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Influence of moisture conditioning on healing of asphalt binders

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HIGHLIGHTS

- Healing ability of asphalt binder is greatly influenced by moisture conditioning.
- A healing model is developed to separate the total healing into instantaneous and long-term healings.
- Instantaneous healing decreases as moisture conditioning decreases the cohesion or energy of separation of binder.
- Moisture conditioning reduces the long-term healing rate of asphalt binder.

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ABSTRACT

The self-healing property of asphalt binder in the asphalt concrete has been reported in recent years. Healing is an important property of asphalt binder as it helps to recover the fatigue damage during rest period. However, the effect of moisture conditioning on asphalt binder healing has not been studied yet. In this study, Moisture Induced Sensitivity Test (MIST) is used to moisture-condition the binders and then tested using a Fourier Transform Infrared (FTIR) and Dynamic Shear Rheometer (DSR) to evaluate the chemical and healing properties respectively. Also, cohesion properties of the binder are calculated from the tack test using DSR. FTIR results show that water is absorbed in the asphalt binder due to the moisture conditioning. Additionally, results show that the healing rate of asphalt binder decreases due to moisture conditioning. A healing model is developed to separate the total healing into instantaneous and long-term healings. The instantaneous healing is the instant healing that occurs just after the loading is removed. Moisture conditioning decreases the amount of instant healing by reducing the cohesion or energy of separation of the binder. The long-term healing occurs only if there is a very long rest period and depends on the activation energy (or diffusion rate). Results show that moisture conditioning reduces the long-term healing rate by increasing the required activation energy for diffusion. Therefore, the overall healing of fatigue damage reduces due to moisture conditioning of the asphalt binder.

1. Introduction

Several studies in recent years showed the evidence of healing in asphalt concrete and the effect of healing on the fatigue life of the asphalt pavement [1–5]. Healing is the ability of asphalt to recover microdamage caused due to loading [6]. Healing of asphalt concrete depends on the chemical and physical properties of the asphalt binder and several external factors such as temperature, aging, moisture, etc. This study focuses on asphalt binder healing or cohesive healing in asphalt mixture. Healing of asphalt binder is highly sensitive to aging and moisture conditioning, as aging and moisture conditioning changes the physical and chemical properties of asphalt binder [7–9]. Some studies have evaluated the effect of aging on the healing of the asphalt binder [10], However, there is no work to the authors' knowledge which demonstrates the effect of moisture on the healing of asphalt binder.

It is already known that moisture plays an important role on the damage of asphalt pavement. As water enters the asphalt concrete it diffuses with the asphalt binder at the molecular level, resulting in binder softening. This leads to cohesive failure within the asphalt binder film of the asphalt concrete, which is called moisture damage [11–15]. However, the focus of this study is the healing of fatigue damage not the moisture damage. Another study by Islam and Tarefder showed that the increase of moisture in the asphalt concrete does not always increase the damage or reduces the strength of the mix [16]. From the above studies, it can be said that moisture reduces the binder's cohesive properties and the asphalt binder's chemical property might change. These changes in the binder due to moisture conditioning can also effect the

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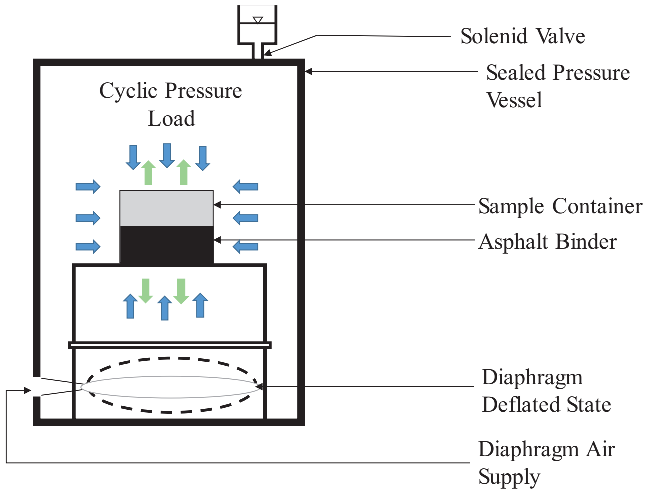

Fig. 1. MIST moisture conditioning setup.

healing. However, the effect of chemical changes due to moisture in healing of binder has not been studied yet. Therefore, the effect of moisture conditioning on asphalt binder healing is an important mechanism that should be evaluated. This will provide a better understanding about how moisture affects the healing of asphalt, which eventually affects cracking and long-term performance of the pavement.

2. Objective

The main objective of this study is to evaluate the influence of moisture conditioning on the healing of asphalt binders. To achieve this objective, two different asphalt binders are moisture conditioned in three different levels. The chemical changes that might have occurred due to the moisture conditioning are then evaluated using the Fourier Transform Infrared (FTIR) Spectroscopy. The healing and cohesive properties of the binders are measured using the Dynamic Shear Rheometer (DSR). Healing model for all the moisture conditioned binders are developed using the Wool and O'Connor healing model [17]. The study of chemical and mechanical changes and their effects on asphalt binder healing due to moisture conditioning, may lead to a better understanding of the effect of moisture on asphalt healing.

