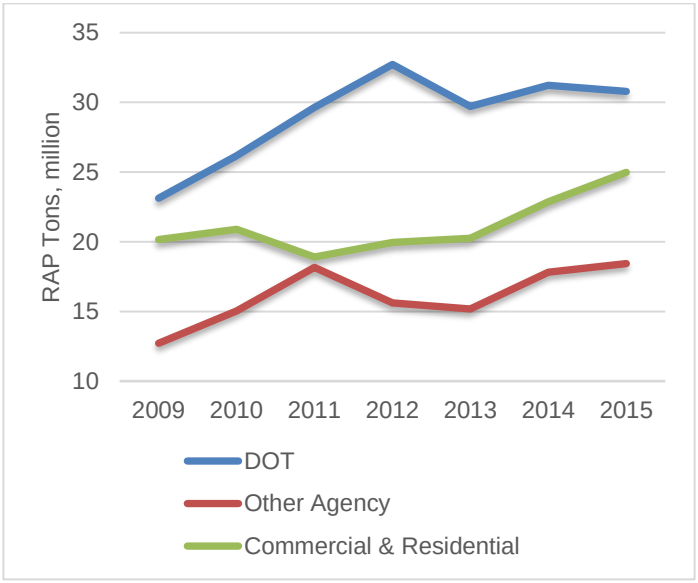


Figure 3: RAP Use by Sector (Million Tons)

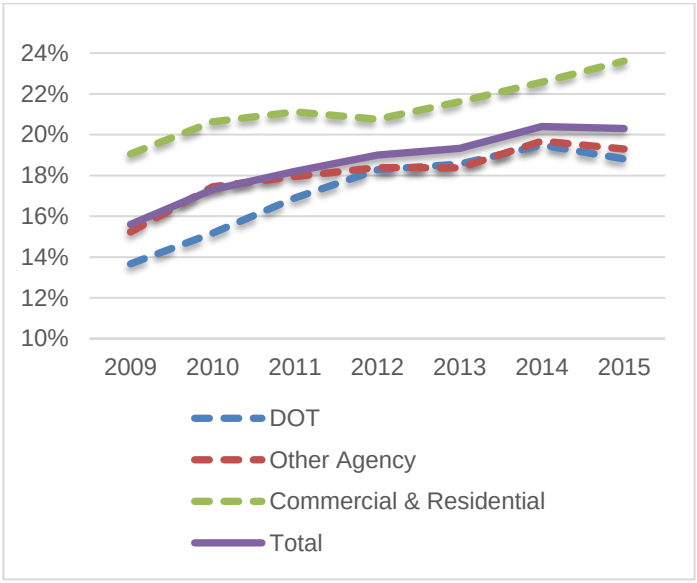


Figure 4: Average Percent RAP Used by Sector

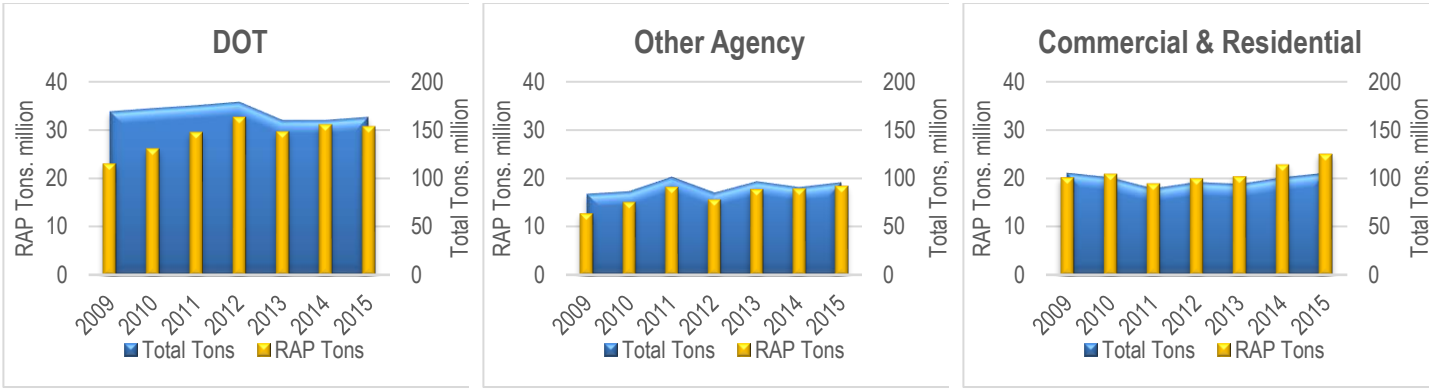


Figure 5: RAP Tons and Total Mix Tons Comparison (Million Tons)

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. This is shown in Figure 5. For the 2015 construction season, the percent RAP in the DOT and Other Agency sectors declined from 2014 to 2015, but it increased for the Commercial & Residential sector.

The increased percent of RAP used in the Commercial & Residential sector, combined with an increase in the tons of mix used for this sector offset declines in the DOT sector, resulting in an insignificant loss (0.1%) in the national average of percentage of RAP used.

RAP Use by State

Figure 6 and Table 6 show the average percent 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 each state and the total number of tons accounted for in the responses.

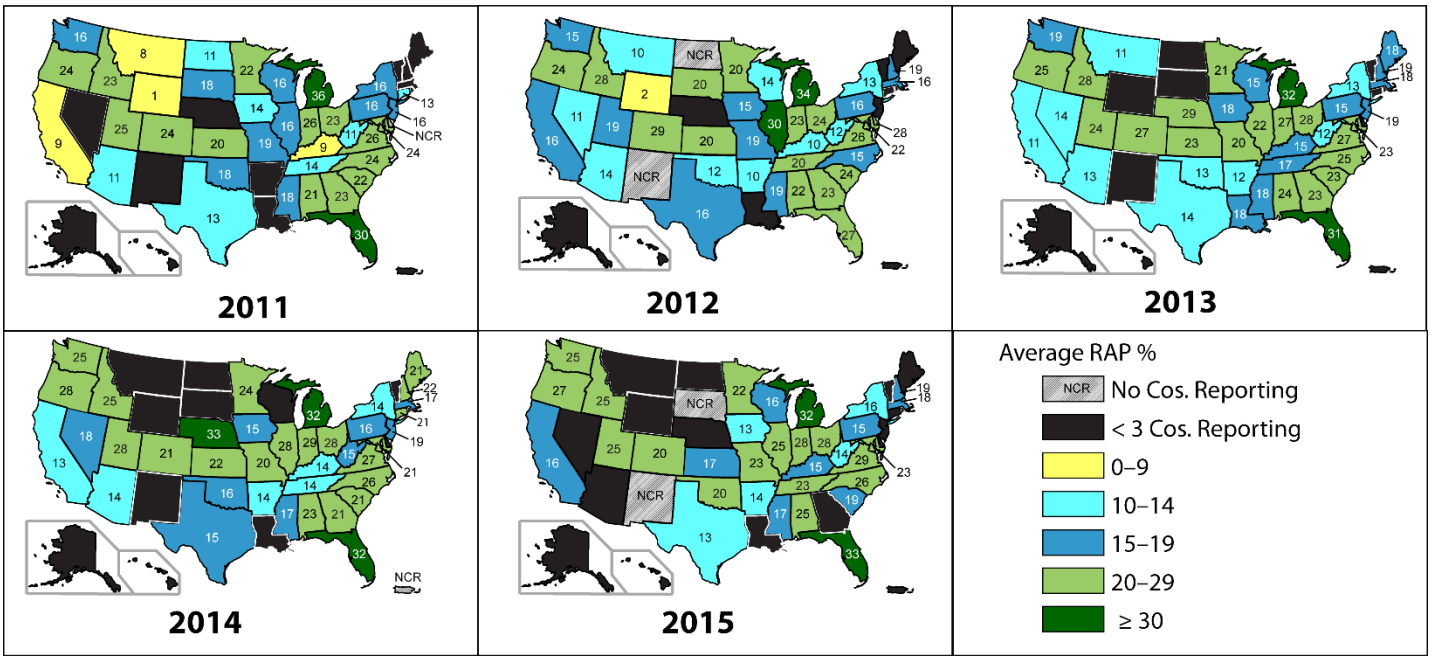


Figure 6: Estimated Average Percent of RAP by State for Each Construction Season Survey

Figure 7 revisualizes the Table 6 data, showing the number of states reporting average RAP percentages at the various ranges by construction seasons. The number of states reporting average RAP percentages greater than 20 percent has increased significantly, rising from nine states in 2009 to 27 states in 2014; however, for the 2015 construction season it decreased to 21 states. The number of states reporting RAP percentages less than 15 percent has decreased from 29 states in 2009 to just two states in 2014 and 10 states in 2015. While the states using RAP at high percentages (greater than 20 percent) decreased slightly from the 2014 to 2015 construction season, it is worth noting that states producing the greatest tonnages of asphalt pavement mixture have increased the percent of RAP used in their mixtures.

