Storage Stability Testing of Asphalt Binders Containing Recycled Polyethylene Materials (Phase II-B Study)

A Draft Report *Submitted to*

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by

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February 22, 2019

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Introduction

This report summarizes the results and findings of the Phase II-B study on additional storage stability testing of asphalt binders containing recycled plastics [mainly recycled polyethylene (RPE) materials]. The Phase II-A study completed in December 2018 found that all of the modified binders containing 5% RPE materials failed the storage stability requirement per Georgia Department of Transportation's (GDOT) specifications; phase separation was observed on all tested binders (*1*). The objective of this follow-up study was to investigate the use of compatibilizers and lower RPE dosages to mitigate the phase separation issue of RPE-modified binders.

Based on a review of existing literature, three compatibilizers were selected. The first compatibilizer, referred to as CA3, is a reactive copolymer, which is expected to act as a steric stabilizer in RPE-modified binders, hindering the coalescence of RPE materials. The second compatibilizer, referred to as CA4, is a semi-crystalline polyolefin additive that is known as a facilitator for the dispersion of crumb rubber in asphalt binder and has the potential to enhance the interaction between RPE materials and asphalt binder via crosslinking reactions. The third compatibilizer, referred to as CA5, is an organic polymer additive consisting of polar and non-polar groups that have affinity for asphalt binder and RPE materials, respectively.

Experimental Design

Figure 1 presents the experimental design of the study, which includes the storage stability and softening point testing of 16 RPE-modified binders using one PG 58-28 asphalt binder, two RPE materials (i.e., RPE2 and RPE3), and three compatibilizers (i.e., CA3, CA4, and CA5).

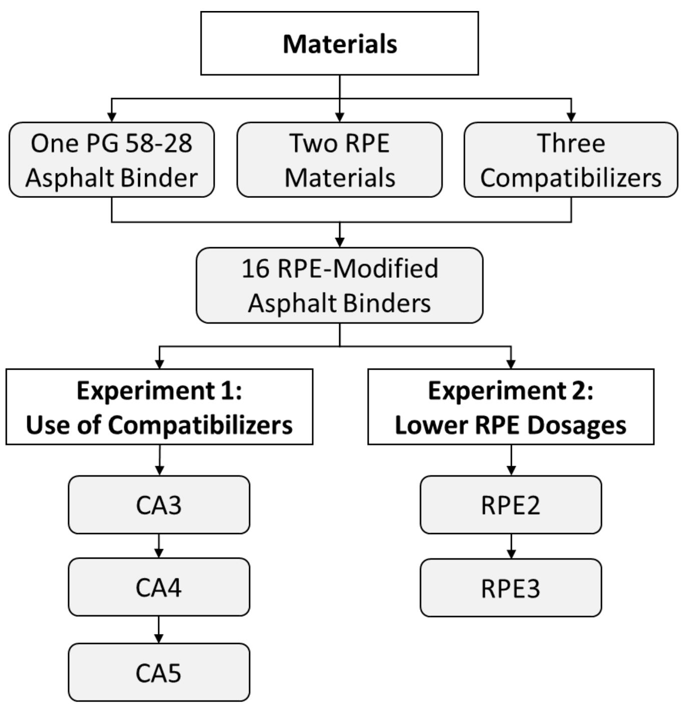

Figure 1. Experimental Design

To accomplish the objective of the study, two separate experiments were conducted: Experiment 1 to evaluate if the three compatibilizers could improve the storage stability of modified binders containing 5% RPE materials, and Experiment 2 to determine the maximum allowable dosage of RPE2 and RPE3 materials for asphalt modification without causing the modified binder to have a phase separation issue.

The storage stability test was conducted in accordance with American Society for Testing and Materials (ASTM) D7173, *Standard Practice for Determining the Separation Tendency of Polymer from Polymer Modified Asphalt*, and the softening point test was conducted per ASTM D36, *Test Method for Softening Point of Bitumen*. Descriptions of the test procedures can be found in the Phase II-A report (*1*). According to GDOT's specifications on Construction of Transportation Systems, a difference of 10°C or less in the softening point results between the top and bottom samples indicates that the tested asphalt sample is storage stable.

