Final Report

EVALUATION OF VESTENAMER AND GROUND TIRE RUBBER BLEND IN HOT MIX ASPHALT

Prepared for:
Evonik Degussa

Prepared by:
Don Watson
National Center for Asphalt Technology
277 Technology Parkway
Auburn, Alabama 36830
Phone: 334-844-6228
E-Mail: watsode@eng.auburn.edu

September, 2007

Final Report

EVALUATION OF VESTENAMER AND GROUND TIRE RUBBER BLEND IN HOT MIX ASPHALT

Prepared for:
Evonik Degussa

Prepared by:
Don Watson
National Center for Asphalt Technology
277 Technology Parkway
Auburn, Alabama 36830
Phone: 334-844-6228
E-Mail: watsode@eng.auburn.edu

September, 2007

DISCLAIMER

TABLE OF CONTENTS

EVALUATION OF VESTENAMER AND GROUND TIRE RUBBER BLEND IN HOT MIX ASPHALT

INTRODUCTION

In recent years there has been a significant increase in the price of bituminous materials due to the increase in crude oil prices and the demand for gasoline. As gasoline prices have increased, some refineries have shifted production through the use of cokers to effectively get as much gasoline as possible for retail distribution. Due to these price increases, there is a need to evaluate new products and new technologies that may enhance the performance of asphalt mixtures at a comparable price to conventional binders and modifiers. The use of ground tire rubber (GTR) may provide an alternative asphalt modifier that is cost competitive with traditional modifiers and at the same time it may have a significant environmental effect in that used tires may be recycled into HMA rather than added to waste storage piles. For that reason, a modified asphalt consisting of 10% GTR/4.5% trans-polyoctenamer rubber (TOR) was used in this study to determine if the modification may perform as well as SBS modifier.

OBJECTIVE

The objective of this research was to conduct various laboratory tests to verify that hot mix asphalt (HMA) mixture with high RAP content can be made with ground tire rubber (GTR) blended into the asphalt and meet standard specification requirements. The GTR was added at a rate of 10 percent by weight of asphalt binder and was modified with 4.5 percent trans-polyoctenamer rubber (TOR) based on weight of the GTR. The 10% GTR/4.5% TOR mixture was compared with a similar mix that uses styrene-butadiene-styrene (SBS) polymer modifier. Blends were made with 50 percent RAP to determine the effect 10% GTR/4.5% TOR and SBS may have on mixtures with high RAP proportions. Those mixtures were then compared to a "standard mix" which was a similar blend of materials except that only 20 percent RAP was used. Since 20 percent RAP usage is much more common in Georgia, it was decided to use such a blend as the standard. The standard mix also used a SBS-modified PG 76-22 asphalt binder grade.

SCOPE

Mixtures were prepared and tested for conformance with volumetric requirements of Georgia Department of Transportation (GDOT) by using AASHTO PP 28, Standard Practice for Superpave Volumetric Design for Hot-Mix Asphalt (HMA). Samples of 12.5 mm Superpave mixture were prepared at optimum asphalt content for each of the three blend combinations. For comparison of performance at high RAP contents, blends were made using PG 64-22 binder with 50% RAP and 10% GTR/ 4.5% TOR and compared with blends made with 50% RAP and PG 76-22 binder modified with SBS. These two mixtures were then compared to a standard 12.5 mm Superpave mix with 20% RAP and a binder that meets requirements for performance grade 76-22. All mixtures were tested for permeability, moisture susceptibility, rutting resistance, and fatigue resistance.

LABORATORY TEST PLAN

HMA mixtures were subjected to a variety of laboratory test procedures to verify that they will meet Georgia Department of Transportation (GDOT) specification requirements. The proposed test plan to accomplish this work included laboratory tests for rutting susceptibility, moisture susceptibility, permeability, and fatigue resistance.

Materials

Aggregate/RAP

For this study, granite gneiss aggregate from Vulcan Materials at Lithia Springs, Georgia was used. That source is typical of Georgia pavement surfaces and has a Los Angeles (L.A.) abrasion loss of 35 percent and magnesium sulfate soundness loss of less than 1.0 percent. A Superpave 12.5 mm mix was used throughout the study.

