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Comparison and Evaluation of Fatigue Behavior of Asphalt Concrete Mixtures Containing Different Recycled Additives

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Abstract

Fatigue phenomenon is one of the most important mechanisms of failures in road pavement which is caused by repeated loading. In recent years, the use of recycled additives such as crumb rubber, tire thread, waste iron and waste glass are taken into consideration in order to improve the properties of bitumen consequently, improve the properties of asphalt mixtures. Also, the use of these recycled additives prevents their distribution in the nature. In this study, the effects of different recycled additives have been evaluated on the fatigue parameters of asphalt mixtures. The results of this study showed that adding 5% waste tire thread to the asphalt concrete mixtures causes the highest fatigue life, increasing stiffness and the least amount of strain while failure than the other recycled additives such as waste iron, crushed glass and aromatic oil.

1. Introduction

In the road pavement, asphalt layers have the protection role of the road body and compressive stress transfer from the upper layers to the underlying layers. The quality of these layers is one of the determinants factors of safety and convenience of road users, which is today one of the most important factors in the design of asphalt mixtures [1]. Since, with growing the number of vehicles in the world and increasing the size of heavy vehicles, the importance of fatigue phenomenon is increased more and more as of the most important factors in road pavements [2]. Fatigue is one of the most important factors that reduce the asphalt pavement life, which first starts due to the micro cracks in the underlying layers of asphalt and gradually spreads to the upper layers [3].

In recent years, the uses of various recycled additives are taken into consideration by many researchers to improve the fatigue parameters of asphalt mixtures [4]. Additives are substances that have been added to the bitumen under certain conditions or they are added during the preparation of

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the mixture of bitumen and aggregate in asphalt mixtures and asphalt mixing plant [5]. In this study, the effects of using recycled additives such as tire thread, crushed glass, and aromatic oils with crumb rubber were on asphalt concrete mixtures fatigue resistance are discussed.

2. Fatigue Phenomenon in the Pavement

Cracking is the main form of pavement damages and usually, it is considered as the determinant factor determining the appropriate time and method for pavement. Development of cracks in the pavement indicates the signs of loss of integrity and service capability [6]. When materials are exposed to stress over than their capacity, they will have crack. Vehicles' transit intensifies cracks and causes further deterioration in the surface layer and the underlying layers that its result is water intrusion in the pavement. This issue due to the effect of freezing and thawing, fine scour, subsidence and other destructive mechanisms speeds the destruction.

Cracking occur in various forms: Transverse cracks, longitudinal cracks, mosaic cracks and Saurian skin cracks. Saurian skin cracks (Figure 1) are usually related to the pavement fatigue. Fatigue cracks develop in the direction across the movement direction [7].

Figure 1. Fatigue cracks in asphalt pavement

3. Comparison and Analysis the Additives

3. 1. Analysis Based on Stiffness Modulus

Figure 2 shows the effect of additives on the stiffness modulus of asphalt mixtures. To evaluate the stiffness modulus of the samples of asphalt mixtures containing these additives, indirect tensile stiffness modulus test results (ITSM) at 25° C on samples were compared with an almost similar condition.

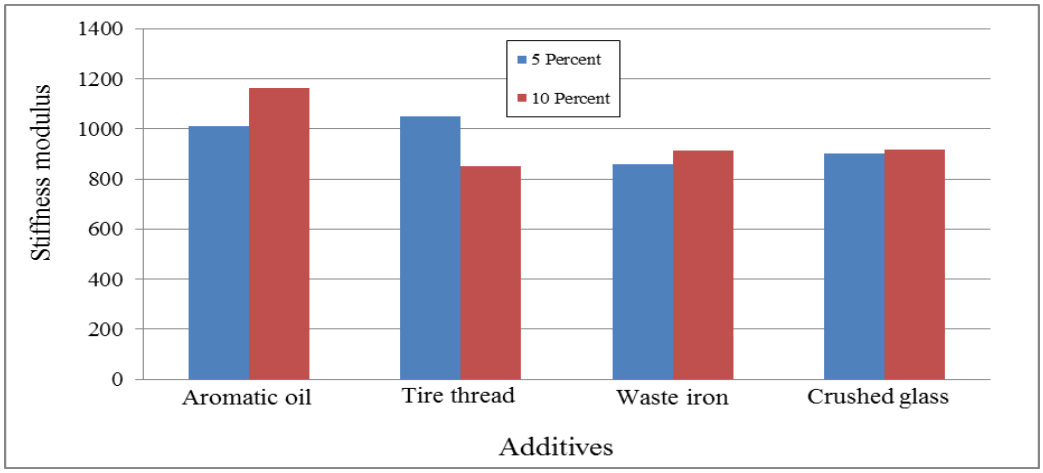

Figure 2. Effect of Additives on the stiffness modulus values at test temperature of 25 ° C

According to Figure 2, it is clear that the modified asphalt mixtures by tires thread and aromatic oils have higher stiffness performance than the mixtures containing waste iron and glass crushes. Also, similarity of stiffness modulus results of modified mixture samples by waste iron and glass crushes show the same performance of two addictive. For this reason, it can be stated that in the same experimental conditions, the use of aromatic oils with 9% crumb rubber and 5% tire thread have better stiffness performance than the other asphalt recycled additives.

