Use of Recycled Materials on Thin Overlays for Pavement Preservation

Farhang Jalali[1], Adriana Vargas-Nordcbeck[2]
([1] National Center for Asphalt Technology, Auburn University, Alabama, USA, fzj0006@ auburn.edu)
([2] National Center for Asphalt Technology, Auburn University, Alabama, USA, vargaad@auburn.edu)

ABSTRACT

Over time, new pavements deteriorate due to the effect of traffic loads and the environment. If appropriate treatments are applied during the early stages of deterioration, it is possible to extend the service life of the pavement without incurring in costly rehabilitation or reconstruction activities. Thin hot mix asphalt (HMA) overlays used as preservation treatments can help protect the pavement structure, reduce the rate of pavement deterioration, correct surface deficiencies, reduce permeability, and improve the ride quality.

As part of the National Center for Asphalt Technology (NCAT) Pavement Preservation study, thin overlay test sections were placed in a low traffic volume road (Lee County Road 159) in Auburn, Alabama. objective of this paper was to evaluate the field performance of recycled-incorporated pavement preservation test sections compared to untreated sections.

Thin overlays were placed on 30.5 m long sections with various amounts of cracking, but in overall good structural condition. A control section was overlaid with a virgin dense-graded 4.75 mm NMAS mix with PG67-22 binder. Similar mixtures containing 50% fractionated reclaimed asphalt pavement (RAP) and 5% recycled asphalt shingles (RAS) were also placed. In addition, a section was treated with a virgin overlay over a 100% foamed recycled base. Two test sections with low and high levels of cracking were left untreated for comparison. All overlays were placed in August 2012 and had a design thickness of 19 mm. Pavement performance was monitored periodically by measuring cracking, rutting, and IRI. After 5 years of service, the test sections continue to exhibit good performance. That is, overall, rutting was less than 5 mm, IRI was 2.1 m/km or less, and cracking was less than 40% of what it would be under the “do-nothing” scenario. Results suggest the use of thin HMA overlays in combination with recycled materials are an effective preservation technique when applied appropriately.

Keywords: Thin Overlays, Pavement Preservation, Cracking, Roughness, IRI, Distress

1. BACKGROUND

The Federal Highway Administration (FHWA) and the Foundation for Pavement Preservation are promoting the idea of using the thin-lift hot-mix asphalt as a main component of the “pavement preservation toolbox.” Thin hot mix asphalt (HMA) overlays used as preservation treatments can help protect the pavement structure, reduce the rate of pavement deterioration, correct surface deficiencies, reduce permeability, and improve the ride quality [1, 2]. Asphalt mixtures may include reclaimed asphalt pavement (RAP) or recycled asphalt shingles (RAS), which results in additional environmental and economic benefits. However, this process produces a binder with different performance characteristics compared to the virgin mix [3, 4]. RAP and RAS Mixtures have stiffer mix and binder, and are more susceptible to cracking at mid to low temperatures.

The success story of recycled materials application in the asphalt industry dates back to the Arab oil embargo in the early 1970s, which resulted in a sharp increase in binder prices. The asphalt industry reacted smartly by developing the asphalt milling machine and devising methods to recycle the old paving material back into new pavements [5]. Asphalt binder and aggregates in RAP and RAS can be incorporated into the new HMA mixtures, which brings down the price of new HMA mixes and makes them more economically appealing alternatives for pavement preservation strategy [6].

As part of the NCAT Pavement Preservation study, thin overlay test sections were placed in a low traffic volume road (Lee County Road 159) in Auburn, Alabama. The location consists of a two-lane county road that provides dead end access to quarry and an asphalt plant, resulting in a low traffic setting with high percentage of heavy truck loads. Treatments were placed on a 14-year old pavement with a 14 cm HMA layer over a 15 cm granular base. The existing pavement exhibited various amounts of cracking, but was in overall good structural condition. Two test sections with low and high levels of cracking were left untreated for comparison. All overlays were placed in August 2012 and had a design thickness of 19 mm. Pavement performance was monitored periodically by measuring cracking, rutting and roughness by means of the International Roughness Index (IRI). Each section is 30.5 m long. The research presented herein primarily intends to shed light on performance of various types of thin overlays. Namely virgin, foamed recycled as base, RAP and RAS sections.