Test Results

Table 1 summarizes the storage stability test results from Experiment 1. Blend A-3 refers to the asphalt binder modified with 5% RPE3 sample (by weight of asphalt binder) and is treated as the no-compatibilizer control blend. Blends B-1 through B-3, B-4 through B-6, and B-7 through B-8 correspond to 5% RPE-modified binders with CA3, CA4, and CA5, respectively, at different dosages.

Table 1. Summary of Experiment 1 Test Results

Blend ID	Blend Description	Softening Point, °C			Pass/Fail (Max. 10°C)
		Top	Bottom	Difference	
A-3	Binder 1 + 5% RPE3 (control)	80+	48	32+	Fail
B-1	Control + CA3 low dosage	80+	49	31+	Fail
B-2	Control + CA3 medium dosage	80+	51	29+	Fail
B-3	Control + CA3 high dosage	80+	52	28+	Fail
B-4	Control + CA4 low dosage	80+	49	31+	Fail
B-5	Control + CA4 medium dosage	Data not available			
B-6	Control + CA4 high dosage	Data not available			
B-7	Control + CA5 low dosage	80+	46	34+	Fail
B-8	Control + CA5 high dosage	80+	43	37+	Fail

For Blends B-1, B-2, and B-3, the softening point of the bottom sample increased as the dosage of CA3 increased, which indicated the presence of increased amounts of RPE materials in the sample. The addition of CA3 at the medium and high dosages was found to greatly improve the dispersion of PRE materials in asphalt binder. As shown in Figure 2, Blends B-2 and B-3 showed a much "smoother" binder surface than Blend B-1 and the no-compatibilizer control blend (i.e. Blend A-3). However, the top sample of all the three RPE-modified blends containing CA3 had a softening point above 80°C. The specific softening point was higher than the upper temperature range of the ASTM low softening point thermometer (i.e., -2 to 80°C), and thus, could not be determined. Based on the difference in softening point between the top and bottom samples, Blends B-1, B-2, and B-3 all failed the storage stability requirement per GDOT specifications.

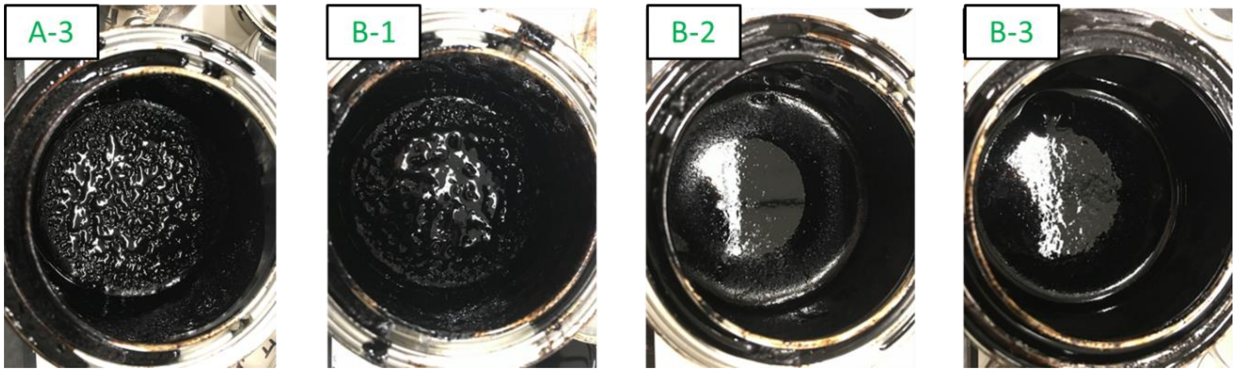

Figure 2. Surface Images of Blends A-3, B-1, B-2, and B-3

As indicated by the softening point results of Blend B-4, adding CA4 at a low dosage did not improve the storage stability of the 5% RPE-modified binder. When a higher dosage of CA4 was used, the modified binder became jelly-like due to thixotropy, as shown in Figure 3, and could not be poured into the aluminum tube for storage stability testing. Thus, the results of Blends B-5 and B-6 are not available.

