Journal of Civil Engineering and Materials Application
Journal home page: https://jcema.com

Received: 17 March 2018 • Accepted: 25 June 2018

Research

doi: 10.22034/JCEMA.2018.91990

Effect of Mineral pitch and Zycosil Nano-Material on Mechanical Properties and Moisture Susceptibility of Asphalt Mixtures

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ABSTRACT

The performance of asphalt pavements against environmental factors such as moisture is important. Many failures are caused by the direct flow of water into the pavement and the weakening of the bond between bitumen and aggregates. Therefore, the purpose of this study was to investigate the effect of anti-stripping nano-materials and Iranian Gilsonite on the moisture susceptibility of asphalt mixtures, and in this research, hot-mix asphalt is investigated. To achieve this goal, the calcined aggregates, bitumen 60-70, and two additives of mineral pitch and Zycosil are used. The mineral pitch was mixed with bitumen at 3, 6 and 9% levels by weight of bitumen and Zycosil was mixed at 0.15% by weight of bitumen for each asphalt specimen. The level of bitumen used in samples is considered to be the same with the optimum bitumen of the control sample. Then, the diagrams of tests conducted on the samples were plotted. These tests, which were used to study the effect of these materials on the adhesion and strength of asphalt mixtures, include indirect tensile test, resilient modulus and Marshall stability. The results from the experiments show that the mineral pitch and Zycosil improve the performance of hot-mix asphalt.

Key words: Zycosil, Mineral pitch, Indirect tensile, Resilient modulus, Marshall stability.

Journal of Civil Engineering and Materials Application is published by *Raika Pajuhesh Pars*; Journal p-ISSN xxxx-xxxx; Journal e-ISSN 2588-2880.

1. INTRODUCTION

Asphalt research is carried out to improve the quality of asphalt and enhance the design life cycle of the asphalt pavements (1). Asphalt pavement subjected to water infiltration often experiences the segregation of the constituting materials of asphalt, which is due to the presence of chemicals absorbed by water, and the bitumen is so-called dislodged of materials (2). As the process of the weakening caused by moisture and cyclic traffic load continues, the separation of bitumen from aggregates becomes a dominant failure mode in the asphalt pavement (3), which this failure appears in the form of rutting, stripping, shoving, raveling, cracking, etc. (4). The anti-stripping agebts can affect the engineering properties of bitumen and asphalt mixture. This effect on the reduction of moisture susceptibility depends on the physical and chemical properties of bitumen and aggregates, as well as the use of anti-stripping agent (5, 6). Most of these materials reduce the surface tension between bitumen and aggregates in the mixture. When surface tension is decreased, on the other side, the adhesion between asphalt and aggregate is increased (7). In general, the experiments developed so far can be divided into two broad categories: the first group are the experiments whose purpose is to control the compatibility between bitumen and aggregates based on the curing of non-dense asphalt mixtures (8), and the second group are the experiments in which the moisture susceptibility of the dense asphaltic mixture is evaluated. The latter can further be divided into two groups: the tests that only use curing under moisture conditions, and the tests that assess the mutual effect of presence of both water and traffic (9). The purpose of this study is to investigate the properties of asphalt mixtures modified by two additives of mineral pitch and Zycosil which are investigated using Marshall stability test, resilient modulus and Indirect tensile strength (ITS).

2. MATERIALS AND METHODS

2.1. Introduction of samples

In this research, the calcined materials extracted from Tello mine in eastern Tehran are used. The grading used for the aggregates is No. 4 grading of the Iranian Road Regulations, as shown in Figure 1. Moreover, the bitumen of penetration grade 60/70 is used as the specifications of Table 1 prepared by Pasargad Oil Company.