Table 6: Average Estimated RAP Percent

State	Average RAP Percent					State	Average RAP Percent				
	2011	2012	2013	2014	2015		2011	2012	2013	2014	2015
Alabama	21%	22%	24%	23%	25%	Montana	8%	10%	11%		
Alaska						Nebraska			29%	33%	
Arizona	11%	14%	13%	14%		Nevada		11%	14%	18%	
Arkansas		10%	12%	14%	14%	New Hampshire		19%	19%	22%	19%
California	9%	16%	11%	13%	16%	New Jersey	16%		19%	19%	
Colorado	24%	29%	27%	21%	20%	New Mexico		NCR			NCR
Connecticut	13%			21%		New York	16%	13%	13%	14%	16%
Delaware	NCR	28%				North Carolina	24%	15%	25%	26%	26%
Dist. of Columbia	NCR	NCR		NCR	NCR	North Dakota	11%	NCR			
Florida	30%	27%	31%	32%	33%	Ohio	23%	24%	28%	28%	28%
Georgia	23%	23%	23%	21%		Oklahoma	18%	12%	13%	16%	20%
Hawaii						Oregon	24%	24%	25%	28%	27%
Idaho	23%	28%	28%	25%	25%	Pennsylvania	16%	16%	15%	16%	15%
Illinois	16%	30%	22%	28%	25%	Puerto Rico				NCR	
Indiana	26%	23%	27%	29%	28%	Rhode Island					
Iowa	14%	15%	18%	15%	13%	South Carolina	22%	24%	23%	21%	19%
Kansas	20%	20%	23%	22%	17%	South Dakota	18%	20%			NCR
Kentucky	9%	10%	15%	14%	15%	Tennessee	14%	20%	17%	14%	23%
Louisiana			18%			Texas	13%	16%	14%	15%	13%
Maine			18%	21%		Utah	25%	19%	24%	28%	25%
Maryland	24%	22%	23%	21%	23%	Vermont					
Massachusetts		16%	18%	17%	18%	Virginia	26%	26%	27%	27%	29%
Michigan	36%	34%	32%	32%	32%	Washington	16%	15%	19%	25%	25%
Minnesota	22%	20%	21%	24%	22%	West Virginia	11%	12%	12%	15%	14%
Mississippi	18%	19%	18%	17%	17%	Wisconsin	16%	14%	15%		16%
Missouri	19%	19%	20%	20%	23%	Wyoming	1%	2%			

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

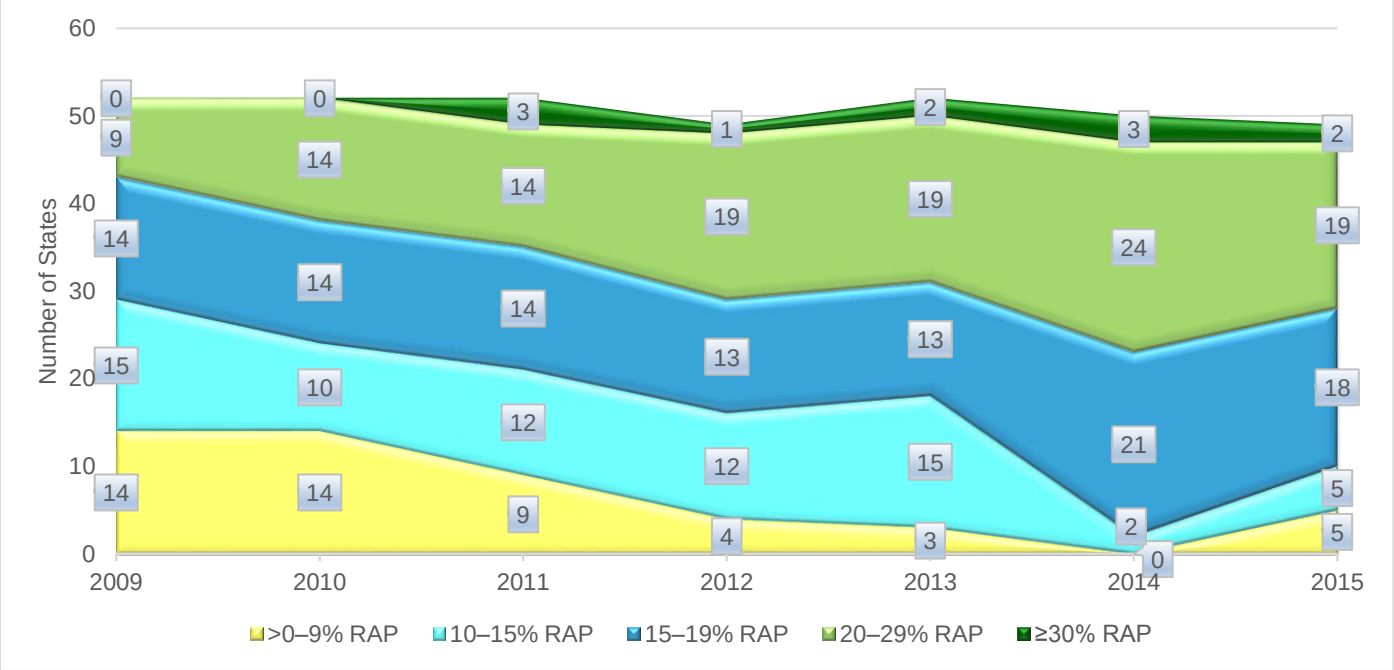


Figure 7: Count of States at Different Average RAP Percentages in HMA/WMA Mixtures

RAP Stockpiles

During the 2015 construction season, as in 2012 and 2014, more RAP was used across all purposes than was received, which indicates producers are drawing upon stockpiled RAP. For 2015, 88 percent of producers reported having excess RAP on hand, compared to more than 91 percent of producers in 2014.

Table 7 shows the reported and estimated amount of RAP stockpiled by state at the end of the 2015 construction season. To calculate the estimated values, reported tons of RAP 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 7 includes stockpiled tonnages from states with fewer than three producers reporting. As expected, the more densely populated states with large urban areas (e.g., California, Pennsylvania, Michigan, and Florida) show the highest amount of RAP stockpiled. While the amount is not shown in Table 7 because fewer than three companies/branches in the state responded to the survey, New Jersey has more RAP stockpiled (reported and estimated) than any other state.

Table 7: Reported Tons of RAP Stockpiled

State	Reported Tons Stockpiled (Million)	Estimated Tons Stockpiled (Million)	State	Reported Tons Stockpiled (Million)	Estimated Tons Stockpiled (Million)
Alabama	0.92	1.85	Montana	*	*
Alaska	*	*	Nebraska	*	*
Arizona	*	*	Nevada	*	*
Arkansas	0.20	0.34	New Hampshire	0.10	0.13
California	2.17	5.93	New Jersey	*	*
Colorado	0.24	1.15	New Mexico	NCR	NCR
Connecticut	*	*	New York	1.11	2.58
Delaware	*	*	North Carolina	1.63	3.02
District of Columbia	NCR	NCR	North Dakota	*	*
Florida	1.55	3.68	Ohio	1.98	3.13
Georgia	*	*	Oklahoma	0.55	1.67
Hawaii	*	*	Oregon	0.52	1.51
Idaho	0.26	0.72	Pennsylvania	0.97	4.11
Illinois	1.13	3.43	Puerto Rico	*	*
Indiana	1.69	3.51	Rhode Island	*	*
Iowa	0.20	0.48	South Carolina	0.11	0.35
Kansas	0.51	1.07	South Dakota	NCR	NCR
Kentucky	0.71	1.13	Tennessee	1.98	2.80
Louisiana	*	*	Texas	1.29	3.13
Maine	*	*	Utah	1.72	1.84
Maryland	0.77	1.76	Vermont	*	*
Massachusetts	0.51	1.10	Virginia	1.65	3.06
Michigan	2.32	4.14	Washington	0.56	0.87
Minnesota	1.64	3.61	West Virginia	0.05	0.11
Mississippi	0.57	1.22	Wisconsin	1.27	1.71
Missouri	0.20	0.76	Wyoming	*	*
			Total†	37.62	85.13

NCR No Companies/Branches Reporting

* Fewer than 3 Companies/Branches Reporting

† Includes Values from States with Fewer than 3 Companies/Branches Reporting

RAP Fractionation

Table 8 shows the average percent of RAP fractionated into two or more sizes by state, as reported by survey participants. These results are representative only of the survey participants and may not reflect completely practices in a given state. Producers were not questioned about state specifications regarding fractionation and recycled material content. As the scatter plot in Figure 8 shows, there does not seem to be a clear correlation between fractionation and the percentage of RAP used by a state. For example, Oklahoma reports 83 percent of RAP is fractionated and averages 20 percent RAP in mixes, while Florida reported no fractionation but averages 33 percent RAP.

