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Investigating the Effect of Characteristics of Aggregates and SFE components of Asphalt Binder-Aggregate on the Moisture Sensitivity of Asphalt Mixtures Modified with Anti-Stripping Agents

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ABSTRACT: One of the most common failures that occur during the life of asphalt pavements is moisture damage. The penetration of water between asphalt binder and aggregate causes the gradual separation of asphalt binder from aggregates and the weakening of the bonding force between asphalt binder and aggregates. With the expansion of this type of failure, the durability and asphalt mix resistance decreases. Moisture damage is defined as loss of strength and durability in asphalt mixtures. Many studies have been done on the use of anti-stripping additives to improve the quality of asphalt mixtures against the moisture damage in asphalt mixtures using surface free energy and mechanical test. One of the ways to improve the performance of asphalt mixes against moisture damage is the use of anti-stripping materials, which are usually used with hydrated lime or liquid anti-stripping agents. The use of these materials with a number of technical problems. In this research, it has been tried to investigate the effect of nanomaterials and liquid anti-stripping materials on the basis of mechanical and thermodynamic methods. 24 different types of asphalt mixtures have been investigated using three types of aggregates, two types of base asphalt binder and three types of additives. Asphalt binder and aggregate surface free energy components are measured by Sessile drop method and Universal sorption device and the ratio of fatigue life of asphalt mixtures through indirect tensile strength test. The results of this study indicate that the use of nanomaterials and liquid anti-stripping improves strength of asphalt mixtures against the moisture. Also, using these additives will increase the fatigue life and tensile strength of the asphalt mixture. Increasing in the fatigue life ratio was between 2-9%. The increase in fatigue life in wet conditions has been between 10-22%. Additionally, nanomaterial additives have a positive effect on the surface free energy components of asphalt binder, the surface free energy of aggregates, the free energy of adhesion between asphalt binder-aggregate, the debonding energy of asphalt binder and aggregates, and the cohesion free energy of asphalt binders, and improve the performance of these structures against moisture damage.

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1. INTRODUCTION

In a study by Azarhoosh et al, [1] evaluated the effects of the use of nano TiO_2 additive on asphalt-aggregate bonding using a surface free energy method. The surface free energy components of asphalt binder and surface free energy components of aggregate were calculated by Universal sorption device and Wilhelm plate test, respectively. The results of the surface free energy method have shown that the nano TiO_2 additive improves adhesion between asphalt binder and aggregates. In another study, Hamedi [2] used nanoparticles of Al_2O_3 and Fe_2O_3 as an additive to improve the surface of aggregates. In his research, he studied the level of two types of limestone and granite aggregates using nanoparticles and evaluated the resulting mixtures using mechanical and thermodynamic methods. The results of his studies show that the tensile strength of the modified samples in dry and wet conditions was more than the control samples, which indicates an increase in the resistance of these specimens. Arabani and Hamedi [3] evaluated the effect of the use of liquid anti-stripping additives using surface free energy method as well as dynamic modulus testing. The results of their research showed that the addition of additives increases the total free energy of asphalt binder, which prevents the phenomenon of adhesion failure by increasing the adhesion between asphalt binder and aggregates. In a study by Moghadas Nejad et al [4], the effect of using hydrated lime material on moisture deterioration was investigated using a surface free energy

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method. The results of this study showed that the use of this material reduced the acidic components, increased the game components and reduced the surface energy of the aggregates used in this study, which resulted in increased adhesion and coating of aggregates, and finally, Improves the performance of aggregates resistance to moisture damage.

2. METHODOLOGY

In this research, three types of aggregates including limestone, granite and quartzite with a grading structure based on mid limit of ASTM standard for dense asphalt mixtures have been used. The main reason for using these types of aggregates is their different degree of stripping potential. So that the impact of the type of aggregates with different minerals and different sensitivities against moisture degradation can be evaluated. Also, in this research, two types of base asphalt binder with a degree of penetration of 60-70 and 100-85 from the Pasargad Refinery in Tehran have been used. In addition, three types of anti-stripping additive including nano carbonate calcium (nano $CaCO_3$) for aggregate coating and nano Zinc oxide (nano ZnO) and liquid anti-stripping (Wetfix BE) for asphalt binder modification are used. Combined with these materials, 24 different types of asphalt mixtures (18 mixed asphalts and 6 control mixtures) were created.

In this study, Universal sorption device developed by Bhasin [5] is used to measure the surface free energy of aggregates. The method of measuring the surface free energy of aggregates by this device is as follows: three test liguids, whose surface free energy components are already known, are selected.

Determining the surface free energy components using the Sessile drop method is one of the common methods used today for asphalt binder. To measure the surface free energy of the asphalt binder by this device, the asphalt binder sample is first placed between the light source and the camera and the control panel chamber is brought to the desired temperature. Then fill the micro-syringe with the test liquid and spread a drop of test liquid on the asphalt binder surface at a distance of 5 mm. After a few seconds, the camera takes a droplet on the surface.

