Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Effect of Antioxidant Additives and Recycling Agents on Performance of Asphalt Binders and Mixtures – Phase I

Research Objectives

This research aims to investigate the effect of various RAs and one antioxidant additive on performance of asphalt binders and mixtures. Testing will be performed on various blends of RAs and antioxidants containing laboratory aged materials (up to 100%). The laboratory tests will be performed to evaluate chemical properties (e.g., SARA, FTIR, elemental analysis) of the additives and binders, rheological performance (e.g., PG, Glover-Rowe) of the binders, and mechanical properties (e.g., SCB and TSR) of the mixtures. In addition, the possible correlation between chemical characteristics of the additives and rheological/mechanical properties of the binders/mixtures will be examined.

Research Benefits

The findings of this research study will affect Nebraska asphalt binder mixtures specifications. Test results and findings will be used to provide useful implementation guidelines of Nebraska asphalt binders and mixtures containing laboratory aged materials. This research would also bring clear benefits in sustainability of pavements by expanding their service life.

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Background

The use of restoration agent (RA) (i.e., rejuvenators or softening agents) have gained popularity in recent years since they can effectively restore the engineering properties (e.g., stiffness) of the aged asphalt binder. The National Center for Asphalt Technology (NCAT) has categorized these chemical additives (i.e., RAs) into five main groups based on their origins and production process: 1) Paraffinic Oils, 2) Aromatic Extracts, 3) Naphthenic Oils, 4) Triglycerides & Fatty Acids, and 5) Tall Oils. Currently, there is general agreement that RAs can improve the cracking resistance and diminish the rutting resistance of the RAP blended mixtures. However, there are some concerns about the effect of RAs on the moisture damage resistance and the long-term performance (aging) of these additives. For instance, Haghshenas evaluated the long-term performance of three chemically different RAs (i.e., petroleum-, tall oil- and agriculture-based). They reported that the tall oil- and agriculture-based additive did not mitigate the effects of long- term aging and tall oil RA increased the moisture sensitivity of the mixtures, however, the immediate performance of these RAs was acceptable and was a lower cost alternative than petroleum-based. the phase I of this research will focus on the effect of chemical properties of RAs on rheological and Mechanical properties of asphaltic materials, especially, on long-term performance of asphalt binders and mixtures. In addition, the long-term performance of the restored binders modified by one type of antiaging will be examined. Finally, the combination effect of RAs and antioxidant additive will be evaluated in two different levels: mixture and binder. The results of this research may result in a guideline for RAs and antioxidants selection and developing a laboratory testing protocol to evaluate the performance of the binders modified by RAs and antioxidants.

Conclusion

The use of reclaimed asphalt pavement (RAP) in asphalt mixtures has notably increased in recent times. Nevertheless, the inherent stiff and aged characteristics of RAP materials have consistently raised concerns regarding cracking performance. The use of recycling
agents (RAs) has gained popularity in recent years since they can effectively modify the engineering properties of the aged asphalt binder. Besides that, the combination of RA with antioxidant (AO) additives has shown promise in enhancing the long-term performance of RAP mixtures. This research aims to investigate the effect of various RAs and one AO additive on performance of asphalt binders and high-RAP mixtures. Five RAs (paraffinic oil, naphthenic oil, aromatic extracts, triglycerides/fatty acids, and tall oils) and one AO (zinc diethyldithiocarbamate - ZnDEC) were selected. Initially, the effects of RA and AO were analyzed at the binder level considering chemical (SARA, FT-IR, CHNOS) and rheological as well as physical (DSR, BBR, and Wihelmy Plate) testing results. Secondly, following the findings at the binder level, two specific RAs (naphthenic oil and triglycerides/fatty acids) were chosen and utilized in combination with ZnDEC to modify the binder used in producing high-RAP mixtures. The studied mixtures were subjected to semi-circular bending test (SCB) and Hamburg wheel tracking test (HWTT) to evaluate cracking, rutting and moisture damage resistance of the mixtures, respectively. The chemical analysis of the RAs showed that those based on triglycerides/fatty acids and tall oils demonstrated pronounced peaks near the 1740 cm-1region and a greater oxygen content relative to other RAs. As expected, the RAs had a softening effect on the binder blends. Additionally, ZnDEC helped retard the oxidation of the RA-modified binders, and its effectiveness depended on the RAs' susceptibility to aging. At the mixture level, the simultaneous use of RAs and ZnDEC in the high-RAP mixture improved cracking performance and reduced oxidative aging but might negatively affected rutting and moisture damage resistance.

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NDOT Recommendations Based Off Research Project

Upon completion of the present research, several potential future research need to continue to be investigated. The Department funded a second phase of this research title Effect of Antioxidant Recycling Agents of Asphalt Binders. The second phase of this research will study the effect of various RAs and antioxidant additives and their performance with modified asphalt binders and mixtures. Various tests will be performed on different combinations of RAs and antioxidants containing virgin and RAP materials to characterize physical characteristics and rheological performances of the binders as well as mechanical properties of the mixtures.

Test results and findings will be used to provide implementation guidelines for common binder grades and mixes used containing RAP materials. This research will also bring significant pavement life cycle cost savings, provide longer lasting and more sustainable roadway pavements.

- *As provided by Robert Rea and Bruce Barret, Lead TAC Members*

Research Readiness Level (RRL) Assessment

Level: Applied Research/Proof of Concept/Laboratory Level

RRL 2

Technology Transfer

Transportation Research Board (TRB) papers and Publications

- Haghshenas, Hamzeh F., Robert Rea, Gerald Reinke, Martins Zaumanis, and Elham Fini. "Relationship between colloidal index and chemo-rheological properties of asphalt binders modified by various recycling agents." Construction and Building Materials 318 (2022): 126161.
- Haghshenas, Hamzeh F., Robert Rea, Gerald Reinke, Afshar Yousefi, Davoud F. Haghshenas, and Pooyan Ayar. "Effect of recycling agents on the resistance of asphalt binders to cracking and moisture damage." Journal of Materials in Civil Engineering 33, no. 10 (2021): 04021292.
- Haghshenas, Hamzeh F., Elham Fini, Robert Rea, and Ali Khodaii. "Increasing the efficacy of recycling agents with simultaneous addition of zinc diethyldithiocarbamate as an antioxidant." Construction and Building Materials 271 (2021): 121892.
- Haghshenas, Hamzeh F., Robert Rea, Gerald Reinke, and Davoud Fatmehsari Haghshenas. "Chemical characterization of recycling agents." Journal of Materials in Civil Engineering 32, no. 5 (2020): 06020005.

US patent

- Fatmehsari, Hamzeh Haghshenas, and Robert Rea. "Use of antioxidants and recycling agents for improving long-term performance of asphaltic materials." U.S. Patent 11,795,109, issued October 24, 2023

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