Table 8: Reported Percent RAP Fractionated by State

State	Percent RAP Fractionated	State	Percent RAP Fractionated
Alabama	45%	Montana	*
Alaska	*	Nebraska	*
Arizona	*	Nevada	*
Arkansas	18%	New Hampshire	—
California	—	New Jersey	*
Colorado	26%	New Mexico	NCR
Connecticut	*	New York	15%
Delaware	*	North Carolina	34%
District of Columbia	NCR	North Dakota	*
Florida	—	Ohio	19%
Georgia	*	Oklahoma	83%
Hawaii	*	Oregon	3%
Idaho	8%	Pennsylvania	19%
Illinois	56%	Puerto Rico	*
Indiana	46%	Rhode Island	*
Iowa	—	South Carolina	24
Kansas	—	South Dakota	NCR
Kentucky	50%	Tennessee	20%
Louisiana	*	Texas	50%
Maine	*	Utah	6%
Maryland	—	Vermont	*
Massachusetts	6%	Virginia	34%
Michigan	10%	Washington	18%
Minnesota	—	West Virginia	—
Mississippi	43%	Wisconsin	2%
Missouri	—	Wyoming	*
		National Average†	23%

NCR No Companies/Branches Reporting

* Fewer than 3 Companies/Branches Reporting

† Includes Values from States with Fewer than 3 Companies/Branches Reporting

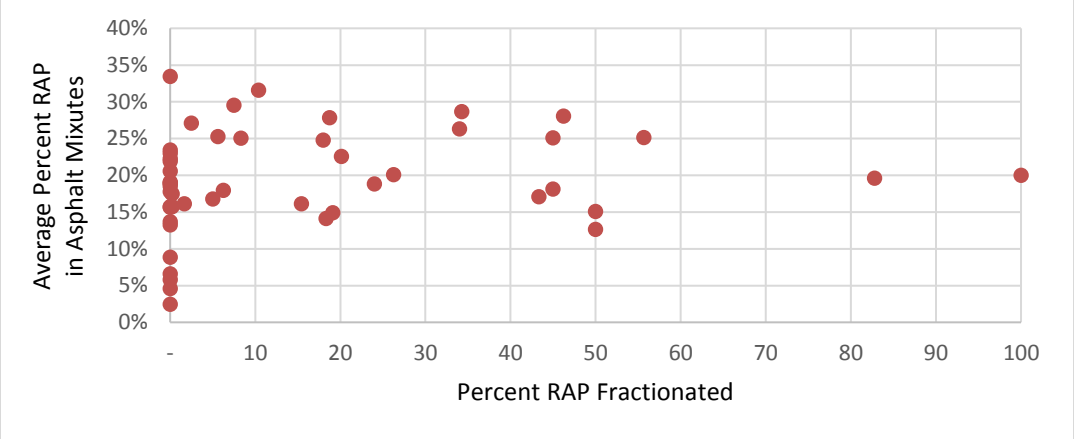


Figure 8: Scatter Plot Showing Reported Average Percentage of RAP in Asphalt Mixtures Relative to Reported Percent of RAP Fractionated

RAP Rejuvenator Use

Table 9 shows the percent of tons of RAP-containing mixtures produced using softer binder or rejuvenators by state. These results are representative only of the survey participants and may not reflect completely practices in a given state. While there is no strong relationship between the amount of RAP mixtures using softer binder or rejuvenators and percentage of RAP used by the state, it should be noted that most states using more than 20 percent RAP also report using softer binders or rejuvenators. One example is Florida, which averages 33 percent RAP in mixes and produces about 87 percent of mixtures with softer binder or rejuvenators.

Table 9: Percentage of RAP Mixes Using Softer Binder and/or Rejuvenators by State

State	Softer Binder	Rejuve-nators	State	Softer Binder	Rejuve-nators	State	Softer Binder	Rejuve-nators
Alabama	7%	2%	Louisiana	*	*	Ohio	28%	0%
Alaska	*	*	Maine	*	*	Oklahoma	9%	0%
Arizona	*	*	Maryland	6%	0%	Oregon	42%	11%
Arkansas	9%	0%	Massachusetts	10%	0%	Pennsylvania	8%	10%
California	3%	2%	Michigan	28%	0%	Puerto Rico	*	*
Colorado	54%	6%	Minnesota	8%	0%	Rhode Island	*	*
Connecticut	*	*	Mississippi	0%	0%	South Carolina	0%	0%
Delaware	*	*	Missouri	57%	19%	South Dakota	NCR	NCR
Dist. of Columbia	NCR	NCR	Montana	*	*	Tennessee	5%	29%
Florida	80%	7%	Nebraska	*	*	Texas	26%	0%
Georgia	*	*	Nevada	*	*	Utah	51%	16%
Hawaii	*	*	New Hampshire	0%	0%	Vermont	*	*
Idaho	75%	0%	New Jersey	*	*	Virginia	1%	0%
Illinois	68%	0%	New Mexico	NCR	NCR	Washington	4%	0%
Indiana	36%	0%	New York	2%	2%	West Virginia	0%	0%
Iowa	58%	18%	North Carolina	57%	0%	Wisconsin	4%	0%
Kansas	48%	3%	North Dakota	*	*	Wyoming	*	*
Kentucky	9%	0%				National Average†	24%	3%

NCR No Companies/Branches Reporting

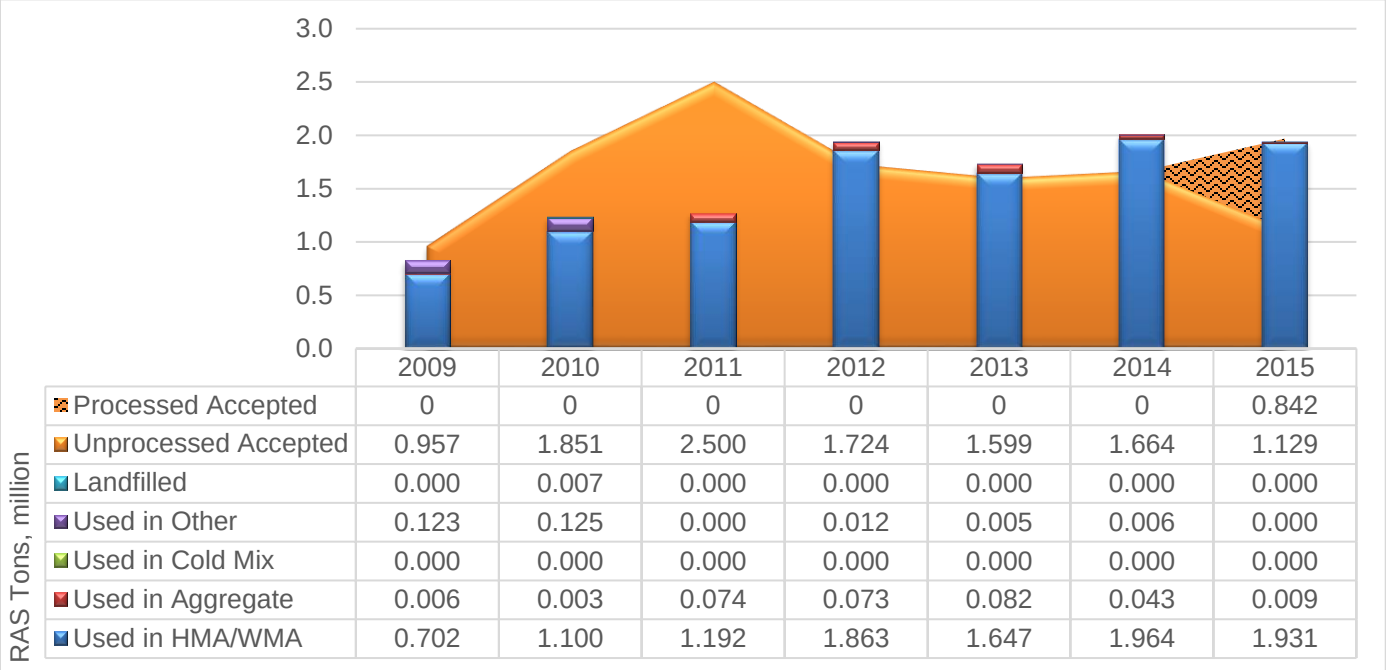
* Fewer than 3 Companies/Branches Reporting

† Includes Values from States with Fewer than 3 Companies/Branches Reporting

Reclaimed Asphalt Shingles

Table 5 includes the national summary of RAS data from the 2014 and 2015 construction season surveys. The information requested in the survey is detailed in Appendix A and summarized in Table 1, Section 3. State-level data is reported in Appendix B. Producers 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 mixes, aggregate, cold mix, and other uses, as well as the amount landfilled, from the 2009 to 2015 construction season surveys.

During the 2015 construction season, the total estimated amount of unprocessed and processed shingles received by producers was 1.971 million tons, which is slightly higher than the combined amount of RAS used in asphalt mixtures (1.931 million tons) and in aggregate (9,000 tons). This is a 2.1 percent decline from the 2.013 million total tons of RAS used during the 2014 construction season and is due in large part to a decrease in the average percent of RAS being used in Commercial & Residential sector mixes. As in 2014, during the 2015 construction season none of the RAS accepted by producers was landfilled. An estimated 13.2 million tons of waste shingles are produced annually;[1] therefore, asphalt mix producers in 2015 used nearly 15 percent of the total available supply of waste shingles.