The RAP was selected from a Georgia contractor’s stockpile. The RAP had been crushed so that all material would pass a 1/2 inch sieve and could be used in all mixes. The effect of RAP binder stiffness was determined by preparing samples with the same PG grade at proportions of 20% and 50% RAP.

Asphalt Binder and GTR/TOR Blend

Two mixtures were prepared with Superpave PG 76-22 grade asphalt binder. The same binder was used for both the 20% and 50% RAP proportions. An additional mixture was prepared with the 10% GTR/4.5% TOR blend and 50% RAP. However, the additional mix was made with a softer grade base asphalt (PG 64-22) before blending with the GTR and TOR materials. The tire rubber had been processed and classified as minus No. 30 mesh size particles. Preliminary testing by Degussa indicated that every 5% increase in GTR would result in a PG increase of one grade. Based on that information, GTR was added at a rate of 10% of the asphalt binder weight, and it was assumed that the resulting blend would increase the PG grade by two levels.

Performance Testing

For this study, four laboratory tests were conducted to determine how well the 10% GTR/4.5% TOR blend would perform in comparison to a similar mix without GTR, and compared to a typical Superpave mixture with only 20% RAP. Permeability tests were conducted to determine whether the rubber particles from the GTR would affect the amount and size of air voids which would ultimately affect the permeability of the mixture.

There was also some concern that the rubber particles would absorb some of the asphalt binder. Since this would result in less effective binder to coat aggregate particles and bond the mixture together, it was necessary to conduct fatigue tests to evaluate the effect on fatigue life and resistance to cracking.

Due to the potential use of the modified asphalt blend on high traffic interstate-type projects, there was a need to conduct tests to evaluate the susceptibility of these mixtures to rutting under heavy traffic. The Asphalt Pavement Analyzer (APA) was used for this analysis.

The concern for moisture damage also needed to be evaluated due to the nature of Georgia aggregates and the wet climate. Many of the Georgia granite aggregate sources have a known potential for stripping so that an anti-stripping agent is typically required in all asphalt mixtures placed on the state route system.

DISCUSSION OF TEST RESULTS

Mix Design

The TOR material was identified as Vestenamer 8012 produced by Degussa. It was added at a rate of 4.5% based on the weight of the GTR. The process for laboratory mixing of samples was as follows:

- Pre-heat aggregate to 340 °F; pre-heat asphalt binder to 320 °F
- Add RAP, tire rubber, and TOR material to aggregate and thoroughly mix for 20 seconds
- Add asphalt based on total mix weight at the amount determined for optimum asphalt content.
- Thoroughly mix the materials for an additional 60 seconds
- Set the mixture aside for 30 minutes in a pre-heated 320 °F forced-draft oven
- Stir the mix, put into gyratory molds, and compact for 65 gyrations
- Keep the compacted mix in the mold under 600 kPa pressure for 30 minutes

The rubber particles tended to swell as the chemical reaction from binder absorption took place, so it was important to keep samples in the mold under pressure for 30 minutes. This allowed sufficient time for the sample to cool so it would not become distorted when being removed from the mold.

Superpave 12.5 mm mixtures were blended near anticipated optimum asphalt contents for each type asphalt modifier and for each RAP proportion including the standard mix with 20% RAP. Mixtures were compacted to 65 gyrations in a Superpave gyratory compactor. Optimum asphalt content was selected at the point where incremental increases in asphalt content resulted in 4.0 percent air voids in the compacted samples. Hydrated lime was added as an anti-strip agent in each mix according to standard GDOT procedures at a rate of 1.0 percent of the virgin aggregate and 0.5 percent of the RAP aggregate. Optimum asphalt content for the mixture with 20% RAP was 5.3%, and the optimum was 4.8% for each of the blends with 50% RAP.

Permeability

Each of the three mixtures were blended at optimum asphalt content and compacted to obtain 6 ±1 percent air voids. Mixtures were then tested for permeability in accordance with ASTM-PS-129-01. Permeability test results may not exceed 125×10^{-5} cm/s (3.60 ft/day) in order to be acceptable. Permeability samples were prepared at NCAT and sent to the GDOT central lab at the Office of Materials and Research (OMR) in Forest Park, Georgia for testing. Permeability results were determined for each of three samples and average values are shown in Table 1. Based on these results, none of the samples tested are considered to be permeable.