3. Laboratory testing

3.1. Moisture conditioning

This study evaluates two unmodified performance grade (PG) asphalt binders from Holly Asphalt Co.: PG 70-22 and PG 58-22. Several methods are developed to moisture condition the samples over the time: Nottingham asphalt test equipment, AASHTO T 283, Moisture Induced Sensitivity Test (MIST), etc. [18]. Among these, only MIST is used in this study for moisture conditioning the binders. MIST conditioning is chosen over the AASHTO T 283 for this study, because MIST does not apply freeze-thaw conditioning. MIST uses a cyclic pressure loading and high water temperatures to simulate a harsh moisture condition for asphalt pavement, which affects the overall material strength [19]. In MIST, high temperature (60 °C) and pressurized (40 psi) water is forced into the asphalt binder and this accelerates the moisture conditioning of the binder. The schematic of the MIST conditioning is presented in Fig. 1. The binders were placed in a small container inside the chamber and fully submerged in water. A thin layer (5 mm) of binder is conditioned to ensure the proper conditioning of the binder from all the sides. Then the MIST lid was closed and a diaphragm at the bottom of the chamber inflated and deflated by hydraulic pump and piston mechanism. Due to this the water pressure inside the chamber increased and decreased. When the pressure increases, water is pushed into the binder sample (blue arrows in Fig. 1) and during depressurizing some of the water is pushed off (green arrows in Fig. 1). This leads to the absorption and diffusion of water in the asphalt binder. The recommended test conditions for MIST consist of 3500 cycles under 40 psi pressure at 60 °C, which is considered as the equivalent of one cycle under AASHTO T 283 conditioning [20,21]. Samples were conditioned by three repeated cycles in the MIST chamber to moisture conditioned the sample into three different degrees. These conditioned samples are labeled as MIST-cycle 1 (3,500 cycles), MIST-cycle 2 (7,000 cycles) and MIST-cycle 3 (10,500 cycles).

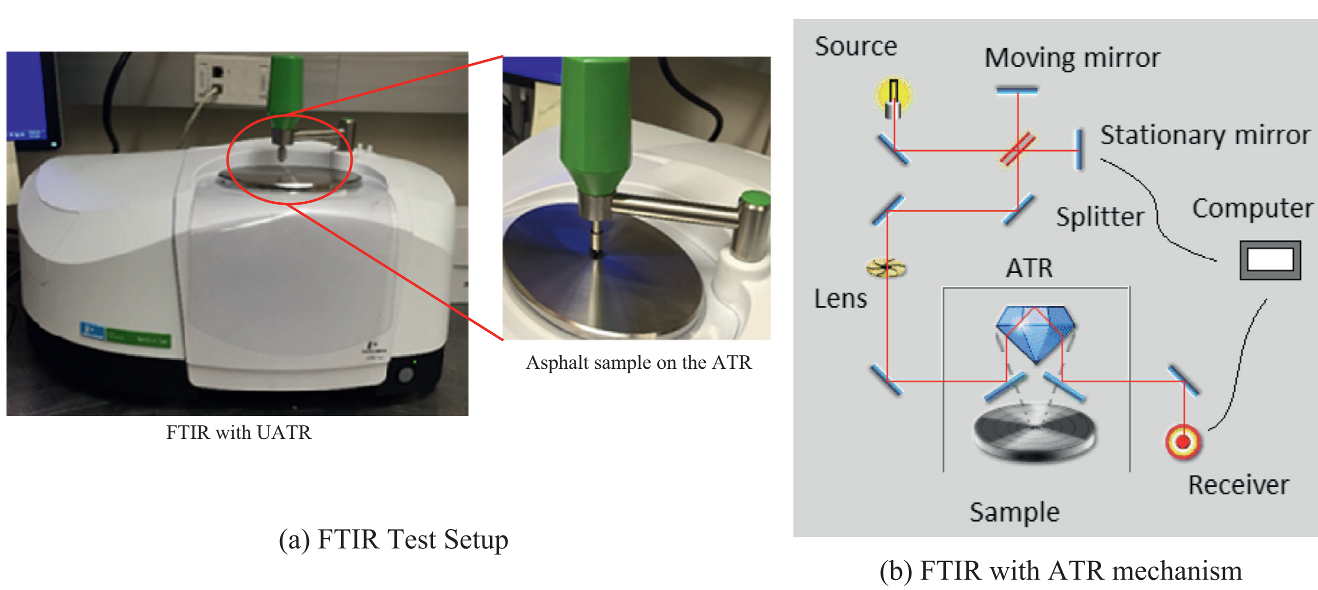

Fig. 2. FTIR setup.