Geosynthetics: Leading the Way to a Resilient Planet – Biondi et al (eds)

Characterization of asphalt mixtures with geosynthetic-reinforced asphalt millings

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ABSTRACT: The incorporation of geosynthetic interlayers during the asphalt overlay construction has proven successful in mitigating the reflective cracking and enhancing the pavement structural capacity. However, milling an asphalt layer reinforced with geosynthetic interlayer is a huge concern, since there is a possibility of geosynthetic interlayers compromising the reclaimed asphalt pavement (RAP) quality and characteristics. On the other hand, inclusion of RAP into the hot mix asphalt (HMA) is a common practice. Hence, it is important to understand the characteristics of RAP collected from geosynthetic-reinforced asphalt layers (referred herein as GRAP) and their influence on the performance of asphalt mixtures. The objective of this study is to understand the characteristics of GRAP and subsequently, investigate the performance of asphalt mixtures with 15% and 30% GRAP contents. Additionally, the performance of asphalt mixtures with 15% and 30% RAP contents, and 100% virgin aggregates (referred as control mixture) was evaluated for comparison with that of asphalt mixtures combining GRAP. The characterization of GRAP and RAP included particle size gradation and binder extraction tests, while the performance evaluation of the asphalt mixtures included indirect tensile strength, and moisture susceptibility tests. Comparison of binder extraction test results revealed that the GRAP samples had binder content slightly higher than that of the RAP samples. While the comparison of indirect tensile strength and moisture susceptibility test results indicated the performance of asphalt mixtures with GRAP similar to that with RAP, where both mixtures outperformed the asphalt mixtures made solely of virgin aggregates. This indicates the potential of incorporating GRAP and RAP up to 30% into the asphalt mixtures without compromising the performance of asphalt mixtures.

1 INTRODUCTION

The search for sustainable and innovative solutions gave rise to a new material in paving works, the reclaimed asphalt pavement. Specifically, during the rehabilitation program, the

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DOI: 10.1201/9781003386889-170

pre-existing asphalt layer is either partially or completely milled resulting in tons of aggregate-sized particle material, commonly known as RAP. This material has been transforming paving works in many countries around the world since late 30's. Additionally, with waste reuse and recyclability policies, a great intensification on the utilization of RAP in recent years has been observed. Consequently, there is less waste generation and reduction in the extraction of raw materials required for pavement construction, thereby providing significant environmental and economic benefits.

The Texas Department of Transportation (TxDOT) promotes using RAP on a larger scale in many pavements works, including composition of a new asphalt mix, extra widening of roadways, replacement of granular base course and subbase materials, construction of shoulders, residential driveways, parking lots, bicycle paths, gravel road rehabilitation, trench backfill, and embankment's design. Previous literatures (Plati & Cliatt 2018; Saxena *et al.* 2023) have reported that the pavement containing RAP could perform equally well when used in base course and in some instances better than the conventional granular base course comprising virgin aggregates (VA), in terms of its structural performance.

Additionally, due to the increased binder cost and scarcity of virgin aggregates, the demand for using RAP in asphalt mixtures has increased. In 2010, the utilization of RAP in asphalt mixtures conserved approximately 20.5 million barrels of asphalt binder (NAPA 2011). Moreover, the advantages of using RAP in asphalt mixtures are not limited to only economic and environmental benefits. Research studies (Shu *et al.* 2012; Uribe *et al.* 2022) have shown that the replacement of virgin aggregates with RAP can improve the indirect tensile strength of asphalt mixtures by about 50% and additionally improve the resistance against moisture damage (Shu *et al.* 2012). However, Singh *et al.* (2017) reported that moisture damage of asphalt mixtures containing RAP improves only up to the addition of 30% RAP content, and further increase of RAP content makes the asphalt mix vulnerable to moisture damage.

