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# Evaluation of Asphalt Mixtures Containing Recycled Asphalt Shingles

## INTRODUCTION

Asphalt binder prices are at an all-time high with no relief in sight. With the asphalt mixtures prices continuously climbing, highway agencies and owners are continually searching for methods to decrease material costs and maximize their benefits without compromising performance. One such method is to develop innovative technologies to incorporate as much amount of waste and recycled materials, such as recycled asphalt shingle (RAS) and reclaimed asphalt pavement (RAP), as possible in asphalt mixture production and pavement construction. Usage of RAP in asphalt paving has increased in recent years. However, despite the potential benefits of increased RAP contents, state agencies have not proceeded in utilizing high percentages of RAP in asphalt mixtures, due to their concerns of non-uniformity of RAP materials and the lack of confidence in the long-term field performance of mixtures containing RAP. This is further complicated when RAS is used in conjunction with RAP. Some of the main concerns with the utilization of RAS in asphalt mixtures are the consistency, availability, and quality of the RAS asphalt binder. In addition, there are concerns with satisfactory high, intermediate, and low-temperature pavement performance with the usage of RAS.

## OBJECTIVE & SCOPE

The objective of this study was to determine the impact of recycled materials, such as RAP and RAS, on the high-, intermediate-, and low-temperature pavement performance of asphalt pavements in conjunction with the asphalt binders' molecular compositions. Specific objectives include:

- Characterizing laboratory performance of asphalt mixtures containing recycled materials at low, intermediate, and high service temperatures;
- Characterizing molecular components of asphalt binders extracted from various asphalt mixtures containing RAP, RAS, and/or RA; and
- Determining the influence of recycled materials related to their molecular components to the mechanical performance characteristics of asphalt mixtures.

## METHODOLOGY

To achieve the afore mentioned objectives, a suit of laboratory tests was performed on asphalt binders and mixtures as shown in Table 1. A total of 11 asphalt mixtures, as shown in Table 2, and their extracted asphalt binders were evaluated.

*Table 1*
*Laboratory asphalt binder and mixture tests*

| Mixture Experiments | Binder Experiment |
|---|---|
| • Dynamic Modulus<br>• High Temperature – Loaded Wheel Tracking (Hamburg Type)<br>• Intermediate Temperature –Semi-Circular Bend (SCB) Test<br>• Low Temperature – Thermal Stress Restrained Specimen Tensile Strength Test | • Asphalt Binder Performance Grading<br>• Multiple Stress Creep Recovery<br>• Linear Amplitude Sweep Test<br>• Complex Shear Modulus<br>• Glover-Rowe Parameters<br>• $\Delta T_c$ - Change in Critical Binder Temperature<br>• Saturate, aromatic, resin, and asphaltene (SARA)<br>• GPC - Gel Permeation Chromatography<br>• FTIR –Fourier Transform Infrared Spectroscopy |

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*Table 2*
*Asphalt mixtures*

| Mixture | | Mixture Variables | | | | | | | High Temp | | Inter. Temp | Low Temp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | E* | LWT | SCB | TSRST |
| 12.5 mm NMAS – Superpave Level 2 | Mix Designation | Shingle Type | %RAS | %RAP | %RA-1 | %RA-2 | %RA-3 | %RA-4 | Unaged | | Aged | Aged |
| | 70CO | N/A | | | | | | | 3 | 2 | 3 | 3 |
| | 70PG5M | MWS | 5 | | | | | | 3 | 2 | 3 | 3 |
| | 70PG5P | PCWS | 5 | | | | | | 3 | 2 | 3 | 3 |
| | 70PG5P5HG | PCWS | 5 | | 5 | | | | 3 | 2 | 3 | 3 |
| | 70PG5P12CYCL | PCWS | 5 | | | 12 | | | 3 | 2 | 3 | 3 |
| | 70PG5P20FLUX | PCWS | 5 | | | | 20 | | 3 | 2 | 3 | 3 |
| | 52PG5P | PCWS | 5 | | | | | 4.6 %AC | 3 | 2 | 3 | 3 |
| | 70PG15RAP | N/A | | 15 | | | | | 3 | 2 | 3 | 3 |
| | 70PG5P15RAP | PCWS | 5 | 15 | | | | | 3 | 2 | 3 | 3 |
| | 70PG5PHG15RAP | PCWS | 5 | 15 | 5+ | | | | 3 | 2 | 3 | 3 |
| | 52PG5P15RAP | PCWS | 5 | 15 | | | | 3.5 %AC | 3 | 2 | 3 | 3 |

