



PennDOT RECYCLING MATERIAL FACT SHEET

Reclaimed Asphalt Pavement (RAP)

Introduction and Background

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, resurfacing. Recycling of asphalt pavements dates back to 1915^(1,3). The “Oil Embargo” of the 1970’s had many consequences; among these was a renewed interest in recycling asphalt pavement owing to dramatic cost increases for asphalt binder. 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⁽²⁾:

- 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., (2004)

These innovations, among others, are reported to have improved performance, safety, and longevity of asphalt pavement. In addition, these innovations have contributed to economics of producing the material as well as the environmental aspects of material production⁽²⁾. 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.

Asphalt pavement is America’s most recycled and reused material. A recent FHWA survey reported that asphalt pavement recycled and reused rate are approaching 99 percent for Warm Mix. The amount of RAP used in asphalt pavements was 56.0 million tons in 2009 and 62.1 million tons in 2010^(2,4). Another organization estimated that as much as 91 million metric tons and 73 million metric tons of RAP may be produced/recycled each year in the United States.⁽⁵⁾

This fact sheet provides information on the recycling of reclaimed asphalt pavement including the resultant aggregate properties, engineering parameters, and applications for the Pennsylvania Department of Transportation (PennDOT) use in civil engineering applications. The fact sheet is divided into the following sections:

Material Properties – describes the physical properties and engineering parameters of Reclaimed Asphalt Pavement (RAP).

Applications – describes RAP applications.

Specifications – present existing PennDOT specifications.

Conclusions – presents conclusions and discusses implementation issues.

Material Properties

Table 1. Physical and mechanical properties of Reclaimed Asphalt Pavement (RAP)⁽³⁾

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: 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

Potential applications for RAP described in detail (follow document link below) include⁽³⁾:

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

Specifications

Currently the Pennsylvania Department of Transportation uses RAP in highway construction.

- Pennsylvania Department of Transportation Publication 408 2011⁽⁶⁾
(<ftp://ftp.dot.state.pa.us/public/bureaus/design/pub408/pub%20408-2011.pdf>)
 - Sections: 309, 341, 342, 409, 419, and 703

- Pennsylvania Department of Transportation Standard Special Provisions⁽⁷⁾
(<http://www.dot14.state.pa.us/ECMS/SVSPSearch?action=showResults>)
 - a11101 HOT SURFACE RECYCLING AND REPAVING OF BITUMINOUS PAVEMENTS
 - a11201 HOT SURFACE RECYCLING OF BITUMINOUS PAVEMENT
 - a13301 DELIVERY OF MILLED MATERIAL TO DEPARTMENT STOCKPILE

Unresolved Issues⁽³⁾

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).

Some additional issues that require resolution include:

- Further information on the variability of RAP, especially from blended stockpiles;
- Validation of SUPERPAVE mix design procedures with mixtures containing RAP;
- An environmental code of practice regarding gaseous emissions from hot mix plant recycling.

While cold asphalt pavement recycling technologies are well established, there is still a need for additional performance information, particularly with regard to creep (rutting resistance), fatigue endurance, and durability. In addition, there is a need to assess whether RAP can be used in wearing surface cold mixes. Further investigation is also needed to evaluate the ability of cold recycled plant mixes to perform on higher traffic volume roadways. There is also a need for more correlation of field and laboratory measurements to refine guidelines for laboratory prediction of field performance, including, for instance, laboratory curing procedures that best simulate field conditions.

Some specific issues that require resolution include:

- Further information on the variability of RAP, especially from blended stockpiles;
- A consensus regarding mix design and testing procedures for plant recycled cold mix and CIPR asphalt mixtures;
- The suitability of CIPR 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; and
- An environmental evaluation of any potentially harmful impacts from cold mix plant recycling and/or cold in-place recycling.
- There is a need to establish standard specifications for the incorporation of RAP into granular base and standard methods for determining in-place compacted density.
- In addition, there is a need to resolve some environmental concerns regarding leachability characteristics for RAP, as well as various RAP-aggregate blends, in order to develop procedures for the stockpiling and placing of base or subbase materials containing RAP in situations where there may be groundwater contact.

There is a need to establish standard specifications for the incorporation of RAP into granular base and standard methods for determining in-place compacted density.

In addition, there is a need to resolve some environmental concerns regarding leachability characteristics for RAP, as well as various RAP-aggregate blends, in order to develop procedures for the stockpiling and placing of base or subbase materials containing RAP in situations where there may be groundwater contact.

Although RAP is not frequently incorporated into embankments, there is a need to establish standard specifications for the use of RAP in embankment construction, either by itself as an embankment base material, or blended with soil and/or crushed aggregate.

Although the available body of technical data indicate that RAP is a non-leachable material, there is a need to develop a procedure for stockpiling and placing of fill materials containing RAP in situations where there may be groundwater contact or concerns about runoff quality.

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.

References

Ref (1) – Ref (7)