Effect of Aging and Rejuvenation on Surface Free Energy Measurements and Adhesive Property of Asphalt Binder

Authors: Kamal Hossain, Ahmet Karakas, Punit Singhvi, Imad L. Al-Qadi, and Hasan Ozer
University of Illinois at Urbana-Champaign
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Illinois Center for Transportation

Introduction

Aging of asphalt binder is inevitable and occurs during construction and in-service state. Factors affecting aging includes oxygen, moisture, ultraviolet irradiation, heat radiation, and traffic. These effects ultimately lead to the changes in the molecular structures and chemical functional groups of asphalt binder. These changes may result in stiffening of asphalt concrete (AC), which accelerates fatigue cracking. In addition, aging may result in moisture induced distresses; especially stripping. AC stripping results in separation of asphalt binder from aggregate in two spatial domains: first, at the interface of asphalt binder film and aggregate, and secondly, within the mastic phase, which are loss of adhesion and cohesion, respectively. Such losses can be associated with asphalt binder and aggregate surface energy.

Objective

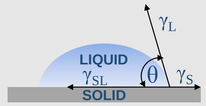
The major objective of the study is described as follows:

Evaluate the impacts of asphalt binder aging and rejuvenation on the behavior of various surface free energy (SFE) components of asphalt binder and aggregate binder interaction.

Concept of Surface Free Energy

Surface free energy (SFE) of a solid or liquid material refers to the magnitude of work required to create a unit area of a new surface of the material in a vacuum.

The total surface free energy (γ) of a solid or liquid material consists of three surface energy components occurred by the molecular forces: a nonpolar Lifshitz-van der Waals component (γ_{LW}), a Lewis acid component (γ+), and a Lewis base component (γ-).



$$\gamma^{Total} = \gamma^{LW} + 2\sqrt{\gamma^{+}\gamma^{-}}$$

$$W_{SL} = \gamma_S + \gamma_L - \gamma_{SL}$$

Concept of Surface Free Energy

W_{SL} is the work of adhesion between a solid (S) and a liquid (L), γ_S is the surface free energy of solid, γ_L is the surface free energy of liquid, and γ_{SL} is the interfacial surface free energy that is separated during adhesion process.

$$\gamma_{SL} = \left(\sqrt{\gamma_S^{LW}} - \sqrt{\gamma_L^{LW}}\right)^2 + 2\left(\sqrt{\gamma_S^{+}\gamma_S^{-}} + \sqrt{\gamma_L^{+}\gamma_L^{-}} - \sqrt{\gamma_S^{+}\gamma_L^{-}} + \sqrt{\gamma_S^{-}\gamma_L^{+}}\right)$$

Experimental Design and Materials Used

TYPES OF LIQUID

- Distilled Water
- Glycerol
- Formamide

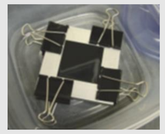
Base and Modified Binder

TYPE OF AGGREGATE

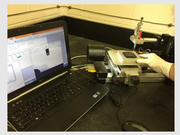
- Limestone
- Granite

AGING CONDITIONS

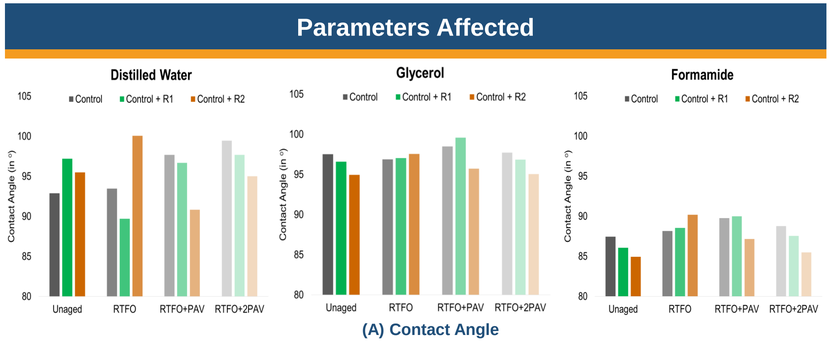
- Unaged
- RTFO Aged
- RTFO + PAV Aged
- RTFO + 2PAV Aged


Sample Preparation


Liquids Used

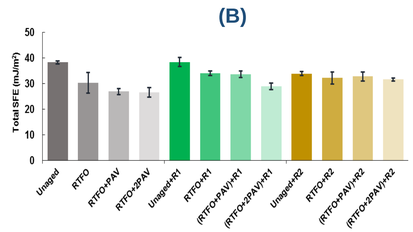

SFE Testing

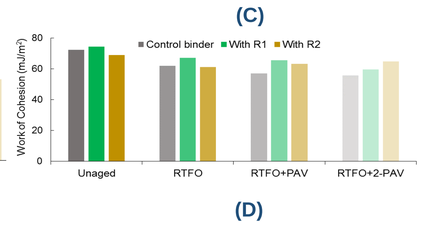
Parameters Affected

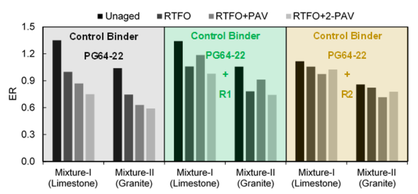


(A) Contact Angle

Parameters Affected







(B) Surface Free Energy
(C) Work of Cohesion
(D) Energy Ratio Parameters

Conclusions

- Contact angle increases with aging for the case of distilled water, showing liquid's ability to spread.
- The contribution of Lifshitz Waals component was found to be higher than other components of SFE. In addition, the Lifshitz Waals component decreased with aging.
- Addition of rejuvenators improved the cohesive energy, enhancing the resistance to moisture damage. The effect rejuvenator R2 was more prominent in extremely aged binders while R1 effect was more evident in less aged binders.
- Granite has greater work of adhesion than limestone.
- Energy ratio (ER) parameter decreased with aging for both aggregate types

Acknowledgment

The poster is based on an ongoing study, R27-175 - Development of Long-Term Aging Protocol for Implementation of Illinois Flexibility Index test (I-FIT). The study is conducted in cooperation with the Illinois Center for Transportation; the Illinois Department of Transportation, Division of Highways; and the U.S. Department of Transportation, Federal Highway Administration.

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