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Initiation of Distress in Asphalt Concrete After Practicing Moisture Damage

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Abstract

The moisture damage of asphalt concrete is considered as major type of distress in heavy rainfall environment. In this work, the decline in the initial flexural stiffness of asphalt concrete was monitored after practicing the moisture damage process. The variations were analyzed relative to the control mixture. Asphalt concrete mixtures were created in the laboratory with the optimal binder content. Extra mixtures were also prepared with ±0.5% variation of binder content from optimum for comparison. The compaction of the asphalt concrete mixtures were conducted into a slab mold with the aid of roller. A diamond saw was used to cut the beam varieties from the slab samples. Beam specimens were separated into two groups, the first group practiced the moisture damage process and the second group was denoted as the control mixtures. The prepared beam specimens were subjected to dynamic flexural stresses at three various constant strain levels. It was observed that moisture damaged specimens tested under 250 and 400 constant Microstrain levels exhibit failure at 75 and 70% of the original flexural stiffness respectively. The elapsed time increases by 100 and 166.6% at mixtures prepared with 4.8 and 4.3% binder respectively after moisture damage process while the elapsed time declines by 50% for mixture prepared with 5.3% binder content after moisture damage. It was concluded that the moisture damaged mixtures exhibit early stage of failure before reaching the 50% of its original flexural stiffness.

Keywords: Moisture damage, asphalt concrete, constant strain, flexural stiffness, distress

INTRODUCTION

Das *et al*. examined how three different levels of moisture conditioning affected the fatigue behavior of asphalt concrete [1]. They measured the fatigue life and stiffness of asphalt concrete mixtures, finding that both decreased as the number of moisture conditioning cycles increased.

It was observed that moisture conditioning exhibits a higher negative influence on the fatigue life of asphalt mixtures at cold environment. Chauhan and Narayan stated that evaluating the variations in the fatigue behavior of asphalt concrete after practicing the moisture conditioning may be evaluated by implementing the dynamic four-point beam fatigue tests on the dry and the moisture conditioned beam specimens [2]. Four different strain amplitudes have been implemented. The test results of the moisture damaged specimens were compared with the test results of the dry beam specimens. It was observed that moisture conditioning led to a decline in both the initial flexural stiffness and the fatigue life of the asphalt concrete beam specimens. Li *et al*. evaluated the impact of moisture on the durability of asphalt concrete, focusing on moisture sensitivity [3]. They noted changes in air voids within the asphalt concrete mixture and found that the strength recovery ratio trend was similar to that of tensile strength. Karimi *et al*. explored the fracture

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potential of asphalt concrete mixtures with varying degrees of moisture damage [4]. Their results suggested that the area under the service time-fracture property curve could serve as a useful index for assessing fracture resistance in asphalt mixtures. Yang *et al*. studied the effects of moisture damage on the fatigue cracking of asphalt concrete and found that the material properties of the mixtures could change post moisture damage, leading to a 40–80% reduction in the service life of asphalt concrete pavement [5]. Omar *et al*. stated that the loss of bonding between aggregates and asphalt cement can shorten the service life of the pavement top layer [6]. The extensive literature concerning the loss of bonding strength in asphalt concrete due to moisture damage process was assessed. The contributing factors which cause the moisture damage and the existing methods for improvement of the bond between the aggregates and the asphalt binder were also assessed. Carmo *et al*. investigated the asphalt concrete pavement sensitivity for the strength [7]. It was stated that it shows variations in its physical properties which is attributed to the changes of asphalt binder content. A minor change in the asphalt binder content of ±0.5% within the optimum asphalt requirements was considered as an accepted service tolerance during the preparation process of asphalt concrete mixture. The testing results showed that any changes in the asphalt binder content will influence the variations in the structural responses as well as the physical properties of the investigated flexible pavement. Sarsam addressed that moisture damaged and long term aged specimen exhibit higher flexural stiffness when compared with the control mixtures [8]. The flexural stiffness was noticed to be highly sensitive to the variations in the asphalt binder content. Aljubory *et al*. noted that comprehensive data on the effects of moisture damage on the fatigue susceptibility of asphalt concrete are limited and dispersed [9]. The fatigue damage susceptibility of asphalt concrete due to practicing moisture damage conditioning was assessed with the aid of fatigue modulus test and the indirect tensile stiffness test at constant strain controlled mode. It was stated that after the process of moisture conditioning, the stiffness of asphalt mixes significantly increased. However, a decline in the fatigue life of the asphalt mixtures after the moisture damage effects was noticed. Soenen *et al*. revealed that it is still not fully understood which mechanism, causes the moisture damage to asphalt concrete, and how such mechanisms can be influenced by factors such as environment, binder aging, water exposure time, mix design, and traffic [10]. Almeida *et al*. investigated the negative influence of moisture and temperature on the fatigue resistance, complex modulus, and rheological behavior of asphalt concrete mixture [11]. It was addressed that it was possible to study the influence of the action of moisture and temperature on the graphical representation of the reduction in the fatigue life and the complex modulus of the asphalt concrete.