RAS Tons, million

	2009	2010	2011	2012	2013	2014	2015
Processed Accepted	0	0	0	0	0	0	0.842
Unprocessed Accepted	0.957	1.851	2.500	1.724	1.599	1.664	1.129
Landfilled	0.000	0.007	0.000	0.000	0.000	0.000	0.000
Used in Other	0.123	0.125	0.000	0.012	0.005	0.006	0.000
Used in Cold Mix	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Used in Aggregate	0.006	0.003	0.074	0.073	0.082	0.043	0.009
Used in HMA/WMA	0.702	1.100	1.192	1.863	1.647	1.964	1.931

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

As shown in Figure 9, beginning in the 2012 construction season, producers began reporting using RAS in greater quantities than they accepted. When this trend was first noticed, producers were contacted to confirm the reported values. All producers contacted indicated they either had RAS stockpiled or were purchasing RAS from shingle processors. To capture the volume of processed shingles accepted by producers, the 2015 survey began asking producers "How many tons of processed shingles were accepted/delivered to your facilities in the state in 2015?" During the 2015 construction season, the estimated amount of unprocessed shingles accepted by producers declined 32 percent from 2014 to 1.129 million tons.

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

However, this decline in acceptance of unprocessed shingles was offset by the 842,000 tons of processed shingles accepted by producers (recorded for the first time in the 2015 construction season survey).

The number of companies/branches using RAS has increased from 87 in the 2014 construction season to 89 in 2015. This is below the 97 companies/branches reporting RAS usage in the 2012 and 2013 construction seasons; however, the percentage of companies reporting using RAS has held relatively steady at around 40 percent since 2012.

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 moderate increase in the tons of RAS used by DOTs from the 2014 to 2015 construction season due to an increase in total DOT mix tonnage and the percent RAS used in DOT mixtures. During this same period, RAS use by Other Agencies increased slightly while the Commercial & Residential sector saw a significant decrease in RAS use.

Figure 11 shows the average RAS percent used in asphalt mixes for the three sectors. 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. Overall, RAS use has seen relatively steady growth across all sectors from 2009 to 2015 with some year-to-year variation. Growth has been greatest in the Commercial & Residential (0.08 percent per year) and Other Agency (0.07 percent per year) sectors with slower growth in the DOT sector (0.04 percent per year).

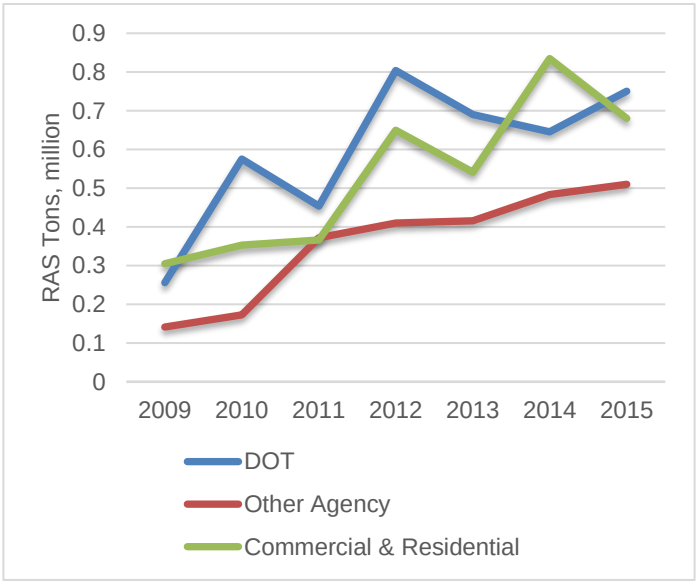


Figure 10: Estimated RAS Use by Sector (Million Tons)

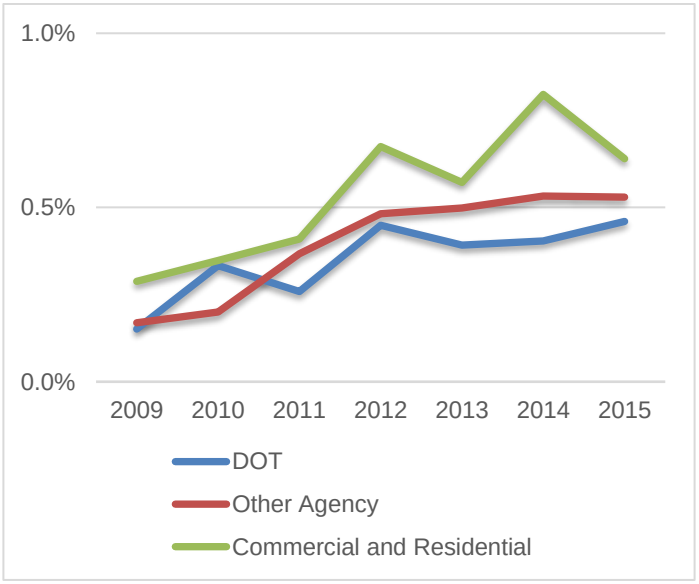


Figure 11: Average Percent RAS Used by Sector

In 2015 producers were also asked which sectors allow RAS to be included in asphalt mixtures. Thirty-two states provided responses, and this information is summarized in Table 10. All 32 states responding reported no limits on the use of RAS in the Commercial & Residential sectors. Thirteen DOTs reportedly allow RAS in some asphalt pavement mixes, and 11 DOTs allow it in all mixtures. RAS use is allowed in the Other Agency sector in 24 states; however, the responses do not distinguish between use allowed in all mixes versus just some mixes. Five states do not allow RAS in any public-sector (DOT or Other Agency) work, while three states (Kansas, Maryland, and North Carolina) allow RAS in at least some DOT mixes, but not in Other Agency mixes.

Table 10: Sectors Allowing RAS

State	RAS Allowed In?		
	DOT Mixes	Other Agency Mixes	Commercial & Residential Mixes
Alabama	Some Mixes	Allowed	Allowed
Arkansas	Some Mixes	Allowed	Allowed
California	Not Allowed	Not Allowed	Allowed
Colorado	Not Allowed	Not Allowed	Allowed
Connecticut	Not Allowed	Not Allowed	Allowed
Delaware	All Mixes	Allowed	Allowed
Florida	Not Allowed	Allowed	Allowed
Illinois	All Mixes	Allowed	Allowed
Indiana	All Mixes	Allowed	Allowed
Iowa	All Mixes	Allowed	Allowed
Kansas	Some Mixes	Not Allowed	Allowed
Kentucky	All Mixes	Allowed	Allowed
Maine	Some Mixes	Allowed	Allowed
Maryland	All Mixes	Not Allowed	Allowed
Massachusetts	Some Mixes	Allowed	Allowed
Minnesota	Some Mixes	Allowed	Allowed
Mississippi	Not Allowed	Not Allowed	Allowed
Missouri	Some Mixes	Allowed	Allowed
New Hampshire	Not Allowed	Not Allowed	Allowed
New York	Some Mixes	Allowed	Allowed
North Carolina	All Mixes	Not Allowed	Allowed
Ohio	Some Mixes	Allowed	Allowed
Oklahoma	Not Allowed	Allowed	Allowed
Oregon	Some Mixes	Allowed	Allowed
Pennsylvania	All Mixes	Allowed	Allowed
South Carolina	Some Mixes	Allowed	Allowed
Tennessee	All Mixes	Allowed	Allowed
Texas	Some Mixes	Allowed	Allowed
Vermont	Not Allowed	Allowed	Allowed
Virginia	Some Mixes	Allowed	Allowed
Washington	All Mixes	Allowed	Allowed
Wisconsin	All Mixes	Allowed	Allowed

RAS Use by State

Figure 12 shows states where asphalt pavement mixture producers reported using RAS from 2011 through 2015. Table 11 shows states where producers reported using RAS in 2009 through 2015. Red indicates states where RAS use was not reported that construction season. The number of states where producers reported using RAS increased annually from 22 in 2009 to 38 in 2013, but decreased to 34 in 2014 and 32 in 2015. Of the states reporting previous RAS use, only South Carolina, which reported using RAS in 2014, did not report using it in 2015. South Dakota, which reported using RAS in 2014, did not have any companies participate in the 2015 construction season survey.

Table 11: States Reporting RAS Use

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

NCR	= No Companies/Branches Reporting
Yes	= RAS Use Reported
No	= No RAS Use Reported

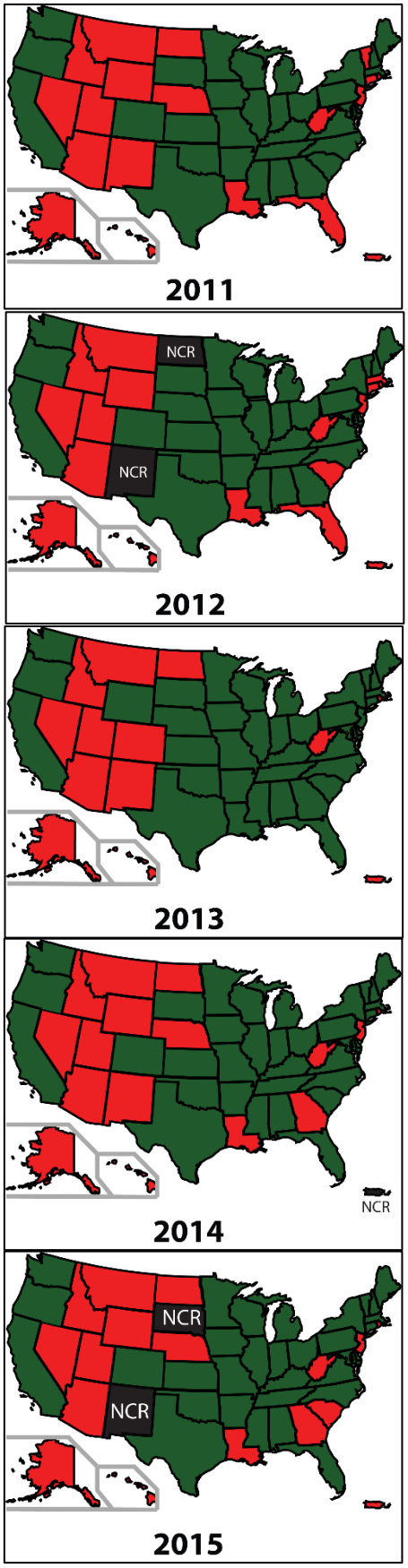


Figure 12: States with Companies/Branches Reporting Using RAS by Construction Season

Presumed RAS Binder Blending

For the 2015 construction season, producers were also asked what percent of the RAS binder do they assume is blending with new asphalt binders when performing mix designs. The amount of blending depends upon the properties of the aged asphalt in the RAS and is important to assure there is enough of the blended binder in mixtures to resist cracking (West, 2016). Lower blending values will normally increase the amount of virgin asphalt required in a mixture, and indicate that the amount of RAS added to mixtures could increase. Note that higher percentages of RAS will normally require the use of softer binders and/or rejuvenators.