3. 2. Analysis Based on Strain-number of Cycles Leading to Failure

Figure 3 shows the fatigue curve of the modified asphalt mixtures with four addictive of tire thread, waste iron, crushed glass, and aromatic oils with crumb rubber under indirect tensile fatigue test at 25 ° C and stress of 250 kPa.

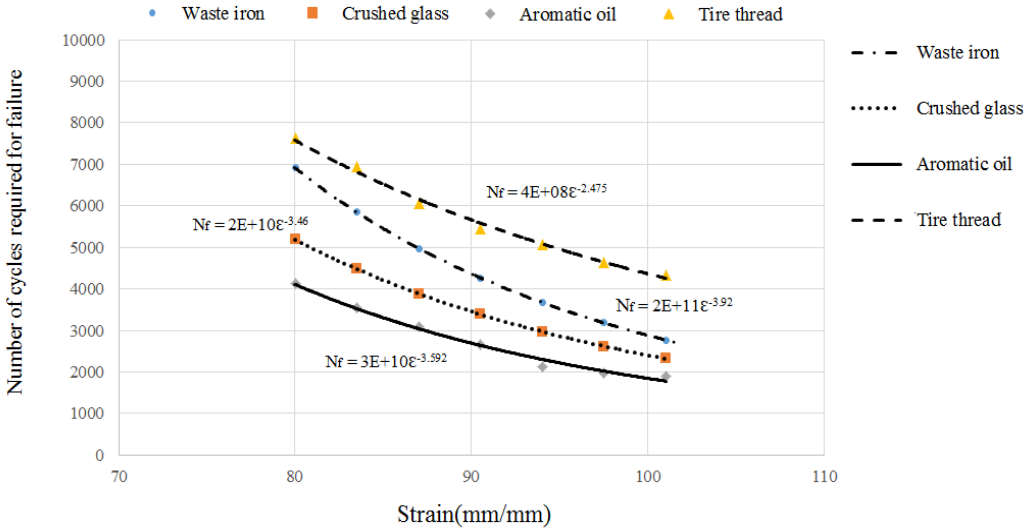

Figure 3. Comparison of the fatigue curve of the modified asphalt mixtures with aromatic oil, tire thread, iron powder and crushed glass

According to Figure 3, the highest and lowest fatigue curve respectively is related to mixtures containing tire thread and aromatic oils that this issue indicates that adding tire thread and aromatic oil along with crumb rubber in asphalt mixtures have maximum and minimum fatigue life than the other recycled additives. Hence, adding 5 to 10 percent tire thread to asphalt mixtures are associated with increasing the fatigue life 12, 43 and 68 percent, respectively than the other recycled additives like waste iron, crushed glass, and aromatic oils.

3. 3. Analysis Based on Fatigue Life

Figure 4 shows the fatigue life results or the number of cycles leading to modified asphalt mixtures failure with recycled additives under indirect tensile fatigue test with 250 kPa stress at 25 ° C on the samples with similar dimensions (diameter and height, respectively, 100 and 40).

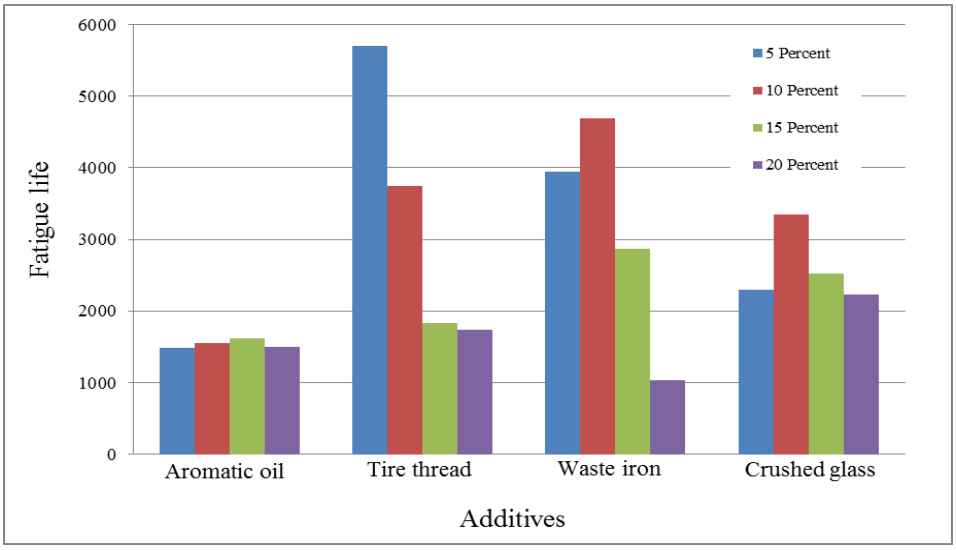

Figure 4. The number of cycles leading to modified asphalt mixtures failure with recycled additives with 250 kPa stress at 25 ° C

