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Investigation of different test methods to quantify rutting resistance and moisture damage of GFM-WMA mixtures

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HIGHLIGHTS

- WMA mixtures containing RAP and glass fiber were evaluated.
- As the percentage of RAP was increased, the moisture susceptibility was decreased.
- The static deformation strength test can be used to measure rutting of asphalt mix.

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ABSTRACT

Permanent deformation (rutting) and moisture damage are two dominant failures which threaten the performance of asphalt pavements. Dynamic creep and wheel track tests have been widely used to evaluate permanent deformation characteristic of asphalt mixture while AAHTO T283 and wheel track test were usually employed to determine moisture susceptibility properties of asphalt mixture. However wheel track test is costly and time consuming and the results obtained from different tests by different researchers were sometimes contradicted. In this paper, the dynamic creep test, wheel track test, deformation strength test and AASHTO T283 are conducted. Therefore the aim of this research was first to compare the results of permanent deformation and moisture susceptibility for different tests and secondly to use a simple and static deformation strength test for evaluation of rutting resistance of asphalt mixture. To this end the effect of short term aging on the performance of rutting and moisture sensitivity in warm mix asphalt (WMA) mixtures containing glass fibers and the 0, 20, 40 and 50 percentages of reclaimed asphalt pavement (RAP) by aforementioned tests are evaluated. According to the results of this study, the rutting resistance determined from the simple and static deformation strength test had a good correlation with parameters obtained from wheel track test with R squared of 0.9. On the contrary, moisture susceptibility resistance evaluated with AASHTO T283 appears to have contradiction with the result obtained in wheel track testing.

1. Introduction

The rising number of vehicles and, consequently, the increasing amount of asphalt pavement are followed by a rising volume of asphalt production in transportation industry. Since the transportation industry is one of the most important environmental pollutants, this industry is urged to produce a technology capable of reducing environmental pollutants and decreasing energy consumption. In this regard, the use of WMA technology and reuse of a high percentage of RAP in asphalt mixtures are considered as the most important strategies for pavement industry. WMA technology was employed in Europe for the first time. In this technology, a decrease in temperature from 30 °C to 50 °C has been reported compared to hot-mix asphalt (HMA) [1,2]. This drop in temperature results in numerous environmental and economic benefits. Among the most important of these benefits, we can note reduced fuel consumption, reduced aging of bitumen, an increase in the percentage of RAP used in the mixtures, and reduction of environmental pollutants [3–5]. Using organic or chemical additives or foam-forming techniques, WMA technology reduces the viscosity of bitumen. The main advantage of reduced viscosity is decreasing the production and compaction temperature of the mixture [6]. Among all the mentioned advantages, the reduced production and laying temperature cause concerns about the moisture sensitivity and rutting of WMA mixtures [7,8].

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Apart from the environmental and economic benefits of RAP usage, one of the main approaches in pavement industry is recycling old asphalt materials and reusing them in new pavement constructions. Reusing RAP materials in the construction of new pavements can obstruct the consumption of non-renewable natural resources of aggregate and bitumen [9,10]. Generally, stiffness of the mixture increases as the RAP content is increased. Therefore the main concern in the use of high RAP percentage in HMA mixtures is that to increase stiffness of the mixtures[11,12]. By reducing the viscosity of bitumen, hardness caused by RAP in WMA mixtures will be offset and it will be possible to use higher percentages of RAP in the mixtures [13].

To improve the performance of asphalt mixtures, various additives are utilized by considering asphalt weakness on tension compared to compression. Fiber is an addition which improves the performance of asphalt mixtures. The main advantages of using fiber in asphalt mixtures can be noted as an increase in tensile strength, fatigue resistance, and rutting resistance, as well as reduced moisture susceptibility [14–16].

In a study conducted on WMA and HMA samples in base and surface course, Zhao et al. found increased rutting resistance against increasing RAP percentage. According to their results, WMA samples containing a high percentage of RAP show an acceptable moisture sensitivity performance [7]. In a research conducted by Ghabchi et al. on HMA mixtures containing RAP and reclaimed asphalt shingles (RAS), an increase was observed in dynamic modulus, tensile strength ratio (TSR), and rutting resistance with an increased RAP percentage [17]. In the research conducted by Shu et al. with the aim of evaluating the moisture sensitivity of WMA and HMA mixtures with high RAP percentages, AASHTO T283, dynamic modulus, and wheel tracking tests were implemented. In this study, an improved rutting and moisture sensitivity resistance was seen by increasing RAP percentage [3]. Based on the laboratory research conducted by Doyle et al. to evaluate the rutting and moisture resistance of WMA mixtures containing RAP, enhanced rut and moisture resistance was observed [18,19]. Doyle et al. introduced moisture sensitivity and rutting as the main problems of WMA mixtures and suggested the use of a high percentage of RAP in the mix as an option to solve these problems. According to the results of their study, the observed rutting performance and moisture sensitivity were similar to those of WMA mixtures containing high percentages of RAP when compared to an HMA mixture with a lower percentage of RAP [20]. Based on laboratory and field studies conducted by Wu and colleagues on WMA and HMA samples containing different percentages of RAP and comparing the results with those of control samples without RAP, a satisfactory field performance after one year of service, improved stability in high temperatures, and improved dynamic stability were reported for WMA samples with RAP. No negative impact of RAP on moisture sensitivity was observed in the WMA samples of this study [21].

