TechBrief

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

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Practices and Lessons Learned When Using Reclaimed Asphalt Shingles in Asphalt Mixtures

This Technical Brief shares summary information related to practices and suggestions implemented by States and local agencies based on the literature and on-site visits in six States. The full report on the site visits is available as a reference should additional information be needed for any of the topics discussed (1).

The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. This document references American Association of State Highway and Transportation Officials (AASHTO) standards, which are voluntary standards that are not required under Federal law or statute.

Introduction

The use of reclaimed asphalt pavement (RAP) and reclaimed asphalt shingles (RAS) in asphalt mixtures can provide initial cost savings through the replacement of a portion of the aggregate and virgin asphalt binder in a mixture. Use of reclaimed materials has been driven by the need for cost-effective alternatives to virgin asphalt binder and the desire to make asphalt pavements more sustainable. This keeps the reclaimed material from being discarded in landfills. However, the use of RAS has created challenges for some State Departments of Transportation (DOTs) to specify, design, and control the quality of asphalt mixtures containing RAS to assure long-term pavement performance.

The primary concern with mixtures containing RAS is assuring that the high stiffness RAS binder does not lead to long-term durability issues such as raveling and cracking. Several State DOTs have found improvements in mixture design and materials processing and handling that have increased the amount of RAP and RAS that can be used in asphalt mixtures today. When properly engineered, produced, and constructed, recycled mixtures can provide comparable levels of service as asphalt mixtures with no reclaimed materials, referred to as virgin asphalt mixtures. However, in some asphalt mixtures containing RAS have not met performance expectations.

Use of Recycled Materials in Asphalt Pavements

The most common materials recycled into asphalt pavements include RAP, RAS and recycled tire rubber (RTR). When RTR is ground and recycled into asphalt pavement applications (asphalt mixture and binder), it is often referred to as ground tire rubber (GTR). A summary of the recent annual use of each of these three recycled materials is provided in Table 1 (2, 3, 4, 5).

Table 1. Approximate Annual Generation, Re-Use and Disposal of Several Recycled Materials.

Annual Tons (1,000's)	RAP	RTR	RAS
Generated	97,000	4,464	13,200 to 17,000
Landfilled	100	680	12,000 to 16,000
Recycled into Asphalt Binder and/or Mixtures	89,200	185	921
Recycled Elsewhere	5,500	3,373	50
Stockpiled	138,000	N/A	N/A
No. of DOTs Allowing (includes D.C. and Puerto Rico)	52	12	28

In 2019 more than 97 percent of RAP from old asphalt pavements was put back to use in new pavements and 17 percent (0.185 million tons) of ground tire rubber was used in asphalt mixtures (2, 3). Almost one million tons of RAS was used in asphalt mixtures (2).

From the NAPA survey data compiled annually since 2009 and a 2017 FHWA survey, the overall trend of RAS usage in mixture production has been on the decline since the peak use in 2014 (2, 6). The 2018 RAS tonnage was up slightly over 2017, while the 2019 tonnage decreased 12.5 percent from 2018 to 921 thousand tons, the lowest amount used since 2010. This trend reflects less desire by agencies and some producers to use RAS since the peak in 2014. For example, TxDOT use has declined significantly since 2014 based on reported poor performance and an FHWA fatigue cracking research project using its accelerated load facility (ALF) at the Turner Fairbanks Highway Research Center showed mixtures containing six percent RAS (20 percent RBR) exhibited less than 15 percent of the fatigue life of a virgin mix control section and about 50 percent of the fatigue life of RAP sections as illustrated in Figure 1 (6,7).

Benefits and Risks of Using Reclaimed Asphalt Shingles

The usage of RAS offers benefits and risks. A benefit is the angular fine aggregate and fibers within RAS can improve mixture properties. Although the amount of RAS in an asphalt mixture design is generally small, typically 3 to 5 percent by weight or about 15 to 20 percent binder replacement, the non-asphalt components (aggregates and fibers) can have a significant effect on the mixture. Voids in the mineral aggregate (VMA) will generally increase due to the hard and angular properties of the RAS granules as well as the presence of fibers (8).

There are also engineering risks related to binder quantity requirements for effective asphalt content and binder quality requirements for binder embrittlement. MWAS typically contain about 20 percent asphalt binder, while PCAS typically contain about 30 percent asphalt binder. Regarding binder embrittlement, the RAS binder is often aged, oxidized, very stiff, and brittle with PCAS binder being more aged, oxidized, stiff and brittle than MWAS binder. The asphalt binder in RAS is more aged, more oxidized, much stiffer, and more brittle than typical base asphalt binders (8). The increased binder stiffness from shingles is likely to decrease the resistance of the asphalt mixture to cracking (9). Addressing these risks is an engineering challenge to ensure responsible use, long-term pavement performance and safety. DOTs have new challenges to specify and control the quality of asphalt mixtures in their design and field acceptance. There are other concerns such as the compatibility of RAS and virgin binders, chemical differences in RAS binders compared with virgin binders, actual RAS binder availability and others.

