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Impacts of rejuvenators on performance and engineering properties of asphalt mixtures containing recycled materials

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HIGHLIGHTS

- Performance comparison of asphalt mixtures by performing various laboratory tests.
- Simple cost analysis to investigate the cost benefits of using rejuvenators.
- Cost effective way to enhance the overall performance of asphalt mixtures containing recycled materials.

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ABSTRACT

Recycled materials, such as recycled asphalt shingles (RAS) and reclaimed asphalt pavement (RAP), have been widely used in asphalt paving industry, and the trend seems to use more and more, which can save taxpayer dollars, preserve energy and protect the environment. However, these recycled materials are often highly aged and cause potential durability issue for asphaltic layers. To balance out the impact of stiff binder of recycled materials, rejuvenators have been recently evaluated. This study investigated the impacts of various rejuvenators on the performance and engineering properties of hot-mix asphalt (HMA) mixtures containing recycling materials (i.e., RAP and RAS). Various laboratory tests, including Hamburg test, overlay test, dynamic modulus test, and repeated load test, were performed to compare the performance and engineering properties of HMA mixtures without rejuvenators to those of mixtures incorporated with rejuvenators. In addition, a simple cost analysis was performed to investigate the cost benefits of using rejuvenators. The laboratory test results and the cost analysis were presented and discussed in this paper.

1. Introduction

In the last several years, both reclaimed asphalt pavement (RAP) and recycled asphalt shingles (RAS) have been widely used in asphalt mixtures and the trend seems to use more and more because they can significantly reduce the cost of asphalt mixtures, conserve energy, and protect the environment. However, the use of more RAP and RAS often makes asphalt mixtures too stiff, and consequently less workable and difficult to compact in the field, which may ultimately lead to premature field failure [1]. In attempt to reduce the stiffness of RAP and/or RAS mixtures, one option is to use rejuvenators. Recently, rejuvenating agents have been receiving attention from the pavement research community because they can improve the engineering properties of asphalt mixtures containing high content recycled materials. Generally, rejuvenator is a kind of asphalt additives to soften the stiffness of the oxidized asphalt mixtures. Typically, rejuvenators contain a high proportion of maltenes constituents that help re-balance the composition of the aged binders that lost its maltenes during construction and field service [2]. According to Carpenter and Wolosick [3], the working mechanism (or diffusion process) of a rejuvenator consists of the following four steps:

I. The rejuvenator forms a very low viscosity layer that surrounds the asphalt-coated aggregate which is highly aged binder layer.
II. The rejuvenator begins to penetrate into the aged binder layer, decreasing the amount of raw rejuvenator that coats the particles and softening the aged binder.
III. No raw rejuvenator remains, and the penetration continues, decreasing the viscosity of the inner layer and gradually increasing the viscosity of the outer layer.

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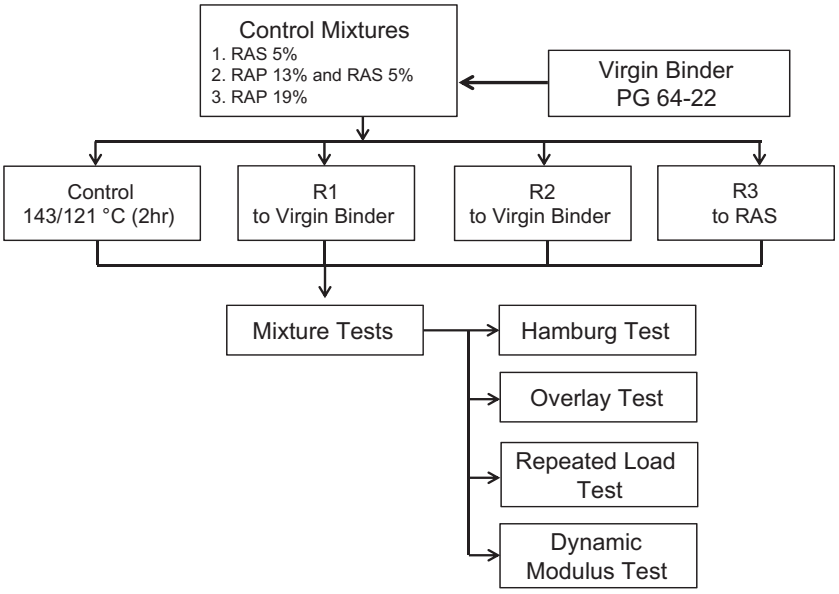