According to Figure 4, the use of waste tire thread shows higher fatigue life than other additives such as waste iron, crushed glass, and aromatic oil. However, the addition of more than 5% of tire thread leads to significant decreases in fatigue life. For this reason, the use of 5% tire thread is the best amount to modify the asphalt mixtures. Also, modified mixtures with crushed glass and waste iron have a longer effect on fatigue life of asphalt mixtures than modified mixtures with aromatic oil. Hence, adding 10, 10, and 15% waste iron, crushed glass, and aromatic oil, respectively with crumb rubber is an appropriate mixture to use as additive for asphalt mixtures and leads to the higher failure cycles between different values.

3. 4. Analysis Based on the Strain-test Temperature

Figure 5 shows the behavior of the ultimate strain at failure in the modified asphalt mixtures by tire thread, waste iron, crushed glass, and aromatic oils with similar experimental conditions and similar size in stress level of 250 kPa and test temperatures of 5, 25, 40 °C.

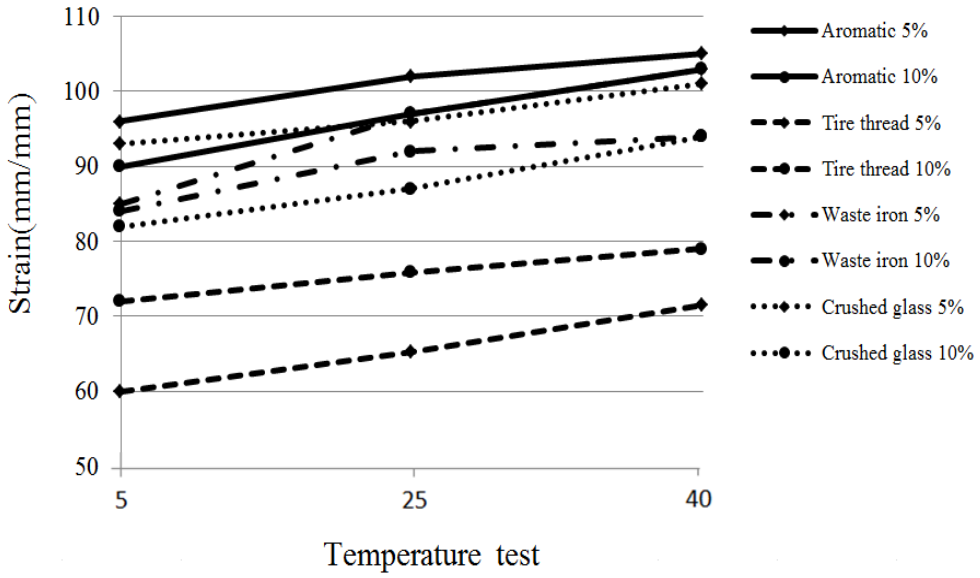

Figure 5. Ultimate tensile strain versus different temperature tests in stress level of 250 kPa

According to Figure 5 it can be found that fatigue behavior of asphalt mixtures significantly depends on the temperature of the test, so that with increasing the test temperature, the mixture samples' strain dramatically increases and reduces the fatigue life. Also, the asphalt mixture containing 5% tire thread shows the least amount of strain at failure than other recycled addictive, thus, they have higher fatigue life than them. Also, the amount of 10% crushed glass and 10% waste iron have the same strain behavior. Thus, using the same amount of the substance in asphalt mixtures leads to the similar result in fatigue life.

4. Conclusions

According to the presented concepts in the functional properties of asphalt concrete mixtures, the results show that the use of recycled addictive not only improves the properties of bitumen, but also increases the resistance of asphalt mixtures to fatigue phenomenon:

- Adding 5 percent waste tire thread to asphalt concrete mixtures leads to the highest fatigue lifetime and stiffness performance and the least amount of strain at failure than the other recycled addictive such as waste iron, crushed glass, and aromatic oils.

- Adding 5 to 10 percent waste tire thread lead to 12, 43 and 68 percent increasing in fatigue lifetime failure than the other recycled addictive such as waste iron, crushed glass, and aromatic oils.
- Adding 10 percent waste iron and crushed glass and adding 15 percent aromatic oil with crumb rubber is the best amount as additives for asphalt mixtures and lead to the highest number of cycles resulting in different amounts.
- Fatigue behavior of asphalt concrete mixtures significantly depends on the temperature of the test, so that with the increase of temperature, the mixture samples' strain dramatically increases and reduces the fatigue life.

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