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Evaluation of moisture sensitivity of asphalt mixtures modified with nanoparticle (zinc and silicon oxides)

Gh. H. Hamedi[1*], A. Alipour[2]

[1] Department of Civil Engineering, University of Guilan, Guilan, Iran

[2] Department of Civil Engineering, Islamic Azad University, Ahar Branch, North Khorasan, Iran

ABSTRACT: Moisture damage is one of the most common distresses in asphalt mixtures due to the effect of moisture on asphalt binder and asphalt binder-aggregate adhesion. There are different ways to improve adhesion and reduce moisture damage in asphalt mixtures. One of the most common ways to reduce moisture damage is to use asphalt binder modification with an additive. In this research, the effect of two types of nanomaterials (nano zinc and silicon oxides) in two different percentages as additive to asphalt binder, two types of aggregate (granite and limestone) and a type of asphalt binder are studied. To investigate the effect of nanomaterials on reducing the moisture damage of asphalt mixtures, indirect loading of cyclic loading in dry and wet conditions as a mechanical method and surface free energy method has been used as a thermodynamic method. The moisture sensitivity index, the percentage of aggregate surface stripped in loading cycles using the results of surface free energy and indirect loading, are derived based on the results of mechanical and thermodynamic experiments. The mechanical test results used in this study indicate that nanomaterials have significantly improved the strength of asphalt mixtures compared to control samples. The results of the surface free energy method indicate that the surface free energy of cohesion of nanomaterial increases. This will reduce the risk of failure in the asphalt binder film. Also, nanomaterials increase and decrease basic and acidic surface free energy components of asphalt binders, which improves the bonding of asphalt binder to acidic aggregates that are susceptible to moisture damage.

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1. INRTODUCRION

Many offices have made extensive efforts to reduce their maintenance costs. One of the failures that cost a lot of asphalt pavements is moisture failure [1]. Damage to moisture The loss of mechanical properties of the material is defined as the result of the presence of water in asphalt mixtures. This failure, in addition to being a significant deterioration, can cause or aggravate other asphalt crashes. The factors affecting the occurrence and severity of the failure can be divided into two categories: a) internal factors such as aggregate characteristics, asphalt binder properties, asphalt mix properties such as percentage of free space and permeability, apparent thickness of the asphalt binder membrane on the surface Aggregates, surface free energy of asphalt binder and aggregate; and b) external factors of environmental conditions and traffic levels [2]. In various writings, five main mechanisms of detachment, including separation, displacement, spontaneous emulsion, water pressure and hydraulic boiling on the asphalt binder-aggregate system, have been mentioned [2]. In the separation process, a very thin layer of moisture is placed between the asphalt binder and the aggregate and causes the separation of the membrane from the surface of the aggregate without any apparent breakdown in the asphalt binder [3]. Nanotechnology is used in the design, construction, and operation of applied materials with at least one of the dimensions specified in nm units [4]. This technology is steadily expanding with the advancement of science and technology [5]. The advancement of this technology has also reached its application in asphalt mixtures.

*Corresponding author's email: Hamedi@guilan.ac.ir

2. METHODOLOGY

In the present study, the effect of using silica and zinc nitric oxide on the moisture deterioration of asphaltic mixtures using free surface energy and the results obtained from cyclic loading experiments in wet and dry conditions checked. The main reason for the use of these materials is that the asphalt binder mixture is predominantly mixed in the asphalt mixture. In contrast to previous studies, which are mainly based on the results of mechanical experiments to investigate anticonvulsant additives, in this study, free surface energy method and mechanical loading results are used to study the exact assumptions.

