

PennDOT RECYCLING MATERIAL FACT SHEET

Reclaimed Asphalt Pavement (RAP)

Introduction and Background

As the highways and roads in the Commonwealth age, they must be maintained and rehabilitated. One way to do this is to salvage and reuse the materials that were used during their initial construction. Reclaimed asphalt pavement (RAP) is the term given to removed and/or reprocessed pavement materials containing asphalt and aggregates. These materials are generated when asphalt pavements are removed for reconstruction, rehabilitations, or resurfacing. Recycling of asphalt pavements dates back to 1915. However, in the 1970s the “Oil Embargo” resulted in many consequences to the petroleum industry. One major repercussion was the dramatic increase in crude oil prices which resulted in amplified asphalt binder costs. The asphalt paving industry reacted to this situation by developing recycling methods to reduce the demand on asphalt binder and, thereby, reduce the costs of asphalt paving mixtures. These innovations included:

- 1980’s
 - Increased use of polymer-modified asphalt binder
- 1990’s
 - Advent of the Superpave PG binder specification
 - Stone-matrix asphalt (SMA) introduced to the U.S. (premium asphalt surfacing)
 - Improved Open-Graded Friction Courses (OGFCs) mix design procedure
- 2000’s
 - Warm-mix asphalt (WMA), introduced to the U.S.

These innovations have contributed to economics of producing the material as well as the environmental aspects of material production. The economic benefits include materials cost savings from replacing a portion of virgin aggregates and binders with RAP as well as reduced costs associated with transporting virgin materials to a site. The environmental benefits include reduced emissions and fuel usage due to reduced extraction and transportation of virgin materials, reduced demands on non-renewable resources, and reduced landfill space for disposal of used pavements. In addition, these innovations are reported to have improved performance, safety, and longevity of asphalt pavement.

Asphalt pavement is America’s most recycled and reused material. A recent FHWA survey reported that asphalt pavement recycled and reused rate is approximately 99 percent for WMA. In 2018, the National Asphalt Pavement Association (NAPA) reported:

- RAP usage in asphalt mixtures reached an all-time high of approximately 82.2 million tons,
- the average percentage of RAP used in asphalt mixtures reached a record high of 21.1%,
- approximately 6.4 million tons of RAP was used as aggregate, and
- approximately 110.3 million tons of RAP was stockpiled throughout the country for future use.

To address a resurgence of interest in increasing RAP percentages in asphalt mixtures, in 2018 PennDOT in cooperation with the Pennsylvania Asphalt Pavement Association (PAPA) developed a Standard Special Provision (SSP) facilitating the use of up to 50% RAP for 19.0 WMA on low volume roadways.

In 2019, PennDOT implemented a policy that directed the use of WMA over hot mix asphalt (HMA) for all PennDOT Projects. PennDOT performed research and studies on the differences of the mixtures, the resulting data affirmed that quality of the asphalt mixture is not compromised from the difference in temperature between the hot and warm mixes, this includes the use of RAP in mixtures.

This fact sheet provides information on the recycling of RAP including the resultant aggregate properties, engineering parameters, and approved use applications for the Pennsylvania Department of Transportation (PennDOT) use in civil engineering applications.



Examples of RAP stockpiling and processing.

Material Properties

The properties of RAP vary; specifically, the properties largely depend on the reclaimed materials and the type of asphalt mix (wearing surface, binder course, etc.). There can be substantial differences between asphalt concrete mixes in aggregate quality, size, and consistency. For instance, aggregates in surface course (wearing course) have high resistance to wear/abrasion to contribute to acceptable friction resistance properties, these aggregates may be of higher quality than the aggregates in binder course applications, where abrasion/wear resistance is not of concern.

Table 1. Physical and Mechanical Properties of RAP

Type of Property	RAP Property	Typical Range of Values
Physical Properties	Unit Weight	1940 - 2300 kg/m ³ (120 - 140 lb/ft ³)
	Moisture Content	Normal: up to 5% Maximum Range: 7 - 8%
	Asphalt Content	Normal: 4.5 - 6% Maximum Range: 3 - 7%
	Asphalt Penetration	Normal: 10-80 at 25°C (77°F)
	Absolute Viscosity or Recovered Asphalt Cement	Normal: 4,000 - 25,000 poises at 60°C (140°F)
Mechanical Properties	Compacted Unit Weight	1600 - 2000 kg/m ³ (100 - 125 lb/ft ³)
	California Bearing Ratio (CBR)	100% RAP: 20 - 25% 40% RAP and 60% Natural Aggregate: 150% or higher

Applications

The following are common applications for RAP (where provided, follow the link for more information):

- [Asphalt Concrete \(Hot In-Place Recycling\)](#)
- [Asphalt Concrete \(Cold In-Place Recycling\)](#)
- [Granular Base](#)
- [Embankment or Fill](#)

- [Full Depth Reclamation](#)
- *Asphalt Concrete Central Plant Mixtures* ([Cold](#) and [Warm](#) mixes)