In recent decades, the incorporation of geosynthetic interlayers during the asphalt overlay construction has proven successful in mitigating reflective cracks and thereby, enhancing the pavement performance (Saride & Kumar 2017, 2019). Thus, it is possible to mill asphalt layers that may include geosynthetic interlayers within them. Therefore, it becomes crucial to conduct experimental research studies to comprehend the characteristics and behavior of RAP obtained from milling such asphalt layers that have been reinforced with geosynthetic interlayers. Although the literature on this topic is very limited, it is important to note that the growing trend of incorporating geosynthetics within asphalt layers may increase the prevalence of RAP containing geosynthetic fragments. Recently, Gu *et al.* (2021) demonstrated that a 30% RAP containing milled polypropylene geotextile fragments presented an excellent resistance to moisture damage, rutting and cracking. In addition, they reported that geosynthetic RAP and control RAP asphalt mixtures had comparable flexibility index values.

In summary, studies on the recyclability of geosynthetic-reinforced asphalt millings are very limited in number, which requires more attention. Hence, this study is undertaken to understand the characteristics of RAP containing geosynthetic fragments (GRAP) and consequently, investigate the performance of asphalt mixtures with 15% and 30% GRAP. Moreover, performance of asphalt mixtures with 15% and 30% RAP contents, and 100% virgin aggregates was determined to answer whether the presence of geosynthetic fragments in RAP has an adverse impact on the quality of asphalt mixtures. The characterization of GRAP and RAP included particle size gradation, and binder extraction tests, while the performance of asphalt mixtures has been investigated through indirect tensile strength, and moisture susceptibility tests.

2 CHARACTERIZATION OF RAP AND GRAP

The RAP with and without geosynthetic fragments were collected during the milling program conducted along the US 70/84 Highway at Muleshoe, TX. The roadway comprised of a sandy subgrade, 300-mm-thick granular base, and 110-mm-thick asphalt layer that comprised of a 50-mm thick first lift and a 60-mm thick second lift with a paving fabric between them. The paving fabric was a polypropylene nonwoven geotextile used as a stress relieving interlayer to mitigate reflective cracking. The milling process involved two stages: the top 50 mm of the 110 mm thick asphalt layer was first milled to obtain RAP samples, followed by milling of the remaining 60 mm thick asphalt layer (having geosynthetic 10 mm below the first milled surface), to obtain GRAP samples. The collected RAP and GRAP samples were completely dried out in the laboratory and need of crushing them was identified before characterization tests. Specifically, 3 kgs of sample was crushed each time by dropping a modified Proctor hammer weighing about 4.5 kg, from a height of 450 mm for about 100 times. Figure 1 shows the RAP (Figure 1a) and GRAP samples (Figure 1b) collected from the site which were crushed into the laboratory due to their bigger sizes, and crushed GRAP samples (Figure 1c) used in characterization tests.

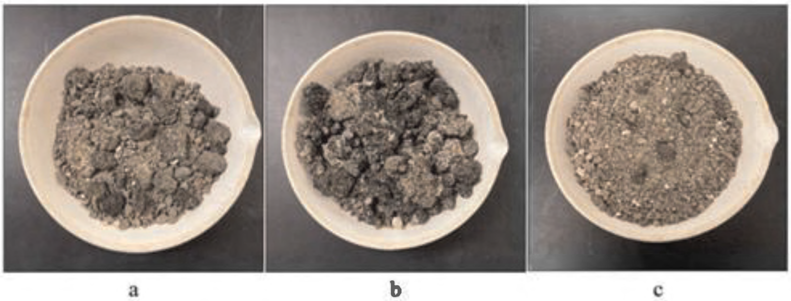

Figure 1. Collected RAP samples: (a) RAP; (b) RAP with geosynthetic fragments (GRAP); and (c) GRAP after crushing process.

The crushed RAP and GRAP samples were first sieved to determine their grain size distribution. Moreover, this analysis allowed for the determination of whether screening of the geosynthetics fragments is required for GRAP samples. Finally, bitumen extraction tests were conducted on RAP and GRAP samples, using centrifuge method with trichloroethylene, per AASHTO T164, to obtain the percentage of binder in the collected samples.