The results of previous studies on the influence of RAP on the moisture sensitivity of asphalt mixtures are inconsistent. In a laboratory study conducted by Guo et al. in order to evaluate the performance of rutting, moisture sensitivity, and low-temperature cracking resistance, tests such as rutting, bending, fatigue, freeze thaw-splitting, Marshal immersion, and freeze thaw-cycles were performed on unaged and aged samples. The results indicated superior resistance to moisture and low-temperature cracking, as well as reduced resistance against rutting in WMA samples without RAP when compared to samples with RAP. The research also reported an increased moisture resistance by applying short-term aging as well as the reduced moisture resistance of samples by applying long-term aging [22]. Ma et al. observed a decreased resistance to moisture sensitivity in WMA samples by increasing the percentage of RAP. This research reported the reduction of TSR value by increasing the amount of RAP used in the mixes [23]. Wu et al. evaluated moisture sensitivity and rutting performance in porous asphalt mixtures by utilizing polyester and cellulose fibers. TSR value was increased in samples modified by fiber. This study also found reduced rutting depth in samples modified by fibers [24]. In a study by Han et al. where lignin, poly acrylonitrile, and mineral fibers were used in order to modify asphalt mixtures, an improved rutting depth was seen in fiber-modified samples compared to control samples [25]. In their laboratory study, Anurag et al. evaluated the moisture sensitivity of asphalt mixes modified by waste polyester fibers and concluded that the modified samples had an improved moisture sensitivity because of using fibers [26]. Mahrez et al. reported the growing rutting resistance of asphalt mix modified with glass fibers where 0.3% of fiber usage showed the greatest increase in resistance [27].

Considering the inconsistency in the influence of RAP on the moisture sensitivity of WMA mixtures as reported by different researchers, it is essential to study the moisture susceptibility of the WMA mixture containing a high percentage of RAP, which was one of the objectives of the present research. Another objective of this research was finding a correlation between deformation strength test and wheel track test. To achieve these objectives, we compared the results of permanent deformation and moisture susceptibility of different tests for WMA mixture (control mixture) and glass fiber-modified WMA mixtures containing 0, 20, 40, and 50 percentages of RAP. Moreover, the deformation strength test which is very quick and cost-effective was utilized for evaluating rutting performance. Samples were prepared in the laboratory and artificially aged in an oven to simulate short-term aging according to the AASHTO R30. In this research, dynamic creep test, deformation strength test, AASHTO T_{283} and wheel track test were conducted in dry and wet conditions.

2. Materials and mix design

2.1. Materials

One virgin binder (PG 58–16) and one aggregate source were utilized in this research. The aggregate particles used in this study were crushed limestone. The gradation of aggregates is shown in Fig. 1. Table 1 and Table 2 list the bulk specific gravity and engineering properties of the aggregates used in the current research, respectively. The physical properties of the bitumen are presented in Table 3.

In order to produce modified WMA samples, glass fiber was used. Table 4 shows some physical and mechanical properties of glass fiber. The GFM-WMA mixture uses a fiber content of 0.3% by mass of AC mixture according to the manufacturer

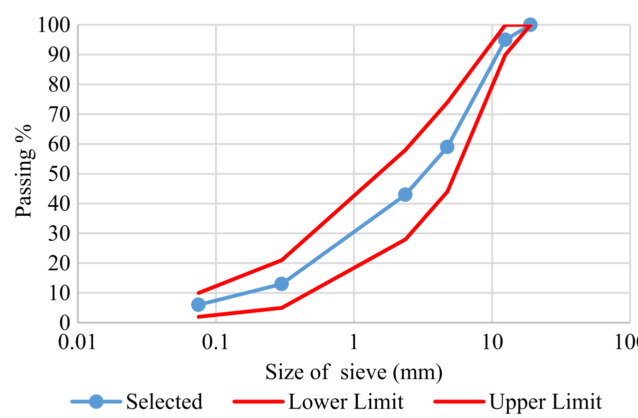

Fig. 1. Gradation of designated aggregate.