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Experimental Investigation on Rheological Properties of Recycled Asphalt Pavement Mastics

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Abstract:
Studies have shown that rheology of asphalt mastic plays an important role in pavement performance, specifically for the case of recycled asphalt pavement (RAP) mastics which contains mostly aged binder. This study determines the rheological properties of RAP mastics and a comparison is conducted with the no-RAP binder. Influence of RAP fines on rutting and cracking performances is also studied. A performance grade PG 70-22 binder is mixed with varying percentages (10, 20, and 40 %) of crushed stone (no-RAP) and RAP fines to prepare mastics. Dynamic Shear Rheometer testing is conducted to measure the complex shear modulus G^*, and phase angle δ of these mastics at high and intermediate temperatures through frequency sweep. Bending Beam Rheometer test is conducted at low temperatures (-10, -16, and -22 °C) to measure the stiffness S and relaxation (m-value). Direct Tension Test is conducted to compute the failure strain at -22 °C. Results show an improvement in rutting with the addition of RAP fines (increase in $G^*/\sin\delta$), a decline in low-temperature cracking resistance (increase in S). Addition of RAP fines up to 20 % does not affect the fatigue resistance of the mastics adversely. However, fatigue cracking of 40 % RAP mastic is shown to be high (increase in $G^*\sin\delta$). 40 % RAP mastic shows a smaller failure strain than the virgin binder and 40 % no-RAP mastic, which indicates that mastics containing RAP are more susceptible to low-temperature cracking. To characterize the viscoelastic properties of the RAP mastics, the G^* master curve is constructed at 22 °C reference temperature. RAP mastics' master curves follow the sigmoidal function irrespective of %RAP in mastics. However master curves do not show any significant difference between RAP mastics and no-RAP mastics.

Key words:
asphalt, recycled asphalt pavement, mastics, dynamic shear rheometer, bending beam rheometer, direct tension

1 INTRODUCTION

In hot mix asphalt (HMA) concrete aggregate provides resistance to traffic loads and asphalt binder acts as a cementing agent to hold aggregates together. For better packing, aggregate is selected as such that some are coarse aggregate (retained in Number 4 sieve), some are fine aggregate (passing Number 4 sieve) and the rest are fines (passing Number 200 sieve). Aggregate packing is directly related to achieving the desirable density and durability of HMA [1]. During the mixing, fines absorb more asphalt binder due to their larger surface area resulting a mixture of fines and binder, which is called mastic [2]. Studies have shown that mastic is one of the most influential constituents of asphalt concrete for controlling rutting and fatigue performance [3]. Studies have shown that cracks propagate through asphalt mastic rather than through aggregates or the aggregate-mastic interface [4]. Some studies showed that high and low-temperature properties of asphalt depend on mastic properties [5 – 6]. A study conducted by Hesami et al. [7] investigates the effect of filler bitumen interaction numerically and experimentally. They concluded that the filler type, size and shape are important parameters on the mastic behavior. However, the effect of recycled asphalt pavement (RAP) binder in the mastic was not investigated. This is important because, mastic contains a lot of binders and sometimes fines are entrapped inside the binder film. So there is a need for examining the effects of RAP binder in the mastic properties. Mastic can be studied as semisolid or liquid depending on the temperature and percent of fines in the mastic. In this study, RAP mastics' rheology is studied for better understanding of asphalt concrete performance.

Recycled asphalt pavement mix contains a significant amount of fines compared to no-RAP mix. RAP fines also contain aged binder, making a study of mastic even more important to evaluate the RAP mix and no-RAP mix to understand the behavior of RAP fines in the asphalt concrete. There are a number of studies on RAP mix percy, 40 % RAP mastic has higher G^* than others, which implies it has more susceptibility to low-temperature cracking. Finger 11 does not show any significant difference between RAP and no-RAP mastics except the 40 % RAP mastic. Therefore, the master curve may not be the ideal way for the comparison of RAP fines and no-RAP fines in mastics, though the mix master curve has been used in the recent MEPDG [20].

5 CONCLUSIONS

In this study, virgin binder, three different RAP mastics, and three different no-RAP mastics are studied to compare and understand the effect of RAP fines in the mastics' rheological properties. To determine this, a series of laboratory tests were conducted to measure the rheological properties of all the samples. From the test results, the following conclusions can be made:

- RAP and no-RAP mastics show a decrease in shear modulus G^* with increasing temperatures. Mastics show an increase in phase angle δ with increasing temperatures. The isothermal curve for all mastics shows a reduction in δ value and an increase in G^* value due to the addition of fines. It can be concluded that that addition of RAP or no-RAP fines increases the elastic behavior and makes the binder stiffer.
- The rutting parameter $G^*/\sin\delta$ at high temperatures increases significantly with the addition of fines. Also, 40 % RAP mastic has higher $G^*/\sin\delta$ value than the 40 % no-RAP mastic. That is, the addition of 40 % or more RAP fines improves the rutting resistance.
- The fatigue cracking parameter $G^*\sin\delta$ at intermediate temperature increases significantly with the addition of 40 % RAP fines when compared to 40 % no-RAP fines. However, the addition of up to 20 % RAP fines shows a similar $G^*\sin\delta$ value as no-RAP mastic. That is, adding more than 20 % RAP fines makes mastic more prone to fatigue cracking.
- At low temperatures, stiffness increases and the m-value decreases with decreasing temperatures for all mastics. Therefore, the addition of RAP and no-RAP fines increases the low-temperature cracking potential of mastics. Overall, RAP mastics experience high low-temperature cracking compared to that of no-RAP mastics.
- At low temperature, failure strength of mastic increases with the addition of RAP and no-RAP fines. However, RAP mastics have more failure strength than no-RAP mastic. Therefore, the addition of RAP fines makes mastic more brittle than no-RAP mastics.
- G^* data of mastics can be fitted to a sigmoidal shape master curve irrespective of percentage of fines contents. Increase in G^* is noticed due to the addition of fines, however, no significant difference is found between RAP and no-RAP mastics.