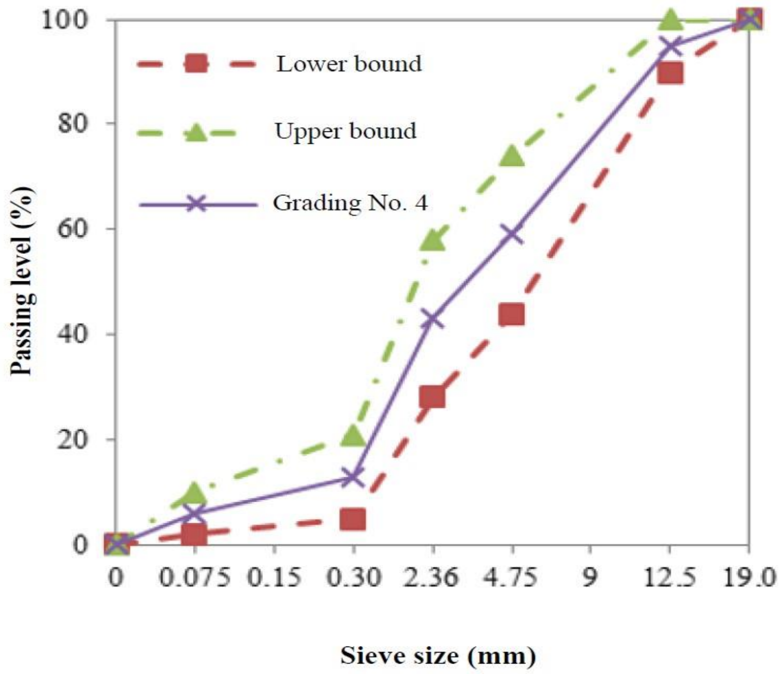

Figure 1. Grading of aggregates

Table 1. Technical specifications of used bitumen

Properties	Bitumen 60/70	Test Method
Specific gravity at 25 °C	1.03	ASTM D-70
Penetration at 25 °C	64	ASTM D-5
softening point (°C)	54	ASTM D-36
Ductility at 25 °C	102	ASTM D-113
Flash point	305	ASTM D-92
Fire point	317	ASTM D-70

2.2 *Bitumen modification*

In this study, two additives, Gilsonite and Zycosil, were used for the modification of bitumen. The used Gilsonite is prepared from the mines of Kermanshah province, Iran, and the Zycosil from the Indian Zydex company is used. In Table 2, the nomenclature of mixtures containing the modified bitumen is listed. To combine bitumen and additives, a high-speed agitator was used.

Table 2. Nomenclature of mixtures by modified bitumen

Sample	Additives	Level of additives
N0	–	0
Za	Zycosil	0.15
GL3	mineral pitch	3
GL6	mineral pitch	6
GL9	mineral pitch	9

Also, the bitumen level used for the control sample was determined using the Marshall method equal to 4.3 and the samples containing the modified bitumen were also made with this bitumen level.

2.3. Marshall stability

ASTM D 1559 was used for this test. Two characteristics are defined in this test, which are the maximum load the sample can resist without fracture (Marshall stability) and the deformation that occurs in the specimen at the moment of failure (Marshall flow) (10). Another concept, sometimes used to evaluate asphalt mixtures, is the Marshall stiffness index, which is the Marshall stability divided by flow and is an empirical measure for the stiffness of asphalt mixtures. The higher Marshall stiffness index indicates a stiffer mixture, suggesting that the mixture is likely to have more resistance to permanent deformation. In this research, according to the primary goals, the results from the Marshall stability is reported.

2.4. Resilient modulus

In this test, the asphalt specimen is first adjusted with the help of a special frame so that it would be completely symmetrical when loaded by the device and the load would be applied to the center of specimen. Then, the device input data are set. The first step in setting the device software is to select the standard and test method. After determining the standard for testing, information on each sample, including the height and diameter of specimens must be entered. Then, by applying a load of 400 N as a semi-sinusoid load with 0.5 s loading and 1.5 s unloading at 25°C, the resilient modulus of asphalt specimens is measured. Calculating the resilient modulus is done by the UTM5 device using the ASTM D4123 standard (11).

2.5. Indirect tensile test

In this test, the samples should have the void content of 6 to 8 percent in order to ensure that the asphalt is compacted according to the conditions of the pavement. Six asphalt specimens are made for each type of additive. To make the specimens after heating and mixing the aggregates, the gyrator compactor was used in the compaction stage to compact the samples so that the void content reaches up to 7±0.5%. The asphalt specimens are divided into two ternary groups of dry and wet ones. The first group is tested under dry conditions and the second group is treated with moisture and then tested. The AASHTO T283 standard is used for this test.

