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Moisture sensitivity of asphalt mixtures under different load frequencies and temperatures

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HIGHLIGHTS

- Moisture sensitivity of HMA under various environmental and traffic conditions were evaluated.
- Dynamic creep test was performed to compare permanent deformation of dry and wet samples.
- At 40 °C with decreasing frequency, percent of increase in permanent strain was more in wet samples.
- At 40 °C moisture has more detrimental effect on the HMA compared to 5 °C.
- Ratio of creep to resilient modulus can be a good indicator for evaluating moisture susceptibility.

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ABSTRACT

Effects of different parameters including aggregate type, asphalt mix design and construction, traffic and environmental conditions on moisture sensitivity of asphalt mixtures have been investigated by a large number of researchers. But, only a few researchers have reported combined effects of these parameters. The aim of the current study is to evaluate moisture sensitivity of asphalt mixtures under various environmental and traffic conditions and to assess their combined effect on permanent deformation. Dynamic creep test was carried out on the saturated and dry samples of asphalt mixtures made with dense graded aggregate to compare their permanent deformation behaviors in the presence and absence of moisture. The results of examining different temperature and loading combinations indicated that, at 40 °C with decreased frequency, the rate of increase in permanent deformation was more in saturated compared with the dry samples. Moreover, at this temperature, moisture had more detrimental effect compared with the temperature of 5 °C. Also, at 5 °C, the effect of moisture damage on the samples increased with the increase in frequency. According to the test results, the ratio of creep modulus to resilient modulus can be an appropriate indicator for evaluating moisture susceptibility at high temperatures.

1. Introduction

Water is always expected to be present in an asphalt pavement. Several sources can lead to the presence of water in the pavement and cause premature as well as severe pavement failures [1]. Moisture damage can be defined as the loss of strength and durability in asphalt mixtures due to the effects of moisture [2]. When serious environmental conditions act together with poor and/or unsuitable materials and traffic, premature failure is expected [3].

Moisture damage of asphalt concrete may be resulted due to two basic failure mechanisms of adhesion and cohesion, which are essential to be distinguished from each other while discussing moisture damage. When the asphalt film is separated from the aggregate surface completely, adhesion failure becomes apparent and bare aggregate is visible when pavement is broken apart. Cohesion failure manifests itself as softening of the asphalt binder in an emulsification process as water penetrates into the binder. Cohesion failure may not create bare aggregate; but asphalt mixture will have low strength. A combination of these two mentioned failure mechanisms may result in moisture damage; however, relative effects of each mechanism on the failure is difficult to be distinguished [4].

Factors that can affect moisture sensitivity of a mixture can be classified in three main categories. The first category is material properties including physical and chemical properties of asphalt and aggregate. The second one is mixture properties including asphalt content, film thickness and permeability of the mixture (interconnectivity of air voids). The third one is external factors including construction, traffic and environmental factors [1].

Not only the moisture damage is an independent damage, but also it can be a prelude to other damages. Rutting is one of the common types of distresses that can be related to moisture [5].

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Rutting or permanent deformation is accumulation of small deformations caused by densification and/or repeated shear deformations under the applied wheel loads. Permanent deformation can be attributed to plastic properties of asphalt mixture under repeated loading but it cannot be related to elastic properties of asphalt mixture [6]. A number of different methods can be employed in the laboratory to evaluate resistance of asphalt mixtures to permanent deformation, which include axial compression creep, shear and wheel-tracking tests [6]. Effects of evaluation method on the prediction of moisture damage of hot mix asphalt were investigated by Abo-Qudais [7]. His results demonstrated that creep test was the best method to monitor influence of the used asphalt and aggregate grading on hot mix asphalt (HMA) moisture damage. Moreover, the creep test has been identified as the most appropriate method for evaluating effect of additives on reduction of moisture damage. A complete review of the state of the art of moisture sensitivity of bituminous mixtures and methods of its evaluation is given by Mehrara and Khodaii [8].

Permanent deformation tests on asphalt mixture were performed using repeated loading by Cheng et al. under the presence and absence of moisture [9]. Their findings indicated that the specimens tested after moisture conditioning accumulated more damage than those tested before moisture conditioning.

The effect of moisture on strength and permanent deformation of foamed asphalt mixes incorporating reclaimed asphalt pavement (RAP) materials was assessed by He et al. [10]. Indirect tensile and dynamic creep tests were carried out under dry and soaked conditions to find moisture effects on indirect tensile strength and susceptible–resistance to permanent deformation of these mixes. They selected repeated loading axial creep test to evaluate susceptibility of mixes to permanent deformation because the plastic deformation caused by repeated loading can be derived from the dynamic creep curve. The result of these tests indicated that grade of bitumen and ageing of RAP material had considerable effect on moisture susceptibility in permanent deformation.