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REFERENCES

[1] Read J, Whiteoak D: The Shell Bitumen Handbook, Thomas Telford Publishing, London (2003).
[2] Lesueur D: The Colloidal Structure of Bitumen: Consequences on the Rheology and on the Mechanisms of Bitumen Modification, Adv. Colloid Interface Sci. 145 (2009) 42 – 82.
[3] Zulkati A, Diew W, Delai D: Effects of Fillers on Properties of Asphalt-concrete Mixture, J. Transport. Eng. 138 (2012) 902 – 910.
[4] Tarefder RA, Kias E, Stormont J: Evaluating Parameters for Characterization of Cracking in Asphalt Concrete, ASTM J. Test. Eval. 37 (2009) 1 – 11.
[5] Yi-Qiu T, Li Z, Zhang X, Dong Z: Research on High- and Low-Temperature Properties of Asphalt-Mineral Filler Mastic, J. Mater. Civil Eng. 22 (2010) 811 – 819.
[6] Kandhal PS, Lynn CY, Parker F: Characterization Tests for Mineral Fillers Related to Performance of Asphalt Paving Mixtures, Publication NCAT Report No. 98 – 2 (1998).
[7] HesamiE, Birgisson B, Kringos N: Numerical and experimental evaluation of the influence of the filler–bitumen interface in mastics, J. Mater. Struct. 47 (2013) 1325 – 1337.
[8] Zubeck HK, Vinson TS: Prediction of Low-Temperature Cracking of Asphalt Concrete Mixtures with Thermal Stress Restrained Specimen Test Results, J. Transport. Res. Board 1545 (1996) 50 – 58.
[9] McDaniel RS, Soleymani H, Shah A: Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method: Technician's Manual, NCHRP Report 452, National Research Council, Washington D.C. (2001).
[10] Amirkhanian SN, Xiao F: Resilient Modulus Behavior of Rubberized Asphalt Concrete Mixtures Containing Reclaimed Asphalt Pavement, Road Mater. Pavement Design 9 (2008) 633 – 649.
[11] Hajj EY, Sebaaly PE, Shrestha R: Laboratory Evaluation of Mixes Containing Recycled Asphalt Pavement (RAP), Road Mater. Pavement Design 10 (2009) 495 – 517.
[12] Huang B, Zhangand Z, Kinger W: Fatigue Crack Characteristics of HMA Mixtures Containing RAP, Proceedings of the 5th International RILEM Conference on Cracking in Pavements, Limoges (2004) 631 – 638.

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[13] Al-Qadi IL, Carpenter SH, Roberts GL, Ozer H, Aurangzeb Q, Elseifi MA, Trepanier, J: Determination of Usable Residual Asphalt Binder in RAP, FHWA-ICT-09-031, Federal Highway Administration, Washington D.C. (2009).
[14] Meyers F, Tessier GR, Haas R, Kennedy TW: Study of Hot Mix Recycling of Asphalt Pavements, Report TP 2964 E. Roads and Transportation Association of Canada, Ottawa (1983).
[15] Huang B, Shu X, Vukosavljevic D: Laboratory Investigation of Cracking Resistance of Hot-Mix Asphalt Containing Screened Reclaimed Asphalt Pavement, J. Mater. Civil Eng. 23 (2011) 1535 – 1543.
[16] AASHTO T 315-06: Standard Method of Test for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer, Standard Specifications for Transportation Materials and Methods of Sampling and Testing 27th Edition, AASHTO, Washington D.C. (2007).
[17] AASHTO T 313-06: Standard Method of Test for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer, Standard Specifications for Transportation Materials and Methods of Sampling and Testing 27th Edition, AASHTO, Washington D.C. (2007).
[18] AASHTO T 314-06: Standard Method of Test for Determining Fracture Properties of Asphalt Binder in Direct Tension, Standard Specifications for Transportation Materials and Methods of Sampling and Testing 27th Edition, AASHTO, Washington D.C. (2007).
[19] McDaniel RS, Soleymani H, Shah A: Use of Reclaimed Asphalt Pavement (RAP) Under Superpave Specifications: A Regional Pooled Fund Project, North Central Superpave Center, West Lafayette (2002).
[20] AASHTO: Mechanistic-Empirical Pavement Design Guide, A Manual of Practice, July 2008, Interim Edition, American Association of State Highway and Transportation Officials (AASHTO), Washington D.C. (2008).

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