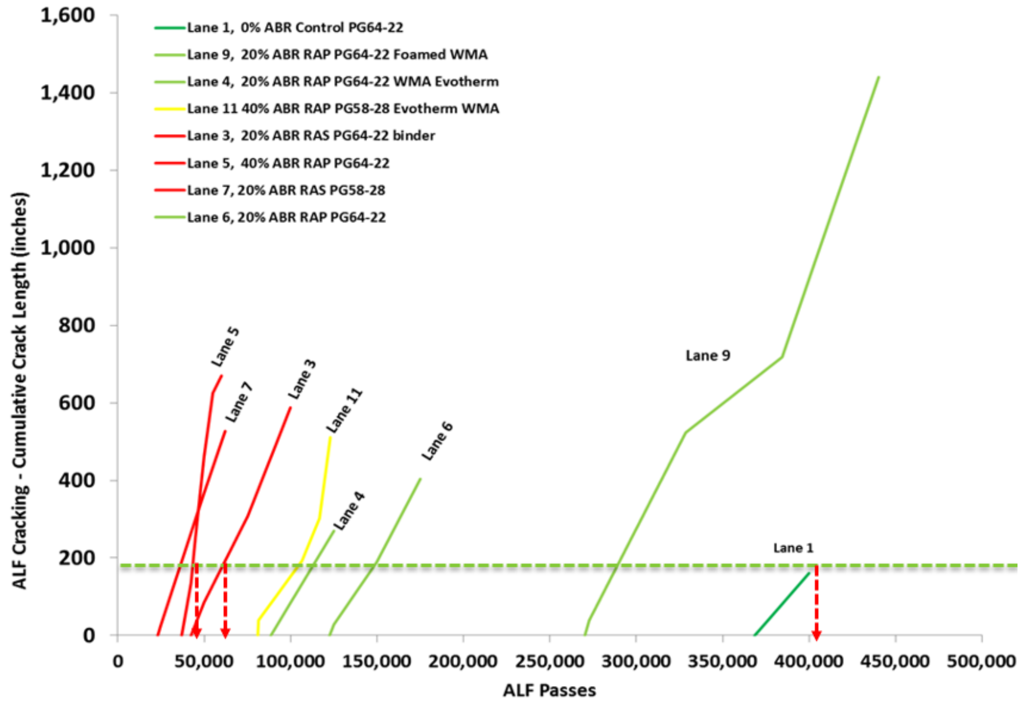

Figure 1. FHWA ALF Fatigue Study Data.

State and Local Agency Site Visits

Site visits and interviews of key public agencies, along with material producers and contractors that serviced the agencies, were conducted. The participating agencies were geographically dispersed across the U.S. and are shown in Figure 2. Additionally, the following characteristics were used to select the six agencies:

- City of Eugene, OR: local agency with high percentage of RAP and RAS use.
- Delaware DOT (DelDOT): top 3 State DOT in percent of asphalt mixture tonnage with RAS at 25 percent.
- Illinois DOT (IDOT): top 2 State DOT in tons of RAS used (about 30,000 to 40,000 tons) in asphalt mixtures.
- Missouri DOT (MoDOT): top 5 State DOT in tons of RAS used (about 20,000 tons) in asphalt mixtures and recent specification changes based on pavement performance.
- Pennsylvania DOT (PennDOT): top 5 State DOT in tons of RAS used (about 10,000 tons) in asphalt mixtures.
- Texas DOT (TxDOT): top 5 State DOT in tons of RAS used (about 20,000 tons) in asphalt mixtures and recent specification changes based on pavement performance.

Implementation Considerations

Each State and local agency visited has its own methodology to accommodate the use of RAS and RAP. Should other agencies decide to implement RAS, the following factors should be considered. They include, but are not limited to:

- RAS programmatic considerations.
- RAS mixture design considerations.
- Observations at RAS processing and asphalt plant production facilities.

Some of the factors used by the State and local agencies visited are discussed below.