3 MIX DESIGN

The asphalt mixture investigated in this study was a TY-D binder course mix typically used by TxDOT for pavement construction. In order to evaluate the recyclability of GRAP samples as a potential aggregate material for surface course, five different asphalt mixtures are designed. These mixtures included 0% (control mixture), 15% and 30% RAP and GRAP samples. All mixtures were found to fit well within the gradation limits of TY-D surface course mixture, as specified by Item 341 TxDOT. It should be noted that all the specimens were prepared using the same virgin aggregate, procured from the Marble Fall Quarry - Texas Material in Texas. Virgin aggregate used was primarily crushed rock. Moreover, Performance Grade (PG) 64-22 was used as the virgin binder for the sample preparation. In this study, the notation used for mixtures containing only virgin aggregate is VA (control specimen) and mixtures containing RAP and GRAP are respectively denoted as 15-85 RAP/30-70 RAP and 15-85 GRAP/30-70 GRAP, where the first term represents the percentage of

RAP or GRAP, the second term represents the percentage of virgin aggregate, and the last term indicates the type of RAP used in a given mixture. An optimum binder content corresponding to 7% air void content for all the prepared mixtures was determind to be 4.45 (VA), 4.10 (15-18 RAP), 4.00 (15-85 GRAP), 3.70 (30-70 RAP), and 3.55 (30-70 GRAP), respectively. This implied that the asphalt mixtures containing GRAP samples require less virgin binder to compose the hot mix asphalt as compared to mixtures containing RAP or virgin aggreagtes.

4 LABORATORY TESTS

4.1 *Indirect tensile strength (IDT) test*

The indirect tensile strength of asphalt mixtures is used to evaluate their rutting and cracking potential by characterizing the tensile strength and viscoelastic properties of the mixtures. The indirect tensile strength test was performed on five different asphalt mixtures designed herein at different test temperatures (5, 10, 25°C), per ASTM D6931. The cylindrical specimens were prepared in dimensions of 150 mm diameter and 95 mm thickness at a target void content of 7%, using Superpave gyratory compactor. The compacted specimens were then conditioned in a temperature controlled chamber at test temperatures for a period of 24 h prior to testing. Three specimens were prepared for each mix design and tested until failure using a loading rate of 50 mm/min.

4.2 *Moisture susceptibility test*

Moisture susceptibility tests are conducted to evaluate the moisture-induced deterioration of asphalt mixtures subjected to moisture over extended periods. The moisture susceptibility of the asphalt mixtures is evaluated in terms of tensile strength ratio (TSR), per ASTM D4867. Specifically, tensile strength ratio is defined as the ratio of indirect tensile strength of specimens at wet condition to the indirect tensile strength of specimens at dry condition. Six specimens of 150 mm diameter and 95 mm thickness were prepared for each of the five different asphalt mixtures at a target air void content of 7%, using Superpave gyratory compactor. The specimens (six in number) of each mixture were then separated into sets of three to test them under both dry and wet conditions. The dry condition specimens were conditioned at 25°C for about 2 h prior to testing, while the wet condition specimens were partially saturated through vaccum-saturation until 70% to 80% of the voids were filled with water and then immersed in water bath at 60°C for 24 h. The wet condition specimens after moisture damage were then conditioned at 25°C in a water bath for 2 h before testing. Indirect tensile strength test were conducted on both the dry and wet specimens at a loading rate of 50 mm/min. The load-displacement characteristics were recorded for all the specimens tested and the corresponding maximum load was used to calculate the indirect tensile strength of the respective asphalt mixtures evalauted in this study, which in turn was used to calculate the tensile strenth ratio of the respective asphalt mixtures. A high TSR value (>80%) indicates better resistance to moisture and vice-versa.

5 RESULTS AND DISCUSSIONS

5.1 *Characterization of RAP and GRAP*

During the sieve analysis of crushed GRAP sample, geosynthetic fragments were observed only up to 12.7 mm sieve, after which no traces of geosynthetics were observed in the mix. This may be due to the fact that geosynthetic particles were bigger in size and the presence of mastic asphalt on their surface has increased their size. Table 1 shows the design gradation of RAP and GRAP samples used for the preparation of asphalt mixtures. Table 1 demonstrates that the crushed RAP and GRAP samples were almost similar, with no significant change in their volumetric or gradation requirements. On the other hand, while considering the binder extraction test on the collected samples, the binder content of RAP and GRAP samples is determined to be 4.92% and 5.87%, respectively, indicating that there was a difference of 0.95% in binder content for the collected RAP and GRAP samples. The higher binder content of GRAP can be attributed to the application of tack coat during installation of paving interlayer at the site.