3. RESULTS

3.1. Marshall stability

The Marshall Test is used to measure the resistance of a cylindrical sample of asphaltic mixtures against plastic deformation when the lateral surface of the sample is loaded by the Marshall device. Figure 2 shows the effect of mineral pitch levels on the Marshall stability of the asphalt mixture. As shown in the diagram, all additives have a positive influence on the Marshall stability, and this has a positive effect on different samples, so that by increasing the level of mineral pitch in the mixture, the Marshall stability of the samples is increased, which is partly due to the increase in the stiffness of the mixture as a result of the addition of mineral pitch. On the other hand, by adding the Zycosil, the Marshall stability is better than the control sample, but this positive effect due to the addition of Zycosil is not as high as 9% for mineral pitch but is better than 6% mineral pitch.

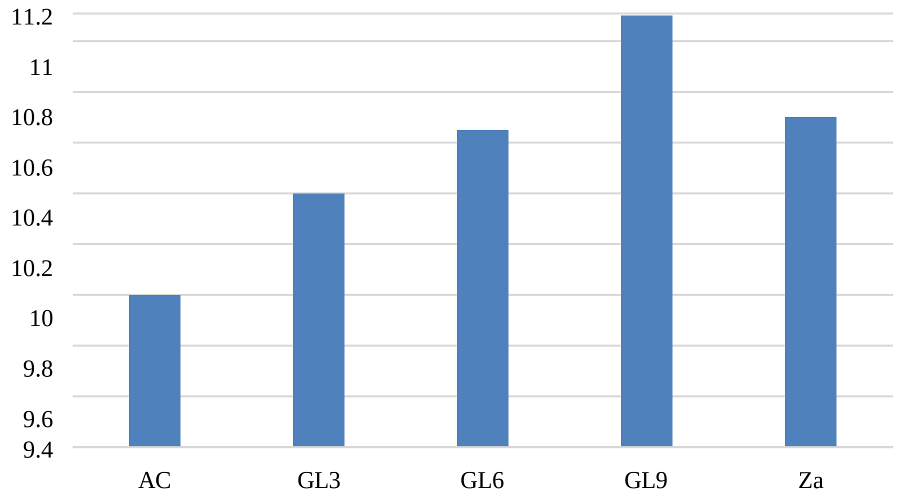

Figure 2. Marshall stability of samples (KN)

3.2. Resilient modulus

Resiliency modulus is the elasticity modulus in cyclic loading with very small strains and is an important mechanical characteristic of asphalt mixtures for determining the thickness of pavement layers. Figure 3 shows the variation of the resilient modulus in terms of the change in mineral pitch levels. According to the results presented in the diagram, the increase in the content of bitumen has increased the resilient modulus; as shown in the diagram, as the level of mineral pitch increases from 3 to 6 and from 6 to 9 percent, the upward trend is seen in the diagram. On the other hand, it is noted in this diagram that the value of the resilient modulus is related to the Zycosil sample, which is close to the resilient modulus of the control sample, and there is a little difference between the modulus of the two samples. The reasons for this process can be explained by the fact that by adding Zycosil to the mixture and due to the main properties of this material, no change is happened in the stiffness and other characteristics involved in the resilient modulus, and hence, the resilient modulus of the sample containing Zycosil is approximately same as the control sample. On the other hand, the incremental trend for the sample containing the mineral pitch can be explained by the fact that by increasing the content of mineral pitch in bitumen, the level of stiffness of the bitumen and consequently, the stiffness of the mixture is increased and as a result, the content of mineral pitch in the mixture is increased. The level of resilient modulus is consequently increased.