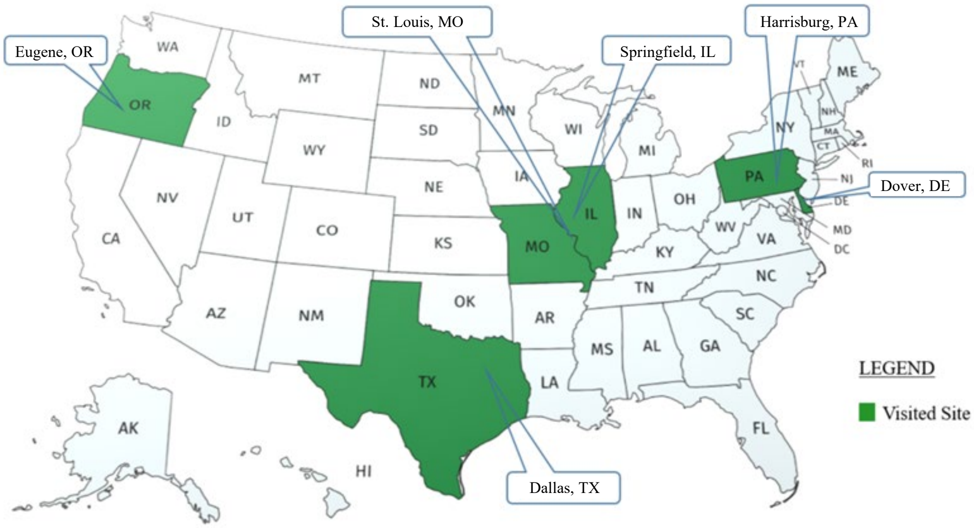

Figure 2. Participating Agencies.

RAS Programmatic Considerations

When a State or local agency implements RAS in its asphalt pavement program, several "programmatic considerations might be considered. Examples of some of these are listed below.

- All of the State and local agencies visited had some form of project selection guidelines. Project selection guidelines describe what mixtures may contain RAS, how much RAS is allowed in mixtures, and in what locations in a pavement structure. This could also include the type of RAS (MWAS/PCAS), inclusion in specialty mixtures, traffic levels, the use of RAS with polymer modified asphalt, and others. These agencies have found that it is especially important to provide clear guidance when using both RAP and RAS.
- IDOT had a rigorous Quality Control (QC) Plan requirement for RAS sources, developed in partnership with the Illinois Environmental Protection Agency, which approves and authorizes the RAS suppliers' beneficial use determination (BUD) application. The QC Plan and corresponding activities lead to RAS sources being on the IDOT qualified producer list. IDOT found that having a strong Quality Assurance (QA) program that includes clear QC responsibilities for the contractor and acceptance responsibilities for the agency ensures the desired mixture is provided.
- The City of Eugene visually inspects all projects with high recycled contents annually and the observations are put in a geo-referenced pavement management system. Specifications are often adjusted based on pavement performance. It monitors pavement performance of those mixtures with RAS compared to those without RAS. The city has found it is important to use the data from the pavement management system as well as making occasional project visits. It also conducts video logging of the pavement network on a regular basis to compare the existing pavement condition to that prior to overlay.

RAS Mixture Design Considerations

Each State DOT or local agency visited has its standard mixture design requirements and specifications that were modified to accommodate high quantities of recycled materials. A list of these agency's requirements is provided in Table 2. Not every agency has requirements in each category, but some often have requirements in multiple categories. There can be challenges with characterizing RAS, as well as RAS with RAP and recycling agents. The NCHRP Project 09-58 identified techniques that can be used along with a draft AASHTO Standard Practice documented in NCHRP Research Report 927 (10). The report also includes a technique for determining binder availability of RAP and RAS that is more descriptive than the information in AASHTO PP 78 on binder availability. NAPA QIP-131, "*Practical*

Guide for Using Recycling Agents in Asphalt Mixtures," is a guideline on high recycled mixture designs using recycling agents based on the NCHRP Project 09-58 outcomes and practical application of them, which also addresses characterization of RAS (11).

Table 2. State and Local Agencies RAS Usage.

Component	City of Eugene	DelDOT	IDOT	MoDOT	PennDOT	TxDOT
MWAS RAS Type	X	X	X	X[1]	X	X
PCAS RAS Type	X	X	X	X[1]		X
% RAS Criteria (by weight)	X		X		X	X
RAS Binder Availability Factor			X			
RBR Criteria	X	X	X	X[2,3]		X
Softer Binder by Grade Bump	X		X	X		X
Softer Binder by Blending Chart		X[2]		X[4]	X	
Softer Binder by PG Binder Blend		X		X	X	
Additional Asphalt by Design	X	X			X	
Additional Asphalt by Acceptance	X	X	X	X	X	
Recycling Agent Additive		X		X		
WMA Additive	X[5]					
Lift Location Criteria			X	X		X
Traffic Criteria			X	X		
Specialty Mixture Criteria		X	X	X	X	X
RAP Type Criteria			X			X
Binder Type Criteria			X	X		
Performance Test(s)		Pending	X	Pending	X	Pending

[1]MWAS and PCAS are allowed, but only PCAS is used.