Specifications

As listed in PennDOT's Publication 408 – Specifications, PennDOT has approved the following applications for RAP in highway construction:

Section	Application
341	Cold Recycled Asphalt Base Course, Cold-In-Place
342	Cold Recycled Asphalt Base Course, Central Plant Mix
344	Full Depth Reclamation
413	Superpave Mixture Design, Standard and RPS Construction of Plant-mixed Asphalt Courses with Percent Within Limits and LTS Testing (PWL-LTS)
420	Pervious Asphalt Pavement Systems
473	Asphalt Seal Coat Using Aggregate From RAP
702	Asphalt Material

PWL-LTS – (Percent Within Limits-Laboratory Testing Section)

Special Provisions

The below table provides a listing of Standard Special Provisions that have been approved for RAP usage, copies of these Special Provisions are available on PennDOT's Engineering and Construction Management System Website (ECMS).

Special Provision Number	Title
c03411	Cold In Place Recycled Asphalt Base Course
r030005	RAP Industry-Wide Coproduct Determination
C0413	Superpave Asphalt Mixture Design, Binder Course (Leveling) – Modified HIGH RAP

On May 7, 2018, PennDOT issued a memo that announced the approval of a standard special provision (SSP) for the use of up to 50% of RAP by weight in 19.0 mm asphalt mixtures for low volume roadways. The memo outlined the use guidelines for contracting the paving work via ECMS using the SSP (Provision Name – c0411 Item 4411-0010 Superpave Asphalt Mixture Design, WMA Binder Course (Leveling), - High RAP).

Unresolved Issues

While the asphalt pavement recycling technologies are well established, there is still considerable need for additional performance information, particularly with regard to creep (rutting resistance), fatigue endurance and durability, and the use of reclaimed asphalt pavement in premium surface course mixes. There is also a need for more correlation of field and laboratory measurements to refine guidelines for laboratory prediction of field performance (for instance, laboratory curing procedures that best simulate field conditions).

Additional matters that require resolution include:

- Variability of RAP, especially from blended stockpiles;
- Validation of Superpave mix design procedures with mixtures containing RAP;
- A consensus regarding mix design and testing procedures for plant recycled cold mix and cold in-place recycling of asphalt mixtures;
- The suitability of cold in-place recycling for use with surface treatments and/or rubberized paving materials;

- A more accurate determination of the structural layer coefficient for plant recycled cold mix asphalt mixtures;
- An environmental evaluation of any potentially harmful impacts from cold mix plant recycling and/or cold in-place recycling;
- Establish standard specifications for the incorporation of RAP into granular base and standard methods for determining in-place compacted density; and,
- Evaluation of environmental concerns regarding leachability characteristics for RAP, as well as various RAP-aggregate blends, to develop procedures for the stockpiling and placing of base or subbase materials containing RAP in situations where there may be groundwater contact.

Conclusions

RAP has been used in numerous roadway construction projects throughout the U.S. The use of RAP has shown significant costs savings, environmental benefits, and has demonstrated performance comparable to conventional asphalt pavement. PennDOT continues to make strides in performing testing and research to advance the uses of RAP; this includes identifying new applications as well as finding new ways to increase percentages used in asphalt mixtures. As they are approved and issued, Publication 408 will be updated to include new Specifications, as well as the PennDOT electronic Construction And Materials Management System (eCAMMS) database to include Special Provisions for the advancement of RAP usages.

References

Federal Highway Administration, 2011. Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice (<https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/11021/11021.pdf>).

Federal Highway Administration, 2016. User Guidelines for Waste and Byproduct Materials in Pavement Construction - Reclaimed Asphalt Pavement (<https://www.fhwa.dot.gov/publications/research/infrastructure/structures/97148/rap131.cfm>).

National Asphalt Pavement Association, 2020. RAP Recycling (<https://www.asphaltpavement.org/expertise/sustainability/sustainability-resources/recycling>).

Pennsylvania Department of Transportation, 2018. Use Guidelines for 19.0 mm Warm Mix Asphalt High RAP Mixtures for Low Volume Roadways Memo (http://www.pa-asphalt.org/assets/_control/content/files/SSP%20Use%20Guidelines%20for%2019.0%20mm%20Warm%20Mix%20Asphalt%20%20High%20RAP%20Mixtures%20for%20Low%20Volume%20Roadways%281%29.pdf).

PennDOT's eCAMMS Database, 2020. (<https://www.ecamms.pa.gov/LoginSM.aspx?TYPE=33554433&REALMOID=06-6e34214c-175e-4389-b4b2-7fc7db2335bf&GUID=1&SMAUTHREASON=0&METHOD=GET&SMAGENTNAME=-SM-hn5Gq61Z1CZjlpvMXFetxcXquXKfJ%2fHFfa2gVhKTQomOj6fNvYL6jIHbZoLfw%2bIM&TARGET=-SM-https%3a%2f%2fwww%2ecamms%2epa%2egov%2f>)

PennDOT's ECMS Website, 2020. (<https://www.ecms.penndot.gov/ECMS/>).