The aim of this study is to identify the impact of moisture conditioning process of the asphalt concrete on the variation in the initial flexural stiffness percentage of the mixture. Asphalt concrete mixtures will be prepared with three percentages of binder and compacted in a slab mold by roller. Beam specimens of asphalt concrete will be tested using three levels of constant strain before and after practicing the moisture conditioning process under the dynamic flexural stresses. Test results will be analyzed and compared.

MATERIALS AND METHODS

Asphalt cement was obtained from AL-Nasiriya oil Refinery and implemented in the present work. A combination of natural and crushed fine aggregates, along with crushed coarse aggregates, was sourced from the AL-Ukhaider quarry. Limestone dust, used as the mineral filler, was obtained from the Karbala quarry. Details of the physical properties and chemical composition of the raw materials may be referred to the earlier paper by Sarsam [12]. Dense aggregates gradation according to the requirement of SCRB specification is usually used for construction of wearing course pavement layer was selected in this work [13]. The aggregate gradation features a nominal maximum size of 12.5 mm, as shown in Figure 1.

Preparation of the Asphalt Concrete Mixture, Slab Samples, and Beam Specimens

The asphalt binder was heated to 150ºC and then mixed with the combined gradation of aggregates and mineral filler, which were heated to 160ºC. Asphalt concrete mixtures were prepared with an optimum binder content of 4.8%. Additional mixtures were prepared with a ±0.5% variation in binder content for comparison. The optimum binder content was determined using the Marshall Test in accordance with ASTM standards [14]. The asphalt concrete mixtures were compacted into a slab mold measuring 300×400 mm with a depth of 60 mm. Compaction was achieved using a laboratory roller to reach the target bulk density, following the procedure outlined in EN12697-33 [15], and the samples were allowed to cool overnight.

A diamond saw was utilized to cut asphalt concrete beam specimens from slab samples. Each specimen measured 62 mm in width, 56 mm in height, and 400 mm in length. Six slab samples were prepared, producing a total of 18 beam specimens. These specimens were tested in duplicate, with the average test results used for analysis. Figure 2 displays the laboratory roller compactor.

Moisture Damage Process

One portion of the prepared asphalt concrete beam specimens was subjected to laboratory moisture damage by immersion in a water bath at 25ºC for 120 min. A vacuum of 3.74 kPa was applied for the evacuation of air of the voids in the asphalt concrete mixture for 10 min according to the requirements prescribed by AASHTO, R-30, so that 80% saturation of the beam specimens could be obtained [16]. The beam specimens were stored in a deep freezer at –18±1°C for at least 16 h. Afterward, they were transferred to a water bath set at 60±1°C for 24±1 h. Subsequently, the specimens were placed in a water bath at 25±0.5°C for about 2 h before undergoing dynamic flexural fatigue testing.

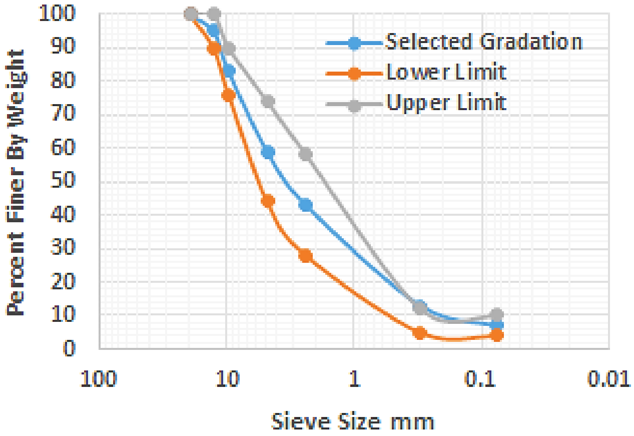

Figure 1. The selected combined aggregates gradation.

Figure 2. Laboratory roller compactor.

Testing for Fatigue by Implementing the Dynamic Flexural Bending Beam Test

The four-point dynamic flexural beam test was implemented as recommend by AASHTO T321 at 20℃ environment [17]. Figure 3 shows the test setup. Three constant strain levels of 250, 400, and 750 Microstrain were applied. This testing technique was conducted to detect the failure mechanism of asphalt concrete in the form of the decline in the initial flexural stiffness. The initial failure of asphalt concrete mixture was monitored at 20℃ environment. The beam specimens were kept in the testing chamber under the specified conditions for 3 h before undergoing the dynamic flexural stress test.

