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Performance of Recycled Asphalt Shingles in Hot Mix Asphalt: TPF-5(213)

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Abstract
US transportation agencies have been increasingly using recycled asphalt shingles (RAS) in hot mix asphalt (HMA) applications over the last 25 years. Initial use of RAS started with recycled postmanufacturers shingles, but now agencies are showing a growing interest in using post-consumer (tear-off) RAS in asphalt applications. Post-consumer asphalt shingles typically have 20 to 30 percent asphalt by weight of the shingles as well as fine aggregates, mineral filler, polymers, and cellulosic fibers from the shingle backing. Each year, an estimated 10 million tons of post-consumer shingles are placed in landfills in the US. Utilization of this waste product presents an opportunity to replace virgin asphalt binder with the RAS binder while taking advantage of the additional fibers which can improve performance. Thus, a material that has historically been deemed a solid waste and has been placed in landfills can decrease pavement costs and reduce the burden on ever-decreasing landfill space.

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TECH BRIEF

Performance of Recycled Asphalt Shingles in Hot Mix Asphalt

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RESEARCH PROJECT TITLE:

Performance of Recycled Asphalt Shingles in Hot Mix Asphalt

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Pooled Fund Study Description

US transportation agencies have been increasingly using recycled asphalt shingles (RAS) in hot mix asphalt (HMA) applications over the last 25 years. Initial use of RAS started with recycled post-manufacturers shingles, but now agencies are showing a growing interest in using post-consumer (tear-off) RAS in asphalt applications. Post-consumer asphalt shingles typically have 20 to 30 percent asphalt by weight of the shingles as well as fine aggregates, mineral filler, polymers, and cellulosic fibers from the shingle backing. Each year, an estimated 10 million tons of post-consumer shingles are placed in landfills in the US. Utilization of this waste product presents an opportunity to replace virgin asphalt binder with the RAS binder while taking advantage of the additional fibers which can improve performance. Thus, a material that has historically been deemed a solid waste and has been placed in landfills can decrease pavement costs and reduce the burden on ever-decreasing landfill space.

Many agencies share common questions about the effect of post-consumer RAS on the performance of HMA. Previous research has allowed for only limited laboratory testing and field surveys. The complexity of RAS materials and lack of past experiences led to the creation of Transportation Pooled Fund (TPF) Program TPF-5(213). The primary goal of this study is to address research needs of state DOT and environmental officials to determine the best practices for the use of recycled asphalt shingles in hot-mix asphalt applications. Agencies participating in the study include Missouri (lead state), California, Colorado, Illinois, Indiana, Iowa, Minnesota, Wisconsin, and the Federal Highway Administration. Multiple state demonstration projects were conducted to provide adequate laboratory and field test results to comprehensively answer design, performance, and environmental questions about asphalt pavements containing post-consumer RAS.

Demonstration Projects

The demonstration projects focused on evaluating different aspects (factors) of RAS that were deemed important for each state to move forward with a RAS specification. RAS factors addressed in the different demonstration projects included the evaluation of the RAS grind size, RAS percentage, RAS source (post-consumer versus post-manufactured), RAS in combination with warm mix asphalt technology, RAS as a fiber replacement for stone matrix asphalt (SMA) pavements, and RAS in combination with ground tire rubber (GTR). Several of the demonstration projects also included control sections to compare traditionally used mix designs containing either RAP only or no recycled product to mix designs containing RAS. Field mixes from each demonstration project were sampled for conducting the following tests: dynamic modulus and flow number for rutting evaluation, four-point beam fatigue for fatigue cracking evaluation, semi-circular bending for low temperature cracking evaluation, and binder extraction and recovery with subsequent binder characterization. Pavement condition surveys were then conducted for each project after completion. The experimental plan for each agency's demonstration project is summarized in the following table.

Agency	Research Interest	Mix Designs Developed for Agency Experimental Plans*			
Colorado	Replacement of RAP with RAS	0% RAS 20% RAP	3% RAS 15% RAP		
Illinois	5% RAS in SMA (no fibers added)	PG 70-28 Lab Mix	PG 70-28 Plant Mix	PG 58-28 12% GTR	
Indiana	RAS with Foaming WMA	15% RAP HMA	3% RAS HMA	3% RAS WMA	
Iowa	Percentage of RAS	0% RAS	4% RAS	5% RAS	6% RAS
Minnesota	Post-Manufactured versus Post-Consumer	0% RAS 30% RAP	5% Manufactured RAS	5% Post-Consumer RAS	
Missouri	Coarse versus Fine Grind RAS	0% RAS 15% RAP	5% Fine RAS 10% RAP	5% Coarse RAS 10% RAP	
Wisconsin	RAS with RAP and 3G Compaction Aid	5% RAS No 3G	5% RAS 3G Evotherm®		

*Example: Two mixes were developed in the Colorado project, one with 20% RAP and one with 15% RAP and 3% RAS

Key Findings

The demonstration projects showed that pavements using RAS alone or in combination with other cost saving technologies (e.g., WMA, RAP, GTR, SMA) can be successfully produced and meet state agency quality assurance requirements for mix asphalt content, gradation, and volumetrics. These mixes have very promising prospects since laboratory test results indicate good rutting resistance based on the flow number and dynamic modulus tests. The mixes also demonstrated good fatigue cracking resistance in the four-point bending beam apparatus, with the SMA mixes from Illinois (which used 5% RAS and no added fibers) exhibiting the most desirable fatigue characteristics. Fracture properties of the mixes at low temperatures determined by the SCB fracture energy test showed no statistical change in mixes with RAS compared to the mixes without RAS for the Missouri, Minnesota, Indiana, Wisconsin, Illinois and Colorado projects. Based on the SCB results, the addition of RAS materials to HMA is not detrimental to its fracture resistance, and fibers in the RAS could be contributing to the mix performance.

The test results of the extracted binder from these mixes showed that when RAS is used in HMA, the performance grade of the base binder increases on the high and low side. The average results of all the mixes in the study showed that for every 1 percent increase in RAS, the low temperature grade of the base binder increased 1.9°C; and for every 1 percent increase in RAP, the low temperature grade of the base binder increased 0.3°C. Therefore, as a rule of thumb, 3 percent RAS or 20 percent RAP would be the maximum amount of recycled material allowed without requiring a low temperature grade bump (6°C) in the base binder. This corresponds to a 14 percent binder replacement when using RAS and a 20 percent binder replacement when using RAP, when considering the average asphalt content values for all the mix designs in the study.

The pavement condition of the mixes in the field after two years corroborated the laboratory test results. No signs of rutting, wheel path fatigue cracking, or thermal cracking was exhibited in the pavements. However, transverse reflective cracking from the underlying jointed concrete pavement was measured in the Missouri, Colorado, Iowa, Indiana, and Minnesota projects. The pavement condition surveys in Missouri revealed the pavement containing coarsely ground RAS exhibited more transverse cracking than the pavement containing finely ground RAS, but the non-RAS pavement exhibited less cracking than both coarse and fine RAS pavements. The non-RAS pavement in Colorado also showed slightly less cracking than the RAS pavement. In contrast, the RAS pavements exhibited the same amount of cracking or less than the non-RAS pavements for the Iowa, Indiana, Illinois, and Wisconsin demonstration projects.

These results show great promise for future RAS applications in HMA and will be shared among the transportation agencies participating in the pooled fund study to help them develop specifications for optimizing the performance of HMA with RAS. The final report can be downloaded at the pooled fund study website.

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Transportation Pooled Fund Website for TPF-5(213):
http://www.pooledfund.org/Details/Study/441

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