[2]RAS portion weighted twice RAP.

[3]RBR calculated with effective asphalt content.

[4]RAP only.

[5]Required with recycled materials use at lower temperatures.

Criteria for RAS by Weight and/or Reclaimed Binder Ratio (RBR)

Examples of the criteria used for RAS or RAS and RAP are summarized in Table 3. For example, in the City of Eugene, the maximum RBR for RAS only is 0.20 and a minimum RBR of 0.35 for RAS and RAP, was effective and PennDOT found an RBR of 0.20 with only MWAS at 5 percent (and no RAP) was effective. When using a combination of RAP and RAS, MoDOT calculates the RBR using a relative weighting of "two" for the RAS to account for the additional binder stiffness. Additionally, MoDOT calculates the RBR using the effective virgin asphalt content. When MoDOT (and other State and local agencies) allows the use of both RAS and RAP it is important that policy, materials selection, mixture design and specifications clarify how to integrate both together.

Use of Softer Binder

Examples of the criteria used for softer binder are summarized in Table 4. These State and local agencies have found using a softer binder has been a very effective method for using RAS and higher quantities of RAP. This can be done by bumping the performance graded (PG) binder's low and high temperature down, using blending charts, or extracting and grading the binder from final mixture. For example, in the City of Eugene, grade bumping down from PG70-22 to PG58-28 improved pavement performance. Note that the linear assumption of blending chart analysis may not hold for RAS, high RBR, or RAS and RAP blends.

Table 3. Summary of RAS by Weight or RBR from Various State and Local Agencies.

State or Local Agency	Percent by Weight	RBR	Notes
City of Eugene	≤ 5% RAS	RAS + RAP ≥ 0.35[1]	
DelDOT	N/A	RAS only ≤ 0.20 RAS + RAP ≤ 0.40	
IDOT	≤ 5% RAS	RAS + RAP ≤ 0.10 to 0.30 RAS + FRAP[2] ≤ 0.10 to 0.50	This is a summary as the criteria has many different categories.
MoDOT	N/A	RAS ≤ 0.10 RAP ≤ 0.20 RAS + RAP ≤ 0.20 RAP (PG*) ≤ 0.40 RAS + RAP (PG*) ≤1.00	Effective asphalt content used to calculate RBR. When calculating RBR with RAS and RAP, the RAS percentage is doubled. *Softer binder required applies.
PennDOT	= 5% RAS	N/A	
TxDOT	≤ 3% RAS (non-Surface) ≤ 20% RAP (Surface) ≤ 30% RAP (Intermediate) ≤ 35% RAP (Base)	RAS + RAP ≤ 0.15 (Surface) 0.25 (Intermediate) 0.30 (Base)	Proposed changes for Item 344 Superpave mixtures. All RAP is fractionated.

[1]A maximum RBR of 0.20 for just RAS and a minimum RBR of 0.35 for RAS and RAP combined.
[2]FRAP is Fractionated RAP.

Additional Asphalt Content

Two items commonly mentioned were the type and quantity of binder. The previous section discussed the type of binder in relation to the grade of virgin binder used. Softer virgin binder (i.e., type) is often selected in an effort to reduce embrittlement. This results in grade bumping down one or two grades. It is also important that the asphalt mixtures contain adequate amount (i.e., quantity) of virgin asphalt binder. To emphasize the importance of the virgin binder content, MoDOT and TxDOT also mentioned the emphasis on meeting dust to asphalt content ratio requirements. IDOT is the only agency of the six using a RAS binder availability factor, which is 0.85. Examples of methods to ensure that there is an adequate amount of virgin asphalt content were:

- IDOT and PennDOT had stringent requirements in the mixture design and acceptance to ensure adequate voids in mineral aggregate (VMA). This also involved using bulk dry specific gravity (Gsb) of the RAS and RAP aggregates, rather than effective specific gravity of the aggregates (Gse), to assure the most accurate indication of VMA possible.
- DelDOT increased optimum asphalt contents by about 0.2 percent by using lower design gyrations and increasing VMA requirements by 0.5. Depending on roadway classification, adjusting the asphalt mixture design criteria in AASHTO M 323 and AASHTO R 35 to achieve a higher optimum asphalt content. This could include strategically designing at a lower air void content, a higher VMA requirement and/or a lower number of design gyrations.

Table 4. Summary of Criteria for Using Softer Binder from Various State and Local Agencies.