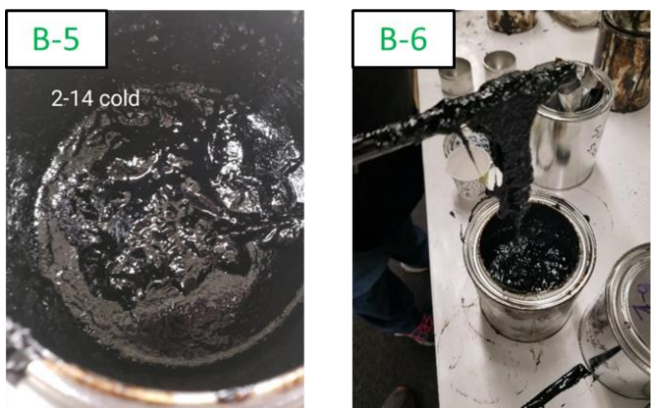

Figure 3. Surface Images of Blends B-5 and B-6

The two RPE-modified binders containing CA5 (i.e., Blends B-7 and B-8) also failed GDOT's storage stability requirement. Although the addition of CA5 improved the dispersion of RPE materials in asphalt binder, it did not mitigate the phase separation issue. When the two blends cooled to room temperature, a thick layer of rubber-like binder was observed on the surface of the blends (Figure 4), which indicated the separation and agglomeration of RPE materials.

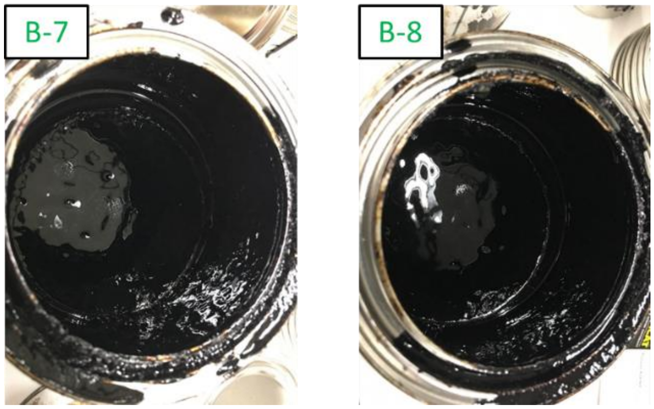

Figure 4. Surface Images of Blends B-7 and B-8

Table 2 summarizes the storage stability test results from Experiment 2. Blends A-3 and Blends B-9 through B-11 refer to modified binders containing 2% to 5% RPE3 sample. Blends B-12 and B-13 are 2% and 4% RPE-modified binders with CA3, respectively. Blends A-2 and Blends B-14 through B-16 correspond to modified binders containing 2% to 5% RPE2 sample.

Table 2. Summary of Experiment 2 Test Results

Blend ID	Blend Description	Softening Point, °C			Pass/Fail (Max. 10°C)
		Top	Bottom	Difference	
A-3	Binder 1 + 5% RPE3	80+	48	32+	Fail
B-9	Binder 1 + 4% RPE3	60	45	15	Fail
B-10	Binder 1 + 3% RPE3	47	44	3	Pass
B-11	Binder 1 + 2% RPE3	46	43	3	Pass
B-12	Binder 1 + 4% RPE3 + CA3	57	48	9	Pass
B-13	Binder 1 + 2% RPE3 + CA3	51	51	0	Pass
A-2	Binder 1 + 5% RPE2	80+	47	33+	Fail
B-14	Binder 1 + 4% RPE2	80+	47	33+	Fail
B-15	Binder 1 + 3% RPE2	80+	44	36+	Fail
B-16	Binder 1 + 2% RPE2	40	37	3	Pass