RESULTS AND DISCUSSIONS

Impact of Constant Microstrain Level and Moisture Damage Process on Initial Flexural Stiffness

Figure 4 demonstrates the impact of three constant microstrain levels on the initial flexural stiffness of moisture damaged and control asphalt concrete mixture. For the control mixture, the decline in initial flexural stiffness becomes more pronounced as the constant strain level increases. The failure criteria of asphalt concrete beam specimen is considered when the flexural stiffness declines to 50% of its original value. The initial flexural stiffness declines gently with a constant strain level of 250 Microstrain up to 600 sec of practicing dynamic flexural stresses. This behavior could be attributed to the possible seating of the asphalt concrete structure, while it declines sharply up to its initial stage of failure through 9000 sec of loading. Similar findings were reported by Aljubory *et al*. [9].

When the applied constant strain level rises to 400 Microstrain, the initial flexural stiffness declines sharply in a constant trend and reaches the initial stage of failure within 500 sec of practicing the dynamic flexural stresses. A further increase in the constant strain level to 750 microstrain results in a more pronounced decline in the initial flexural stiffness, with the asphalt concrete reaching the early stage of failure after just 60 sec. Based on the analysis of the creep behavior of asphalt concrete under these constant strain levels, it is observed that the reduction in initial flexural stiffness due to moisture damage occurs after approximately 94.4 and 99.3% of the loading time when the strain level increases from 250 to 400 and 750 microstrain, respectively.

Such behavior is in agreement with the work of Almeida A, Momm L, Trichês G, Shinohara K. [11] 2017. On the other hand, the moisture damaged mixtures exhibit early stage of failure before reaching the 50% of its original flexural stiffness. Specimens tested under 250 and 400 constant Microstrain levels exhibit failure at 75 and 70% of the original flexural stiffness respectively. The elapsed time taken by the moisture damaged asphalt concrete beam specimen to failure was lower than that taken by the control mixtures regardless of the implemented constant strain levels. This could be related to the possible stripping of the asphalt binder by the action of water conditioning which causes disintegration of the structure of asphalt concrete due to the process of the moisture damage.

Figure 3. Dynamic Four-point flexural beam test setup.

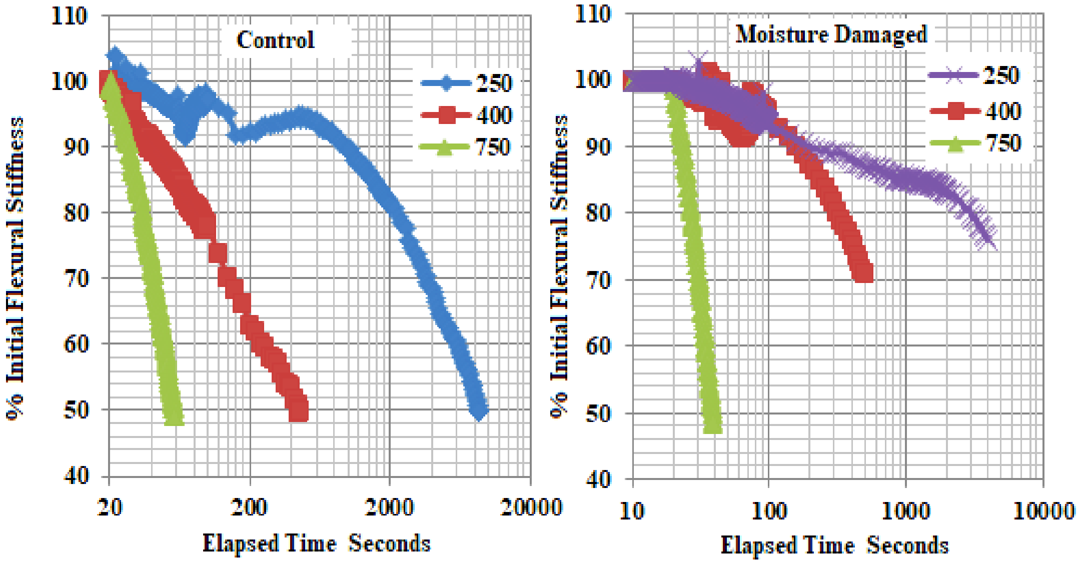

Figure 4. Influence of strain level and moisture damage process on initial flexural stiffness.

The elapsed time to failure of moisture damaged mixture declines by 44.4% when 250 Microstrain was implemented, however, the decline of the elapsed time was not significant when higher constant strain levels were implemented. Such behavior is further supporting the disintegration of asphalt concrete mixtures under higher strain level [1].