2. OBJECTIVES

This study focused on evaluating the field performance of recycled-incorporated pavement test sections at a low-volume traffic setting (Lee County Road 159) in Auburn, Alabama. The performance was compared with the performance of control (untreated) sections to shed light on benefits of utilizing the reclaimed/recycled materials in HMA mixtures.

3. OVERLAY DESCRIPTION

As of the four sections that received different treatments, two received a recycled type thin-lift overlay as a pavement preservation treatment. One received a virgin thin overlay over a 100% foamed recycled base, and one other section received a conventional virgin thin overlay treatment. In addition, two control sections with low and high degrees of initial cracking were included as part of this experiment design.

All mixtures had a nominal maximum aggregate size (NMAS) of 4.75 mm and were designed using the Superpave method for a compactive effort of 75 gyrations and an air void content of 4.0%. The virgin aggregates used were limestone and sand. All mixes contained 1.0% hydrated lime (by weight of dry aggregate) as an antistripping agent. The design gradation for all mixtures is presented in Table 1.

Three mixture types were used in total: a virgin PG67-22 mix, a mix containing 50% RAP, and a mix containing 5% RAS. The binder grading was selected based on the geographic location and current state of practice. Table 1 exhibits the design volumetric properties and binder information for all mixtures. All virgin mixes used the same gradation and asphalt binder content. Recycled mixes had to be adjusted to accommodate the desired content of RAP or RAS. Overall, mixtures were kept as similar as possible.

In all sections, the design overlay thickness was 19 mm. A tack coat was applied to the existing surface using a NTSS-1HM emulsion (trackless tack) at an undiluted rate of 0.27 L/m^2. In the section with foamed recycled treatment, a full-depth reclamation was performed, where the entire HMA thickness and part of the underlying base material were removed and treated with foamed asphalt to produce a 15 cm base.

TABLE 1 Design Gradation and Volumetric Properties for All Mixtures

	Percent Passing Sieve		
Sieve Size	**Virgin PG 67-22**	**50% RAP**	**5% RAS**
3/8”	100	100	100
No. 4	99	99	99
No. 8	76	78	77
No. 16	53	56	54
No. 30	36	38	37
No. 50	23	22	23
No. 100	15	15	16
No. 200	11.5	11.1	12.2
Property	**Virgin PG 67-22**	**50% RAP**	**5% RAS**
Virgin Binder PG Grade	PG 67-22	PG 67-22	PG 67-22
Binder content, %	6.1	6.5	6.2
Binder replacement, %	--	54%	19%
VMA, %	16.9	17.2	17.1
VFA, %	76	77	77
Dust to binder ratio	2.0	1.9	2.1

4. METHODOLOGY

It is always assumed that the application of thin overlays as preservation strategy significantly delays major performance problems (e.g., cracking, rutting and roughness). To test the life-extending benefits of these treatments, field data collection has been in progress since August 2012 on a weekly basis. Data collection has been performed utilizing a specially equipped vehicle. Equipment mounted on the vehicle include a laser system for gauging rutting, an inertial profiler for IRI measurement, and a high-resolution camera for pavement scanning. This will help characterize treatments not only based on their average long-term performance, but more importantly based on the initial condition of the surface which was overlaid. In this way, application of different treatments may be warranted based on the initial condition.

5. RESULTS AND DISCUSSION

5.1 Cracking

Figure 1 shows all treatments outperformed the control (untreated) sections after 5 years of service. Few cracks (approximately 4% of the pavement surface) were observed on virgin thinlays with and without foamed recycled base. Crack propagation rate was quite similar for RAP and RAS thinlays.