Table 12 shows the minimum and maximum amount of assumed blending for the 31 states where producers responded to this question. In general, most responses fell between 60 and 80 percent, with a low of 40 percent and a high of 100 percent. It is important to note that these are reported assumptions used in mix designs, not formal design guidance or state specifications.

Table 12: Percent Presumed RAS Binder Blending with New Asphalt Binder

State	Min.	Max.	State	Min.	Max.
Alabama	60	85	Mississippi	70	70
Arkansas	70	80	Missouri	67	80
California	60	60	New Hampshire	75	75
Colorado	60	85	New York	60	60
Connecticut	70	70	North Carolina	75	90
Delaware	70	75	Ohio	75	80
Florida	50	50	Oklahoma	70	80
Illinois	50	100	Oregon	40	80
Indiana	60	80	Pennsylvania	75	90
Iowa	65	89	Tennessee	75	100
Kansas	60	80	Texas	24	75
Kentucky	75	75	Vermont	70	70
Maine	70	80	Virginia	75	95
Maryland	75	90	Washington	40	90
Massachusetts	70	70	Wisconsin	75	100
Minnesota	60	70			

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 benefit of resource preservation, the use of RAP and RAS can help lower 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 realized during the 2015 construction season from the use of RAP and RAS in asphalt mixtures.

Table 13: Material Savings, 2015

Material	Material Quantity, Million Tons	% Aggregate	% Asphalt Binder	Aggregate Cost Savings, $ Billion	Asphalt Binder Cost Savings, $ Billion	Total Cost Savings, $ Billion
RAP	74.2	95	5	$0.652	$1.781	$2.433
RAS	1.931	50*	20	$0.009	$0.185	$0.194
			Total	$0.661	$1.966	$2.627

* 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 2015 asphalt price indexes from 10 states (New Jersey, Maryland, Virginia, Ohio, Louisiana, Illinois, Georgia, Oregon, Missouri, and Florida). The average price of unmodified asphalts from these states for 2015 was about $470. Three of the states (Florida, Louisiana, and Virginia) also included price indexes for modified asphalts. The average modified asphalt prices from these states for 2015 was about $600. Assuming that 10 percent of asphalt mixtures use modified asphalt binders, the average price of asphalt binders used in asphalt mixtures is about $480 per ton.

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 crushed stone at about $9.50 per ton, and sand and gravel at about $7.00 per ton for 2015 (USGS, 2016). 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 is $9.25 per ton for the 2015 construction season.

Table 14: Material Cost Factors, 2015

Material		Cost/Ton	% of Market
Asphalt	Unmodified	$470	90
	Modified	$600	10
	Weighted Average	$480	
Aggregate	Crushed Stone	$9.50	90
	Sand and Gravel	$7.00	10
	Weighted Average	$9.25	

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 the shingle fibers can replace mineral or cellulose fibers.

Warm-Mix Asphalt

Table 5 includes the national summary of WMA data from the 2014 and 2015 construction season surveys. The information requested in the survey is detailed in Appendix A and summarized in Table 1, Section 4. State-level data is reported in Appendix B. The survey asked producers their estimated percentages of tons of asphalt mixture produced at reduced temperatures for the different sectors and the percent of which WMA technologies were used, as well as whether or not WMA technologies were used at HMA production temperatures.

The percent of companies/branches reporting the production of WMA saw rapid increases from the 2009 to 2011 construction seasons, but only modest increases from 2011 to 2013 and remaining essentially level from the 2013 to 2015 construction seasons, as shown in Figure 13.

WMA Use by Sector

Figure 14 shows a steady increase in the number of tons of WMA produced for each customer sector from 2011 to 2013, with modest increases continuing for the 2014 and 2015 construction seasons. WMA use reached almost 120 million tons in the 2015 construction season, which is a little less than one-third of the total asphalt mix production for the year, as is shown in Figure 15. This is probably attributable to increased acceptance of WMA by all sectors, as illustrated in Figure 14.

