Laboratory Investigation of the Characteristics of Rejuvenated Asphalt Binder

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ABSTRACT

To improve the sustainability quotient of pavement materials, recycled asphalt products are utilized. However, asphalt recycling includes the use of oxidized asphalt binder. Aged binder is highly brittle and causes cracking related distresses in flexible pavements. To improve the rheological properties of Asphalt Concrete (AC) mixes with recycled materials, rejuvenators are used. The current study focuses on evaluating the performance of AC mixes prepared by blending three different kinds of rejuvenators in already aged asphalt cement at different percentages by weight of the total binder. The mixed asphalt samples were then aged for 5, 10, 15, 20, 40, and 60 hours in the Pressure Aging Vessel (PAV). Chemical tests were conducted and frequency sweep tests were carried out to characterize binder rheology and calculate various damage parameters. A strong correlation was found between the rejuvenator types used in different amounts and the level of aging in asphalt. Rejuvenators restored the rheological properties of aged asphalt, but the impact at different temperatures depended on the rejuvenator type used. Damage parameters were found to increase with aging and correlated well with the chemical properties.

RÉSUMÉ

Pour améliorer le quotient de développement durable des matériaux de chaussée, des produits d’asphalte recyclés sont utilisés. Cependant, le recyclage de l'asphalte amène l'utilisation d'un liant d'asphalte oxydé. Ce liant vieilli est très cassant et provoque des fissures dans les chaussées souples. Des régénérateurs sont utilisés pour améliorer les propriétés rhéologiques des mélanges d’enrobés (AC) et de matériaux recyclés. Cette étude se concentre sur l’évaluation de la performance des enrobés préparés en mélangeant aux enrobés déjà vieillis trois types différents de régénérateurs à différents pourcentages en poids du liant total. Les échantillons d’asphalte mélangés ont ensuite été vieillis pendant 5, 10, 15, 20, 40 et 60 heures dans l’autoclave de vieillissement sous pression (PAV). Des tests chimiques et des tests de balayage de fréquence ont été effectués pour caractériser la rhéologie du bitume et calculer divers paramètres de dégradation. Une forte corrélation a été identifiée entre les types de régénérateurs utilisés en quantités différentes et le niveau de vieillissement du bitume. Les régénérateurs ont restauré les propriétés rhéologiques de l'asphalte vieilli, mais l'impact à différentes températures dépend du type de régénérateur utilisé. Il a été constaté que les paramètres de dégradation augmentaient avec le vieillissement et qu'ils étaient bien corrélés avec les propriétés chimiques.

1.0 INTRODUCTION

In flexible pavements, asphalt cement is responsible for providing the desired viscoelastic properties in the asphalt mix. It plays an important role in strengthening of the asphalt concrete pavements including the resistance to thermal or traffic induced cracking and rutting. However, due to the impact of environmental factors, complex physicochemical interactions within asphalt deteriorate its viscoelastic characteristics. This effect is also known as age-hardening of asphalt. As a result, there is a reduction in ductility & penetration, and an increase in the stiffness of asphalt.

At a molecular level, asphalt is known to have an extremely large number of chemically diverse molecular groups. Some of these chemical entities are more vulnerable to the effect of aging than others as they have different oxygen-uptake capacities. It has been observed that molecular structures change as the number of oxidized groups increase over time [1]. Therefore, viscoelastic, and adhesive properties of asphalt get poorer with aging due to mechanisms such as oxidation, evaporation, exudation, and physical hardening [2].

Numerous studies have suggested that molecular groups within aged asphalt are influenced by the addition of a softening or rejuvenating agent [3, 4]. By mixing rejuvenator in asphalt, a change in rheological and engineering properties of asphalt including cracking, rutting, and fatigue resistance, and low or high-temperature properties can be observed [5, 6, 7]. Other benefits of using rejuvenators include cheap storage, simple techniques of addition to the mix, ease of adding the precise dosage based on Reclaimed Asphalt Pavement (RAP)/Recycled Asphalt Shingles (RAS) asphalt properties and level of aging, flexibility of adding RAP from 0 to 100 percent with the same product, and low cost [8].

In order to understand the rheological behaviour of aged and rejuvenated asphalt binders, many studies have been carried out [9, 10, 3, 11, 12, 13, 14]. Hossain and Hossain (2019) recently summarized various approaches and methods developed to improve the rheological and mechanical properties of asphalt binders [15]. Romera et al. (2006) stated that the viscosity (η) of asphalt varied significantly as a function of rejuvenator type and amount [16]. Dony et al. (2013) found the complex modulus of asphalt with rejuvenator to be similar to that of the virgin binder [3]. Some other studies noticed an improvement in the performance of asphalt binder by adding rejuvenators. Shen & Ohne (2002) found that the fatigue resistance of asphalt binder significantly improved while the rutting resistance slightly reduced on rejuvenation [13]. Mogawer et al. (2013) also observed a similar reduction in rutting resistance [6]. As most rejuvenators are maltene dominant with less asphaltene content, in order to balance the maltenes to asphaltenes ratio in the asphalt mix, rejuvenators with oily maltene can be responsible for the reduction of rutting resistance in aged binder blended with a rejuvenator [10, 17].

Evaluation of the impact of adding rejuvenating agents to asphalt is also important from the point of view of promoting sustainable asphalt pavement construction practices. Transportation agencies have increasingly started using recycled materials such as RAP and RAS in asphalt mixes. However, by using recycled products in increased amounts or under cold climatic conditions, the stiffness of asphalt mixes increases, resulting in more cracking. To restore the chemical and rheological characteristics of recycled asphalt mixes, rejuvenators are used. Rejuvenators help to reduce the viscosity of asphalt binder and minimize asphalt binder oxidation by penetrating the voids in asphalt pavement [18].

In the past, various studies have focused on understanding the impact of rejuvenation on recycled asphalt concrete mixes. However, limited effort has been made to examine the performance of rejuvenated asphalt mixes for the next round of service. In this study, an attempt is made to fill this knowledge gap by evaluating the influence of adding different types of rejuvenators to aged asphalt, which is then again subjected to long-term aging.

2.0 RESEARCH OBJECTIVES

The objectives of this paper include:

- Investigate the impact of long-term aging on the rheological and chemical properties of rejuvenated asphalt binder samples;
- Determine the effect of varying rejuvenator dosage on the rheological performance of asphalt;