TABLE 1 Permeability Results

Mix Blend	20% RAP	50% RAP	50% RAP with 10% GTR/4.5% TOR
Air Voids, %	6.5	6.5	6.5
Permeability, $\times 10^{-5}$ cm/sec	9.4	55.3	4.7

Moisture Susceptibility

Each mixture was also blended at optimum asphalt content and compacted to obtain 7 ±1 percent air voids for moisture susceptibility testing. Mixtures were subjected to vacuum saturation and one freeze-thaw cycle in accordance with the GDT-66 procedure for determining moisture susceptibility. GDT-66 is similar to AASHTO T 283 except that no saturation range is used and the loading rate for the breaking head is 0.065 inches/minute.

A minimum retained tensile strength ratio of 0.80 is required, except that a ratio no less than 0.70 may be acceptable so long as all individual tensile strength values exceed 100 psi. In either case, the average control and conditioned tensile strength must be at least 60 psi. The test results shown in Table 2 indicate that the 10% GTR/4.5% TOR blend with 50% RAP marginally failed to meet specification requirements. However, the minimum tensile strength of 99.2 psi for one of the individual samples was very close to the required minimum value of 100 psi when only 70% TSR is obtained. The high control strength for the 10% GTR/4.5% TOR blend indicates that the mix is about 30% stronger (stiffer) than the comparable mix with 50% RAP.

Rutting Susceptibility

Mixtures were subjected to proof-testing for rutting susceptibility in the Asphalt Pavement Analyzer (APA). Samples were prepared at optimum asphalt content, but the number of gyrations was reduced to produce compacted samples at 5 ±1 percent air voids according to GDOT specifications. A 100 pound load and 100 psi hose pressure was used and the test conducted according to GDT 115 test procedure. Samples were tested at 64°C for 8,000 cycles. NCAT prepared the samples and GDOT personnel conducted all rut testing. Table 3 shows that all of the samples tested met the maximum rut depth allowed of 5 mm.

TABLE 2 Moisture Susceptibility Test Results

<table>
<tr><th>Mix Blend</th><th>Control Strength</th><th>Conditioned Strength</th><th>TSR</th></tr>
<tr><td rowspan="4">20% RAP</td><td>109.7</td><td>105.3</td><td rowspan="4">0.87</td></tr>
<tr><td>107.4</td><td>98.4</td></tr>
<tr><td>123.9</td><td>94.2</td></tr>
<tr><td>Avg.= 113.7</td><td>Avg.= 99.3</td></tr>
<tr><td rowspan="4">50% RAP</td><td>119.4</td><td>104.7</td><td rowspan="4">0.91</td></tr>
<tr><td>114.5</td><td>99.9</td></tr>
<tr><td>121.3</td><td>119.3</td></tr>
<tr><td>Avg.= 118.4</td><td>Avg.= 108.0</td></tr>
<tr><td rowspan="4">50% RAP and 10% GTR/4.5% TOR</td><td>134.0</td><td>112.1</td><td rowspan="4">0.70</td></tr>
<tr><td>164.8</td><td>99.2</td></tr>
<tr><td>162.4</td><td>111.1</td></tr>
<tr><td>Avg.= 153.7</td><td>Avg.=107.5</td></tr>
</table>

TABLE 3 Rutting Susceptibility Results

Mix Blend	Rut Depth, mm
20% RAP	4.70
50% RAP	1.33
50% RAP and 10% GTR/4.5% TOR	0.03

Fatigue Resistance

Fatigue tests were conducted according to AASHTO T 321, to evaluate the stiffening effect of RAP on the mixture and its impact on the long-term fatigue life of the pavement. Specimens were compacted to produce samples with 6 ±1 percent air voids as required by GDOT specifications and tested at 800 micro-strain (με) as shown in Figure 1. Test results of samples with high RAP content (both 10% GTR/4.5% TOR and SBS modified) were compared with results of the PG 76-22 standard mixture with 20% RAP.

The mixture stiffness after 50 cycles is determined and used as the initial beam stiffness. The failure point is the number of cycles at which the beam stiffness is only one-half the initial stiffness. A minimum of 10,000 cycles is recommended in AASHTO T 321 to ensure that the mixture does not lose stiffness too quickly under loading.