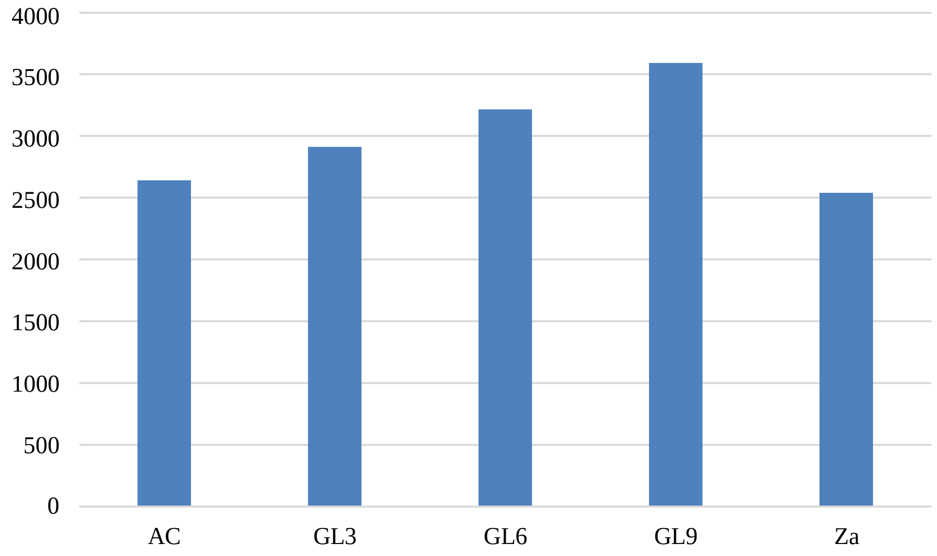

Figure 3. Resilient modulus (Mpa)

3.3. Indirect tensile test

The indirect tensile test is one of the most commonly used performance tests, which can be a reliable indicator for the cracking potential of asphalt mixtures. This test was carried out in two dry and wet conditions. The results of the indirect tensile strength of the specimens in both wet and dry conditions are presented in Figure 4. As shown in the diagram, the indirect tensile strength of the samples is improved by adding mineral pitch to the mixture. Also, by increasing the content of mineral pitch in the mixture, the indirect tensile strength of the samples is increased, but this increase in resistance when the Gilsonite value ranges from 3 to 6% is a faster process than when reaching from 6 to 9%. On the other hand, with the addition of Zycosil, the indirect tensile strength is decreased. The process of increasing and decreasing the strength is the same for samples modified with Zycosil and mineral pitch in wet and dry conditions. To discuss the causes of the variation in the diagram, the indirect tensile strength can be discussed in two sections. First, the incremental changes with the addition of Gilsonite can be explained by the fact that with the addition of Gilsonite, the level of stiffness of bitumen and as a result, the stiffness of the mixture is increased and ultimately, leads to an increase in the indirect tensile strength of the samples. In the second part of the variation study, we can examine the decrease in the indirect tensile strength of Zycosil sample, which is also due to the low reduction in strength and, on the other hand, the reduction of the difference in dry and wet states relative to each other, which as a result, it provides a better moisture susceptibility for the mixture, this reduction in the strength can be attributed to the properties of the material itself.