Fig. 1. Experimental test plan.

Table 1
Gradation of aggregates and asphalt contents used in this study.

Combination of Materials		Sieve analysis (sieve number and size in mm)						
Aggregate sources	%	19 (mm)	9.5 (mm)	#4 (4.75)	#8 (2.36)	#30 (0.60)	#50 (0.30)	#200 (0.075)
5% RAS Mixture								
Limestone (type C)	26	100	56.4	10.9	4.7	3.3	2.6	2.2
Limestone (type D)	19	100	70.7	14.3	6.3	3.7	3.3	2.7
Limestone (type F)	21	100	100	76.4	20.6	6.2	4.8	3.9
Manufactured sand	22	100	100	99.9	89.8	40.3	24.2	7.6
Field sand	7.8	100	100	99.8	98.1	90.5	66.9	3.7
RAS	5	100	100	99.7	98.9	62.8	53.7	23.4
Combined gradation	100	100	83.1	55.5	38.3	21.4	15.1	4.8
PG 64-22		5.2 (%)						
13% RAP plus 5% RAS Mixture								
		12.7 (mm)	9.5 (mm)					
Limestone (type D)	51	100	96.7	39.1	8.6	3.5	3.0	2.6
Screenings	25	100	100	99.0	78.5	27.5	16.0	4.3
Sand	6.7	100	100	100	99.7	99.3	85.3	8.7
RAP	13	100	98.7	69.3	41.0	27.2	20.9	7.0
RAS	5	100	100	100	100	67.5	51.1	14.5
Combined gradation	100	100	98.1	64.7	40.3	21.8	16.2	4.5
PG 64-22		5.1 (%)						
19% RAP Mixture								
Limestone (type D)	46	100	99.2	40.1	10.1	6.2	3.1	1.5
Manufactured sand	29	100	100	99.3	83.6	39.1	19.9	3.0
Field sand	6	100	100	100	99.0	96.0	73.0	3.0
RAP	19	100	96.5	66.3	43.8	27.7	22.8	7.0
Combined gradation	100	100	99.0	65.8	43.2	25.2	15.9	3.1
PG 64-22		4.8 (%)						

IV. After a certain time, equilibrium is approached over the majority of the recycled binder film.

Recent studies on evaluating the effect of rejuvenators on engineering and performance properties of mixtures and/or binders can be also found in the literature [4–7]. Shen et al. [8] investigated the effects of a rejuvenator on properties of rejuvenated asphalt binders and mixtures by adding varying dosages. They found that the rejuvenator percentage significantly affected the properties of both rejuvenated aged binders and the mixtures. They also noted that the optimum percentages of the rejuvenator could be obtained by satisfying SHRP specifications (strategic highway research program) through the blending charts. Similar studies conducted by Booshehrian et al. [9] and Tran et al. [10] reported that rejuvenators mitigated the stiffness of the resultant binder and improved the cracking resistance of the mixtures. However, most of the studies focused on one specific rejuvenator. Indeed, there are different types of rejuvenators available in the market. Therefore, it is necessary to evaluate them and compare the cost-benefit of these rejuvenators.

This study evaluated the impacts of three commercial rejuvenators on performance and engineering properties of mixtures containing recycled materials (i.e., RAP and RAS) in terms of moisture resistance, cracking resistance, dynamic modulus, and