State or Local Agency	Softer Binder	Blending Chart	Actual PG of Blended Asphalt
City of Eugene	Asphalt binder grade lowered one full grade from PG 64-22 to PG 58-28.		
DelDOT		Low temperature PG cannot be raised. High temperature PG can be raised one grade.	
IDOT	RBR > 0.20: softer binder is required with both the low and high PG temperatures lowered by one grade.		
MoDOT	RBR from RAS > 0.10: softer binder required with either low or both the low and high PG lowered one grade.		RBR from RAS > 0.20: actual grading of binder extracted from aged mixture required to meet contract PG.
PennDOT		Blending Chart required for all RAP and RAS combinations.	Any RAP and 5% RAS requires extraction and must meet PG for environment.

Use of Additives

Some State and local agencies are using additives to support their recycling with RAS and RAP to address binder embrittlement. These include WMA additives and recycling agents.

- City of Eugene requires WMA using foaming at lower temperatures. The maximum temperature at mixing is 275°F and the maximum temperature behind the paver is 215°F. The City reported that WMA at lower temperatures was specified to minimize the activation or mobilization of RAS binder. The City is considering requiring WMA chemical additives.
- DelDOT allows recycling agents at the contractor’s option. Recycling agents are voluntarily being used by a major contractor to improve mixture performance. This is based on performance testing results on binders and mixtures.
- MoDOT allows recycling agents. The recycling agents are used to meet the requirement that the actual grading of the binder extracted from the aged mixture meets the contract PG. About 15 to 25 percent of MoDOT’s asphalt mixtures contain recycling agents. Some contractors suggested that using

additional virgin asphalt binder might be more effective than a recycling agent to reduce binder embrittlement.

Criteria for RAS Based on Other Factors

There are many other factors that State and local agencies use to allow an increase in the amount of RAS. It is not uncommon for these agencies to allow greater amounts of RAS in base and intermediate pavement layers than in surface courses. For example, based on the preference from the TxDOT's Districts, planned changes will not permit RAS in surface mixtures unless otherwise shown on the plans with a general note from a District. As another example, IDOT allows a maximum of 5 percent RAS by weight in surface courses. In addition, the RBR criteria are shown in Table 5 for RAS and RAP and Table 6 for RAS and fractioned RAP (FRAP). It also includes criteria for specialty mixtures such as stone matrix asphalt (SMA) and small nominal maximum aggregate size (NMAS) mixtures (IL-4.75). The criteria were developed over time based on research, field performance and negotiation.

Table 5. IDOT's Maximum RBR for RAS and RAP by Asphalt Mixture Type.

Asphalt Mixture N_{design}	Binder Course Maximum RBR for RAS and RAP	Surface Course Maximum RBR for RAS and RAP	Polymer Modified Maximum RBR for RAS and RAP
30	0.30	0.30	0.10
50	0.25	0.15	0.10
70	0.15	0.10	0.10
90	0.10	0.10	0.10

Table 6. IDOT's Maximum RBR for RAS and FRAP.

Asphalt Mixture N_{design}	Binder Course without I-FIT Maximum RBR for RAS and FRAP	Binder Course with I-FIT Maximum RBR for RAS and FRAP	Surface Course without I-FIT Maximum RBR for RAS and FRAP	Surface Course with I-FIT Maximum RBR for RAS and FRAP	Polymer Modified without I-FIT Maximum RBR for RAS and FRAP	Polymer Modified with I-FIT Maximum RBR for RAS and FRAP
30	0.50	0.55	0.40	0.45	0.10	0.15
50	0.40	0.45	0.35	0.40	0.10	0.15
70	0.40	0.45	0.30	0.35	0.10	0.15
90	0.40	0.45	0.30	0.35	0.10	0.15
SMA	N/A	N/A	N/A	N/A	0.20	0.25
IL-4.75	N/A	N/A	N/A	N/A	0.30	0.35

Mixture and/or Binder Performance Tests

IDOT and PennDOT have a performance test and DelDOT, MoDOT, and TxDOT all indicated that they are evaluating mixture performance test method options. The addition of recycled materials makes an asphalt mixture more susceptible to cracking (9). These DOTs believe a mixture performance test that relates to field performance would allow contractors room for innovation. Mixture cracking tests observed include the Texas Overlay Test (TxOT), CT-Index, Illinois Flexibility Index (I-FIT), and flexural beam fatigue. TxDOT specifications will soon include binder testing for the change in the critical low temperature (ΔT_c). Since cracking is related to long-term aging (LTA), several agencies expressed interest in cracking tests conducted on long-term aged materials, though none had implemented it.