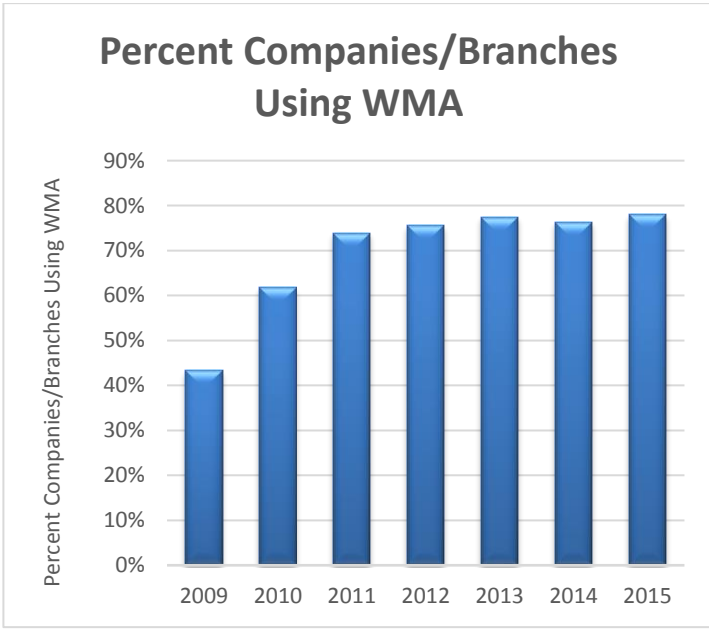


Figure 13: Percent of Companies/Branches Using WMA

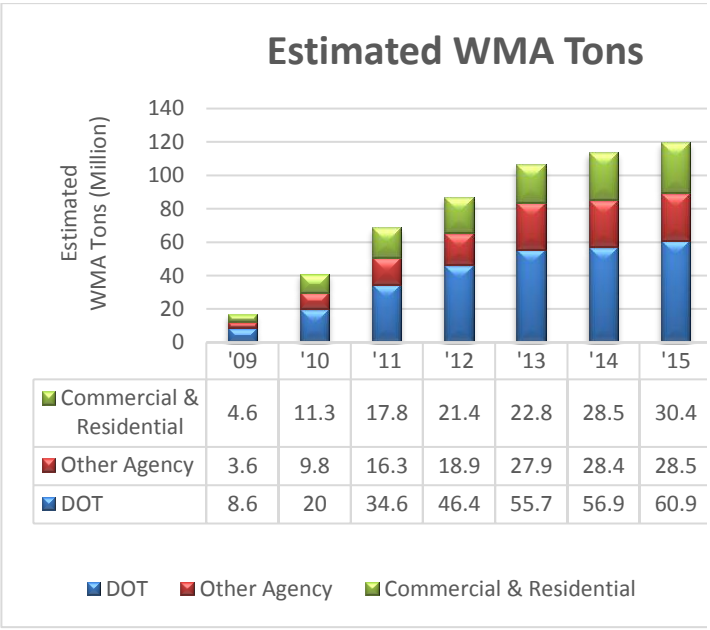


Figure 14: Estimated Tons (Millions) of WMA by Sector

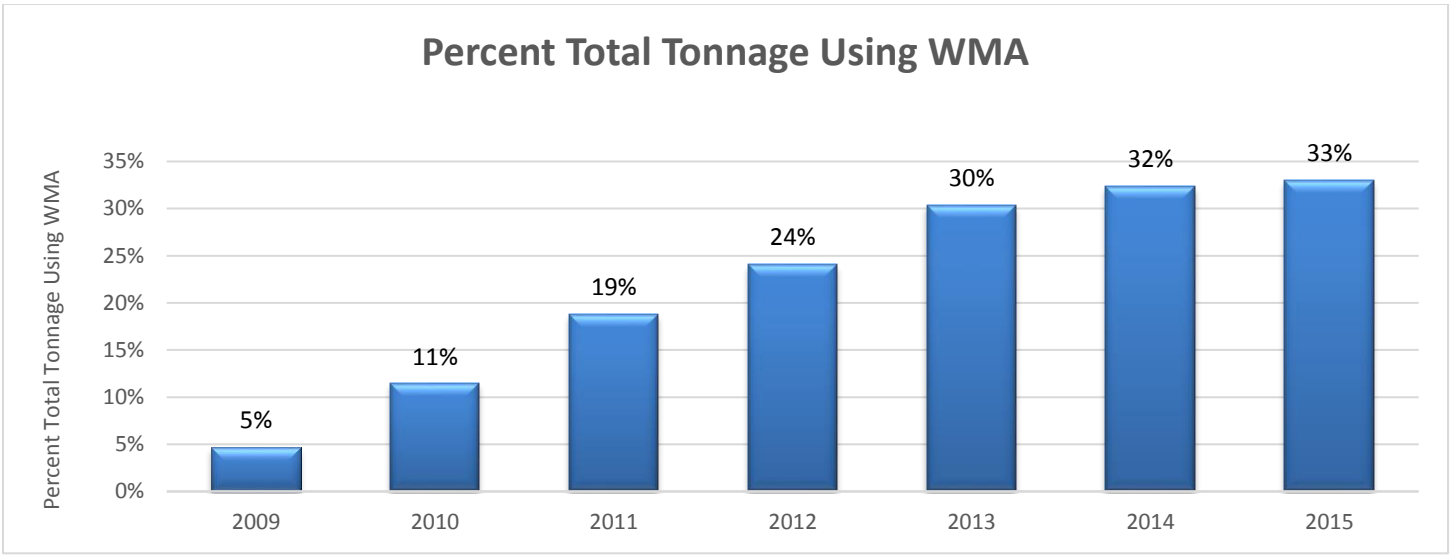


Figure 15: Percent of Total Tonnage Using WMA, 2009–2015

WMA Use by State

Figure 16 shows the estimated total tons of WMA produced in each state. It should be noted that the accuracy of data for individual states will vary depending on the number of responses received from each state and the total number of tons represented by the respondents. Nationally, the estimated total tons of WMA increased from 113.8 million tons in 2014 to 119.8 million tons in the 2015 construction season, a greater than 5 percent increase.

From 2014 to 2015, 18 states saw an increase of 5 percentage points or more in WMA production, while 14 states had a decrease of 5 percentage points or more in WMA production. Three states — Georgia, Michigan, and South Carolina — had an increase of 25 percentage points or more in WMA production. Georgia and Michigan had dramatic 38 and

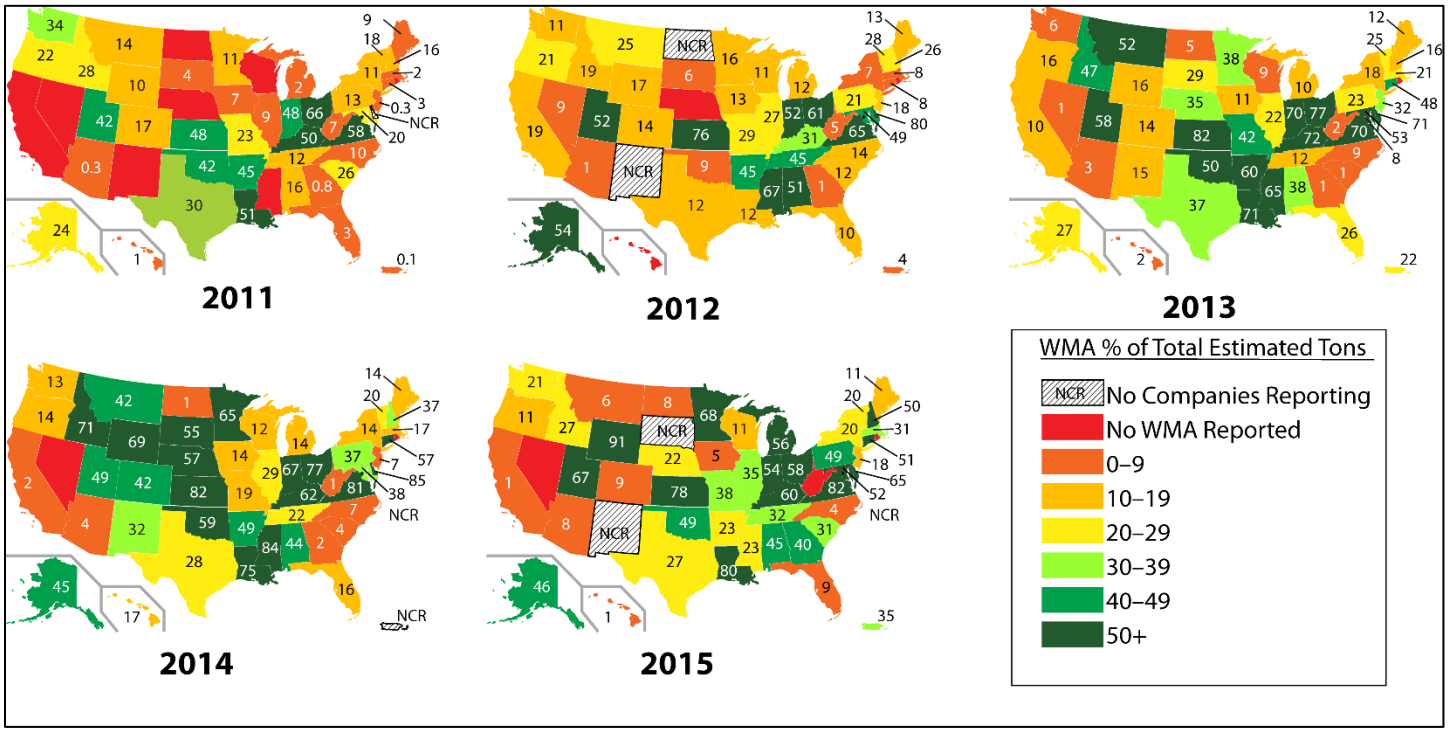


Figure 16: Estimated Percent of Total Production Using WMA

42 percent increases, respectively. Six states — Arkansas, Colorado, Idaho, Mississippi, Montana, and Nebraska — had a decrease of 25 percentage points or more in WMA production. The reasons for these fluctuations are uncertain.

WMA makes up over half of the total asphalt mix production in 14 states, down from 15 states in 2014, and four of them — Kansas, Louisiana, Virginia, and Wyoming — reported WMA as 75 percent or more of total production in 2015. Nevada, West Virginia, and Rhode Island did not report the use of WMA in 2015.

WMA Technologies

As Table 5 shows, plant foaming is the most commonly used technology for the production of WMA. Use of WMA chemical additives increased from 15 percent in 2014 to 25.2 percent in 2015, an all-time high.

WMA additives can have compaction, 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 in the 2015 construction season survey, producers were asked if they use WMA additives to produce asphalt mixtures at HMA temperatures. One hundred producers, 60 percent of respondents, in 41 states reported using WMA additives at HMA temperatures. Because this survey seeks to quantify only the use of WMA technologies to produce reduced-temperature WMA mixtures, survey respondents were instructed to report tons of asphalt pavement mixtures produced as HMA with WMA technologies with total tons of HMA/WMA produced, but not with tons of WMA produced.

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. Table 1, Section 5, summarizes the questions asked. The full questionnaire is included as Appendix A.

Producers were asked how many tons of mix were produced that incorporated other recycled materials, as well as how many tons of specific materials were used in mix production during the 2015 construction season. Four recycled materials — ground tire rubber (GTR), steel slag, blast furnace slag, and cellulose fibers — were specifically listed in the survey. Respondents could specify up to two additional recycled materials used in mixes.

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 by 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 53 companies/branches from 29 states reported using other recycled materials in asphalt mixtures during the 2015 construction season.

Ground Tire Rubber

Table 15 summarizes reported information on the use of ground tire rubber. Twenty-two producers from 14 states reported using GTR in some mixes. It must be noted that Arizona, which is known to use large quantities of GTR in mixes, had a relatively low participation rate in the survey. California, also known for its use of GTR, reported the greatest amount of GTR of any state. The total reported tons of asphalt pavement mix using GTR stayed relatively flat from 2014 to 2015, rising from 1,200,181 tons in 2014 to 1,234,960 in 2015.

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

To give a picture of the total market size for GTR, the Rubber Manufacturers Association (RMA) reports that 25.8 percent of U.S. scrap tires were processed into GTR in 2015. The total market for GTR was estimated at 1.02 million tons, with some 15 percent (153,100 tons) used in asphalt pavement mixes and surface treatments, such as seal coats, in 2015 (RMA, 2016). Therefore, the GTR use reported by survey respondents for the 2015 construction season makes up about 11.4 percent of the total GTR use in asphalt estimated by RMA.

