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Performance of Recycled Asphalt Shingles in Hot Mix Asphalt: TPF-5(213), Minnesota DOT's Project Involvement

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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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Minnesota DOT's Project Involvement

TECH BRIEF

Performance of Recycled Asphalt Shingles in Hot Mix Asphalt

Transportation Pooled Fund Program

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). TPF-5(213) is a partnership of several state agencies with the goal of researching the effects of RAS on the performance of HMA applications. 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. Each state transportation agency in the pooled fund study proposed a unique field demonstration project that investigated different aspects of asphalt mixes containing RAS specific to their state needs. The demonstration projects focused on evaluating different aspects (factors) of RAS that were deemed important for their state to move forward with RAS specifications.

The Minnesota Demonstration Project

The Minnesota Department of Transportation (MnDOT) selected a project that would evaluate the performance of HMA containing post-manufactured RAS versus post-consumer RAS while also evaluating the performance of HMA using recycled asphalt pavement (RAP). MnDOT selected in-service pavement sections at their MnROAD Cold Weather Road Research Facility pavement test track for their demonstration project. The pavement sections were constructed in 2008 and included shoulder mixes and transition traffic lanes that used post-manufactured and post-consumer RAS. The RAS and RAP components of each mix evaluated are presented below.

MnDOT Experimental Plan

Mix Design	% RAS	% RAP	RAS Source
30% RAP Mix	0	30	-
5% Post-Cons. RAS Mix	5	0	Post-Consumer
5% Post-Manuf. RAS Mix	5	0	Post-Manufactured

“Utilization of this waste product [RAS] presents an opportunity to replace virgin asphalt binder with the RAS binder while taking advantage of the additional fibers which can improve performance.”

“The 5% RAS mix designs contained performance grades comparable to the 30% RAP mix design.”

“Fracture energy results showed no differences in cracking performance between the three mixes.”

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

Iowa State University Institute for Transportation Website for TPF-5(213): http://www.intrans.iastate.edu/tpf-5-213/

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Loose samples of each mix type during production were obtained to conduct laboratory performance tests (dynamic modulus, flow number, four-point beam fatigue, and semi-circular bending (SCB)) and binder extraction and recovery for subsequent binder characterization. Pavement conduction surveys were conducted at the MnRoads test sections two, three, and four years after construction to assess the field condition of the pavements.

Key Findings

Asphalt mix designs using the post-consumer and post-manufactured RAS were successfully designed and produced to meet MnDOT specifications. Binder performance grade (PG) values and asphalt contents of the RAS sources in the following table highlight the differences between the two RAS sources. The post-consumer RAS contained a higher asphalt content (23.0%) than the post-manufactured RAS (17.1%). Since post-consumer shingles are older, they are more likely to contain a cellulose felt backing rather than fiberglass backing which is not as absorptive as cellulose felt. The binder in the post-consumer RAS was also stiffer than the binder in the post-manufactured RAS as a result of the post-consumer shingles being in-service and aged for a number of years. Based on the PG testing of the extracted binders, the 5% RAS mix designs contained performance grades comparable to the 30% RAP mix design.

Asphalt content and PG grading results

Material Identification	Asphalt Content	% Asphalt Repl. in HMA	High PG Temp, °C	Low PG Temp, °C	PG
Post-Manufactured RAS	17.1	-	109.1	-	-
Post-Consumer RAS	23.0	-	122.5	-	-
RAP	5.9	-	73.5	-10.8	70-10
5% Post-Manuf. RAS Mix	4.8	18.8	71.3	-21.7	70-16
5% Post-Cons. RAS Mix	5.0	26.0	71.1	-21.2	70-16
30% RAP Mix	5.3	33.3	68.8	-22.7	64-22

Results from the laboratory performance tests on the mixes suggest that the RAP and RAS mixes will perform well in the field. The flow number test showed the RAS mixes were more resistant to permanent deformation than the RAP mix. The post-consumer RAS mix demonstrated the greatest resistance to permanent deformation with a flow number of 2497 while the 30% RAP mix’s flow number was only 767.

The four-point bending beam results showed that both RAS mixes exhibited longer fatigue lives than the RAP mix in a strain controlled test. These results are counterintuitive when considering the RAS binder is substantially stiffer than the RAP binder. However, the RAS contains fibers, as a result of the shingle grinding process, which may be improving the fatigue performance of the RAS mixes by enhancing their ductile properties. The post-manufacturer RAS mixture had a longer fatigue life at higher strain levels than the post-consumer RAS mixture, but both mixes had similar fatigue lives at lower strain levels. For the SCB low temperature cracking test, statistical analysis of the fracture energy results showed no differences in cracking performance between the three mixes.

Pavement condition surveys conducted two, three, and four years after construction revealed similar performance in the post-consumer RAS shoulder pavement section and the RAP shoulder pavement section. The post-manufactured RAS sections performed substantially lower, however, the shoulders containing the post-manufactured RAS mix design were adjacent to a jointed concrete pavement in the mainline which seemed to accelerate the cracking in the HMA shoulder. When comparing the mainline transitions, the post-consumer RAS transition contained slightly less transverse cracking (173 linear feet) than the post-manufactured RAS transition (199 linear feet).

These results show that post-consumer RAS mixes can perform as well as post-manufactured RAS mixes. When properly designed, RAS mixes can also exhibit similar performance properties as RAP mixes. These results will be shared with other departments of transportation participating in the pooled fund study to help MnDOT and other state agencies develop specifications for optimizing the performance of HMA containing RAS. The final report can be downloaded at the pooled fund study website.