A reasonable approach to assess the cracking performance of thin overlays is to assess what would have happened if the existing surface was left untreated. The cracking measurements obtained from the control sections were used to estimate the cracking performance of the remaining sections for a “do-nothing” scenario based on the existing condition at the beginning of the study (2012). A “performance ratio” was determined by calculating the percentage of cracking in the treated section relative to the projected percentage of cracking for the untreated section, as shown in Eq. (1). Values closer to zero translate into higher effectiveness for treatment strategy purposes.

$$Performance\ ratio = \frac{cracking\ in\ treated\ section\ at\ time\ t}{projected\ cracking\ if\ untreated\ at\ time\ t} \times 100\% \quad (1)$$

Figure 2 shows the performance ratio for the studied thin overlays. For virgin thin overlays, the ratio is below 10%, which demonstrates excellent performance. The ratios for RAP and RAS are fairly close, at around 35%, which is considered as highly effective compared with the control sections.

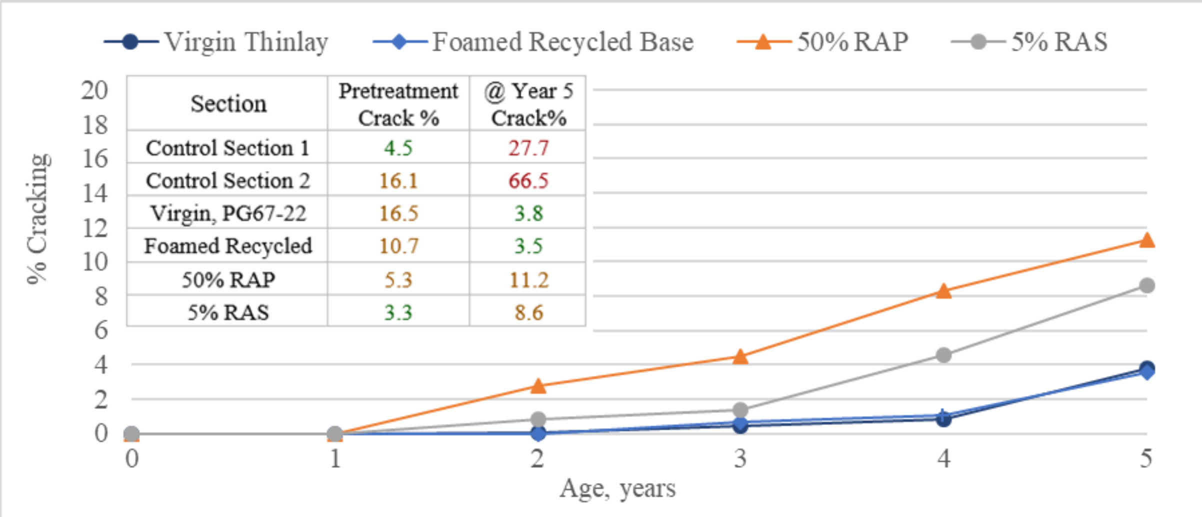

FIGURE 1 Crack Propagation Trends for Thin Overlays