RAS Processing and Asphalt Plant Production Facilities Observations

RAS Processing Facilities

RAS processing facilities were visited in Pennsylvania, Missouri and Texas. Two were co-located at contractor asphalt plant facilities, while one was a recycling center that processed many other types of materials. The contractors in the States and local agencies at all three facilities used several voluntary practices for processing RAS including:

- Having regular inspection of incoming supply.
- Eliminating shingles containing asbestos in the supply stream.
- Minimizing deleterious materials (wood, nails, etc.).
- Keeping MWAS and PCAS separated. A RAS processor in Oregon blended MWAS and PCAS during processing which limited the amount of shingles a contractor can use to meet the asphalt mixture's acceptance criteria for asphalt content.
- Shredding to the specified size and at least passing the 3/8-inch sieve. A trommel was used to size RAS to ¼-inch minus by one contractor in Texas processing RAS.
- Minimizing moisture during RAS production as much as possible.
- Metering and verifying accurate blending of RAS with fine aggregate or RAP when blending is used.
- Using plant equipment (bins, weighing systems and controls) specifically designed for use with RAS.
- Minimizing the moisture in RAS by having sloped, paved, and/or covered stockpile areas. RAS stockpiles were sloped, paved and covered in Pennsylvania and Oregon Figure 3.
- Having on-site QC. IDOT requires the contractor to have a QC Plan for RAS and RAS blended with manufactured sand. It includes frequencies, tolerances, and acceptance criteria for gradation on four sieves and asphalt binder content. RAS stockpiles are dedicated, and IDOT's rigorous criteria must be met to supplement a dedicated stockpile.

Image: University of Nevada Reno

Figure 3. Paved and Tented RAS Stockpile Near Asphalt Plant.

Asphalt Plant Production Facilities

Asphalt plant production facilities were visited in Pennsylvania, Oregon, Missouri, Delaware and Texas. All were counterflow continuous mix plants with RAP collars. All produced mixture for State and local agencies and private customers. All were also equipped with the ability to produce WMA either by foaming or with chemical additive. Two of the plants were equipped to introduce recycling agents on-site. Some common practices used by contractors in the States and local agencies visited for producing asphalt mixtures with RAS included:

- Considering plant calibrations and all feed systems interlocked with the plant control and recordation system.
- Using plant equipment (bins, weighing systems and controls) specifically designed for use with RAS that can accurately supply and meter the materials as shown in Figure 3.
- Close monitoring of RAS and RAP moisture content and updating it in plant control software.
- Having scalping screens over RAS and RAP bins to prevent feed of clumped material as shown in Figure 4.
- Using multiple cold feed bins when blended RAS/RAP exceeds more than 30 percent of a mixture composition.
- Using air cannons and/or vibrators on RAS and RAP/RAS feed bins as shown in Figure 5.
- Using limit switches to identify material flow on RAS and RAP/RAS feed as shown in Figure 6.
- Having a weigh bridge on the conveyor feeding to the RAP collar on continuous mix plants.
- Having covers over weigh bridges on collector belts to minimize environmental impacts.
- Using WMA technology to produce mixtures at WMA temperatures.
- Having accurate means of metering recycling agents if introduced at the asphalt plant.
- Using plant primary collector and baghouse fines return systems that can accurately meter, and reject if necessary, these materials.
- Considering post dryer drum mixers with high RBR mixtures.

Image: University of Nevada Reno

Figure 4. Coldfeed Bin Designed to Feed RAM with Scalping Screen to Remove Clumps.

Image: University of Nevada Reno

Figure 5. Air Cannon and Vibrators on RAS Coldfeed Bins.

Image: University of Nevada Reno

Figure 6. RAS Coldfeed Bin with Limit Switch Used to Positively Identify Material Flow.

Field Performance Observations

Each State and local agency site visit included informal pavement condition surveys of in-service mixtures containing RAS or RAS and RAP. The length of each project was windshield surveyed. Additionally, close inspection was performed at two or more locations per project that could safely be inspected. A total of 19 pavements that had been in service for up to 10 years were inspected. The asphalt mixtures were either 9.5 or 12.5mm NMAS and dense graded or SMA. Fifteen were overlays ranging in thickness from 1.5 to 2.5 inches. Three of the overlays were on PCC pavements. Four were reconstruction or full-depth reclamation projects with the asphalt mixture ranging in thickness from 5.5 to 8.0 inches. RBR of the mixtures ranged from 0.17 to 0.48. RAS dose ranged from 0 to 5 percent while RAP dose ranged from 0 to 30 percent. RAS/RAP dose combinations by weight ranged from 3/30 to 5/25.

State or local agencies use their PMS to rate their pavements from good to poor. The FHWA and the host State engineers observed several pavements to better understand the State or local agencies rating systems as illustrated in Figure 7 and Figure 8. Some agencies rated their pavement performance as good, while others rated their pavement performance as good and poor. No State or local agency visited had only poor performance. Figure 9 shows RAS and RAP RBR levels with pavement performance indicated. Figure 10 shows total RBR (RAS + RAP) levels versus RAS RBR with pavement performance. The figures illustrate that as increasing amounts of RAP are added to mixtures with RAS, it becomes more difficult to maintain good performance. There is a fine line separating good and poor performance when using combinations of RAP and RAS.