Another study carried out by Abo-Qudais et al. investigated effects of chemical and physical properties of aggregate on the creep and moisture damage behavior of hot-mix asphalt [11]. In their study, the percent of increase in creep strain of mixtures due to moisture conditioning was utilized to assess moisture sensitivity. Moreover, Xiao et al. conducted a laboratory investigation of rutting resistance in WMA mixtures containing moist aggregates. Their experimental design included two aggregate moisture contents and three aggregate sources. Test results indicated that the aggregate source significantly affects the rutting resistance regardless of the WMA additive. Also, they showed the influence of moisture on rut depth can be neglected and it even results in a better rut resistance in some cases [12]. Xiao et al. at another research [13] evaluated the moisture susceptibility of mixtures using indirect tensile strength (ITS). Their finding indicated that the dry and wet ITS values of HMA mixtures are higher while the WMA mixtures show lower ITS values regardless of the aggregate and storage duration.

Permanent deformation of unmodified and SBS modified asphalt mixtures were assessed by Khodaii and Mehrara using dynamic creep test. The findings indicated that coarse graded asphalt mixtures had more resistance to permanent deformation than dense graded mixtures [14]. In another study, Mehrara and Khodaii made an attempt to assess moisture sensitivity and its interaction with permanent deformation through performing a dynamic creep test on coarse graded and dense graded asphalt mixtures [15]. According to their results, the coarse graded mixtures had lower moisture sensitivity and could better resist permanent deformations than the dense graded mix. They also concluded that low stress levels could not appropriately show the behavior of asphalt specimens.

2. Statement and objectives

Conventional moisture susceptibility tests are not able to simulate actual process of moisture damage formation in the field. This is partly because testing sample goes through conditioning and loading processes in two separate steps throughout the test. But, effects of environmental conditions and traffic loading cannot be separated according to the extensive field investigations on propagation of moisture damage [16]. Selecting the dynamic creep test over other available tests in the present study was done to consider the combined effect of loading and moisture simultaneously. Also, since moisture affects mechanical properties of asphalt mixture such as resilient modulus and deformations, the dynamic creep test was considered as one of the more appropriate tests available for evaluating susceptibility of asphalt moisture.

The purpose of this study was to investigate effect of moisture on permanent deformation and assess moisture susceptibility of asphalt mixtures using the outcomes of dynamic creep test under different environmental and traffic conditions. The following steps were followed in this study:

1. Comparison of permanent deformation potential of conditioned and unconditioned mixtures at different temperatures under constant applied load frequency.
2. Comparison of permanent deformation potential of conditioned and unconditioned mixtures under different applied load frequencies at a fixed temperature.
3. Simultaneous evaluation of effects of moisture and loading on permanent deformation.
4. Derivation of resilient and creep modulus parameters in different combinations of temperature and applied load frequencies.

3. Materials

Aggregate grading has an effect on the magnitude of moisture damage. Comparing a dense and coarse graded aggregate, Khodaii and Mehrara reported dense graded mixtures as more susceptible to moisture damage and permanent deformations [14]. The load transfer in coarse graded mixtures depends more on the contact between stones due to the presence of a large number of coarse aggregates in the mixture; consequently, behavior of asphalt mixture is less dependent on the mastic properties. But, properties of mastic in dense graded mixtures have a significant role in determining behavior of asphalt mixtures and also have an influence on its deformation, particularly at high temperature when viscosity of bitumen decreases. Thus the samples made with dense graded mixture are more susceptible to permanent deformation.

A dense graded aggregate that is used for topeka and binder layers according to ASTM D3515 [17] was selected for performing the test. Fig. 1 presents the aggregate grading used in this study. The two dotted curves in the figure represent the upper and lower limits of the permitted grading for pavement surface layer based on ASTM D3515 [17]. The used aggregates were siliceous crushed with 85% broken in two faces and the asphalt used in the study had 60/70 penetration grade comparable with PG 64-22. Tables 1 and 2 list mechanical and physical properties of the

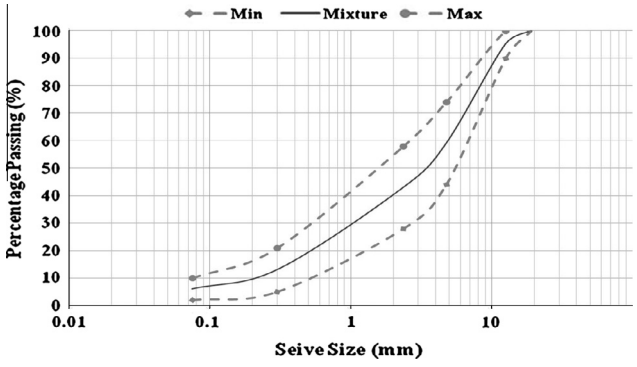

Fig. 1. Aggregate grading of asphalt mixtures.