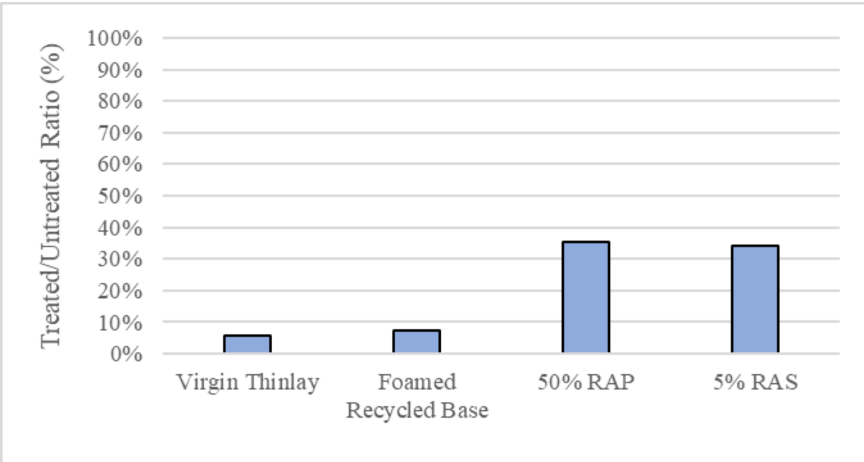

FIGURE 2 Performance Ratio after 5 Years

5.2 Rutting

As mentioned earlier, at the beginning of this study sections were 14 years old and showed minimum rutting (less than five millimeters). As shown in Figure 3, average rutting during each year remained under five millimeters, which indicates excellent performance. Some small variations can be observed over time, which can be attributed to random measurement errors. Overall, rut depths are very low and these differences are of no practical significance.

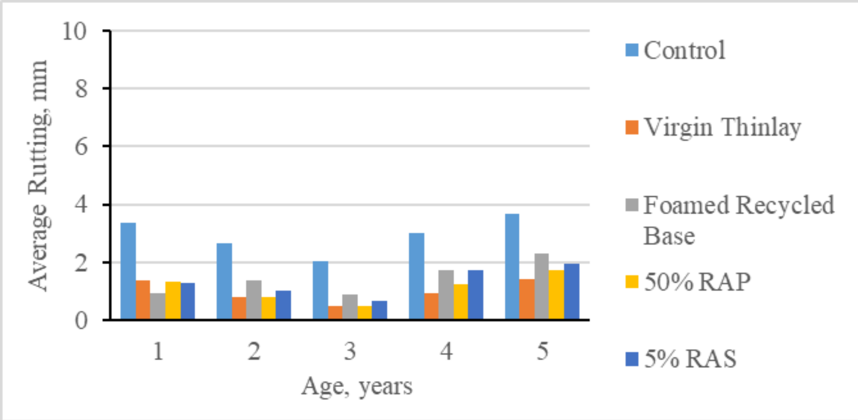

FIGURE 3 Average Rutting over Time

5.3 Roughness

In this study, roughness was measured using the International Roughness Index (IRI). Figure 4 shows the IRI trend for the four treatments. RAP and RAS sections demonstrated similar roughness, while the virgin thin overlay had the smoothest surface. IRI for the thin overlay over foamed recycled base had a modest increasing trend, and had the highest roughness among treatments. It is worth mentioning that after 5 years of service, roughness remained nearly constant for all treatments. As a result, IRI is not considered a decisive factor for treatment evaluation in this study at this point in time.