Table 1. Design gradation of collected materials.

	Percentage Passing (%)	
Sieve size*	RAP	GRAP
19.05	100	100
12.7 mm	99	99
9.53 mm	90	95
4.75 mm	60	65
2.36 mm	40	44
0.6 mm	20	25
0.3 mm	13	15
0.075 mm	5	5

*Sieve size in millimeters.

5.2 *Indirect tensile strength test*

5.2.1 *Effect of temperature on the indirect tensile strength of asphalt mixtures*

The indirect tensile strength for the five different asphalt mixtures evaluated in this study at different test temperatures are reported in Table 2. The results show that the indirect tensile strength of the asphalt mixtures decreases rapidly with increase in test temperature. For example, the indrect tensile strength of 30-70 RAP was reduced by 22% and 65%, when the test temperature changed from 5 to 10°C and 5 to 25°C, respectively. These reduction in indirect tensile strength values was due to the reduction in the viscosity and cohesion of the asphalt binder particles at higher temparature, thereby causing lower resiatnce to tensile forces. Moreover, specimens containing RAP and GRAP samples has shown less reduction in indirect tensile strength value with increasing test temperature compared to control specimens. The reason behind this was the presence of aged binder on the surface of RAP and GRAP samples providing greater stiffness to the mix, which in turn causing higher resistance to tensile stresses.

Table 2. Tensile strength of asphalt mixtures at different temperatures.

	Temperature (°C)		
Mixture type*	5	10	25
VA	2223	1487	589
15–85 RAP	2343	1679	733
15–85 GRAP	2231m	1614	722
30–70 RAP	2722	2113	955
30–70 GRAP	2433m	1826	859

*Tensile strength is in kPa.

5.2.2 *Effect of RAP and GRAP content on the indirect tensile strength of asphalt mixtures*

The indirect tensile strength test results for the specimens containing different percentages of RAP and GRAP samples are reported in Table 2. As can be seen in the table, the average indirect tensile strength value was highest for 30-70 RAP specimen at any given test temperature, followed by 30-70 GRAP, 15-85 RAP, 15-85 GRAP and VA specimens respectively. The higher indirect tensile strength of specimens containing RAP or GRAP samples compared to control specimens was due to the presence of aged asphalt binder on the surface of collected samples, imparting higher stiffness to the asphalt mixtures. Moreover, the indirect tensile strength of control specimen was observed to be 30%, 19%, 11%, and 8% lower than the indirect tensile strength of 30-70 RAP, 30-70 GRAP, 15-85 RAP and 15-85 GRAP, respectively, at test temperature of 10°C. In contrast, no significant difference between the indirect tensile strength of specimens containing RAP and GRAP samples (at any given percentage) were observed. While addition of GRAP samples resulted in lower tensile strength of specimens compared to those containing RAP samples, which can be attribute to the presence of geosynthetic fragments that might have reduce the stiffness of the asphalt mixtures.

5.3 *Moisture susceptibility test*

The moisture susceptibility of the five different asphalt mixtures evaluated in this study was determined in terms of the tensile strength ratio by evaluating the indirect tensile strength of dry and wet specimens. Table 3 shows the moisture susceptibility results (tensile strength ratio values) of the tested specimens. As can be seen in the table, 30-70 RAP specimen has shown the highest TSR value followed by 30-70 GRAP, 15-85 RAP and 15-85 GRAP specimens, respectively. While the control specimen has shown the lowest TSR value. These results indicate that the replacement of VA with RAP or GRAP samples can improve the stability of asphalt mixtures against moisture damage. Specifically, the RAP and GRAP samples contains aged, hardened asphalt binder which increases the stability of asphalt mixtures due to the higher viscosity of aged binder. In addition, oxidized binder is hydrophobic in nature and absorb less water, thus causing RAP and GRAP specimens to absorb less water than control specimens. Moreover, the TSR value of 30-70 RAP and 15-85 RAP was found to be slightly higher than that for 30-70 GRAP and 15-85 GRAP, respectively, because the geosynthetic fragments can absorb moisture. However, asphalt mixtures evaluated in this study, containing either RAP or GRAP samples were found to perform better against moisture damage compared to control specimen.