Table 15: Reported Tons Ground Tire Rubber

State	Reported Tons of Mix Using GTR				Reported Tons of GTR Used			
	2012	2013	2014	2015	2012	2013	2014	2015
Arizona	33,590	26,300	12,000	11,500	532	380	142	100
California	101,000	523,213	623,953	936,100	—	3,748	9,173	13,514
Florida	86,441	250,779	198,046	110,000	195	531	419	356
Georgia	281,958	65,000	162,000	—	—	260	750	—
Illinois	—	4,500	—	3,500	—	20	—	36
Indiana	—	13,000	—	5,000	—	30	—	140
Louisiana	25,000	104,395	—	—	—	550	—	—
Maine	—	14,000	—	—	—	219	—	—
Massachusetts	—	24,897	81,882	79,680	—	324	1,146	1,090
Michigan	2,400	12,000	9,300	2,780	20	71	51	17
Missouri	100,000	50,000	—	—	300	180	—	—
New Hampshire	—	28,000	50,000	8,400	—	358	780	114
New York	—	10	—	—	—	—	—	—
Ohio	36,200	1,500	23,000	6,000	—	8	150	60
Oregon	—	—	—	5,000	—	—	—	—
Pennsylvania	—	18,000	—	—	—	140	—	—
Puerto Rico	—	10,000	NCR	—	—	170	NCR	—
Texas	25,000	50,000	40,000	50,000	—	—	200	—
Utah	—	—	—	3,500	—	—	—	61
Washington	—	—	—	6,500	—	—	—	—
Wisconsin	—	—	—	5,000	—	—	—	30
Total	691,589	1,195,594	1,200,181	1,234,960	1,047	6,989	12,811	17,518
No. of Producers	15	29	19	22				

NCR = No Contractors/Branches Reporting

Steel & Blast Furnace Slag

Tables 16 and 17 summarize the reported use of steel slag and blast furnace slag in asphalt mixes, respectively. Eleven states reported using steel slag and eight states reported using blast furnace slag in the 2015 construction season. It is interesting to note that while the total tons of mix and materials for each slag type vary from year to year, there has been a consistent increase in the combined use of both slags, as illustrated in Figure 17 through 2014, but a decrease of about 12 percent in 2015.

The National Slag Association estimates that more than 20 million tons of slag is produced and marketed annually (NSA, 2015). With a reported 1.1 million tons of slag in asphalt mixes for 2015, the asphalt pavement mix production industry uses well over 5 percent of the total available slag, based upon reported usage alone. For the states reporting slag use, 11 percent of their total asphalt pavement mixture production tonnage includes slag.

Table 16: Reported Tons for Steel Slag, 2012–2015

State	Reported Tons of Mix Using Steel Slag				Reported Tons of Steel Slag Used			
	2012	2013	2014	2015	2012	2013	2014	2015
Alabama	625,000	750,000	837,083	400,000	133,441	165,000	112,480	95,000
Arkansas	120,000	25,000	84,900	229,800	12,000	2,500	12,735	60,000
Illinois	23,000	43,700	56,407	70,000	8,000	16,300	21,991	19,000
Indiana	70,000	161,115	111,800	245,000	44,000	61,985	41,500	90,000
Iowa	20,000	97,500	57,689	27,623	—	10,200	9,432	4,111
Kentucky	5,714	508,000	125,000	—	800	173,265	15,000	—
Michigan	—	750,000	754,131	1,549,291	—	95,000	136,382	225,819
Minnesota	145,500	200,000	238,000	268,000	21,800	30,000	34,000	37,500
Mississippi	—	—	—	22,803	—	—	—	3,000
Ohio	150,000	185,319	185,125	220,000	42,030	79,085	60,133	40,000
Tennessee	30,000	—	—	40,000	6,000	—	—	8,000
Washington	450,000	586,000	416,000	305,000	80,000	82,954	60,000	56,700
Total	1,639,214	3,306,634	2,866,135	3,382,517	348,071	716,289	503,653	639,130

Table 17: Reported Tons for Blast Furnace Slag, 2012–2015

State	Reported Tons of Mix Using Blast Furnace Slag				Reported Tons of Blast Furnace Slag Use			
	2012	2013	2014	2015	2012	2013	2014	2015
Alabama	100,000	110,000	100,000	15,000	10,100	12,500	10,000	10,000
Illinois	—	—	40,000	20,000	—	—	10,000	15,000
Indiana	1,487,000	116,500	375,000	—	304,000	57,000	150,000	—
Iowa	—	5,000	15,000	—	—	500	1,500	—
Kentucky	—	16,000	828,243	100,000	—	7,500	191,067	25,000
Michigan	500,000	700,000	329,000	500,000	50,000	107,000	43,750	2,000
Ohio	208,028	416,250	794,6000	884,000	72,400	110,613	145,105	208,268
Virginia	54,520	—	—	—	16,356	—	—	—
West Virginia	588,120	504,704	1,065,382	748,922	180,308	155,032	190,000	183,357
Wisconsin	—	—	—	5,500	—	—	—	795
Total	2,937,668	1,868,454	3,547,225	2,273,422	633,164	450,145	741,422	444,420

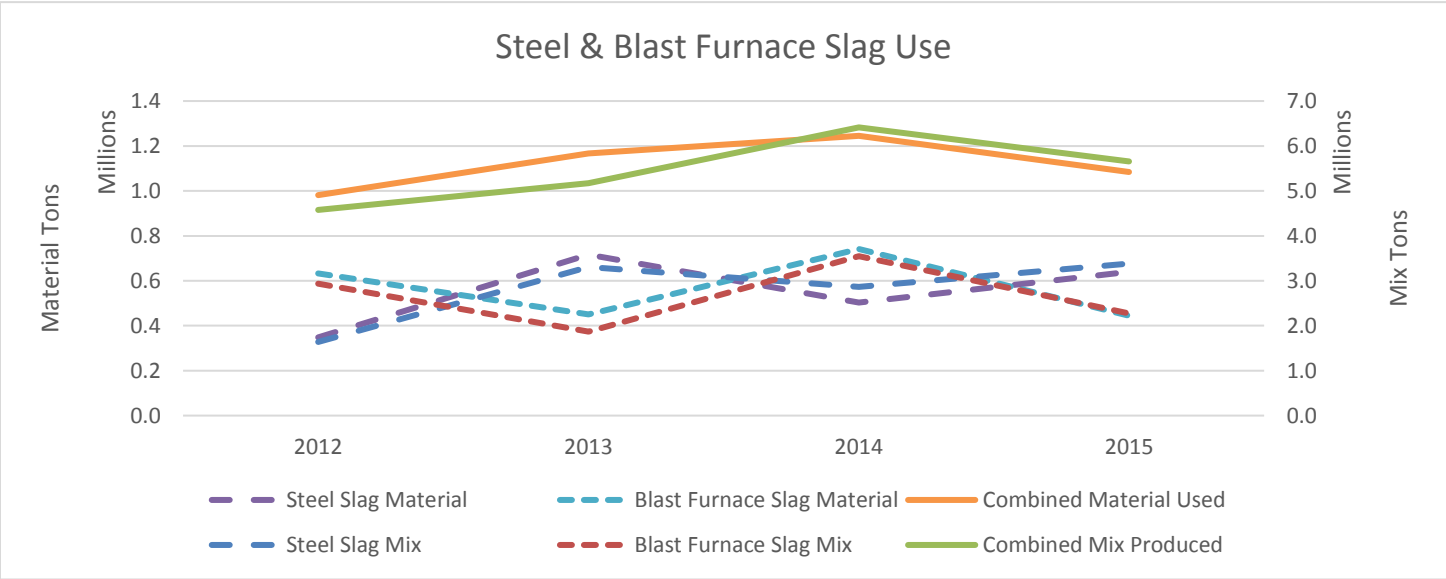


Figure 17: Steel and Blast Furnace Slag Use, 2012–2015

Other Recycled Materials

Table 18 summarizes other recycled materials used in asphalt mixtures. Other reported recycled materials include fly ash, cellulose fiber, foundry sand, recycled glass, and contaminated soil. Recycled glass was reported by Virginia in 2012 and Florida in 2015. Fly ash use was reported in Mississippi and Texas each year of the survey through 2014, but was not reported in 2015; Wisconsin reported using fly ash in 2014 and 2015; Tennessee first reported using fly ash in 2015.

The reported use of cellulose fiber reached an all-time high of 17 states in 2015, far exceeding the previous high of seven states in 2014. This is likely due to the specific request for data about cellulose fiber use in the 2015 construction season survey; in previous years, reporting data about cellulose fiber use was at the discretion of the respondent.