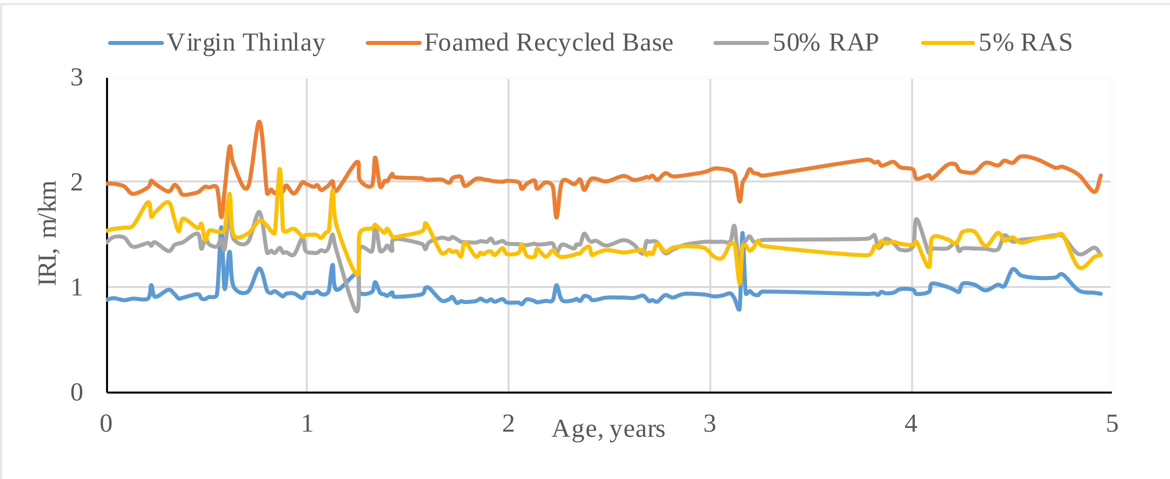

FIGURE 4 IRI Measurement over Time

Because this study is sponsored primarily by State Departments of Transportation (DOTs), it is important that pavement condition be evaluated in a way that is consistent among agencies. The MAP-21 performance criteria established by the Federal Highway Administration [7] provide condition categories for the performance indicators used to evaluate the treatments presented in this document, as shown in Table 2.

TABLE 2 Condition Ratings for MAP-21 Performance Measures

Condition Rating	% of Area Cracked	Rutting, in (cm)	IRI, in/mi (m/km)
Good	< 5%	< 0.20 (0.51)	< 95 (1.5)
Fair	5 – 20%	0.20 – 0.40	95 – 170
Poor	> 20%	> 0.40 (1.02)	> 170 (2.7)

Table 3 shows the condition categories of the treatments after five years of service. Although the RAP and RAS thin overlays exhibit more cracking, pavement deterioration was significantly reduced compared to the untreated sections, which are currently in the "poor" cracking category. Overall, use of recycled materials in thin overlays as preservation treatments has shown to be an effective alternative for extending pavement life.

TABLE 3 Performance Measures at Year 5

	Treatment				Control Sections	
Performance Measure	Virgin thinlay	Foamed Recycled Base	50% RAP	5% RAS	Section 1	Section 2
Cracking, %	3.8	3.5	11.2	8.6	27.7	66.5
Roughness (IRI), m/km	0.9	2.1	1.3	1.3	1.4	1.2
Rutting, mm	1.4	2.3	1.7	1.9	3.3	3.3

6. CONCLUSIONS

The objective of this study was to evaluate the performance of thin HMA overlays in combination with recycled materials as pavement preservation treatments. The following conclusions were obtained:

1. Rutting and roughness values were stable for all treatments throughout the first 5 years of the study. At the end of year 5, almost all thin overlays exhibited excellent rutting and roughness performance, with the exception of the mixture placed on foamed recycled base, which is categorized as "fair" for roughness. The stable status of these performance measures despite the heavy truck traffic is mainly due to existence of a sound structure before treatment placement. Nevertheless, structural-related distresses could have impacted rutting and roughness negatively. Other reason might be that crack percentages are not high enough yet to impact roughness.
2. All treatments outperformed the control section in terms of cracking. Virgin thinlays showed excellent performance in which very few cracks, less than 5%, were observed on the surface. RAP and RAS sections are just beginning to show minor signs of crack reappearance after 5 years, which is again above all expectations.
3. Although RAP and RAS sections exhibited more cracking after 5 years compared to the virgin overlays, incorporation of recycled materials for pavement preservation results in improved pavement performance. It should be noted that the recycled mixtures used in this study had high amounts of binder replacement. Performance can be further improved by reducing the amount of aged binder in the mix. In addition, use of foamed recycled base has also shown to be an excellent alternative to extend the life of the pavement while providing economic and environmental benefits.

The ongoing study will be continued until all treatments experience higher distresses and reach the end of their service lives. The results are expected to provide valuable information on the appropriateness of various treatments for pavement preservation needs.

7. ACKNOWLEDGEMENTS

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