To test the moisture sensitivity of the modified Lottman method, three samples should be made in wet conditions and three in dry condition for each mixture. Half of the samples in each group (three samples) remain in dry condition, and half of them are taken to wet conditions (wet samples). Dry and wet samples are subjected to indirect tensile strength tests to determine the fatigue life. In the indirect resistance test, cyclic loading is performed until the sample is failed. The amount of fatigue life (the number of cycles the load) is recorded at the moment of the failure. The average fatigue life of dry samples (three samples) and wet (three samples) are calculated separately. The moisture sensitivity or the potential for asphalt mixture is determined by the ratio of the fatigue life of wet-dry samples (in percent).

3. DISCUSSION AND RESULT

The results obtained from the fatigue life test for samples made with two types of asphalt binder, AC 60-70 and AC 85-100, are presented in Fig.s 1-2, respectively. Based on the results, it can be seen that the use of all three anti-stripping additives has significantly improved the fatigue life of the samples made with all three aggregates and both types of asphalt binder used in this study. Samples made with asphalt binder, AC 85-100, nano calcium carbonate also has the greatest effect on the improvement of this index. Finally, it can be admitted that each of these components, along with the asphalt mixing properties, can weaken or increase the strength of the asphalt mix against moisture damage.

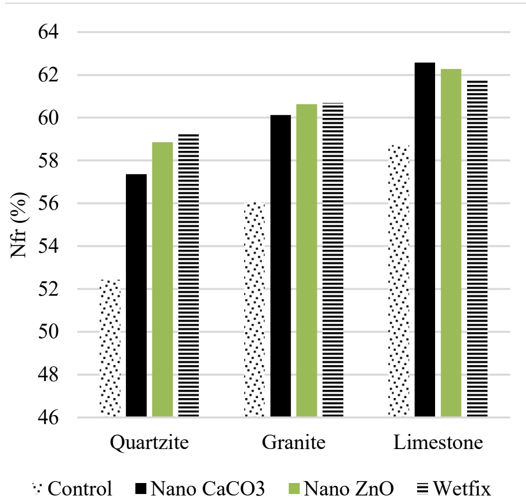

Fig. 1: Fatigue life of samples with AC 60-70

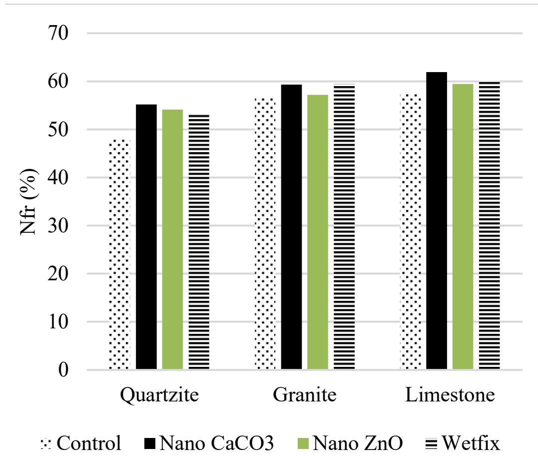

Fig. 2: Fatigue life of samples with AC 85-100

Samples containing limestone aggregates, with proper adhesion and high surface area, have the best indirect tensile strength compared to those made with other aggregates.

In samples with asphalt binder and the same additive, the amount of SiO_2 and CaO in the aggregate structure causes a significant change in the water-absorption properties of the asphaltic mixture. The higher the percentage of SiO2 minerals, the more water-intensive the aggregates are, and the higher the CaO content of the mineral, the greater the milling effect of the aggregate.

4. CONCLUSIONS

The purpose of this study was to investigate the effect of nanomaterial additives on effective components in moisture breakdown events such as asphalt binder-aggregate bonding, mastic adhesion, and aggregate-forming structure. According to the results of this research, the most important results of this research include:

• The use of calcium nano-carbonate increases the bonding between asphalt binder and aggregate and improves the indirect tensile strength of asphaltic specimens.

• The use of an additive calcium nano carbonate results in the formation of a layer of material with a game structure on granite or quartzite aggregates, which improves the adhesion of this material to asphalt binder, which has almost acidic properties. The use of aggregate surface coating makes it possible to create a protective barrier that, on the other hand, makes it possible for the aggregate to be cooled and, on the other hand, provides a good adhesion to asphalt binder.

• The use of anti-stripping additives used in this study has led to a decrease in the acidic components and surface free energy play of asphalt binder. This incident causes more adhesion between modified asphalt binder and acidic aggregates.

• The use of anti- stripping additives has increased the amount of total free energy released from the asphalt binder. This will increase the amount of energy needed to melt in the asphalt binder and reduce the risk of moisture damage.

• The use of asphalt binder antiprolining additives has led to an increase in the non-polar component of free-surface asphalt binder energy. This can improve the increase in non-polar bonds between asphalt binder and aggregates.

• The use of asphalt binder anti- stripping adds some improvement to the asphalt binder-surface free energy of the polar component. This can lead to a slight increase in adhesion between asphalt binder and aggregate due to the non-polarity of asphalt binder.

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