Influence of Asphalt Binder Content and Moisture Damage Process on Initial Flexural Stiffness

Figure 5 demonstrates the impact of asphalt content on the initial flexural stiffness of asphalt concrete mixtures. The initial flexural stiffness of the control mixture decreases gradually under dynamic flexural stresses, irrespective of the binder content. However, the asphalt concrete mixture prepared with an optimal binder content of 4.8% shows a greater improvement in initial flexural stiffness compared to mixtures with either higher or lower binder percentages.

It can be stated that the binder content exhibits a sensitive issue when the moisture conditioning is considered. This can be attributed to the higher bulk density of the asphalt concrete mixture obtained when the optimum binder requirement is adopted. The initial stage of failure of asphalt concrete was reached after 150 sec of practicing the dynamic flexural stresses for mixture prepared with a lower binder content of 4.3%. However, mixtures prepared with either the optimal or higher binder content show greater improvement in initial flexural stiffness compared to mixtures with lower binder content.

The asphalt concrete mixture prepared with the optimal binder content reached the initial failure stage after 500 sec under dynamic loading. In contrast, the mixture with a higher binder content of 5.3% reached the initial failure stage after 650 sec of dynamic loading. However, failure occurs when the flexural stiffness declines to 50% of its original value. This could be related to higher binder film thickness which provides more flexible mixture which can sustain the quality throughout the creep of the mixture under dynamic loading. On the other hand, the moisture damaged mixtures show similar trend of deterioration in the initial flexural stiffness but the elapsed time consumed during the failure process is higher than that of the control mixtures especially at lower binder content.

The elapsed time increases by 100 and 166.6% at mixtures prepared with 4.8 and 4.3% binder respectively after moisture damage process while the elapsed time declines by 50% for mixture prepared with 5.3% binder content after moisture damage. It can be revealed that asphalt concrete mixture prepared with optimum binder requirements or lower than optimum within the test limitation can sustain the flexure stiffness for longer elapsed time before failure when compared with mixture prepared with excess binder content. Sarsam [8], and Carmo *et al*. [7] reported similar behavior.

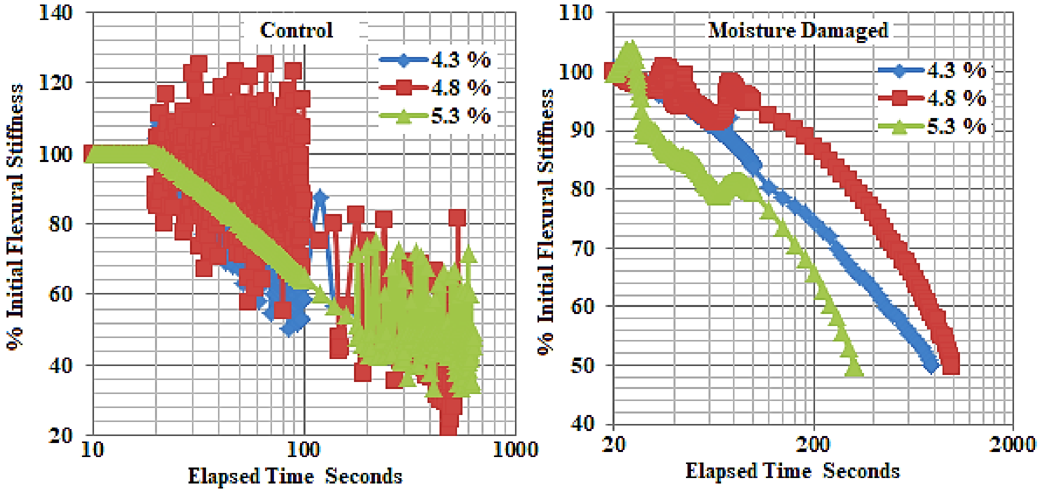

Figure 5. Impact of asphalt content and moisture conditioning process on initial flexural stiffness.

CONCLUSION

1. The moisture damaged mixtures exhibit early stage of failure before reaching the 50% of its original flexural stiffness.
2. Specimens tested under 250 and 400 constant Microstrain levels exhibit failure at 75 and 70% of the original flexural stiffness respectively.
3. The elapsed time to failure of moisture damaged mixture declines by 44.4% when 250 Microstrain was implemented, however, the decline of the elapsed time was not significant when higher constant strain levels were implemented.
4. The elapsed time increases by 100 and 166.6% at mixtures prepared with 4.8 and 4.3% binder respectively after moisture damage process while the elapsed time declines by 50% for mixture prepared with 5.3% binder content after moisture damage.
5. Asphalt concrete mixture prepared with optimum binder requirements or lower than optimum within the test limitation can sustain the flexure stiffness for longer elapsed time before failure when compared with mixture prepared with excess binder content.

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