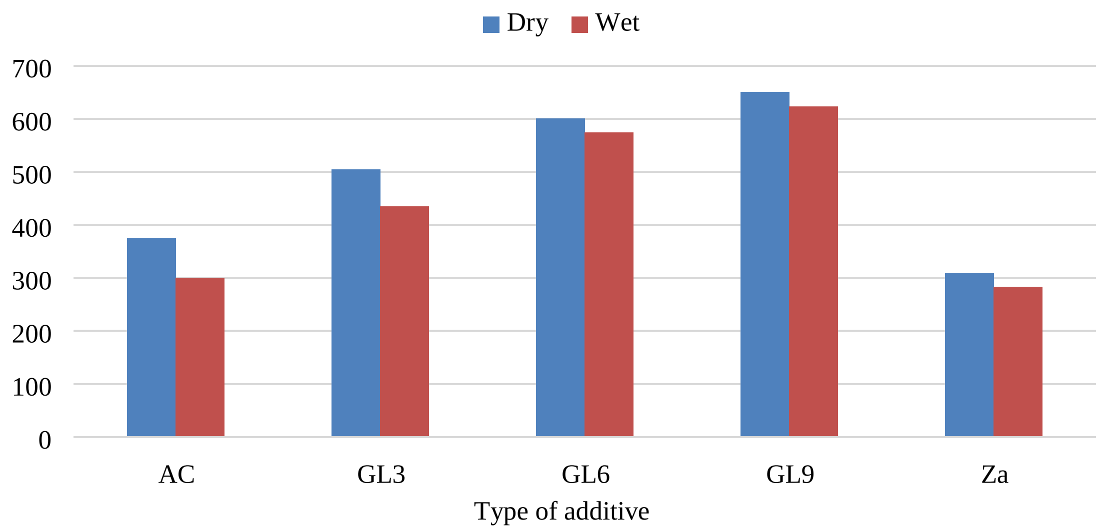

Figure 4. Indirect tensile strength of samples (KPa)

Another important point in this diagram is the difference between the levels of indirect tensile strength in both wet and dry conditions, and the ratio of these two states, that is the wet to dry strength ratio in percent, represents an important parameter called the moisture susceptibility coefficient or TSR, the results of which is presented in Figure 5. The trend observed in the figure represents the positive effect of all additives on the moisture susceptibility, but this effect varies as can be seen. For the mineral pitch additive, by increasing the mixture from 3 to 6%, a significant change can be seen, but the change from 6% to 9% is insignificant and it can be said that the moisture susceptibility of both samples is the same. On the other hand, Ziacosil has a significant effect, so that the susceptibility of moisture is changed from about 80% for the control sample to about 91% for the Zycosil modified sample.

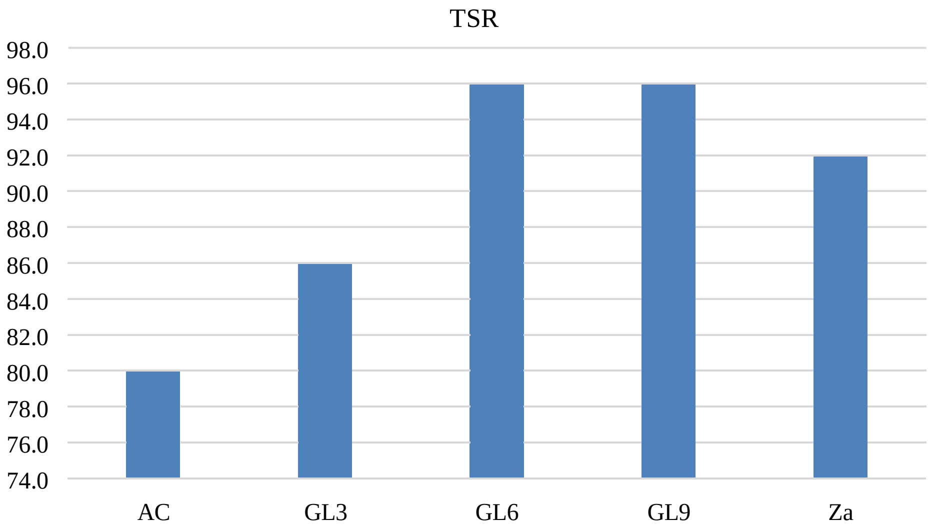

Figure 5. TSR value for modified and unmodified samples

3. CONCLUSION

In this research, the main objective is to investigate the properties of asphalt mixtures modified with mineral pitch and Zycosil. For this purpose, the resilient modulus, Marshall stability and indirect tensile tests are used. According to the conducted experiments, the results of this study can be summarized as follows:

- Adding mineral pitch at any level improves the moisture susceptibility of the mixture; therefore, due to the low price, this material can be used as a suitable anti-stripping agent.
- The resilient modulus in all mixtures containing the mineral pitch is better than the control sample, but the sample containing the Zycosil shows a reverse result and has a lower resilient modulus than the control sample.
- The addition of mineral pitch and Zycosil improves the Marshall stability of the specimens, and the highest effect is initially related to the sample containing 9% mineral pitch, and then followed by Zycosil.

FUNDING/SUPPORT

Not mentioned any Funding/Support by authors.

ACKNOWLEDGMENT

Not mentioned any acknowledgment by authors.

AUTHORS CONTRIBUTION

This work was carried out in collaboration among all authors.

CONFLICT OF INTEREST

The author (s) declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

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