Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 51(6) (2020)347-350
DOI: 10.22060/ceej.2018.14396.5643

Effect of Filler Type on Moisture Susceptibility of Asphalt Mixtures by Successive Freeze-Thaw Cycles and Comparing Results with Components of Surface Free Energy

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ABSTRACT: Based on the important effects of filler on performance-related properties of asphalt mixtures, this study investigates the influence of filler type on moisture susceptibility of asphalt mixtures under multiple freeze-thaw cycles. Furthermore, the effect of changing the type of mineral fillers, especially replacing fillers with recycled concrete materials on moisture resistance of asphalt mixture, with sustainable development approach, is evaluated. In this study, first, the indirect tensile strength and the resilient modulus tests are conducted following 1, 3, 6, and 10 cycles of freeze-thaw and then the fracture energy is calculated through the results of indirect tensile test. Next, the surface free energy components of mastics with different types of filler are calculated using the static contact angle measurement method. The results of performance-based moisture susceptibility tests showed that replacing natural filler with Portland cement can result in the best performance compared to control mixture, limestone filler, and RCA filler. However, the evolution of mechanical properties of control filler, limestone filler, and RCA filler depends on the number of freeze/thaw cycles. At higher conditioning cycles, TSR values demonstrate a different behavior such that the TSR values of the asphalt mixture containing RCA filler increase up to 15% on average compared to the asphalt mixture containing limestone filler after the first cycle. Although the results of mechanical properties in initial freeze-thaw cycles are similar to surface free energy results. However, these results cannot predict the behavior of asphalt mixtures at higher freeze-thaw cycles.

Review History:

Received: 5/2/2018
Revised: 5/28/2018
Accepted: 6/5/2018
Available Online: 6/9/2018

Keywords:

Asphalt Mixture
Moisture Susceptibility
Recycled Concrete Filler
Surface Free Energy
Freeze-Thaw Cycles

1. INTRODUCTION

Moisture damage is the progressive functional deterioration of asphalt mixtures that contribute to the premature deterioration of flexible pavements. Changing the filler part of aggregates or introducing anti-stripping modifiers to asphalt binders could improve the moisture susceptibility of asphalt mixtures. Hydrated lime and Portland cement are the most effective anti-stripping fillers that can considerably improve the moisture resistance characteristics of asphalt mixtures [1-5]. Furthermore, the potential of using various waste powders, such as recycled concrete powder, was shown in replace mineral fillers of asphalt mixtures [6-10].

Several empirical experiment methods were used for evaluating moisture sensitivity of asphalt mixtures. In addition, new concepts were developed based on the basic properties of the materials, such as failure parameters, surface free energy, diffusivity and interfacial interactions to better determination of the moisture sensitivity of asphalt mixtures [11-13].

In this study, the effects of different types of filler such as hydrated lime, Portland cement, silica and recycled concrete powder were investigated on moisture susceptibility of asphalt mixture subjected to several freeze-thaw cycles.

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2. METHODOLOGY

There are various methods for assessing the moisture sensitivity of asphalt mixtures. In this research, values of the indirect tensile strength (ITS), resilient modulus (MR) and fracture parameters of the asphalt mixtures containing different mineral fillers subjected to 1, 3, 6 and 10 freeze-thaw cycles and surface free energy (SFE) of the mastic with different fillers were calculated. In the design of the experiment, three replicates were considered for each test. The average result of three replicates was reported as output.

3. RESULTS AND DISCUSSIONS

3.1. ITS test

The indirect tensile strength ratio of conditioned specimens to unconditioned specimens (TSR value) is presented in Figure 1. As expected, TSR values of asphalt mixtures containing Portland cement for all freeze-thaw cycles were greater than other asphalt mixtures. Furthermore, increase in number of freeze-thaw cycles, shows changes in the TSR trend of different mixtures.

3.2. Resilient modulus test

According to results of MR test, upon the third freeze-thaw cycles, the trend of decrease in resilient modulus of

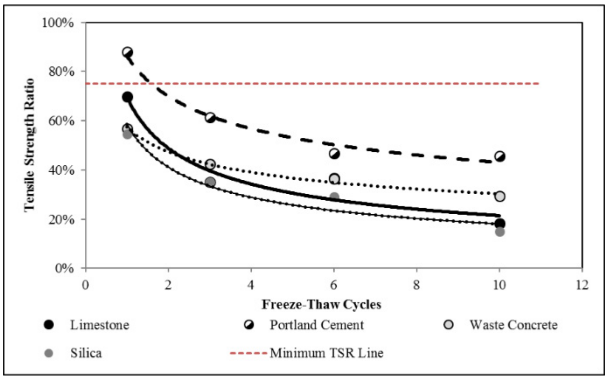

Fig. 1. Tensile strength ratio results of asphalt mixtures versus freeze and thaw cycles