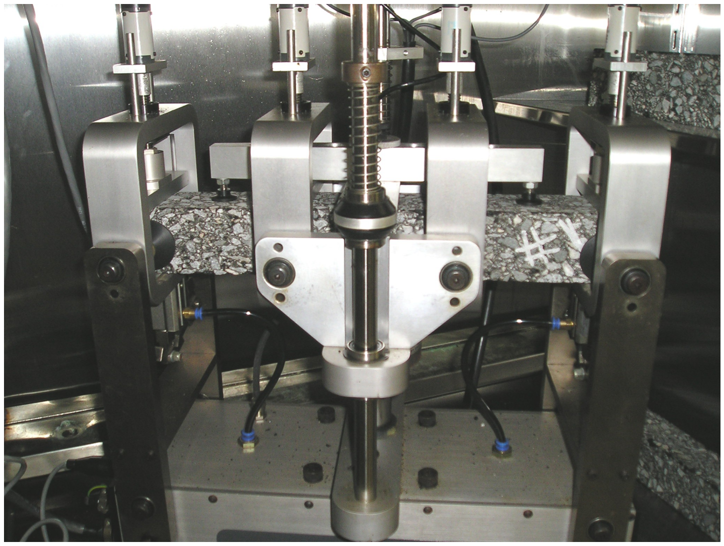

FIGURE 1 AASHTO T 321 Fatigue Test Equipment.

From Table 4, it can be seen that both of the mixtures with 50% RAP were significantly stiffer than the mixture with only 20% RAP. Based on the stiffness indicated from these results, the 50% RAP mixtures may fail in fatigue very quickly. However, there may still be a need for field evaluation of the mixtures. Some materials may show poor fatigue results based on laboratory prepared samples, but may perform differently based on field conditions. One reason for this may be that the laboratory procedure of maintaining pressure on the gyratory samples for 30 minutes to prevent distorting is not practically done for plant-produced mixtures under field conditions.

TABLE 4 Fatigue Results of Laboratory Mix

Mix Blend	Fatigue, Cycles to Failure
20% RAP	20,230
50% RAP	1,920
50% RAP and 10% GTR/4.5% TOR	583

As a result of the low fatigue results of laboratory specimens, samples of plant-produced mix were obtained from a project Reeves Construction Company completed for Georgia Department of Transportation. One mix was a standard mix with 15% RAP used as a control baseline and the other mix contained 45% RAP and was modified with 10% TOR/GTR by weight of asphalt. Fatigue tests were performed at 800 micro-strain at 20°C. The test results were as follows:

TABLE 4 Fatigue Results of Plant-Produced Mix

15% RAP			45% RAP with 10% TOR/GTR		
Air Voids, %	Loads to Failure	Initial Stiffness, MPa	Air Voids, %	Loads to Failure	Initial Stiffness, MPa
5.1	31,080	7,317	6.4	10,670	8,654

The mix was a 9.5 mm Nominal Maximum Aggregate Size asphalt mixture produced for a project on State Route 26. The test results show that high RAP proportions with the TOR/GTR blend had similar initial stiffness to that of the control mix but reduced the fatigue life to about one-third that of the control mix. However, fatigue results were considerably higher than for the laboratory-produced mix and met the minimum of 10,000 cycles as recommended in AASHTO T 321.

CONCLUSIONS

From this study the following conclusions can be made:

1. None of the samples were considered to be permeable at 6.0 ± 1.0% air voids.
2. The 10% GTR/4.5% TOR blend appeared to be about 30% stiffer than other mixtures based on the tensile strength of control samples.
3. The 10% GTR/4.5% TOR blend marginally failed to meet specification requirements for resistance to moisture damage. Although the conditioned strength was similar to the other mixtures, the control strength was significantly higher.
4. All mixtures met requirements for resistance to rutting, but the mixtures with 50% RAP performed exceedingly well.
5. Both laboratory-prepared mixtures with 50% RAP failed to meet the minimum requirement of 10,000 cycles to failure during fatigue testing. Samples of plant-produced mix also showed a significant reduction in cycles to fatigue failure for a mix with 45% RAP proportion, but the samples did meet the 10,000 cycle requirement of AASHTO T321.