Table 3. Moisture susceptibility results.

Mixture type	TSR (%)
VA	81
15-85 RAP mm	85
15-85 GRAP m	82
30-70 RAP mm	90
30-70 GRAP mm	87

6 CONCLUSIONS

This study is performed to present the characteristics of RAP containing geosynthetic fragments and its suitability with virgin aggregates as surface course material. The following conclusions can be drawn from this investigation:

(1) The binder content of GRAP samples was observed to be 0.95% higher than that of RAP samples which can attribute to the presence of tack coat used during the installation of geosynthetic interlayer.
(2) The indirect tensile strength of the asphalt mixtures decreases rapidly with increasing test temperature. However, specimens containing RAP and GRAP samples results in less reduction in the indirect tensile strength values with increasing temperature compared to control specimens due to the presence of aged binder.
(3) The addition of RAP and GRAP samples (up to 30% by weight) can improve the indirect tensile strength and moisture susceptibility of the asphalt mixtures compared to control specimens.

REFERENCES

AASHTO T164 (2022). *Standard Method of Test Quantitative Extraction of Asphalt Binder from Asphalt Mixtures*. Washington, DC: American Association of State and Highway Transportation Officials.

ASTM D4867 (2022). Standard Test Method for Effect of Moisture on Asphalt Mixtures. *ASTM International*, West Conshohocken, *PA, USA*.

ASTM D6931 (2017). Standard Test Method for Indirect Tensile (IDT) Strength of Asphalt Mixtures. *ASTM International*, West Conshohocken, *PA, USA*.

Gu, F., Andrews, D., & Marienfeld, M. (2021). Evaluation of Bond Strength, Permeability, and Recyclability of Geosynthetic Products. *Geosynthetics Conference*, pp. 362–373.

Marín-Uribe, C. R., & Restrepo-Tamayo, L. M. (2022). Experimental Study of the Tensile Strength of Hot Asphalt Mixtures Measured with Indirect Tensile and Semi-circular Bending Tests. *Construction and Building Materials*, *339*, 127651.

NAPA, 2011. *Mix Production Survey Reclaimed Asphalt Pavement, Reclaimed Asphalt Shingles, Warm-Mix Asphalt Usage: 2009–2010*. Washington, DC: National Asphalt Pavement Association, Technical Report.

Plati, C., & Cliatt, B. (2018). A Sustainability Perspective for Unbound Reclaimed Asphalt Pavement (RAP) as a Pavement Base Material. *Sustainability*, *11*(1), 78.

Saride, S. & Kumar, V. V. (2017). Influence of Geosynthetic-interlayers on the Performance of Asphalt Overlays on Pre-cracked Pavements. *Geotextiles and Geomembranes*, 45, No. 3, 184–196.

Saride, S. & Kumar, V. V. (2019). Estimation of Service Life of Geosynthetic-reinforced Asphalt Overlays From Beam and Large-scale Fatigue Tests. *Journal of Testing and Evaluation*, 47, No. 4, 2693–2716.

Saxena, A., Kumar, V.V., Correia, N.S. & Zornberg, J.G. (2023). Evaluation of Geosynthetic-reinforced Asphalt Milling Characteristics and Suitability as Pavement Base Course. *Geosynthetics Conference, Kansas City, MO*, 324–335.

Shu, X., Huang, B., Shrum, E. D., & Jia, X. (2012). Laboratory Evaluation of Moisture Susceptibility of Foamed Warm Mix Asphalt Containing High Percentages of RAP. *Construction and Building Materials*, *35*, 125–130.

Singh, D., Chitragar, S. F., & Ashish, P. K. (2017). Comparison of Moisture and Fracture Damage Resistance of Hot and Warm Asphalt Mixes Containing Reclaimed Pavement Materials. *Construction and Building Materials*, *157*, 1145–1153.

TxDOT. (2014). *Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges*. Texas Department of Transportation (TxDOT), Austin, Texas, USA.