Table 18: Other Recycled Materials

State & Type of Other Recycled Material	Reported Tons of Mix Produced Using Other Recycled Material				Reported Tons of Other Recycled Material Used*			
	2012	2013	2014	2015	2012	2013	2014	2015
Cellulose Fiber								
Alabama	—	—	—	100,000	—	—	—	500
Alaska	—	—	—	1,000	—	—	—	—
Florida	—	20,204	73,600	92,000	—	71	311	147
Georgia	—	43,000	—		—	129	—	—
Illinois	—	—	—	126,150	—	—	—	240
Indiana	—	6,000	—	22,000	—	60	—	1
Louisiana	—	31,651	1,500	22,260	—	63	30	45
Maryland	—	145,000	120,000	85,000	—	440	360	230
Minnesota	—	5,000	—	—	—	15	—	—
Mississippi	76,000	—	—	—	250	—	—	—
Missouri	—	—	—	56,000	—	—	—	100
New Jersey	—	—	—	5,000	—	—	—	—
New York	—	—	700	1,605	—	—	1	—
Ohio	—	—	—	10,220	—	—	—	90
Oregon	—	—	—	20,000	—	—	—	8
Pennsylvania	—	—	—	12,952	—	—	—	—
South Carolina	—	—	—	20,000	—	—	—	—
Tennessee	—	—	—	175,940	—	—	—	80
Texas	—	30,600	36,000	50,300	—	90	44	15
Virginia	—	—	74,000	61,000	—	—	120	183
Total	76,000	281,455	305,800	861,427	250	868	866	1,643
Fly Ash								
Michigan	—	—	—	50,000	—	—	—	—
Mississippi	50,000	50,000	15,000	—	2,400	2,500	600	—
Tennessee	—	—	—	15,940	—	—	—	616
Texas	18,000	25,000	20,000	—	1,200	1,700	1,000	—
Wisconsin	—	—	26,000	102,500	—	—	1,500	6,150
Total	68,000	75,000	61,000	168,440	3,600	4,200	3,100	6,766
Bottom Ash								
South Dakota	52,000	—	—	NCR	4,280	—	—	NCR
Texas	—	—	—	1,000	—	—	—	—
Total	52,000	—	—	1,000	4,280	—	—	—
Foundry Sand								
Missouri	5,000	15,130	22,310	10,000	500	1,514	2,231	500

*Not all producers reporting tonnages of mix using other recycled materials provided quantities of recycled materials used.
NCR = No Contractors/Companies Reporting

Table 18: Other Recycled Materials (Continued)

State & Type of Other Recycled Material	Reported Tons of Mix Produced Using Other Recycled Material				Reported Tons of Other Recycled Material Used*			
	2012	2013	2014	2015	2012	2013	2014	2015
Petroleum-Contaminated Soil								
Massachusetts	—	—	—	35,000	—	—	—	1,050
Recycled Glass								
Florida	—	—	—	1,000	—	—	—	200
Virginia	173	—	—	—	34	—	—	—
Total	173	—	—	1,000	34	—	—	200

*Not all producers reporting tonnages of mix using other recycled materials provided quantities of recycled materials used.
NCR = No Contractors/Companies Reporting

Summary and Conclusions

The objective of this survey was to quantify the use of recycled materials and WMA produced by the asphalt pavement mix production industry during the 2015 construction season. Asphalt mix producers from 48 states and one U.S. territory completed the 2015 survey, and data was collected from 212 companies/branches with data from 1,119 plants. Data collected was compared to annual data from previous surveys since the 2009 construction season.

The survey findings for 2015 regarding the use of RAP, RAS, and WMA are summarized in Table 5.

Comparing the 2015 results to 2014 construction season, estimated total asphalt mix production saw a slight increase from 352 million tons to 364.9 million tons, a 3.7 percent increase. Increases in estimated tonnage were seen across all customer sectors from 2014 to 2015, with DOT tonnage rising 2.1 percent to 163.6 million tons, Other Agency tonnage rising 5.3 percent to 95.5 million tons, and Commercial & Residential tonnage rising 4.6 percent to 105.8 million tons.

The use of recycled material has risen dramatically since the 2009 construction season survey; although, year-over-year growth has slowed in recent years. The 2015 construction season survey shows:

- The total estimated tons of RAP used in asphalt mixes reached 74.2 million tons in 2015. This represents a greater than 32 percent increase in the total estimated tons of RAP used in 2009. During the same time frame, total tonnage increased only 1.8 percent.
- The percent of producers reporting use of RAP decreased slightly from 100 percent of respondents in 2014 to 99 percent in 2015.
- The average percent RAP used by all sectors has seen variable growth from 2009 to 2015. The year-to-year growth in the total percentage of RAP use has slowed from 2009 to 2015, decreasing from a 1.8 percent increase from 2009 to 2010 to 0.1 percent decrease from 2014 to 2015. The average estimated percent RAP used in all mixes has increased from 15.6 percent in 2009 to 20.3 percent in 2015.
- Companies/branches reporting excess RAP supplies decreased from 91 percent to 88 percent from 2014 to 2015. As in the 2012 and 2014 construction seasons, the estimated amount of RAP used for all purposes in 2015, including landfilling, exceeded the amount accepted. RAP use exceeded RAP received by 4.5 million tons in 2015.
- Only three producers reported landfilling RAP during the 2015 construction season.
- The total estimated amount of RAP stockpiled nationwide at the end of the 2015 construction season was 85.1 million tons.

- Producers from 29 states reported fractionating RAP. Nationally, a reported 23 percent of RAP is fractionated.
- Producers from 32 states reported using softer binders and 18 states reported using rejuvenators in RAP mixes. While there is no strong relationship between the amount of RAP used and the use of softer binders or rejuvenators, most of the states using greater than 20 percent RAP also use softer binders or rejuvenators.
- Use of both recycled manufacturing waste and post-consumer asphalt shingles in asphalt mixes decreased slightly (1.6 percent) from an estimated 1.96 million tons in 2014 to 1.93 million tons in 2015. Still the use of RAS in the 2015 construction season increased 175 percent from the estimated 701,000 tons used in asphalt mixtures in 2009.
- The amount of unprocessed RAS accepted by asphalt mix producers decreased from 1.66 million tons in 2014 to 1.13 million tons in 2015. During the 2015 construction season, an estimated 840,000 tons of processed RAS was accepted by producers. The combined total of unprocessed and processed RAS accepted in 2015 was 1.94 million tons, slightly higher than the amount of RAS used in asphalt mixtures.
- Eighty-eight percent of companies/branches using RAS reported having excess RAS on hand at the end of the 2015 construction season.
- Of the RAS used in 2015, more than 99 percent was used in asphalt mixes. The remainder was combined with aggregates. No RAS was landfilled.
- The number of states with reported RAS use decreased from 36 states in 2014 to 34 states in 2015. One state that reported using RAS in 2014 did not have any producers participating in the 2015 construction season survey.
- In 2015, producers were asked which sectors allow RAS in asphalt mixtures. Most RAS is allowed in the Commercial & Residential sector followed by the Other Agency sector. Many DOTs allow RAS in some mixes, but few allow it in all mixtures.
- The combined savings of asphalt binder ($480/ton) and aggregate ($9.25/ton) from the use of RAP and RAS in asphalt mixes is more than $2.6 billion. This helps reduce material costs for asphalt pavement mixtures, allowing road owners to achieve more roadway maintenance and construction activities within limited budgets.
- The number of states reporting use of ground tire rubber (GTR) in asphalt mixtures increased from nine in 2014 to 14 in 2015. The total reported tons of asphalt pavement mix using GTR grew 2.9 percent from 2014 to 1.235 million tons in the 2015 construction season.
- The number of states reporting use of steel or blast furnace slags remained constant at 11 states in 2015, but the amount of mixtures using these materials decreased by about 12 percent from 2014 to 2015.
- The reported use of cellulose fiber reached an all-time high of 17 states in 2015, due to the survey being modified to asking specifically about cellulose fiber this year.
- Two states, Tennessee and Wisconsin, reported using fly ash in asphalt mixtures in 2015. Wisconsin reported a significant increase in the use of fly ash.
- Less commonly recycled materials reported in 2015 included foundry sand, recycled glass, and petroleum-contaminated soil.

The use of WMA continues to increase, but at a slower rate. The 2015 construction season survey shows:

- The estimated total production of WMA for the 2015 construction season was about 120 million tons. This was a greater than 5 percent increase from the estimated 114 million tons of WMA in 2014 and a more than 614 percent increase from the estimated 16.8 million tons in the 2009 construction season.
- WMA was about one-third of the total estimated asphalt mixture market in 2015.
- Plant foaming, representing 72 percent of the market, is the most commonly used warm-mix technology; chemical additive technologies accounted for a little more than 25 percent of the market.
- One hundred producers, 60 percent of respondents, in 41 states also reported using WMA additives in some asphalt pavement mixtures produced at HMA temperatures.

The 2015 survey results show that the asphalt pavement mix production industry has a strong record of sustainable practices and continues to increase its use of recycled materials and WMA. Since the initial industry survey of the 2009 construction season, producers have increased significantly their use of recycled materials and WMA; however, since the 2013 survey, indicators are that the rate of increase in the adoption of RAP, RAS, and WMA may be plateauing.

Slightly more RAP was used than received during the 2015 construction season, and 88 percent of producers indicated they have excess RAP on hand. With an estimated 85 million tons of RAP stockpiled nationwide, opportunities remain to increase the amount of RAP used in asphalt mixes through permissive specifications, education, and improved RAP processing, production equipment, and procedures.

RAS use saw a slight decrease in 2015; however, by including 1.931 million tons of waste shingles in asphalt mixtures, producers recycled 15 percent of the nation's available waste shingles. As with RAP, permissive specifications, education, and improved processing, production equipment, and procedures will help increase the amount and percentages of RAS used in asphalt mixes.

The asphalt pavement mix production industry repurposes many products from other industries. The survey shows that, for the 2015 construction season, steel and blast furnace slag use was reported in 11 states, GTR use was reported in 14 states, cellulose fiber use was reported in 17 states in 2015; and fly ash in two states.

WMA use continued to increase during the 2015 construction season with a total production of nearly 120 million tons, which represents nearly one-third of the total estimated asphalt mix production. All states responding to the survey, with the exceptions of Nevada, West Virginia, and Rhode Island, reported using WMA in 2015. Although the increase in the use of WMA from the 2014 to 2015 construction season was only about 1 percent, WMA use is expected to continue to increase, as more states allow the use of WMA technologies in asphalt mixtures.

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