Construction and Building Materials 95 (2015) 218–223

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

A study of asphalt aging using Indirect Tensile Strength test

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HIGHLIGHTS

- One-day laboratory long-term aging is close to one-year of field aging.
- ITS of laboratory long-term and field aged samples increase with aging period.
- ITS of short-term oven aged loose sample is concave down with aging period.
- Brittleness increases with conditioning period under all aging modes.

ARTICLE INFO

Article history:
Received 24 March 2015
Received in revised form 5 July 2015
Accepted 15 July 2015
Available online 20 July 2015

Keywords:
Asphalt Concrete
Aging
Field conditioning
Laboratory conditioning
Tensile strength

ABSTRACT

While dynamic modulus, diametrical resilient modulus, and loss of ductility are the most common parameters to study aging, this study determines laboratory equivalence of field aging using an Indirect Tensile Strength (ITS) test for its simplicity and wide usages in Asphalt Concrete (AC) performance evaluation. Cylindrical samples were compacted in the laboratory, aged in the laboratory and field, and then loaded diametrically to determine ITS value and flow number. The ITS tests were conducted on six sets of compacted samples after subjecting them to 1, 5, 10, 15, 20, and 25 days of oven aging at 85 °C in the laboratory and on 11 sets of compacted samples after subjecting them to 1, 2, 3, and up to 12-months of field aging. The ITS tests were also performed on a third set of samples whose loose mixes were subjected to 8, 16, 32, 48, 72 and 100 h oven aging at 135 °C. As expected, ITS of the laboratory (both compacted and loose) and field aged samples increase and flow number decrease with the aging period. It is found in this study that one-day laboratory aging is close to approximately one-year of field aging measured in terms of ITS value. Results from loose mix aging show that the ITS value increases with the conditioning period, reaches a peak and then decreases with the conditioning period. Overall, the flow number decreases as aging intensity increases, that is, the brittleness increases with aging.

1. Introduction

Asphalt binder is composed of organic compounds named as asphaltenes, maltenes, and resins. Due to its polar nature, asphaltenes are more likely to react with oxygen and create carbonyl and sulfoxide compounds. These compounds result in the increase of asphaltene compounds leading to the stiffening of binder, increase in stiffness and viscosity. Characterization of this aging process is a challenging topic; it is difficult to relate chemical aspects of binder aging, such as carbonyl and sulfoxide growth, to the change in physical/rheological properties of the binder and consequently to the mixture. Therefore, the authors employed a simplistic approach which involves the relation of one of the mechanical properties (tensile strength) with aging of asphalt mixture. The relationship between the chemical aging of binder and the mixture aging is outside the scope of this study.

Asphalt binder reacts with oxygen at high temperature while mixing with aggregates in the mixing plant and during the construction period. This phenomenon is known as short-term aging. After pavement construction, asphalt binder continuously reacts with oxygen which is known as long-term aging. Both the short- and long-term aging are simulated in the laboratory following the AASHTO R 30-02 [1] test protocol. Loose asphalt mixture is oven heated at 154 °C for 2 h or at 135 °C for 4 h to simulate short-term aging in the laboratory. Long-term aging is performed by subjecting the prepared Asphalt Concrete (AC) sample in an

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http://dx.doi.org/10.1016/j.conbuildmat.2015.07.159
0950-0618/

oven at 85 °C for 120 h (5 days). Researchers have intensively explored the effects of short- and long-term aging on the rheological properties of asphalt binder [13,19,9,27,18,15]. All of these studies focused on the rheological properties such as the shear modulus and viscosity of aged binder. Studies on aging have also been conducted using prepared AC samples. For example, Tarefder and Faisal [22] investigated the aging effect on asphalt mastics using nano-indentation test; Valtorta et al. [24] studied the long-term aging of an asphaltic plug joint of a highway bridge; Walubita [26], Arega et al. [8] investigated the fatigue behavior of AC. Change in asphalt modulus with aging are also widely explored [20,10,17].

On the other hand, not a good amount of research has been conducted to examine the aging effect on Indirect Tensile Strength (ITS). Thomas et al. [23] studied the aging effect of AC using Indirect Tensile (IDT) test device. They determined the resilient modulus changes over aging time. The ITS was not investigated in that study. However, ITS test is very cost effective in the sense of samples preparation or collection from the field, testing and analyzing the data. A study of aging using ITS test may be useful to research community. From tensile strength point of view, ITS is used to determine the tensile properties of the asphalt mixture which is correlated to the cracking properties of the pavement. A higher ITS corresponds to a stronger cracking resistance. At the same time, asphalt mixtures that are able to tolerate higher strain prior to failure are more likely to resist cracking than those unable to tolerate high strains. ITS is also an important input parameter in transverse cracking model used in the Pavement Mechanistic-Empirical (ME) Design Guide [6]. ITS is also a measure of resistance capacity to low temperature cracking of asphalt pavement. Typically, this value is determined in the laboratory using IDT samples and used as an input parameter in the design guide. However, during the service life it may be affected by several factors such as aging, moisture, freeze–thaw etc. Effect of moisture on the tensile strength of AC has been explored in the literature [11,16]; Tarefder and Ahmed, [21]; [7]. Effect of freeze–thaw on the tensile strength of AC has also been investigated [10,12]. However, very few studies examined the aging effect using ITS tests. Walubita et al. [25] studied the tensile strength using aged AC samples using axial tension test (not in diametrical mode). Lolly [14] studied the effect of short-term aging using ITS test. The loose samples were aged up to 8 h. The effect of aging for longer conditioning periods cannot be understood from that study.

