Effect of Ultraviolet Aging on Rheological Properties of Asphalt Cement

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ABSTRACT

Age hardening of asphalt mixtures is an irreversible process, which reduces durability of flexible pavements and increase maintenance cost. In pavement structure, aging of asphalt mixture is mainly associated with changing in asphalt cement properties due to oxidation and ultraviolet (UV) radiation. Intensive studies can be found on oxidation of asphalt cement compared to effect of UV, although UV is one of the predominant factor in age hardening. Therefore, understanding the propensity of UV aging on asphalt cement hardening could lead to enhanced mix design, novel material selection procedures and enhanced long-term performance.

In this study, a set of asphalt cement specimens were aged using natural UV exposure for 3, 7, 28 and 45 days. Rheological study was conducted using Dynamic Shear Rheometer (DSR) on these controlled aged samples to investigate the effect of UV aging and compared with unaged controlled specimen. The analyses of rheological properties including complex modulus and phase angle showed incremental hardening trend of asphalt cement with increasing duration of UV aging. The findings can be used in multi-scale modeling to link the pavement long-term performance with the trend observed in this UV aging controlled study.

RÉSUMÉ

Le durcissement par vieillissement des enrobés bitumineux est un processus irréversible qui réduit la durabilité des chaussées souples et augmente les coûts d'entretien. Dans la structure de la chaussée, le vieillissement du mélange d'asphalte est principalement associé au changement des propriétés du ciment bitumineux dues à l'oxydation et au rayonnement ultraviolet (UV). Des études intensives peuvent être trouvées sur l'oxydation du ciment bitumineux par rapport à l'effet des UV, bien que les UV soient l'un des facteurs prédominants dans le durcissement par l'âge. Par conséquent, la compréhension de la propension du vieillissement aux UV sur le durcissement du ciment bitumineux pourrait conduire à une meilleure conception du mélange, à de nouvelles procédures de sélection des matériaux et à des performances améliorées à long terme.

Dans cette étude, un ensemble de spécimens de ciment bitumineux a été vieilli en utilisant une exposition naturelle aux UV pendant 3, 7, 28 et 45 jours. Une étude rhéologique a été réalisée en utilisant le rhéomètre à cisaillement dynamique (DSR) sur ces échantillons vieillis contrôlés pour étudier l'effet du vieillissement UV et comparé à un échantillon contrôlé non vieilli. Les analyses des propriétés rhéologiques, y compris le module complexe et l'angle de phase, ont montré une tendance de durcissement progressif du ciment bitumineux avec une durée croissante de vieillissement UV. Les résultats peuvent être utilisés dans la modélisation multi-échelle pour lier la performance à long terme de la chaussée avec la tendance observée dans cette étude contrôlée par le vieillissement UV.

1.0 INTRODUCTION

Even though asphalt cement is only one component that makes up asphalt mixtures, it is the component that gives the material its desired viscoelastic nature. In addition to increased driving comfort, this viscoelastic behaviour plays a prominent role in many aspects of mixture durability, such as resistance towards thermally or traffic induced cracking and rutting. Being an organic substance, with time its viscoelastic property can deteriorate due to exposure to the environment, which is known as age hardening.

Aging is a crucial factor in pavement performance and being able to determine its effect on a mixture is necessary to link its initial properties to the properties over time in order to ensure the intended service life. This aging of asphalt cement in the mix is considered to be mainly caused by the oxidation and ultraviolet (UV) radiation, while pavement temperature plays the role of catalyst in this process. Oxidative surface aging is an irreversible chemical reaction between hydrocarbons of asphalt cement and available atmospheric oxygen. The UV radiation catalyzed reaction occurs rapidly, which takes place within the top layer of exposed asphalt cement surface [1, 2]. During both of the aging process, carbonyl, sulfoxide and benzylic carbon groups are formed which increase the polarity of the host compounds and make them much more likely to associate with other polar compounds. As they form these associations, they create less soluble (in n-alkane medium) hydrocarbons that increase the asphalt cement's viscosity and elastic stiffness [1–3].

A long-term asphalt aging test is meant to predict the changing behaviour of the material properties after certain years of service life. To simulate long-term field aging in laboratory, different types of test methods are currently available [4], focusing on accelerated aging on asphalt binder, loose asphalt mixture, or on compacted asphalt specimens. These accelerated aging tests, by assuming the time-temperature superposition principle, are generally conducted at artificially severe conditions, for example at temperatures higher than pavement service temperature and at pressures higher than ambient pressure. Moreover, the influence of sunlight on aging is ignored in these laboratory simulations although asphalt binder is known to be a good light absorber – particularly for UV radiation [3–6] Intensive studies can be found on oxidation of asphalt cement compared to effect of UV, although UV is one of the predominant factors in age hardening. Therefore, understanding the propensity of UV aging on asphalt cement hardening could lead to enhanced mix design, novel material selection procedures, and enhanced long-term performance.

In this study, a set of asphalt cement specimens were aged using natural UV exposure for 3, 7, 28 and 45 days. Rheological study was conducted using a Dynamic Shear Rheometer (DSR) on these controlled aged samples to investigate the effect of UV aging and compared with unaged samples. The analyses of rheological properties including complex modulus and phase angle showed incremental hardening trend of asphalt cement with increasing duration of UV aging.

2.0 LITERATURE REVIEW

Numerous research efforts have been conducted to develop an understanding of aging effects of binder in terms of rheological and chemical characteristics [7–15]. In general, most studies conclude that aging has significant impact on binder's rheological and chemical properties. For example, studies conducted by Noureldin and Wood [7] and Shen et al. [16] found that aging influenced both the molecular properties and size of asphalt binder (increased or decreased). From a polarity standpoint, asphalt molecules can be subdivided into two groups; one is called asphaltene (solid fractionate) and other is maltene (liquid phase) [17, 18]. The maltene molecular group consists of saturates, aromatics and resins. The study reports that