Image: University of Nevada Reno

Figure 7. Good Performing SMA Overlay on PCC After 9 Years of Service.

Image: University of Nevada Reno
Figure 8. Poor Performing Dense Grade After 3 Years of Service.

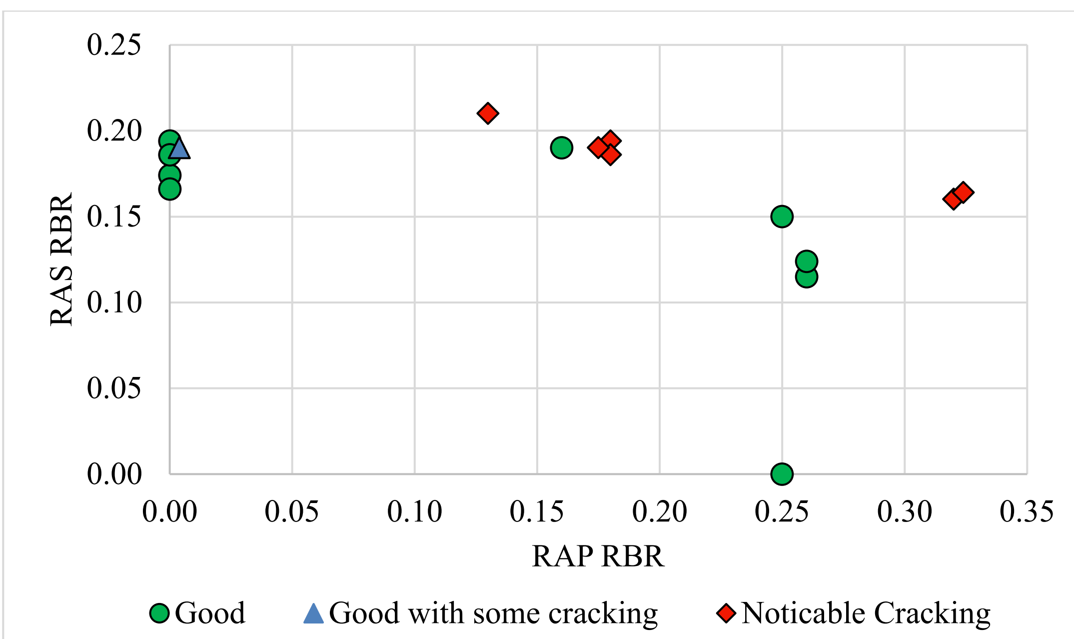

Figure 9. RAS and RAP RBR Levels with Pavement Performance Indicated.

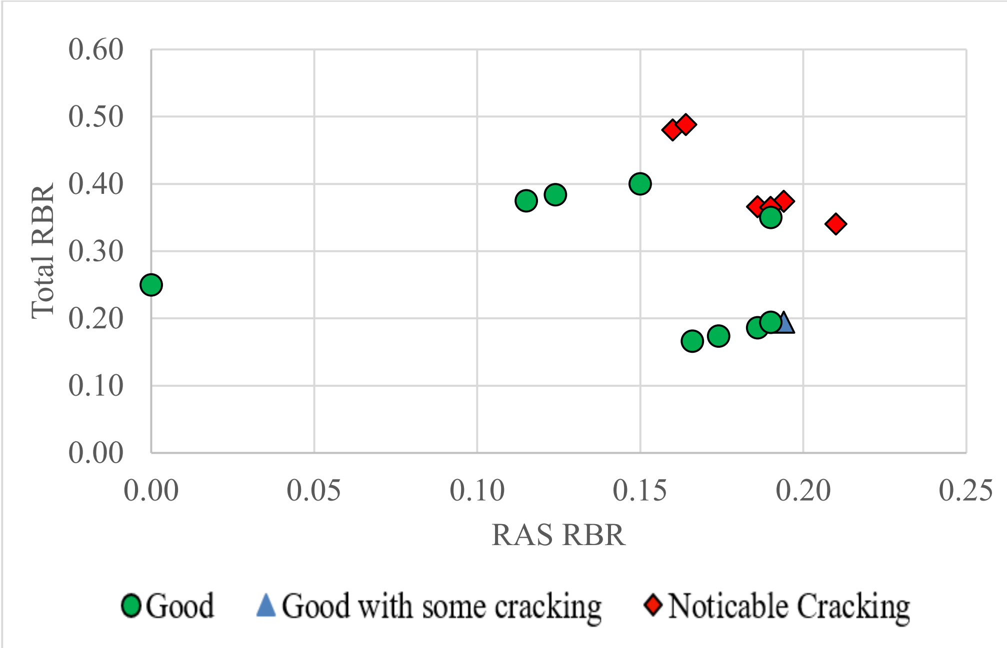

Figure 10. RAS and RAP RBR Levels with Pavement Performance Indicated.