The above discussion concludes that the effects of short- and long-term aging on IDT are still an unsolved issue. In addition, how field aging causes a change in ITS value is an interesting research topic. The current study is conducted to understand the field, laboratory short- and long-term effects of aging on the ITS of AC using IDT test device.

2. Objectives

The main objective of this study is to examine the effects of aging on the ITS of AC. The flow number (vertical deformation in hundredth of an inch) is also examined to determine the ductility change with aging. Different modes of aging such as short- and long- term laboratory aging, and field aging are considered. Specific objectives are mentioned below:

(a) Examine the effects of long-term laboratory oven aging on the tensile strength and flow number of AC.
(b) Examine the effects of field aging on the tensile strength and flow number of AC.
(c) Examine the effects of short-term laboratory aging (on loose mixture) on the tensile strength and flow number of AC.

3. Investigation of long-term aging

3.1. Materials and sample preparation

Samples of 150 mm diameter and 170 mm height were prepared using a Superpave gyratory compactor following the AASHTO T 312-07 [5] test protocol. The samples were cut into 100 mm diameter and 50 mm thick samples using a laboratory saw and coring device. The bulk densities of prepared samples and the theoretical maximum density of the loose mixture were determined following AASHTO T 166-07 [2] and AASHTO T 209-05 [3] test standards respectively. The air voids of the samples before conditioning ranged from 5.1% to 5.9% with an average value of 5.4%.

A plant produced dense graded Superpave (SP) mixture, type SP-III, was used to prepare the samples. Loose mixture was collected in cooperation with the New Mexico Department of Transportation (NMDOT) during the construction period of a site. The design binder was a Performance Grade (PG) binder, PG 76-22, which was used 4.4% by the weight of the mixture. The maximum aggregate size was 19 mm.

3.2. Conditioning of samples

Two types of conditioning were conducted: long-term oven aging and field aging. In the oven aging, the prepared samples were placed on a rack in an oven at 85 °C (185 °F) for 120 h (5 days) following the AASHTO R 30-02 [1] test protocol. Following that time period, the oven was turned off and the door was left open to let the oven and specimens cool down to room temperature for about 16 h. The process was repeated up to 5 times (25 days) using different batches of samples. Fig. 1 shows one batch of the unaged asphalt sample and another batch of 120 h oven aged sample. The color difference between these two batches of samples depicts the aging action of the binder. The color of binder becomes darker with aging.

During the field conditioning, the AC samples were conditioned in the sun beside the Interstate 40 (I-40) instrumentation section at mile post 141, near the city of Albuquerque, New Mexico, for about a year starting from August 2013. The reason for choosing the I-40 test site was that the section measured the environmental data along with the pavement temperature. The asphalt samples were placed on a smooth flat surface as shown in Fig. 2. During the conditioning period, the samples experienced the maximum temperature of 54 °C in summer, the minimum temperature of −11 °C in winter, about 90 freeze–thaw cycles, day-night

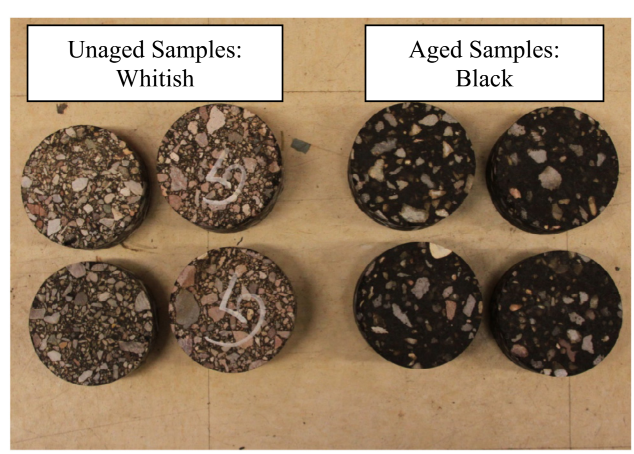

Fig. 1. Thin cylindrical sample before and after long-term laboratory aging.