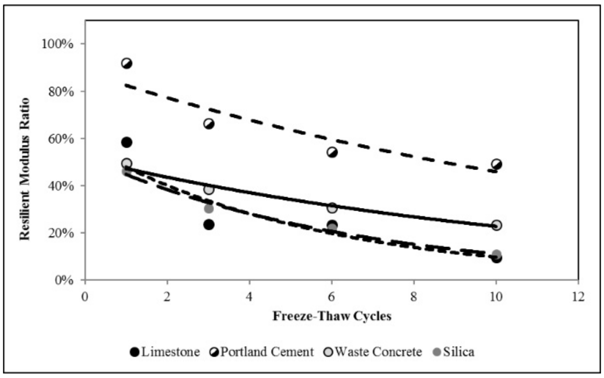

Fig. 2. Resilient modulus ratio values of asphalt mixtures versus freeze and thaw cycles

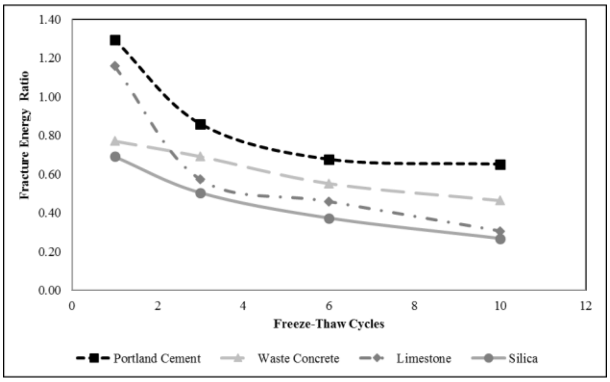

Fig. 3. Fracture energy ratio values of asphalt mixtures versus freeze and thaw cycles

specimens containing recycled concrete filler and limestone filler changes. In higher cycles, specimens containing recycled concrete in comparison with specimens containing limestone show better moisture resistance performance. In addition, the results of MR are in agreement with those ITS tests. The trend of changes in resilient modulus ratio of conditioned specimens to unconditioned specimens of asphalt mixtures containing different types of filler is shown in Figure 2.

3.3. Fracture energy

The surface below the load-deformation curve in the ITS test, which is defined as the fracture energy, was calculated to evaluate the moisture sensitivity of asphalt mixtures. The trend of the ratio of fracture energy in conditioned specimens to unconditioned specimens is shown in terms of freeze-thaw cycles in figure 3. According to the results, the fracture energy ratio in mixtures containing recycled concrete filler has the lowest reduction ratio in freeze-thaw cycles. Except in the first freeze-thaw cycle, it could be observed that, for mixture with Portland cement and limestone filler, the fracture energy shows a trend similar to the results of the indirect tensile strength test and the resilient modulus.

3.4. Surface free energy

In the calculation of SFE, static contact angles were measured by using different probe liquids on the solid surface of mastics. Based on the results, it was observed that the mastic contains Portland cement had highest SFE and mastic content including silica filler had the lowest SFE. Furthermore, it could be seen that the replacement of the control filler with recycled concrete filler, limestone and cement results in an increase in the base component of the bitumen binder, which can improve adhesion.

4. CONCLUSIONS

In this paper, the effect of different types of filler on moisture susceptibility of asphalt mixtures was evaluated. Furthermore, the potential of using recycled concrete aggregate (RCA) powder as a filler in asphalt mixture to improve moisture sensitivity of asphalt mixtures was investigated. Based on the results, the following are the most important conclusions:

• Limestone, Portland cement, and RCA as filler materials improves the ITS values. Results of resilient modulus ratio showed a similar trend as tensile strength ratio.

• Replacing acidic siliceous stone powder with basic fillers in this study increased the base component of the mastic, thereby improving the acid-base bonding of the aggregate and mastic and increasing the polar bonds between these materials.

• The increase in the number of freeze-thaw cycles resulted in the detrimental effect of water on the mastic-aggregate adhesion and an enormous drop was observed in TSR values. However, the use of Portland cement as filler material was more effective for improving the moisture susceptibility of asphalt mixtures in higher freeze-thaw cycles.

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HOW TO CITE THIS ARTICLE

F. Moghadas Nejad , M. Arbabpour Bidgoli, K. Naderi, S.Z. Mirtabar, Effect of Filler Type on Moisture Susceptibility of Asphalt Mixtures by Successive Freeze-Thaw Cycles and Comparing Results with Components of Surface Free Energy, Amirkabir J. Civil Eng., 51(6) (2020) 347-350

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