Summary

The use of RAP and RAS in asphalt mixtures can provide initial cost savings through the replacement of a portion of the aggregate and virgin asphalt binder in a mixture for use in highways and trails. This keeps the reclaimed material from being discarded in landfills. Improvements in mixture design and materials processing and handling have increased the amount of RAP and RAS that can be used in asphalt mixtures today. The performance history of RAS mixtures over the past 20 years, when properly engineered, produced, and constructed, can provide comparable levels of service as asphalt mixtures with no reclaimed materials, referred to as virgin asphalt mixtures (12). Understanding RAS material characterization, limitations, and LTA are fundamental to properly engineer, produce, and construct pavements with comparable levels of service.

This effort showed that the State and local agencies visited that have detailed policies and specifications on RAS use had more control and comparable levels of visual performance. Field performance reviews of in-service pavements up to nine years old containing RAS or RAP and RAS revealed that with appropriate policy, mixture design, testing and control of quality, comparable performance can be obtained. This was typically obtained through the following steps: 1) regular and diligent review of the State and local agency's specifications and mixture design procedures, 2) monitoring pavement performance, 3) working with industry and 4) performing research as a basis for changes.

A wide range of criteria used by State and local agencies specifying and designing mixtures and pavements which incorporated RAS were identified and summarized. The criteria were then compared to pavement performance to assess their effectiveness and identify opportunities for improvement. Considerations of potential interest to other agencies wanting to use RAS included programmatic, mixture design, mixture production, mixture acceptance, RAS production, and QC considerations. Collectively this illustrated that care taken during design, production, and construction may help ensure desired performance. It also revealed that there are opportunities for future improvements that can be accomplished through research needs identified.

References

1. Hand, A.J.T., T. Aschenbrener, and S. Cooper, "A Field Review: Successful Practices and Lessons Learned When Using Reclaimed Asphalt Shingles in Asphalt Mixtures," WRSC-TR-20-01. Pavement Engineering and Science Program, University Nevada, Reno, Reno, NV, 2020.
2. Williams, B.A., J. R. Willis, and J. Shacat, "Annual Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2019, 10th Annual Survey," Information Series (IS) 138. National Asphalt Pavement Association, Greenbelt, MA, September 2020.
3. U.S. Tire Manufacturers Association, "2019 U.S Scrap Tire Management Summary," 2020.
4. Asphalt Roofing Manufacturers Association, Personal communication from R.X. Gumucio, ARMA, Washington, DC, 2015.
5. Construction & Demolition Recycling Association, Personal communication from William Turley, Executive Director, CDRA, Chicago, IL, 2019.
6. Aschenbrener, T., "FHWA Division Office Survey on State Highway Agency Usage of Reclaimed Asphalt Shingles: Quantities, Trends, Requirements, and Direction – Results from May 2017," FHWA-HIF-18-009. Federal Highway Administration, Washington, DC, 2017.
7. Gibson, N., Y. Seo, X. Li, A. Adriescu, and J. Youcheff, "Full--Scale and Laboratory Fatigue Cracking Performance of Combined High-Recycled And Warm Mix Asphalt Pavements," 2014 FAA Worldwide Airport Technology Transfer Conference, Galloway, NJ, 2014.
8. Willis, J.R., and P. Turner, "Characterization of Asphalt Binder Extracted from Reclaimed Asphalt Shingles," National Center for Asphalt Technology, Report 16-01, Auburn University, Auburn, AL, 2016.
9. Stroup-Gardiner, M., "NCHRP Synthesis 495, Use of Reclaimed Asphalt Pavement and Recycled Asphalt Shingles in Asphalt Mixtures," Transportation Research Board, Washington, DC, 2016.
10. Epps Martin, A., F. Kaseer, E. Arámbula-Mercado, A. Bajaj, L. Garcia Cucalon, F. Yin, A. Chowdhury, J. Epps, C. Glover, E.Y. Hajj, N. Morian, J. Sias Daniel, M. Oshone, R. Rahbar-Rastegar, C. Ogbo, and G. King, "Evaluating the Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios," National Academy of Sciences, Washington, DC, 2020.
11. Hand, A.J.T, and A. Epps Martin, "Practical Guide for Using Recycling Agents in Asphalt Mixtures," QIP-131, National Asphalt Pavement Association, Greenbelt, MA, 2020.

Practices and Lessons Learned When Using Reclaimed Asphalt Shingles in Asphalt Mixtures

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