For the four blends containing RPE3 sample, the softening point of both top and bottom samples and the difference between the two increased as the RPE dosage increased from 2% to 5%. At 2% and 3% RPE dosages, the modified binders passed GDOT's storage stability requirement with a difference of 3°C in softening point. However, the modified binders at 4% and 5% RPE dosages failed the storage stability requirement. Blends B-12 and B-13 were included in the experiment to determine if CA3 could improve the storage stability of RPE-modified binders at lower RPE dosages. CA3 was selected over the other two compatibilizers in Experiment 1 because it showed the highest potential of mitigating the phase separation issue. As shown in Table 2, the addition of CA3 improved the storage stability of RPE-modified binders. The difference in softening point between the top and bottom samples reduced from 3°C to 0°C and 15°C to 9°C for the 2% and 4% RPE-modified binders, respectively. These results indicate that CA3 can accommodate the use of 4% RPE3 sample for asphalt modification while 3% is the maximum allowable dosage for producing a storage stable modified binder. Among the four blends containing RPE2 sample, only Blend B-16 passed GDOT's storage stability requirement. Therefore, only up to 2% RPE2 sample can be used for asphalt modification without causing the RPE-modified binder to have a phase separation issue.

Conclusions and Recommendations

Based on the results of the study, the following conclusions are made:

- The three compatibilizers tested in the study did not mitigate the phase separation issue of modified binders containing 5% RPE3 sample.
- Adding a reactive copolymer at a dosage of 1.2% to 1.5% (by weight of asphalt binder) greatly improved the dispersion of RPE materials in asphalt binder.
- Up to 2% RPE2 sample or 3% RPE3 sample can be used for asphalt modification and to produce RPE-modified binders with adequate storage stability.
- The use of reactive copolymer accommodated the use of 4% RPE3 sample for asphalt modification without causing the modified binder to have a phase separation issue.

It is recommended for the next phase of research to evaluate the performance and life-cycle cost benefits of RPE-modified asphalt binders and mixtures using the dosages recommended above. Table 3 summarizes the performance comparison of unmodified, 2% RPE-modified, and SBS-modified binders in the Phase I study (*2*). Cells highlighted in green indicate equivalent or better properties for RPE-modified binders than the unmodified and SBS-modified binders, and cells highlighted in red indicate reduced properties for RPE-modified binders. In general, the use of 2% RPE materials for asphalt modification improved the rutting resistance but reduced the cracking resistance of asphalt binders. Considering that the service life of asphalt pavements in the United States is primarily governed by durability-related distresses such as cracking and raveling, the use of softer asphalt binders and those with better stress relaxation properties is recommended to prepare modified asphalt mixtures containing RPE materials. Furthermore, research efforts should be considered to explore the dry process of adding RPE materials in asphalt pavements. Existing studies from India and the United Kingdom have shown success of using up to 10% to 15% RPE materials in asphalt mixtures with the dry process (*3-5*).

Table 3. Performance Comparison of Unmodified, 2% RPE-Modified, and SBS-Modified Binders in the Phase I Study (*3*)

Binder Type	Viscosity @ 135°C (Pa.S) [1]	High-Temperature (HT) Grade (°C) [2]	Low-Temperature (LT) Grade (°C) [3]	Delta Tc (ΔTc) [4]
PG 64-22 Base A	0.520	70	-16	-3.7
PG 76-22 SBS A	1.438	76	-22	-4.9
Base A + 2% PE1	1.479	82	-10	-6.8
Base A + 2% PE2	1.279	76	-10	-6.6
Base A + 2% PE3	1.638	82	-10	-9.2
PG 64-22 Base B	0.570	70	-16	-4.1
PG 76-22 SBS B	1.579	76	-16	-6.7
Base B + 2% PE1	1.279	76	-10	-6.8
Base B + 2% PE2	1.650	82	-10	-8.5
Base B + 2% PE3	1.454	76	-10	-10.4

Notes:
1. Maximum viscosity criterion is 3.0 Pa.S;
2. Higher HT grade = better resistance to rutting;
3. Lower (more negative) LT grade = better resistance to low-temperature cracking; and
4. Higher (less negative) ΔTc = better stress relaxation property and better resistance to block cracking.

References

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