## CONCLUSIONS

With respect to the mixes without recycling agents, it was concluded that RAS binder does not fully blend with the virgin binder. The availability factor was found to range from 35 to 46%. Based on this fact, it was determined that the inclusion of RAS showed an improvement in rutting performance by resulting in a lower rut depth as compared to the control mixture without RAS. Further, because the RAS binder does not fully blend with the virgin binder, asphalt mixtures containing 5% recycled shingles showed no adverse effects to intermediate temperature properties (fatigue cracking) and low temperature performance (thermal cracking). It was also determined that the addition of RAS did not adversely affect moisture susceptibility and no moisture susceptibility was predicted by LWT for the mixtures studied.

In regards to the asphalt mixtures containing recycling agents, it was shown that the RAS binder did blend with virgin binder when the mixtures were blended in accordance with the developed blending procedures. However, the availability factor was found to range from 50 to 100%. It was indicated that the addition of RAS with recycling agents generally showed an improvement in rutting performance by resulting in a lower rut depth. The RAS mixture containing soft asphalt was the least resistant to permanent deformation. However, the inclusion of recycled shingles with recycling agents adversely affected the resistance to fracture at intermediate temperature even though the recycling agents are classified as rejuvenators. Further, the use of soft asphalt binders generally resulted in the least resistant to fracture at intermediate temperature. Also, RAS mixtures containing recycling agents adversely affected low temperature performance. It was also determined that asphalt mixtures containing RAS and recycling agents did not adversely affect moisture susceptibility and no moisture susceptibility were predicted by the LWT for the mixtures studied.

In reference to the binder fractionation of the extracted asphalt binders from RAP/RAS mixtures with and without recycling agents, it was concluded that there were higher concentrations of high molecular weight species in the RAS binders as compared to the RAP binders. The concentration of the high molecular RAS species exceeds 40% in which 25% of these are highly aggregated with apparent molecular weights approaching 100K. In addition, the use of rejuvenating agents did not reduce the concentration of the very high molecular weight associated species, and thus they failed to improve the cracking resistance of the asphalt mixtures evaluated in this study. Also, it was shown that RAS is much more highly oxidized than RAP as indicated by FTIR spectroscopy. In addition, a relationship between the carbonyl index and fracture at intermediate temperature is inconclusive for the mixtures studied.

The percentage of asphaltenes species fractionated from the SARA analysis was slightly less than that determined from the GPC analysis. The SARA asphaltenes analysis by precipitation did not capture the total amount of associated asphaltenes in the binder as measured by GPC. Some associated asphaltenes may remain in the resin fraction which is not captured by SARA analysis. The fracture temperature and fracture work measured by TSRST have good correlations with asphaltenes contents determined by GPC analysis. Similarly, the low-temperature cracking performance parameters have good correlations with GPC determined polymer and maltenes contents, but showed considerably weaker correlations with SARA fractionated species. Addition of RAS and/or RAP, with and without RAs apparently increase the larger molecular weight species in the blended asphalt binder. In turn, the increased amount of larger molecular weight species adversely impacts the low-temperature fracture properties of asphalt mixtures and increase the likelihood of cracking in the asphalt pavement.

## RECOMMENDATIONS

Based on the results, it is recommended that chemical analysis be performed on the asphalt binders that contain recycled materials. It is recommended that a SARA analysis be conducted to compliment GPC. This will lend to a better understanding of the effects of RAS, RAP, and recycling agents on asphalt mixtures.

It is recommended that specifications for inclusion of RAS into mixtures be developed and pilot field projects be constructed. In doing so, the developed laboratory mixture design blending procedure can be validated. Also, it is recommended that an ALF (Accelerated Loading Facility) project be constructed. This will enable the evaluation of actual cracking and rutting under accelerated loading of mixtures containing RAP and/or RAS.