3. RESULTS AND DISCUSSION

Using the data obtained from the repeat loading test and

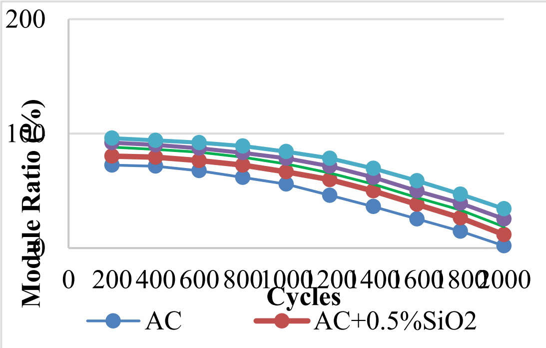

Fig. 1. Module ratio in granite aggregate

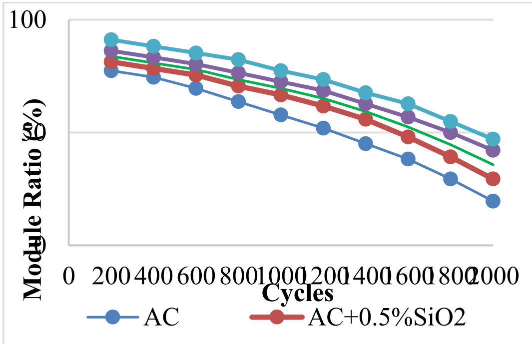

Fig. 2. Module ratio in limestone aggregate

knowing the amount of stress applied during each test, the dynamic module is calculated with the help of maximum strain and stress. These values of the dynamic module are determined by the number of loading cycles for each sample. The dynamic modulus values for dry and wet samples were compared. In this study, the dynamic modulus was performed for all samples in dry and wet conditions. Wet moderately dry to wet ratio is considered as an indicator for determining the moisture sensitivity of asphalt mixtures. The results of the modulus in wet to dry conditions for samples made with limestone and granite aggregates are shown in Figures 1 and 2. It is clear from the data presented in these two shapes that the stiffness modulus in wet to dry conditions is always less than 100. This event is expected because the destructive effect of water changes the asphalt binder properties and loses adhesion reduction at the contact level of asphalt binder-aggregate, which both reduce the modulus of the asphalt mix in wet conditions relative to the dry conditions.

The results show that the use of two types of additive of silica and zinc added to asphalt binder has led to an increase in the stiffness modulus in wet to dry conditions. This means that the drop in the modulus has dropped in wet conditions compared to dry conditions. In fact, the repair of asphalt binder with nano additives has led to less residual loss in asphalt mixtures as a result of water use.

This suggests that energy must be used to separate the two materials, and larger positive values indicate that a better adhesion is provided. The results show that the use of nanomaterials has reduced the free energy of asphalt binder and aggregate adhesion (approaches zero), which means that the system desire to nibble and achieve a stable state with the least energy reduction. An increase in the percentage of nanomaterials also reduces this desire.

In all samples, the free energy of adherence of asphalt-aggregates varies from a positive amount in dry conditions to some negative in the presence of water. This trend was already expected because water with free energy components is a larger surface than asphalt binder. Therefore, when the three materials of asphalt binder, water and aggregates are in contact, the water changes the energy of the system to a state with the lowest energy level, which occurs when the debris occurs. The free energy of adhesion between the two positive materials, and therefore, requires energy to separate from each other. The results of the energy-free column of bituminous-aggregate adhesion show that adhesion between aggregates of limestone and asphalt binder is more than the adhesion between aggregates of granite and asphalt binder. This indicates that in dry conditions (without the presence of water), the separation of the asphalt binder from the aggregate rock aggregate unit is more difficult than the surface of the granite aggregates, and requires more energy. Similarly, the results of this column indicate that the use of metallic nanowires has led to an increased adhesion to free energy. Also, by increasing the percentage of nanomaterials used in this study, the energy needed to break down at the contact level of asphalt binder-aggregates in dry conditions has increased.

Use of both types of metal nanowires has led to a decrease in the percentage of aggregate surface roughness in different loading cycles. This means that coating on the aggregate surface does not allow the penetration of moisture to the contact surface of the aggregate, which increases the strength of the asphalt mix against moisture. The increase in the percentage of additives used in this study has led to a greater reduction in the rate of nibbling. Also, in both series of samples made with granite and limestone aggregates, asphalt binder correction with nano-oxide of zinc has more effect on decreasing the percentage of nesting in loading cycles. Also, studies show that samples made with granite aggregate have a weaker performance than those made with limestone aggregate. The main reason for this event is the stronger adhesion of bituminous aggregates, which is an acidic substance. Also, in the previous sections, it was observed that the rupture of granite bituminous aggregate contact surfaces would release more energy than limestone asphalt binder-aggregate. In fact, the tendency to scatter in samples made with granite aggregates is higher. From the data presented in these figures, it can be seen that the slope of the percentage of nesting against the loading cycles has a bullish trend. In fact, in the initial cycles of loading, almost all of the aggregates are bituminous. The higher the exposure to the specimens in wet conditions and the frequency of loading, the greater the percentages of aggregate levels are undone. This reduces adhesion, along with the reduction in the percentage of aggregates that are connected.

4. CONCLUSIONS

The most important results in this study are:

- The acidic component of the free surface energy of granite aggregates is the largest component of the acidic component of the free surface energy of limestone aggregates.

• The use of nanoparticles used in this study has reduced the acidity of the base asphalt binder and its basic characteristics increase. This makes it possible to improve the adhesion of modified asphalt binder to base asphalt binder for acidic aggregates such as granites that are susceptible to moisture degradation.

• The results of free energy of asphalt binder-aggregate adhesion show that adhesion between aggregate of limestone and asphalt binder is more than the adhesion between aggregates of granite and asphalt binder. This indicates that in dry, the separation of the asphalt binder from the aggregate rock aggregate unit is more difficult than the surface of the granite aggregates, and requires more energy.

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